1993

Seasonal water regimes and leaf litter processing in a wetland on the Swan Coastal Plain

Darren Ryder
Edith Cowan University

Recommended Citation

Ryder, D. (1993). *Seasonal water regimes and leaf litter processing in a wetland on the Swan Coastal Plain*. https://ro.ecu.edu.au/theses_hons/491

Seasonal Water Regimes and Leaf Litter Processing in a Wetland on the Swan Coastal Plain.

DARREN RYDER

A Thesis Submitted in Partial Fulfilment of the
Requirements for the Award of

Bachelor of Applied Science (Honours) Environmental Management
Edith Cowan University

Submission date - 19 / 11 / 93

USE OF THESIS

ABSTRACT

The effect of seasonal or permanent inundation on the processing of leaf litter from two competing emergent macrophytes *Baumea articulata* and *Typha orientalis* was examined at Lake Jandabup, a seasonal wetland on the Swan Coastal Plain. The loss of organic matter from leaf packs was used to quantify leaf litter processing. The contributions made by microorganisms and macroinvertebrates in processing were also assessed.

Leaf packs exposed to seasonal inundation (defined as those areas exposed to alternate wetting and drying) had significantly higher losses of organic matter after six months than those permanently inundated for the same period. The presence of a stratified water column in the permanently inundated sites in summer, resulting in reduced oxygen levels at the bottom of the water column appears to be the driving force behind the low amounts of organic matter loss from leaf packs in this environment. These results are supported by the presence of peaty soils in the permanently inundated sites and not in those seasonally inundated, indicating that this pattern of leaf litter processing has been occurring for some time. The reflooding of seasonally inundated sites resulted in these leaf packs having the highest microbial biomass and therefore become a preferred food source for invertebrates. Losses of organic matter from leaf packs also highlighted the difference in the amounts of organic matter loss between the two species, with *Baumea* losing significantly more.

The classification into groups of macroinvertebrates found in leaf packs using TWINSPAN resulted in a separation of the permanently inundated sites into distinct invertebrate communities, with no preference for *Baumea* or *Typha* leaf packs found in established vegetation commumities. The resulting differences in functioal feeding group representation between vegetation communities may in part be responsible for differences in the amounts of leaf litter processing..

The results from this study indicate that changes to the current seasonal wet/dry hydrological regime experienced by the littoral community at Lake Jandabup will alter the proportions of organic matter available for processing within the wetland

"I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text"

Signature

Date 8/2/94

ACKNOWLEDGMENTS

First and foremost I would like to thank Dr Pierre Horwitz. my supervisor, for his advice, tireless effort and somewhat strange wit in helping me complete this thesis, but mostly I would like to thank him for instilling in me an enthusiasm and passion for wetlands and their conservation.

I would also like to thank both my parents and Allan and Dot Ellies who provided me with help and support throughout the year. Special thanks to my Dad and Allan Ellies (the other members of the Lake Jandabup Rowing Team) who helped in the collection of field data, even if it meant staying up after Fat Cat had gone to bed during the 24 hour sampling. I would especially like to thank my fiancé, Fiona Ellies for her love and support, and for tolerating my long hours at the University or in front of a computer. I would also like to acknowledge Misty, her horse who provided her with hours of amusement in my absence.

I would also like to thank the following people :

Dr Mark Lund and Mr Eddie van Etten who prevented severe damage to the University computers in helping with my statistical analysis,

Alex Gower from WAWA who helped produce the digitised maps of Lake Jandabup,

Kim Richardson who proved to be an endless source of discussions, and distractions about my research and its results as well as showing me that there is a lighter side to doing an Honours thesis (although its not very big), and

Dr Shirley Balla for her help and inspiration, showing me that despite the many obstacles that arise in life, none are too big to overcome.

Permission to use Lake Jandabup as the site for my research, and to remove flora for experimentation was given by the Department of Conservation and Land Management.

LIST OF FIGURES

Figure Page

LIST OF TABLES

TABLE OF CONTENTS

Section 1 - INTRODUCTION Page

Section 2 - LITERATURE REVIEW

2.1 - DECOMPOSITION

Section 3 - MATERIALS AND METHODS

3.2 - MICROBIAL BIOMASS

3.3 - MACOINVERTEBRATES

Section 4 - **RESULTS**

4.1 - LEAF LITTER PROCESSING

4.1.1 - Field Sites

4.1.2 - Laboratory Treatments 1 and 2

4.1.3 - Laboratory Treatment 3

4.2 - PHYSICO - CHEMICAL CHARACTERISTICS OF THE WATER COLUMN

4.2.1 - Field Sites

4.2.2 - Laboratory Treatments

4.2.3 - Diurnal Fluctuations

4.3 - MICROBIAL BIOMASS

4.4 MACROINVERTEBRATES

SECTION 1

INTRODUCTION

1.1 The Seasonality of Swan Coastal Plain Wetland Ecosystems

Lake Jandabup lies on the Swan Coastal Plain, situated in the south west of Western Australia, extending from Geraldton in the north to Dunsborough in the south. The region experiences a temperate Mediterranean climate, which is characterised by warm, dry summers and mild, wet winters (Chambers & Davis, 1989; Arnold, 1990). Rainfall is highly seasonal with 90 % occurring between April and October. Evaporation exceeds precipitation in all months except the period between May and August (Balla & Davis, 1993). Beneath the Swan Coastal Plain is an unconfined groundwater aquifer, recharged from rainfall which leads to a build up of the ground water in the sediments. The result is a mounding of the groundwater table, the Gnangara Mound in Perth's northern suburbs being one example. The shallow permanent and seasonal wetlands of the Swan Coastal Plain are generally surface expressions of these unconfined groundwater aquifers, with this hydraulic connectivity resulting in wetland water levels varying in sympathy with the elevation of the water table (Ayre, Colreavy, Coster, Fisher, Hill, Lymbery, McShane & Threlfall, 1979; WAWA, 1986; WAWA, 1987; Chambers & Davis, 1989). The result is a two to three month lag period between peak groundwater levels and rainfall, with maximum levels recorded in September/October and minimum levels in March/April (Froend, Farrell, Wilkins, Wilson & McComb, 1993).

The seasonal variation in groundwater elevation results in most wetlands of the Swan Coastal Plain exhibiting a seasonal wet-dry cycle, with winter flooding and summer drawdown. The biological, physical and chemical processes of these wetlands are dominated by this hydrological cycle (Chambers & Davis, 1989), and as a result the plants and animals that rely on these ecosystems have adapted to this seasonality.

1.2 Aquatic Vegetation in Wetland Ecosystems

Plant communities are the basis for all life in a wetland ecosystem, and seasonal wetlands are no exception, having a diversity of vegetation communities which are central to wetland processes. They extract nutrients from the water and sediments, ameliorate effects of sediment transfer into wetlands, afford an element of primary production in wetland ecosystems and supplies a range of habitats for aquatic and terrestrial fauna (Storey, Vervest, Pearson and Halse, 1993). Aquatic vegetation provides habitat diversity through the macroclimatic and microclimatic effects provided by their uptake and release of oxygen, carbon dioxide and nutrients, thereby directly affecting the characteristics of the surrounding environment (Mitchell 1980). Vegetation also provides an important structural component to wetland habitats by stabilising and aerating sediments.

Emergent macrophytes constitute a significant ecological group among the plants that grow in wetland habitats. They include plants which are rooted in the sediment, have part of the plant above the water surface for most of the year and have elongate emergent stems with long cylindrical or narrow flat leaves (Polunin, 1984) Two species of emergent macrophytes common to wetlands of south western Western Australia are *Baumea articulata* (jointed twig rush) which is native to this region and *Typha orientalis* (Bulrush) an aggressive coloniser that may have been introduced into south western Western Australia (Froend *et al*, 1993). Emergent macrophytes are typically highly productive plants, capable of rapid and continuous growth, constantly replacing old leaves with new, and thus, are a primary source of organic matter to aquatic food webs.

1.3 Food Webs - Productivity and Decomposition

Within aquatic environments there are two main food pathways, productivity and decomposition. Productivity itself can be divided into two components. Primary production is the process of plant growth through photosynthesis, represented in a wetland by the growth of algae in the water column and macrophytes in the littoral zone. Secondary production occurs through the direct or indirect use by animals of the energy stored in plant material (Chambers & Davis, 1989; Murkin, 1989). Decomposition is the process by which plant and animal materials are degraded into their constituent parts and recycled back into the ecosystem (Chambers & Davis, 1989; Boulton & Boon, 1991). The grazing and detrital food chains are significant components of the overall food web within a wetland ecosystem. The grazing food chain consists of those organisms which feed directly on aquatic plants or algal cells, which are in turn fed upon by other organisms. The detrital food chain is based on organisms which feed on dead and decaying animal and plant material (Chambers & Davis, 1989). It is these organisms which are responsible for the decomposition of organic matter in a wetland.

In a healthy functioning wetland, the processes of primary production, secondary production and decomposition continue at a rate where the input and output of energy and materials are in equilibrium (Chambers & Davis, 1989). A disturbance of this equilibrium, such as an alteration of the water regime, may detrimentally affect the energy flow and nutrient cycling within the wetland.

1.4 Significance of the Project

Since European settlement at least 70% of wetlands on the Swan Coastal Plain have either been lost or severely degraded as a result of urbanisation and agricultural expansion (Riggert, 1966). These processes are continuing despite increasing awareness of the biological significance of the remaining wetlands, resulting in these wetlands assuming great importance for conservation.

Perth's population is expanding rapidly, resulting in more land being required for housing and industrial development, both of which require a reliable and potable water supply. The shallow ground water from the Gnangara Mound and the Jandakot Mound are the cheapest and most readily available resources to meet this demand (Hollick, 1989). The increase in groundwater abstraction adjacent to many wetlands, conversion of bushland to urban areas and other land uses and a policy of artificial maintenance of wetland water levels implemented by the Water Authority of Western Australia (WAWA) have led to altered water regimes in many urban wetlands. Superimposed on these cultural factors are possible long term changes in climate due to the Green house Effect, leading to progressively lower annual rainfall. Where the predictable seasonal changes in a wetland's water regime are altered, there is the potential for an alteration to wetland processes to occur.

As a result of urban development wetland vegetation surrounding the open water is often removed. The input of organic matter from this vegetation which acts as a primary food source in aquatic food webs is lost, as is habitat for a wide variety of fauna utilising the wetland vegetation. Maximum aquatic macrophyte productivity is reliant on a seasonal water regime (Kadlec, 1962; Briggs & Mayer, 1985), as prolonged flooding results in the death of much aquatic vegetation, reduces long term plant productivity and prevents peaks in organic matter availability occurring after reflooding (Briggs and Mayer, 1985; Froend *et al* 1993). The decomposition of organic matter within aquatic food webs is stimulated by a pattern of wetting and drying as reflooding provides an instantaneous food source for aquatic organisms (Reddy & Patrick, 1975; Briggs & Mayer, 1985; Briggs, Mayer & Carpenter, 1985; Balla & Davis, 1993).

The reduced oxygen conditions in the water column as a result of prolonged flooding has been found to severely hinder decomposition (Hill, 1985). The organic matter which survives degradation in the water column and in a shallow zone at the sediment surface is incorporated into the sediments and undergoes a very slow process of decomposition (Cranwell, 1976). The result is the formation of peaty soils. The constitution of successive layers of peat changes with time, as a change to climate or water levels may alter the sequence entirely (Brady, 1990). Peats are important for scientific purposes as much can be learnt about past vegetation and climate from examining past organic remains. In determining a water level regime under a system of artificial maintenance, peat has the potential to provide a unique insight into the past hydrology of the system, therefore, enhancing future management

The processing of leaf litter and its important role in the functioning of aquatic ecosystems has been well documented by Barlocher, Mackay & Wiggins (1978), Godshalk & Wetzel (1978), Puriveth (1980), Hanlon (1982), Herbst and Reice (1982), Polunin (1984), Hill (1985), Bunn (1986), Webster and Benfield (1986), Bunn (1988), Murkin (1989) and Hietz (1992). This literature concentrates mainly on northern hemisphere examples or lotic systems. The result is a deficiency of information on leaf litter processing in the southern hemisphere and more specifically the effect of altered water regimes on leaf litter processing in lentic environs.

Wetland water levels on the Swan Coastal Plain have been the subject of a series of reports from WAWA. These included Froend *et al* (1993) studying the effect of altered water regimes on vegetation dynamics and Balla and Davis (1993) studying the effects of water regimes on invertebrate communities. The results of these studies have contributed to the development of preferred and absolute water levels for many wetlands on the Swan Coastal Plain. However, the seasonality of the water table and its effect on the processing of leaf material (and hence its availability within aquatic food webs) was not examined. This information is crucial in determining a water level regime that will maintain the existing ecological processes and species composition within seasonal wetland ecosystems. These include the processes of organic matter decomposition and the accumulation of peat. The results of this study may help to resolve some of these questions.

1.5 Objectives of the Project

The general objective of the project is to determine the consequences of seasonal water regimes on the processing of leaf litter from two competing emergent macrophytes *Baumea articulata* and *Typha orientalis* in Lake Jandabup, a seasonal wetland on the Swan Coastal Plain.

The specific aims of the project are to :

1. Determine and compare the amount of organic matter loss from *B.articulata* and *T.orientalis* leaf packs :

a) exposed to either a seasonal or permanent water regime.

b) placed in either a *B.articulata* or *T.orientalis* homogeneous community experiencing each water regime.

c) placed within the same *B.articulata* or *T.orientalis* homogeneous vegetation community.

2. Examine the role of microoganisms in the processing of leaf litter by quantifying the microbial biomass of leaf packs

3. Examine the role of macroinvertebrates in the processing of leaf litter through the identification and comparison of macroinvertebrate colonising the leaf packs.

4.Examine the importance of environmental variables (physico-chemical characteristics of the water column, soil composition) in the processing of leaf packs.

5. Use the information gained to outline possible management implications.

SECTION 2

LITERATURE REVIEW

2.1 DECOMPOSITION

2.1.1 Introduction

The flow of energy and the cycling of nutrients are two of the major processes taking place within freshwater ecosystems, and the quantity of energy derived from primary production and the rate of nutrient turnover are generally the prime factors determining the productivity of organisms at successive trophic levels (Hanlon, 1982). In many lakes a large proportion of the energy entering the system originates from phytoplankton productivity however, in seasonal wetlands emergent macrophytes may make a larger contribution in the energy budget in comparison to permanent wetlands (Godshalk & Wetzel, 1978). The rate of plant litter decomposition, particularly in seasonal wetlands, may therefore provide an indication of the role of nutrient cycling and energy flow within these ecosystems.

2.1.2 What is Decomposition?

The term decomposition has been used widely in literature to describe two different processes : (i) the mechanical disintegration of plant material into a stage where the cell structure is no longer recognisable and, (ii) the metabolism of organic compounds into inorganic forms (Satchell, 1974). Hanlon (1982) provides a useful distinction between litter 'breakdown' (the weight loss resulting from physical fragmentation) and litter 'decomposition' (the degradation of plant material into its constitutive elements by microbial activity and animal digestion). This study is primarily concerned with the mass loss of organic matter from leaf material, but goes beyond mere breakdown as the role of microorganisms and invertebrates are taken into account. As a result of this, the term 'leaf litter processing' is to be used to describe the loss of organic matter from the leaf material.

2.1.3 Sources of Detritus

Detritus, the resource of decomposition, can originate from any non-predatory loss of organic matter from any trophic level (Polunin, 1984). The primary resources are those derived directly from the plant, including litter and soluble matter which may be lost from plants while they are still alive. Secondary resources are provided indirectly, for example by the defecation or death of animals feeding on the litter (Polunin, 1984).

The main primary resources of decomposition are the various types of litter. Far more is known about the input of above ground litter to freshwater detrital systems (Polunin, 1984), being particularly easy to study in areas where litter fall occurs at a single, predictable time of year. The routes by which emergent vegetation contributes to the detrital pool are numerous. Closely adjacent plants may vary substantially in their structure, metabolism and chemical constituents (Polunin, 1984), which may in turn influence the features of their decomposition. Many soluble components are released from the standing above-ground parts of the plant with the onset of senescence. Structural materials remain in the above-ground parts of the plant and will enter the water only when the latter fall (Polunin, 1984). The chemical make up of the litter which is eventually provided to the detrital pool is thus very different from that of the material potentially available when growth has ceased.

Despite most attention being given to primary resources, secondary resources, (that detrital matter derived indirectly from emergent macrophytes) can often be significant in the decomposition process (Polunin, 1984). Nelson, Kadlec & Murkin (1990) observed an array of invertebrates feeding directly on emergent macrophytes, however the grazing of living plants accounted for only a small fraction of net production. The low nutritional quality of the plant material was thought to be an important factor in the low level of this herbivory.

2.1.4 Peat Formation - The Fate of Organic Matter

Fundamental to the terminal stages of the biotic transition from a lake system to a landscape is an accumulation of organic matter in excess of degradation (Wetzel, 1975).

Partially decayed organic matter, mainly of plant origin accumulates in aquatic systems under a wide variety of conditions, oxygen deficiency being the most pronounced. Peat is defined by Plaster (1985) as undecayed or slightly decayed organic soil, formed underwater where low oxygen conditions inhibit decomposition. Peat soils are very light, porous and loose being either alkaline or acid depending on the parent material (Wetzel, 1975).

Organic matter in lake sediments is derived from primary production within the lake ecosystem (autochthonous sources) and also from terrestrial biota (allochthonous sources) by transport of leached and eroded material into the lake (Cranwell, 1976). The littoral zone and its autochthonous production have a significant impact on the metabolism of lake ecosystems (Polunin, 1984). Phytoplankton which contains relatively little structural material is relatively easily decomposed. The fate of this material is primarily rapid conversion to carbon dioxide with a small amount of the more refractory compounds remaining in dissolved and particulate form (Godshalk & Wetzel, 1976). A small fraction of the particulate component remains insoluble sufficiently long to reach sediments. Emergent macrophyte plant material, on the other hand, is characterised by having substantial structural material (cellulose, lignin) occurring in very large particle sizes relative to plankton and having a much lower surface to volume area ratio of particles (Godshalk & Wetzel, 1976). These properties make macrophyte tissue relatively resistant to decomposition and prone to accumulation.

Decomposition is further hampered by the reduced oxygen availability as a result of continuous near saturation or underwater conditions (Plaster, 1985). Oxygen may not diffuse into the system as rapidly as microbial and animal respiration uses it up, resulting in deoxygenation and limiting decomposition and favouring accumulation of organic matter in the sediments (Moss, 1980). The result of these processes is the formation of peat. Successive generations of largely undecomposed organic matter forms layers of peat, in which the low oxygen availability acts as a partial preservative (Brady, 1990). The result is the ability to use peat for scientific purposes as much can be learnt about past vegetation communities, water levels and climate changes from the presence, structure and composition of peats in wetland ecosystems.

2.1.5 Processes of Vascular Plant Breakdown

The process of vascular plant breakdown has been documented by many authors (Cummins, Klug, Wetzel, Petersen, Suberkropp, Manny, Wuycheck & Howard, 1972; Cummins, 1974; Bunn, 1986; Webster & Benfield, 1986; Murkin, 1989; Polunin, 1984; Boulton & Boon, 1991) as generally proceeding in three distinct phases :

1. A rapid and substantial decrease in the initial mass almost immediately due to the leaching of soluble components,
2. Microbial colonisation and decomposition of the litter, termed 'conditioning',
3. Breakdown of coarse litter by mechanical and invertebrate fragmentation.

Dead vascular plant material begins to lose soluble organic and inorganic materials shortly after immersion in water. The general pattern of leaching from immersed leaves is a rapid loss over the first 24 hours followed by a gradual decline for an extended period (Webster & Benfield, 1986). Depending on variables such as water temperature, turbulence and leaf species, leaching can account for 5 - 30 % of the initial mass lost on the first day (Petersen & Cummins, 1974).

The second rapid event is the colonisation of leaf litter by microorganisms, principally bacteria, protozoans and aquatic hyphomycete fungi (Bunn, 1986). A significant proportion of the 'conditioning' by microorganisms is complete within the first one or two weeks, depending on the extent of weathering in the terrestrial community and on water temperature (Cummins, 1974). The consequence of conditioning is an increase in the quality of the detritus as food for invertebrate consumers. The observed increase in protein content of the leaves is associated with an increase in microbial biomass resulting in selective feeding by invertebrates on detritus with a rich microbial flora (Bunn, 1986).

After leaching and microbial conditioning, the leaf litter is broken down by a combination of physical abrasion and feeding by macroinvertebrates. Leaf shredding invertebrates preferentially colonise and feed on microbially conditioned leaves, inadvertently supplying a major source of nutrients to other invertebrate groups (in particular the filterers and collector / gatherers) through their feeding activity (Cummins, Wilzbach, Gates, Perry & Taliaferro, 1989). Where shredders are not abundant in some freshwater systems , the processing of leaf material occurs largely by microbial and physical processes alone (Bunn, 1986).

2.1.6 Environmental Factors Effecting Leaf Litter Processing

The influence of environmental factors including water temperature and pH and oxygen and nutrient concentrations on the pattern and rate of decomposition in aquatic ecosystems has been well documented (see review in Webster & Benfield, 1986).

Many studies, using a variety of leaf types and freshwater habitats, have demonstrated seasonal variation in leaf litter processing with faster breakdown in warmer periods (Petersen & Cummins, 1974; Barlocher & Schweiser, 1983; Short, Smith, Guthrie & Stanford, 1984). These showed that temperature primarily affected microbial processes, with invertebrate feeding less influenced by temperature and sometimes overshadowing temperature effects. There is considerable evidence that leaf breakdown is also slower at low pHs (eg. Benner, Moran & Hodson, 1985). Acidity is influenced by the production of carbon dioxide and the release of hydrogen ions from peaty soils (Polunin, 1984). The effect of low pH on leaf breakdown appears to be indirect, inhibiting microbial organisms and invertebrates through the mobilisation of aluminium and other metals (Webster & Benfield, 1986), thus indirectly affecting leaf breakdown.

As described previously it is generally thought that decomposition occurs more slowly under anaerobic than under aerobic conditions. Reed (1979) found that during summer stratification, leaf breakdown occurred more slowly at a greater depth where levels of dissolved oxygen were low. However, associated with low oxygen concentrations are lower temperatures and the absence of oxygen dependant microorganisms and invertebrates, again highlighting indirect effects upon leaf breakdown. Both environmental conditions such as low temperature and oxygen deficiency and factors intrinsic to the detrital material are conducive to this inefficiency of decomposition (Polunin, 1984). The formation of peaty soils in these environments is evidence that these conditions are indeed hampering the process of decomposition.

Direct comparisons of leaf breakdown in nutrient-poor versus nutrient-rich systems have nearly always demonstrated faster breakdown in nutrient rich systems (Webster & Benfield, 1986). The difference is most often attributed to the availability of nitrogen, with leaf breakdown accelerated by the addition of nitrogen (Meyer & Johnson, 1983). The other commonly studied nutrient is phosphorus, however no acceleration of leaf breakdown was found with higher phosphorus concentrations (Webster & Benfield, 1986).

2.1.7 Leaf Litter Processing and Wetland Water Regimes

As a member of the littoral community, emergent macrophytes in seasonal wetland ecosystems are exposed to a predictable wetting / drying cycle, characterised by winter flooding and summer drawdown. Numerous studies have examined the breakdown of leaf litter, with conclusions divided on the relationship between the extent of leaf processing and the frequency and duration of flooding. Day (1982), Herbst & Reice (1982), Hietz (1984), Polunin (1984) and Bunn (1986) concluded that the rate of breakdown of leaf litter was faster in permanent water. They attributed the more rapid breakdown of submerged leaves to more constant conditions for microbial processes, better access for detritivores, greater nutrient availability and more rapid leaching. However, significant differences in leaf litter processing between continuously inundated leaf litter and litter alternately inundated and exposed were found by Reddy & Patrick (1975), Barlocher *et al* (1978), Day (1983), Briggs & Mayer (1985) and Briggs *et al* (1985). They concluded that predictable seasonal water regimes resulted in increased fungal colonisation and protein concentrations of leaf litter enhancing its attractiveness to invertebrate consumers. As a result, decomposition of leaf litter in seasonal wetland ecosystems was found to be more rapid than in permanently inundated wetlands, stimulated by the alternate wet / dry cycle found in these environments.

Despite the lack of consensus on the rates and patterns of decomposition of leaf litter exposed to differing water regimes, decomposition is still the major process which results in the release of energy and nutrients stored in organic matter into wetland food chains. A proportion of this process is accomplished through both the physical and chemical mechanisms, with the dominant pathway of energy transfer the result of microbial activity and macroinvertebrate digestion.

2.2 THE ROLE OF MICROORGANISMS

2.2.1 The Importance of Microorganisms

Microorganisms are an important link between primary and secondary production in the detrital food chains of aquatic ecosystems. They are responsible for the degradation of plant litter and the alteration of its chemical composition and the provision of a food source for macroinvertebrates (Boulton & Boon, 1991). Colonisation of leaf litter by aquatic microorganisms such as fungi and bacteria has been termed 'conditioning', which results in an increase in the quality of the detritus as a food source for macroinvertebrates (Mason, 1976; Anderson & Seddell ,1979; Webster & Benfield, 1986; Boulton & Boon, 1991). In addition to turning the detritus into a more palatable food source, microorganisms also convert detrital organic matter into their own biomass, a form in which the material is more accessible to macroinvertebrates. The conversion of plant tissue into microbial materials, a form of organic matter that is easily digestible by detritivores is an important component in the breakdown of leaf litter. The microorganisms themselves are of far greater nutritive value to detritivores than the leaf litter alone, as the animals cannot digest leaf material efficiently (Polunin, 1984).

Apart from decomposing the substrate, microorganisms may have many indirect effects on the ecosystem in which they form a part. In areas of poor oxygen supply, such as areas exposed to prolonged flooding, their respiration may lead to a substantial depletion of oxygen and this in turn effects the distribution and abundance of other aquatic organisms (Polunin, 1984). Decomposer microorganisms are also important in the recycling of key nutrients, contributing to the high turnover of available forms of phosphorus and nitrogen which may be important to the macrophytes themselves as well as the organisms living in the littoral community (Polunin, 1984). These microorganisms tend to be far more abundant around emergent macrophyte beds, where the input of organic matter is seasonally predictable, and therefore may constitute an important source of food in the littoral zone (Boulton & Boon, 1991).

Barlocher *et al* (1978) found that in temporary pools, there was a lag time in fresh leaf litter being processed by macroinvertebrates, as they appeared to display a preference for microbially conditioned food. In seasonal wetlands where vegetation is exposed to aerobic drying during the summer and autumn period, an increase in protein content and hence nutritional value associated with an increase in microbial biomass was found to be higher than those found in permanent wetlands (Barlocher *et al*, 1978). Because of the importance of protein in animal nutrition, protein levels that develop in detritus have a far reaching influence on the invertebrates using this detritus as a food source following reflooding. The protein rich detritus in seasonal wetlands would support a much faster growth of animals which is critical if they are to complete their life cycles in this short lived habitat (Barlocher *et al*, 1978).

2.2.2 Microbial Biomass

Determining the viable biomass of a microbial community provides an estimate of the amount of active microorganisms in a particular environment and, therefore, the capability for metabolic transformations in that environment (Vestal & White, 1989).

The extraction and analysis of the phospholipid components of a microbial community is one way to measure its biomass. Previous studies have shown that lipid phosphate is an accurate measure of the microbial biomass under a variety of conditions (White, Davis, Nickels, King and Bobbie, 1979; Vestal & White, 1989). Phospholipids are major lipids in microbial membranes and are not storage products but are turned over relatively rapidly during metabolism and therefore represent the viable biomass (Weete, 1974). The phospholipid content remains relatively constant under stresses compatible with survival in nature (White *et al*, 1979). White *et al* (1979) found in detrital microflora, the extractible lipid phosphate correlated accurately with other measures of microbial biomass such as extractible ATP.

2.3 MACROINVERTEBRATES

2.3.1 Introduction

Seasonal wetlands are characterised by a very high abundance of aquatic invertebrates and low taxonomic diversities (Neckles, Murkin & Cooper, 1990). These community attributes have been observed repeatedly in seasonal wetlands and temporary pools, regardless of physiographic region, season of flooding, substrate type, water chemistry or vegetation cover (Neckles *et al*, 1990). Thus the effects of water regime appear to be paramount in maintaining distinct invertebrate communities in these habitats.

2.3.2 Invertebrate Adaptions to Seasonal Water Regimes

The high abundances of invertebrates found in seasonal wetlands have been attributed to a variety of physical and biological features. Firstly the invertebrates of seasonal wetlands are clearly adapted to cope with the seasonal variations in water level and the resulting chemical changes either by means of their life cycle or behaviour (Pinder, 1986; Balla & Davis, 1993). Many species survive extremes of water level and chemical fluctuation by forming resistant stages such as eggs or embryos, others can survive as adults and yet others migrate as mature flying adults and recolonise the wetland in the next wet season. Second, the drying of wetlands seems to increase the productivity in the flooded areas by regenerating nutrients bound in the aquatic biota (Pinder, 1986; Balla & Davis, 1993).

2.3.3 Nutrient Availability to Aquatic Invertebrates

The most often cited advantage of breeding in a seasonal rather than a permanent water regime is the decaying vegetation in a newly flooded wetland contained more protein than permanently submerged detritus and therefore provides an abundant organic food source (Barlocher *et al*, 1978; Neckles *et al*, 1990; Nelson *et al*, 1990; Balla & Davis, 1993). Many aquatic macroinvertebrates are food generalists and have the capacity to switch to more nutritive substances when they become available, with preferences shown for well conditioned, high quality leaf litter (Cummins, 1973; Cummins *et al*, 1989). As a result of these favourable habitat conditions, invertebrates can respond with rapid population growths upon reflooding. Food quality has been shown to effect growth rates and fat contents, consumption rates and assimilation efficiencies of detritivorous larvae (Gardiner & Davies, 1988; Ward & Cummins, 1979; Nelson *et al*, 1990).

Nutrient release from soil and leaf litter in seasonal wetlands results in net primary productivity being greater in these habitats as compared to permanent ones (Conner & Day, 1976). Anderson & Seddell (1979) and Danell & Sjoberg (1979) found that temporary wetlands have large numbers of detritivores and collector-filterers and the rest of the invertebrate community was directly linked to primary production through the detrital food chain. In this way macroinvertebrates make a significant contribution in the processing of leaf litter through the direct consumption of plant material, microorganisms or providing stimulation for microbial activity (Boulton & Boon, 1991). By digesting large pieces of detritus and producing faeces, macroinvertebrates can provide a renewed substrate for microbial colonisation and in turn, a food source for subsequent trophic levels.

2.3.4 The Influence of Water Regime on Invertebrate Occurrence

Lengthening the period of inundation in seasonal wetlands results in the death of aquatic vegetation, reduces long term plant productivity (Froend *et al*, 1993) and prevents peaks in organic matter availability which occurs after reflooding (Briggs & Mayer, 1985). Marchant (1985) found that invertebrate production is decreased following the loss of emergent vegetation on a seasonal and long term basis. Plant species composition was found by Hanson, Cummins, Barnes & Carter (1984) to influence the composition and size distribution of invertebrate communities within the littoral zone of wetlands.

Alterations to the water regimes in seasonal wetlands may result in lower macrophyte productivity or cause macrophytes to be removed or replaced by invasive species. This may result in irreversible changes to the invertebrate communities within seasonal wetlands and therefore altering the proportion of leaf litter processing in these environments.

SECTION 3

MATERIALS AND METHODS

3.1 LEAF LITTER PROCESSING

3.1.1 Study Site

Lake Jandabup is situated 22 km north of Perth and 3 km east of Wanneroo (Figure 3.1), lying in an interbarrier depression between the Spearwood and Bassendean dune systems (Allen, 1979, Ayre *et al* , 1979). The wetland occupies a broad, shallow (<1.5m deep) oval shaped basin, with an area of 330 ha, of which 134 ha is sedgeland (Allen, 1979; Semeniuk, 1987). The bed of the western half of the wetland is covered with organic sediments, mostly diatomite, while the remainder is covered with fine sands (Allen, 1979). Lake Jandabup lies on the Gnangara Mound receiving inflow of water along its eastern bed. As a broad, shallow wetland it behaves as an evaporative basin with around 90 % of groundwater inflow and rainfall lost through evaporation (Allen, 1979).

The central area of the wetland is an A-Class reserve jointly managed by the Department of Conservation and Land Management (CALM) and the City of Wanneroo, with nearly a third of the surrounding land under freehold title (Davis, Rosich, Bradley, Growns, Schmidt & Cheal, 1993). Extensive areas of fringing vegetation within the freehold land have been cleared for horticulture, grazing and agistment. The littoral zone of the wetland remains largely undisturbed, consisting of vast communities of emergent macrophytes, dominated by *Baumea articulata.*

The littoral vegetation experiences a water regime of summer drying and winter flooding. However, these predictable seasonal changes have been altered by groundwater abstraction for private and public use, adjacent maturing pine plantations and a policy of artificial maintenance of water levels implemented by the Water Authority of Western Australia (WAWA). Combined with decreasing annual rainfall, these factors have led to a steady decline in water levels over the past few decades (Figure 3.2).

The issue of Lake Jandabup or Jandabup Lake is an unresolved one. For the purposes of this study Lake Jandabup is used, as taken from the Metropolitan Street Directory.

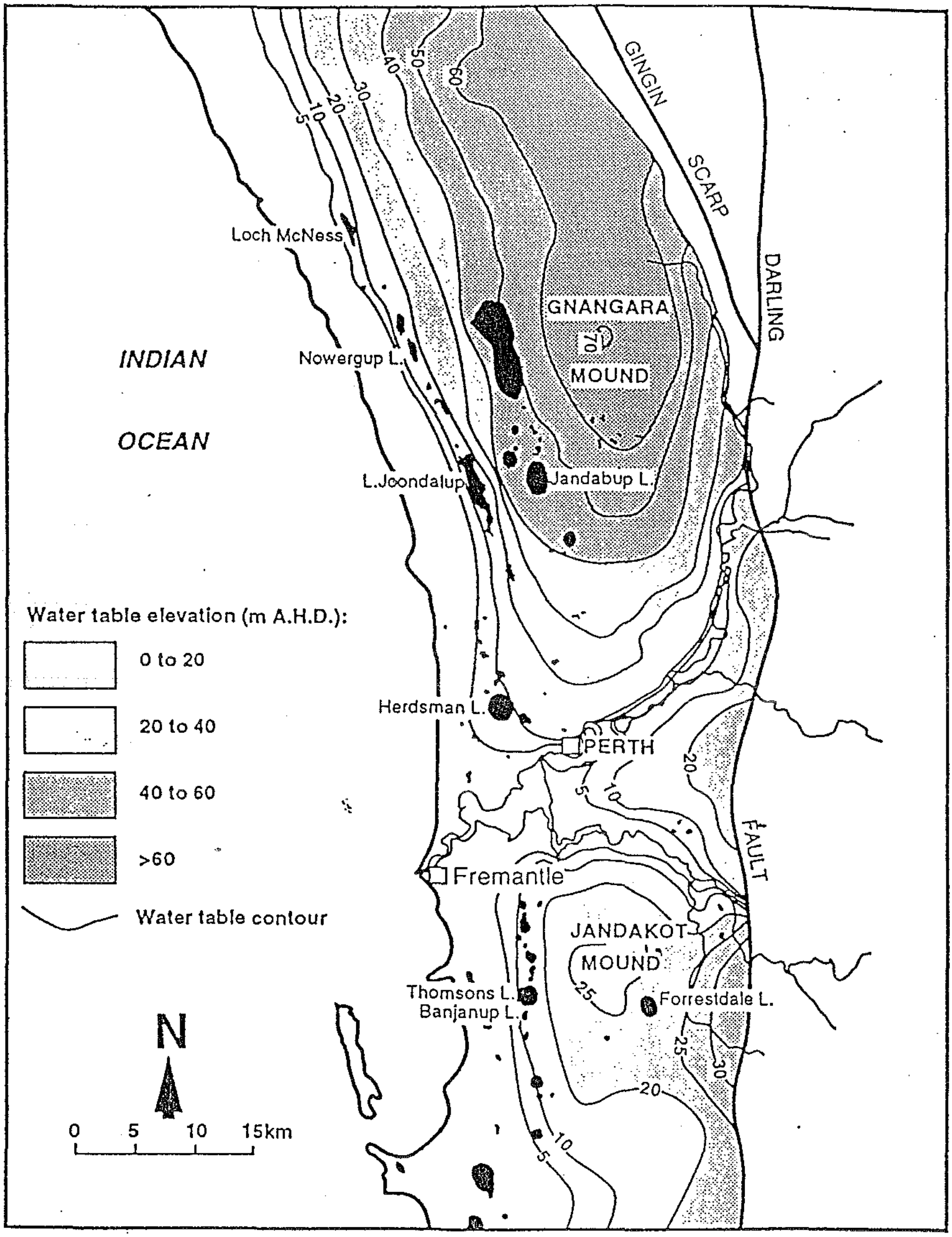


Figure 3.1. The location of Lake Jandabup on the Swan Coastal Plain (Source, Froend *et al*, 1993)

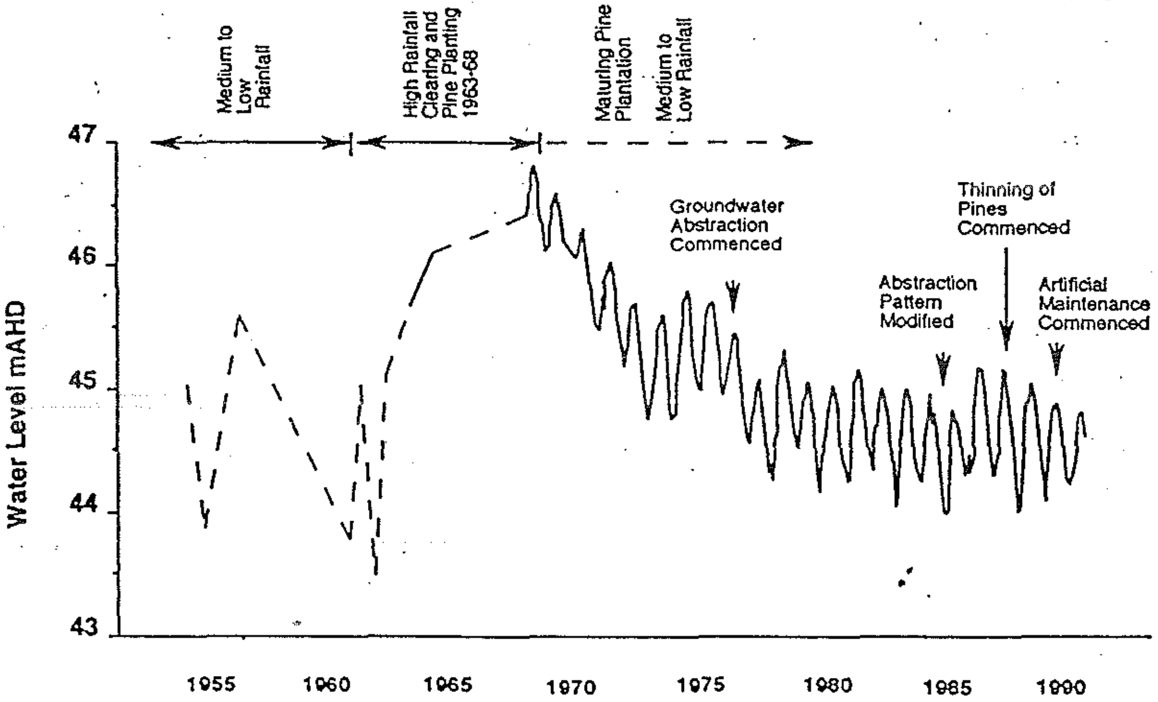


Figure 3.2. A hydrograph showing the long term changes in water levels at Lake Jandabup. (Source, Froend *et al*, 1993)

Artificial maintenance of wetland water to maintain the 'social' and 'environmental' values of the wetland was employed in 1989 and again in 1991 as a result of extreme climatic conditions. (WAWA, 1992). The resulting changes in water levels may adversely effect the distribution and composition of the littoral vegetation through prolonged flooding or exposure.

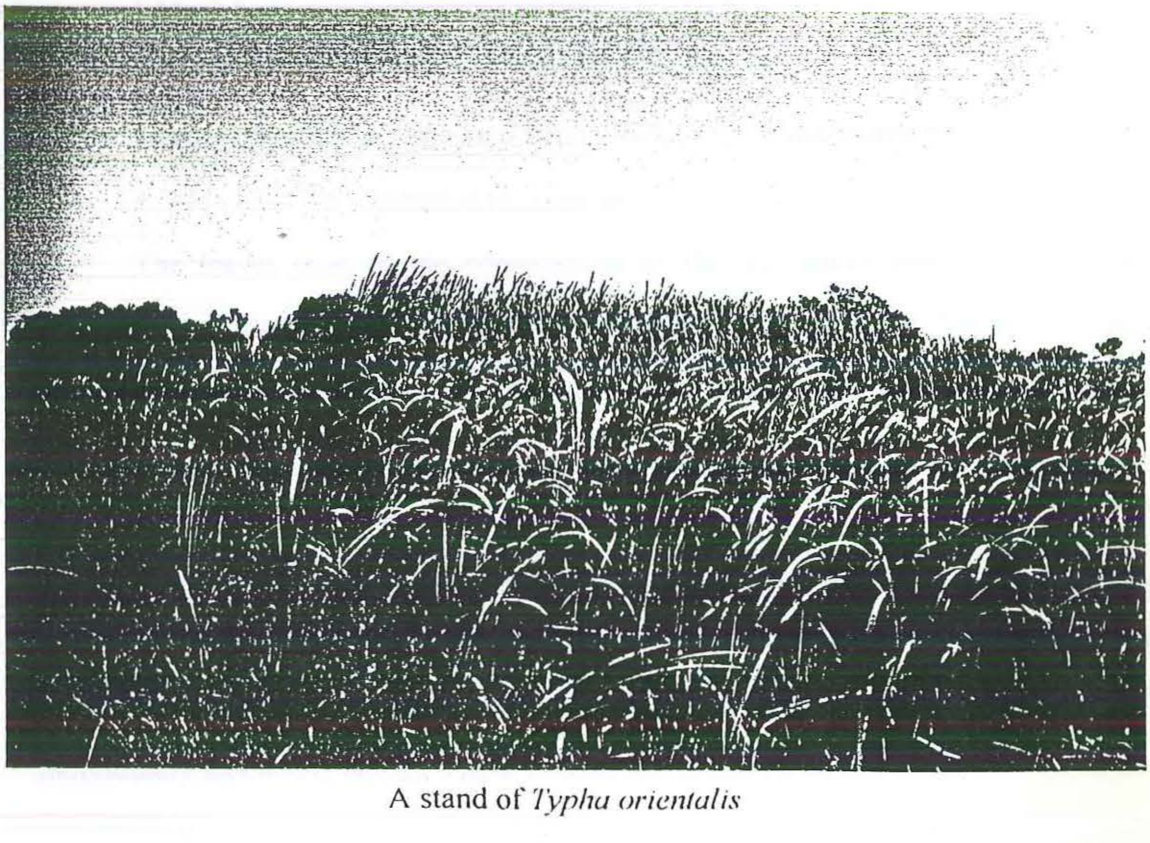
3.1.2 Species Selection

Baumea articulata and *Typha orientalis* are two emergent macrophytes that are common to the winter wet depressions and permanent wetlands of the Swan Coastal Plain (Froend *et al* 1993) (Plate 1). *B.articulata* (jointed twig rush) a native to Western Australia is a large perennial herb (up to 2.5m high) that dominates the littoral communities of many wetlands. Its distribution extends from just north of Perth to the Fitzgerald River National Park, as well as all mainland states except the Northern Territory. Rhizome extension and ramet production are the most common forms of reproduction, although seed germination can be significant during periods of drawdown. Flowering occurs during September to December (Froend *et al*, 1993). *T.orientalis* is similarly a large perennial herb (up to 4.5m high), but has apparently been introduced into Western Australia becoming an aggressive coloniser of disturbed sites. Reproduction is similar to *B.articulata*, with flowering during November to January (Froend *et al*, 1993).

Froend *et al* (1993) found that the two species had similar tolerance ranges to mean water level fluctuations, concluding that prolonged drought or inundation may lead to a reduction in species distribution, creating open areas within the littoral community. The establishment of new species in the littoral zone may lead to dramatic ecosystem changes, especially if the new species is an aggressive coloniser, such as *T.orientalis*.

B.articulata and *T.orientalis* were chosen for use in this experiment for two main reasons. Firstly, *T.orientalis* is an exotic species and an aggressive coloniser capable of displacing *B.articulata*. Froend *et al* (1993) found both species had similar tolerances to water level fluctuations and therefore could compete for the same niche. The difference

A stand of *Baumea articulata*



A stand of *Typha orientalis*

Plate 2

in organic matter processing between the species may give an account of the implications to aquatic food webs if *B.articulata* was displaced. Second, *B.articulata* leaves appear to have a more rigid structure and therefore, may have a higher structural component. This indicates the potential for differences in processing between the two species and a potential for increased peat formation associated with slower decomposition.

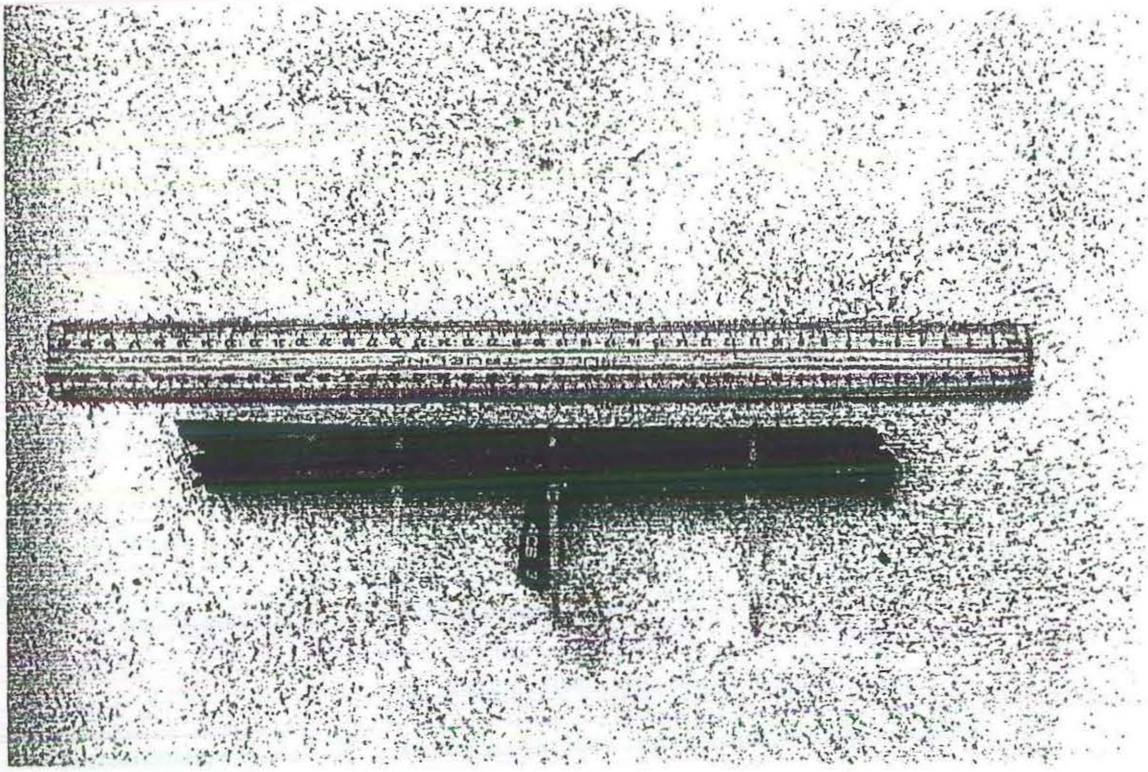
3.1.3 Leaf Pack Design

Two approaches to artificial leaf packs are generally used, the mesh-bag method, in which a quantity of leaf material is enclosed in a mesh bag and the leaf pack method in which leaves are fastened together with monofilament fishing line, plastic buttoners or equivalent (Boulton & Boon, 1991). The use of leaf packs was chosen as the best experimental representative of leaf litter processing for this experiment. Their advantages over mesh bags are numerous and well documented (Boulton & Boon, 1991; Cummins *et al*, 1989; Hanson *et al*, 1984; Webster & Benfield, 1986) and are summarised as :

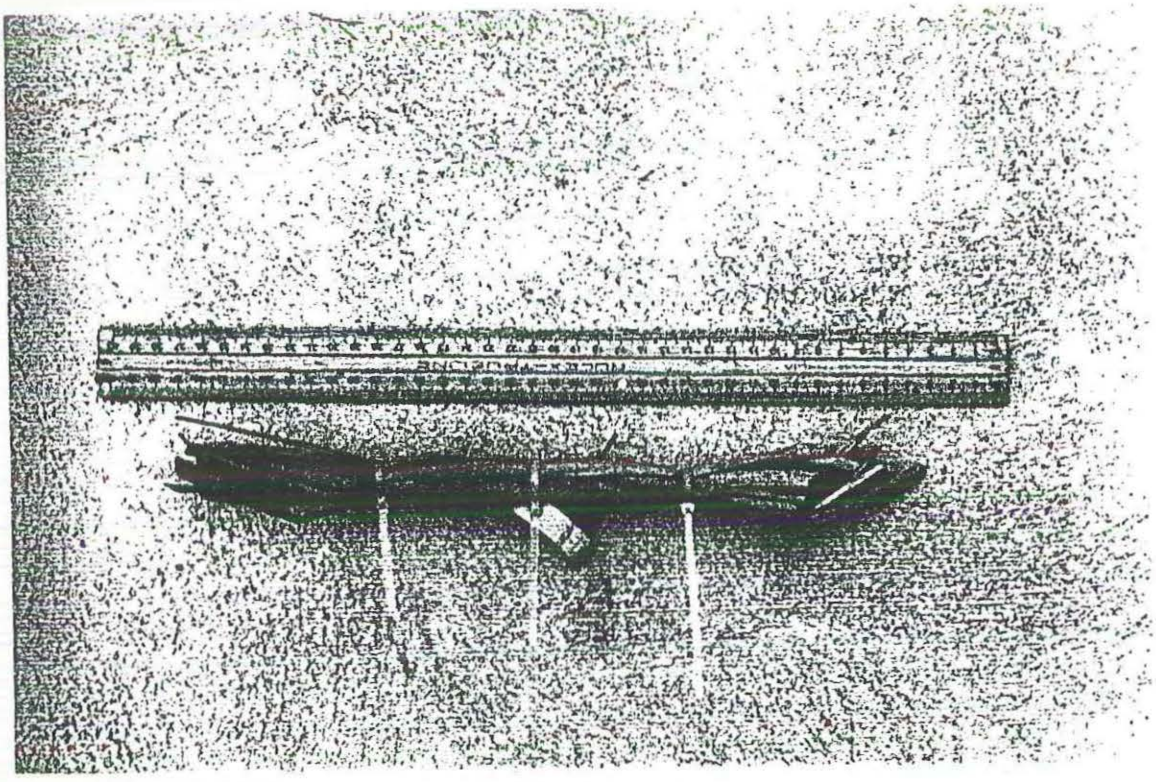
1. Mesh bags can deny access to large shredders,
2. Mesh bags can readily trap detritus,
3. Mesh bags can provide an artificial substrate for macroinvertebrates, and
4. Mesh bags are expensive to construct.

The leaves used in the construction of the leaf packs were harvested on the 16/1/93 from vegetation stands in the north-west corner of Lake Jandabup. The dry, brown leaves collected were cut well above water from plants that were still erect and had not yet fallen into the water.

An individual leaf pack consists of leaf material from *B.articulata* or *T.orientalis.* The leaves were cut into approximately 30cm lengths and made into bundles weighing approximately 10 grams. Each bundle was fastened with three plastic cable ties, weighed to two decimal places on a Sartorius Laboratory L2200 top loading balance and individually labelled (Plate 2). There was no pre-treatment of leaf material.



Baumea articulata leaf pack



Typha orientalis leaf pack

Plate 2

3.1.4 Experimental Design

3.1.4.1 Field Sites

To examine if a difference exists in leaf litter processing under different water regimes, *B.articulata* and *T.orientalis* communities that experience both seasonal and permanent water regimes were located within Lake Jandabup. Vegetation communities considered to experience permanent inundation were located towards the centre of the lake, consistently having water present over the sediments. Seasonally inundated sites were located towards the edge of the lake where the vegetation communities were exposed to aerobic conditions with a drop in the water table over the summer months. This was followed by a rise in the water table in late autumn resulting in the communities being reflooded with water present over the sediments. To examine if different plant communities effect the processing of leaf litter, control sites with no plant community present, experiencing both seasonal and permanent water regimes were also located within the lake. This was done with the use of aerial photographs, vegetation and bathymetric maps and historical water level data.

Figure 3.3 shows the location of the experimental sites within Lake Jandabup, each representing a vegetation community and water regime.

Site 1 - Permanently inundated *B.articulata* stand

Site 2 - Permanently inundated *T.orientalis* stand

Site 3 - Permanently inundated control site (open water)

Site 4 - Seasonally inundated *T.orientalis* stand

Site 5 - Seasonally inundated *B.articulata* stand, and

Site 6 - Seasonally inundated control site (open water)

Lower than expected rainfall over the winter months resulted in insufficient recharge to inundate the leaf packs at sites 5 and 6 after the summer drawdown. As a result of insufficient water levels near the end of the experiment, leaf packs from sites 5 and 6 were carefully moved to areas where inundation was guaranteed to ensure the leaf packs were exposed to a seasonal water regime of flooding/exposure/reflooding.

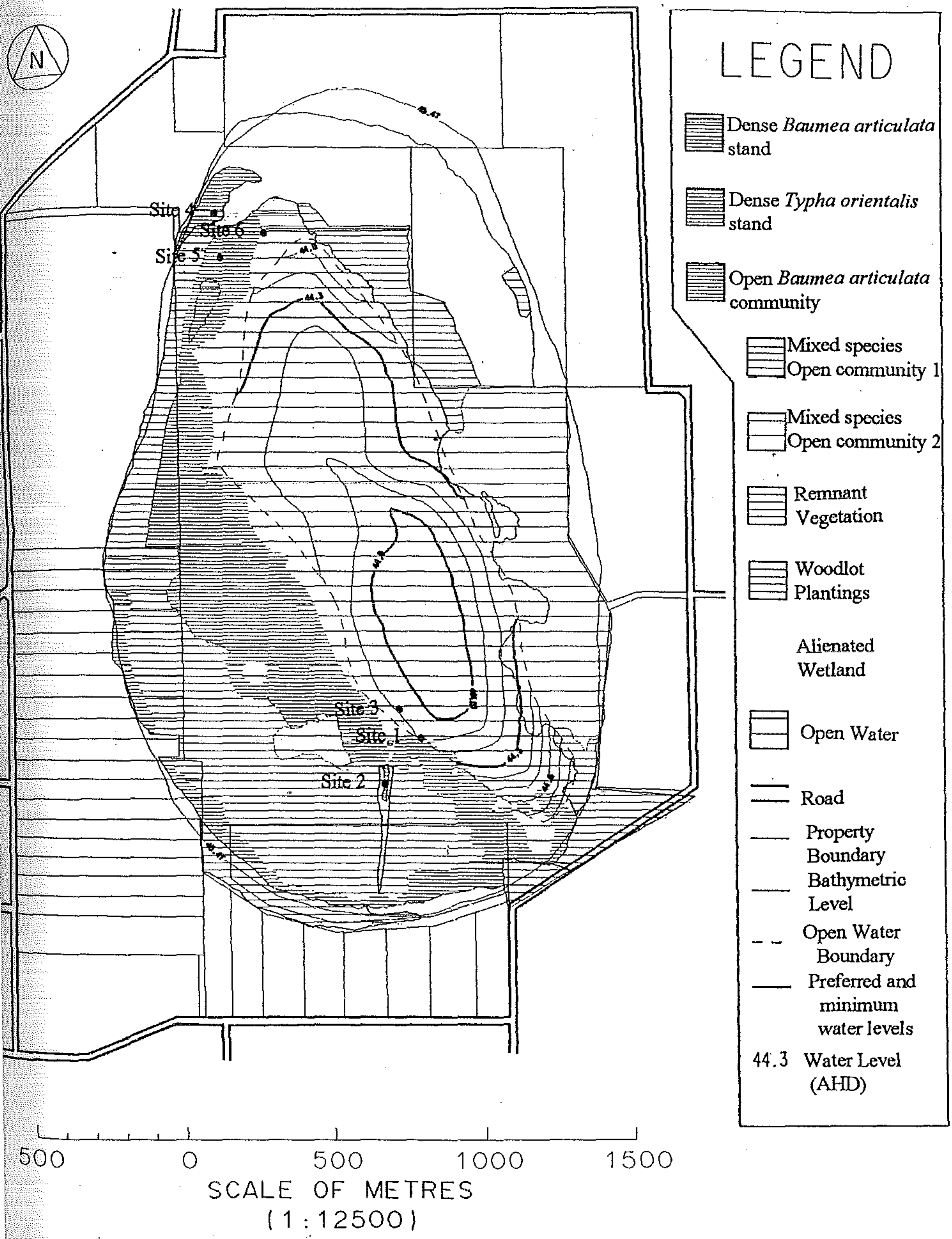


Figure 3.3. The location of the six field sites at Lake Jandabup

Although the leaf packs were relocated they were kept within the same vegetation community as previous time periods.

The experimental design is shown graphically in Figure 3.4. In total 540 leaf packs were constructed for placement in the field sites, 270 of *T.orientalis* and 270 of *B.articulata.* Each of the six field sites contained 90 leaf packs, separated into three independent groups of 15 leaf packs of each species.

6 sites x 2 species x 3 groups x 15 leaf packs = 540 leaf packs

Fifteen randomly chosen leaf packs of the one species were selected and individually tethered to a house brick using monofilament fishing line of sufficient length to allow the leaf packs to float freely. Three replicate bricks each with 15 attached leaf packs of *B.articulata* and *T.orientalis* were randomly placed in each of the field sites. Both species were placed at each site in order to remove any characteristic of the plant community that may influence the processing of its own species of leaf litter.

3.1.4.2 Laboratory treatments

Three separate laboratory treatments were designed to examine the processing of leaf litter under controlled conditions to eliminate the influence of environmental variables, specifically physico-chemical water properties, microbial action and macroinvertebrate feeding. The three treatments are as follows :

Treatment 1-Seasonal inundation : to examine leaf litter processing in a seasonal water regime in the absence of invertebrate feeding and changes to physico-chemical water properties. This treatment was artificially flooded to correspond with the same period of inundation as site 6.

Treatment 2-Permanent inundation : to examine leaf litter processing in a permanent water regime in the absence of invertebrate feeding and changes to physico-chemical water properties.

Treatment 3-Permanent Inundation (Distilled Water) : to examine leaf litter processing in the absence of changes to the physico-chemical water properties, microbial action and macroinvertebrate feeding.

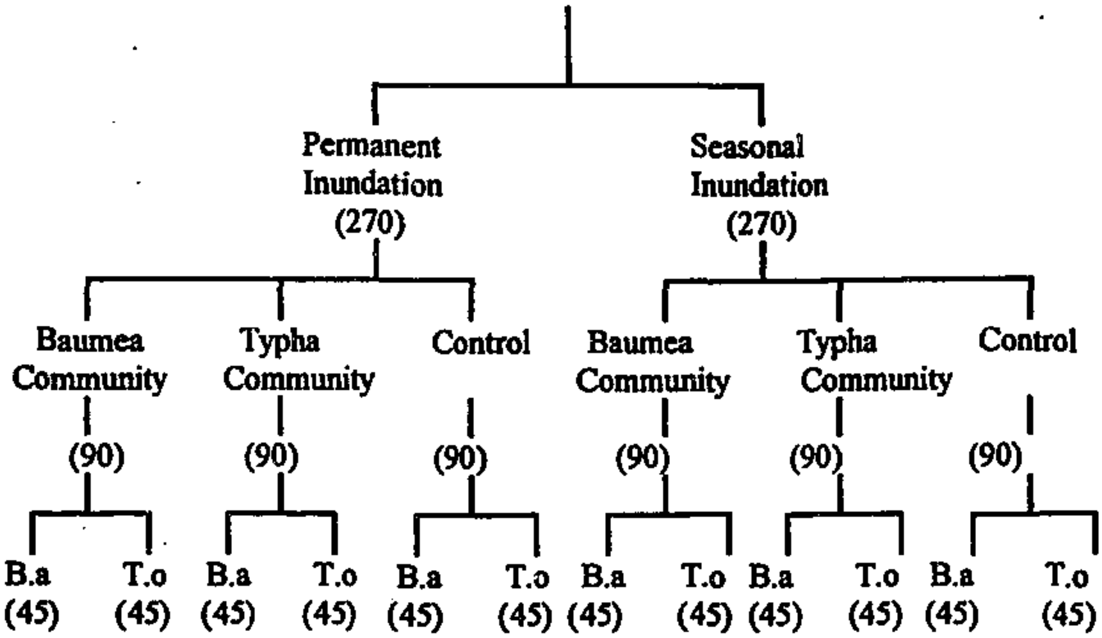


Figure 3.4. A graphical representation of the experimental design. The numbers in brackets represent the number of leaf packs. B.a = *Baumea articulata*, T.o = *Typha orientals*.

The laboratory treatments contain leaf packs identical in design to those placed in the field sites. However, instead of being tethered to bricks, 45 individual leaf packs of each species were placed into separate 30 litre plastic containers. Each one contained the experimental treatment and sterilised lake sediment to a depth of 3cm.

The sediment was collected from the lakes edge, in the north-west corner of Lake Jandabup and sterilised in an Atherton Century Series Autoclave (located at Edith Cowan University Science Department) at 121 degrees Celsius for two hours. The water used in laboratory treatments 1 and 2 was obtained from Lake Jandabup field sites 3 and 6 respectively, and filtered through a 60 µm mesh filter to remove invertebrates before being placed into the treatments.

3.1.5 Recovery and Processing of Samples

Three time periods were chosen in order to examine the processing of leaf litter during different periods of exposure. The time periods were chosen to separate the water regime experienced by the leaf packs in the seasonal sites into flooded, flooded then exposed and flooded, exposed then reflooded.

Time period 1 - Flooded, 17/1/93 to 14/3/93 (8 weeks)

Time period 2 - Flooded then exposed, 17/1/93 to 9/5/93 (16 weeks)

Time period 3 - Flooded, exposed then reflooded, 17/1/93 to 4/7/93 (24weeks)

During each time period, one brick (and 15 attached leaf packs) for each of the species was removed from each site (field and laboratory treatments). 125 µm mesh was placed under each sample as it was removed from the water to collect fauna and leaf pack fragments that might have fallen off during the collection procedure. The fishing line was cut and the 15 leaf packs of each species and site were grouped together, sealed in a plastic bag with the contents of the material trapped by the mesh, placed on ice and returned to the laboratory.

Each sample was opened and the 15 leaf packs and contents of the bag were washed into a white plastic tray. Samples were rinsed with tap water to remove fauna and fine detritus and the contents of the tray passed through a 125 µm mesh filter. The material remaining in the filter was washed into jars, labelled and stored in a solution of 70 % alcohol for later identification. Five leaf packs from each sample were selected, sealed in plastic bags and stored at -20 degrees Celsius for later determination of microbial biomass. The remaining 10 leaf packs were used to quantify the amount of leaf litter processing.

3.1.6 Measurement of Leaf Litter Processing

Upon the removal of invertebrates, the leaf packs were lightly patted with a cloth to remove excess water and individually weighed on a Sartorius Laboratory L2200 top loading balance to achieve a 'wet' weight in grams. Each sample was then placed in a brown paper bag, labelled with species, site and time period and placed in a Contherm Series 5 drying oven (at Edith Cowan University Science Department) at 90 degrees Celsius for 48 hours. Individual leaf packs were then reweighed to achieve a 'dry' weight in grams. A 1 gram 'dry' weight subsample from each leaf pack was used to determine an Ash Free Dry Weight (AFDW). The AFDW was determined by placing the subsample in a pre-weighed crucible and ashing the leaf material at 540 degrees Celsius for one hour in a 'FURNACE' brand muffle furnace (at Edith Cowan University Science Department), the sample removed and reweighed. The resulting AFDW of the sample divided by the initial 'dry' weight gives the fraction of organic matter remaining in the subsample. From this a percentage of organic matter remaining for individual leaf packs was obtained.

In order to work out how much organic matter remained after each period of decomposition, an initial dry weight and a percentage of organic matter was required for each species to determine their values before placement in the field. These values were estimated by obtaining an average from a sample of 30 leaf packs made from the same material as those being placed in the field using the same technique as previously described. The average percentage of organic matter remaining from this sample was used as 100 % organic matter content. This allowed all subsequent values from each time period to take into account the initial differences in the amount of organic matter present between the two species.

3.1.7 Data Analysis

The percentage of organic matter remaining at the end of each time period was used to determine if differences in leaf litter processing within and between sites were significant. The percentage organic matter remaining data were transformed to arcsin values (Zar, 1974) for use in an Analysis of Variance (ANOVA) using the SPSS for Windows statistical package.

3.1.7.1 Field sites

For each time period three factors, species (*B.articulata* and *T.orientalis*), water regime (permanent and seasonal inundation) and vegetation community (*B.articulata* stand, *T.orientalis* stand and open water) were used in a three factor ANOVA with organic matter remaining (transformed raw data) as the dependant variable. For each time period the following null hypotheses were generated :

Main Effects

1.There is no difference in the organic matter remaining for *B.articulata* leaf packs compared to leaf packs of *T.orientalis.*

2.There is no difference in the organic matter remaining in leaf packs between those found in *B.articulata* communities, *T.orientalis* communities and no vegetation community (open water)

3.There is no difference in the organic matter remaining in leaf packs between those sites that are permanently inundated and the seasonally inundated sites.

2-way Interactions

4.The difference in the organic matter remaining in leaf packs among the two species is independent of the three different community types.

5.The difference in the organic matter remaining in leaf packs among the two species is independent of the water regime they are exposed to.

6.The difference in organic matter remaining in leaf packs among the three different community types is independent of the water regime they are exposed to.

3-way Interactions

7.The difference in the organic matter remaining in leaf packs among the two species (or community type or water regime) is independent of the other two.

3.1.7.2 Laboratory treatments

In treatments 1 and 2 for each time period two factors, species (*B.articulata* and *T.orientalis*) and water regime (permanent and seasonal inundation) were used in a two factor ANOVA as above, generating the following null hypotheses :

Main effects

8.There is no difference in the organic matter remaining for *B.articulata* leaf packs compared to leaf packs of *T.orientalis.*

9.There is no difference in the organic matter remaining in leaf packs between the permanently inundated treatment and seasonally inundated treatment.

2-way Interactions

10.The difference in organic matter remaining in leaf packs among the two species is independent of water regime they are exposed to.

For laboratory treatment 3 one factor, species (*B.articulata* or *T.orientalis*) was used in a single factor ANOVA as above, the following null hypothesis :

11.There is no difference in the organic matter remaining for *B.articulata* leaf packs compared to leaf packs of *T.orientalis* in the absence of physico-chemical water properties, microbial action and macroinvertebrate feeding.

3.1.8 Soil Samples

Soil core samples to a depth of 15cm were taken from each of the six field sites on 4/7/93 using a 30cm soil corer with a diameter of 3cm. The samples were sealed in plastic bags and transported to the laboratory.

To determine the percentage of organic material in the soil, Loss On Ignition (LOI), each sample was placed in a pre-weighed crucible and dried in a Contherm Series 5 drying oven at 90 degrees Celsius for 12 hours and weighed to achieve a 'dry' weight. The samples were placed in a 'FURNACE' brand muffle furnace at 540 degrees Celsius for two hours and reweighed to obtain an AFDW. The AFDW of the sample divided by the 'dry' weight gives the fraction of organic material in the sample, from which a percentage of organic matter in each sample can be calculated (LOI).

3.1.9 Physico-Chemical Characteristics of the Water Column

Physico-chemical properties were recorded on site from both the top and bottom of the water column. Readings from permanently inundated sites were taken from the edge of a canoe so as not to disturb the sediment. However, in order to get to the sites within the vegetation communities, the emergent vegetation was disturbed. Readings from seasonally inundated sites were taken by wading through the different sites as carefully as possible, and placing the probe in the water one meter in front. The top reading was taken from approximately 5cm below the water surface and the bottom reading immediately above the sediment - water interface. The following parameters were recorded on field data sheets on a bi-weekly basis from 17/1/93 to 4/7/93 using the following equipment

- Dissolved Oxygen Percentage and mg/L and Temperature - *Wissenshaftlich Technishe Werkstatten* (WTW) Portable Microprocessor Oximeter, Oxi 96 using a EO - 96 probe
- pH - Hanna Instruments Portable HI 9025C Microcomputer pH meter
- Conductivity - WTW Portable Conductivity Meter LF 95 / Set 1 using a Tetracon 96 probe (converted to K20 values using Wiggins 1983)
- Redox - WTW Portable Microprocessor pH Meter - pH 95 / Set 1 using a Redox Ingold Electrode Pt 4805-57

To maintain consistency in the data, the physico-chemical properties were measured at the same point within each site and at the same time of day throughout the experiment. Site 1-10.00am, site 2-10.30am ,site 3-10.15am, site 4-11.15am, site 5-11.45am and site 6-11.30am.

Physico-chemical water characteristics by definition are diurnally variable. To determine the diurnal fluctuations of these properties within the major vegetation communities, sampling over a 24 hour period with two hourly intervals was undertaken on 20/3/93 at sites 1,2 and 3. This time of year was chosen as it represented a period that would experience maximum variation in many of the characteristics being measured due to high maximum temperatures. Sampling procedures were the same as those previously described.

Measures of soluble humic colour (gilvin) were obtained from water samples taken at the beginning of the experiment and from samples taken at the end of each time period at each of the six sites. Samples were taken from the top of the water column and stored in 500 ml plastic containers or glass jars. A 100ml water sample was passed through a Sartorius 0.22µm membrane filter using a filter tower and vacuum flask. The filtrate was measured for absorbance at 440 nm using a Hach DR 2000 Spectrophotometer. Gilvin (abs/m) can be calculated using the following formula (after Kirk, 1986) :

Absorbance at 440nm x Cell pathlength of the spectrophotometer (converted to a 1m pathlength) x 2.303

The same physico-chemical properties were recorded for the three laboratory treatments on the first and final days of the experiment using the methods described.

3.1.10 Miscellaneous

The following variables were recorded on field data sheets with the physico-chemical properties for the bi-weekly and 24 hour monitoring periods :

Water depth at each site

AHD level (Australian Height Datum) for Lake Jandabup from the markers in the south east corner of the lake

Portion of the leaf packs exposed / submerged / floating

General weather conditions (including ambient air temperature, estimated current wind strength and direction)

3.2 MICROBIAL BIOMASS

3.2.1 Lipid Extraction

The procedure of White *et al* (1979) was modified to extract large amounts of plant tissue. The major advantages of this method are that much smaller amounts of solvents are required and less non-lipid material is retained in the extract.

Fifty grams of wet tissue (10 g from each of the 5 leaf packs) containing an estimated water content of 80 % was placed in a glass blender with 50 ml of chloroform and 100 ml of anhydrous methanol and homogenised for four minutes. The mixture was filtered through a Bûchner funnel with fast grade (Whatman # 4) filter paper. The residue was re-homogenised with 25 ml of chloroform and 50 ml of anhydrous methanol and re-filtered. The filtrates were combined and transferred to a 500 ml graduated cylinder. At this stage the solution should have been in a single phase. Fifty ml of 0.88 % Potassium Chloride in distilled water was added to the graduated cylinder, the solution stirred and allowed to settle for 30 minutes. The resulting solution should be bi-phasal with an intermediate 'residue' containing phase sometimes present. The volumes in this procedure can be changed so long as the proportions of water : methanol : chloroform are 0.8 : 2 : 1 (v/v) for the single phase solution are maintained. The upper non-lipid containing phase and intermediate layer were removed by aspiration. The remaining lower phase containing the lipids was passed through a Bûchner funnel with fast grade filter paper and the filtrate placed in a rotary evaporator to remove the solvents before storage. The volume of each sample was recorded before being placed in a glass container cleaned with dilute HCl solution and rinsed with distilled water before being air dried, and stored in a small volume of chloroform at +4 degrees Celsius.

3.2.2 Phospholipid Analysis

Lipid samples were analysed for Total Phosphorus using a Hach DR 2000 Spectrophotometer following standard procedures for Total Phosphorus and Reactive Phosphorus (0 - 2.5 mg/L P) as outlined in the Hach DR 2000 Spectrophotometer Handbook (1989). The results were recorded in mg/L P.

Sample sizes were generally 2ml or less and were made up to 25 ml using deionised water for analysis with the Hach meter. The Hach DR 2000 Spectrophotometer handbook (1991) states that phosphorus levels obtained using the powder pillows are proportional to their dilution. The following formula was used to standardise results.

$$\frac{\text{Sample Volume}}{\text{Volume of Hach sample (25 ml)}} \quad \times \quad \text{Result (mg/L P)}$$

To determine the phospholipid content of *B.articulata* and *T.orientalis* leaf material prior to its placement in the field, five untreated leaf packs and five leaf packs treated with Benlate fungicide of each species were analysed using the procedure described.

3.3 MACROINVERTEBRATES

3.3.1 Invertebrate Sorting and Identification

Grouped samples were collected and stored using the procedure described in section 3.1.5. Stored samples were sorted using a dissecting microscope and identified to the lowest taxonomic level possible using Williams (1980) and a reference collection stored at Edith Cowan University Science Department. The number of taxa found in each sample (species richness) and the number of individuals of each species to a maximum of 100 (total abundance) were recorded.

Individual taxa were assigned to functional feeding groups as described in Cummins (1973). Cummins (1973) produced one of many classification systems by using a combination of food categories and feeding mechanisms. Organisation on the basis of the general types of feeding mechanisms associates each type with a broad food category. For instance : shredders - vascular plant tissue, collectors - detrital particles, scrapers - attached algae and predators - live prey. The compartmentalisation of feeding and food types, particularly when such partitioning reflects the source of food is useful in determining the different roles of macroinvertebrates colonising leaf packs. The classification of all non-predacious aquatic insects as herbivores may obscure the role of the detrital food chain present in most freshwater ecosystems. Where taxa could be assigned to more than one group, additional relevant literature was used to determine their dominant method of food processing. This data was plotted with total abundance data for each time period to examine the food habits of macroinvertebrate communities inhabiting the leaf litter in different stages of decay.

3.3.2 Data Analysis

Relative abundance data was classified using the polythetic divisive computer programme, Two-way indicator species analysis (TWINSPAN) (Kent & Coker,1993) using abundance classes 0,1,10,50,100 as cut levels. Cut levels are used in the grouping of invertebrates by treating each abundance category of each species as a potential indicator (ie a 'pseudospecies'). Relative abundance data was used instead of presence/absence as the relative abundance of certain species varied considerably.

SECTION 4

RESULTS

4.1 LEAF LITTER PROCESSING

4.1.1 Field Sites

4.1.1.1 Introduction

The initial analysis to determine the organic matter content of the leaf material prior to its placement in the field determined that *B.articulata* had a lower organic matter content on average than *T.orientalis* leaf material, as shown in Table 4.1.(*Baumea* and *Typha* representing *B.articluata* and *T.orientalis* respectively will be used in the preceding sections). On average *Baumea* leaves had an organic matter content of 96.39 % compared to 97.92 % found in *Typha* leaves. This data supports the hypothesis that *Baumea* leaves have a higher structural component and therefore the potential to decompose at a slower rate.

The average wet weights and dry weights of the leaf packs are shown in Figures 4.1 and 4.2 respectively. All wet weight, dry weight and organic matter remaining for leaf packs raw data including means and standard deviations are in Appendix 1. *Typha* leaf packs had consistently higher average wet weights than *Baumea* leaf packs in all sites and over each time period. The greatest increase in average wet weight was in *Typha* leaf packs in site 3, an increase of 826 % on initial wet weight, the greatest average increase in *Baumea* leaf packs was 625% in site 2. In the permanently inundated sites, the difference in average wet weight between species became progressively lower as the experiment proceeded, due to a decrease in average *Typha* wet weights and a corresponding increase in average *Baumea* wet weights. In the case of site 3, the difference in average wet weight between species was negligible by the end of the third period.

The average wet weight of leaf packs in the seasonally inundated sites was very low compared to the permanently inundated sites with no difference between the species in the first two time periods as there was no water present in any of the seasonal sites during this period. Following the reflooding of seasonal sites in the third time period,

Baumea articulata

LEAF PACK #	DAY 0 Wet Wt	DAY 0 Dry Wt	WET/DRY DIFF	DAY 0 AFDW	DAY 0 OM% rem.
1	6.60	6.28	0.32	0.052	94.80
2	9.61	9.14	0.47	0.059	94.10
3	9.22	8.56	0.66	0.032	96.80
4	10.52	9.98	0.54	0.032	96.80
5	10.92	10.37	0.55	0.031	96.90
6	10.38	9.89	0.49	0.030	97.00
7	13.67	12.89	0.78	0.049	95.10
8	11.56	10.95	0.61	0.043	95.70
9	11.57	10.96	0.61	0.050	95.00
10	7.16	6.78	0.38	0.022	97.80
11	7.57	7.18	0.39	0.042	95.80
12	6.66	6.31	0.35	0.054	94.60
13	9.64	9.15	0.49	0.039	96.10
14	9.23	8.73	0.50	0.028	97.20
15	7.74	7.40	0.34	0.025	97.50
16	13.14	12.63	0.51	0.042	95.80
17	11.52	10.98	0.54	0.031	96.90
18	7.61	7.18	0.43	0.039	96.10
19	9.25	8.73	0.52	0.025	97.50
20	6.65	6.06	0.59	0.039	96.10
21	9.22	8.58	0.64	0.035	96.50
22	7.74	7.21	0.53	0.023	97.70
23	11.87	11.49	0.38	0.021	97.90
24	6.86	6.29	0.57	0.033	96.70
25	8.52	7.98	0.54	0.032	96.80
26	8.93	8.46	0.47	0.036	96.40
27	11.25	10.71	0.54	0.028	97.20
28	9.62	9.29	0.33	0.035	96.50
29	6.54	6.20	0.34	0.028	97.20
30	7.08	6.79	0.29	0.048	95.20
Total	277.85	263.15	14.70	1.083	2891.70
Mean	9.26	8.77	0.49	0.036	96.39
St. Dev	2.04	1.98	0.12	0.010	1.01

Typha orientalis

LEAF PACK #	DAY 0 Wet Wt	DAY 0 Dry Wt	WET/DRY DIFF	DAY 0 AFDW	DAY 0 OM% rem.
1	7.93	7.13	0.80	0.035	96.50
2	8.62	8.01	0.61	0.024	97.60
3	8.20	7.48	0.72	0.053	94.70
4	9.58	9.01	0.57	0.019	98.10
5	8.51	7.99	0.52	0.018	98.20
6	8.82	8.13	0.69	0.018	98.20
7	6.36	5.84	0.52	0.015	98.50
8	8.24	7.66	0.58	0.018	98.20
9	8.50	7.76	0.74	0.024	97.60
10	6.11	5.84	0.27	0.017	98.30
11	6.47	6.03	0.44	0.022	97.80
12	9.22	8.28	0.94	0.011	98.90
13	6.56	6.18	0.38	0.010	99.00
14	7.49	7.05	0.44	0.015	98.50
15	6.07	5.79	0.28	0.016	98.40
16	9.02	8.42	0.60	0.018	98.20
17	6.38	5.91	0.47	0.018	98.20
18	5.99	5.62	0.37	0.023	97.70
19	8.24	7.51	0.73	0.012	98.80
20	6.67	6.04	0.63	0.018	98.20
21	7.23	6.71	0.52	0.023	97.70
22	7.84	7.09	0.75	0.018	98.20
23	8.56	8.11	0.45	0.018	98.20
24	7.97	7.48	0.49	0.039	96.10
25	6.08	5.39	0.69	0.017	98.30
26	6.39	5.92	0.47	0.013	98.70
27	8.74	8.24	0.50	0.021	97.90
28	8.29	7.80	0.49	0.024	97.60
29	9.04	8.51	0.53	0.018	98.20
30	6.87	6.27	0.60	0.029	97.10
Total	229.59	213.20	16.79	0.624	2937.60
Mean	7.67	7.11	0.56	0.021	97.92
St. Dev	1.13	1.05	0.15	0.009	0.88

Table 4.1. The data used in determining the estimated dry weight and organic matter content of leaf packs prior to their placement in the field.

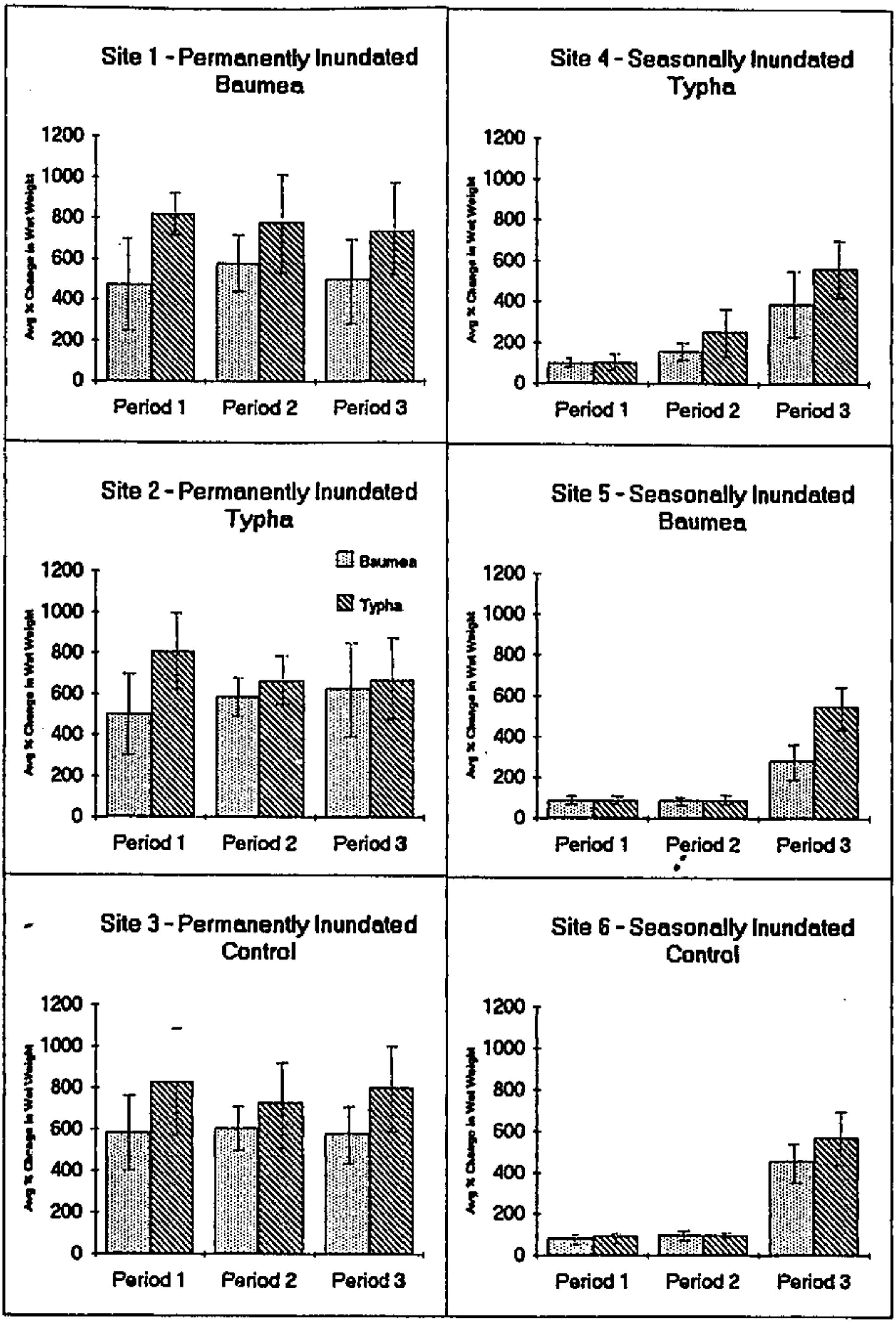


Figure 4.1. Average percent increase in wet weight for *Baumea* and *Typha* leaf packs from sites 1 to 6.

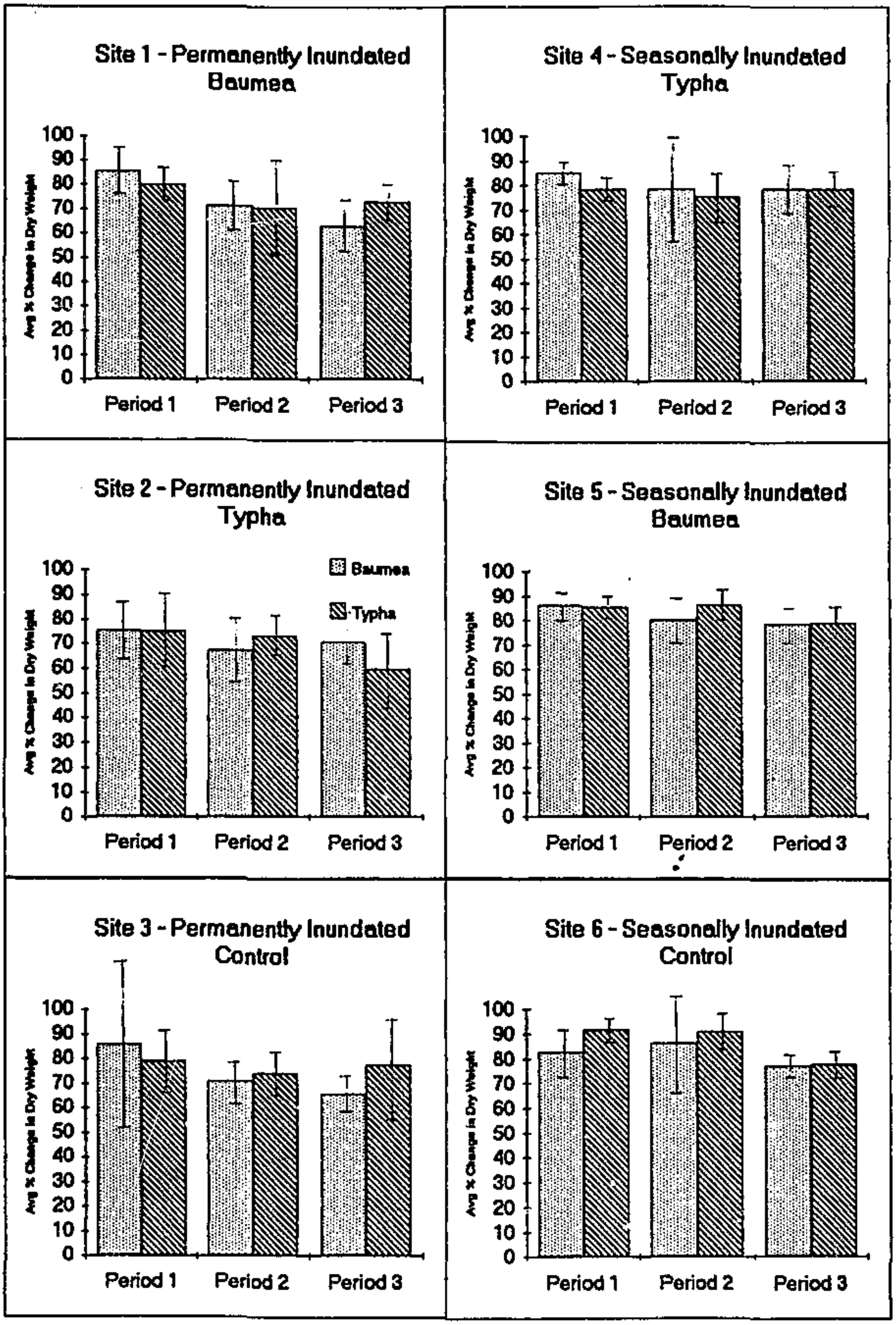


Figure 4.2. Average percent change in dry weight for *Baumea* and *Typha* leaf packs from sites 1 to 6.

Typha leaf packs again had much higher average wet weights than *Baumea* leaf packs, as in the case of site 5 where the difference was almost double.

In the case of dry weights, water regime was the only factor that produced results which were consistent over all of the sites. Permanently inundated sites demonstrated a higher average loss of dry weight over the three periods than the seasonally inundated sites. The greatest average loss of mass for both *Baumea* and *Typha* leaf packs was 37.2 % in sites 1 and 2 respectively.

These results do not bear any relationship to the loss of organic matter, from leaf packs and are not used in determining the amounts of leaf litter processing. Therefore they will not be used in any of the statistical analyses.

4.1.1.2 Organic Matter Loss - Water Regime

The patterns and amounts of leaf litter processing between permanently inundated sites and seasonally inundated sites are shown in Figure 4.3. No difference in the loss of organic matter from leaf packs was found in the first time period when the leaf packs in both water regimes were inundated. Table 4.2 shows the results of theANOVABy the end of the second period when the leaf packs at seasonal sites were exposed to aerobic conditions, a significant difference ($P<0.001$) between the loss of organic matter in leaf packs at the two water regimes emerged. This significant difference in organic matter loss between water regimes continued to the end of the experiment when the leaf packs at seasonal sites had been exposed to a seasonal wet/dry hydrological cycle.

The pattern of leaf pack processing and the low amount of organic matter loss from leaf packs was consistent in all three permanently inundated sites. An initial loss of less than 5 % in the first period was found at all field sites for both species. In both species and in all permanently inundated sites there was an increase in the organic matter content of leaf packs from the second to third time period. A potential source of additional organic matter to leaf packs are microorganisms. An increase in the microbial biomass greater than the loss of organic matter from the initial leaf material may result in a rise in the organic matter content of leaf packs in these environments. Of the three

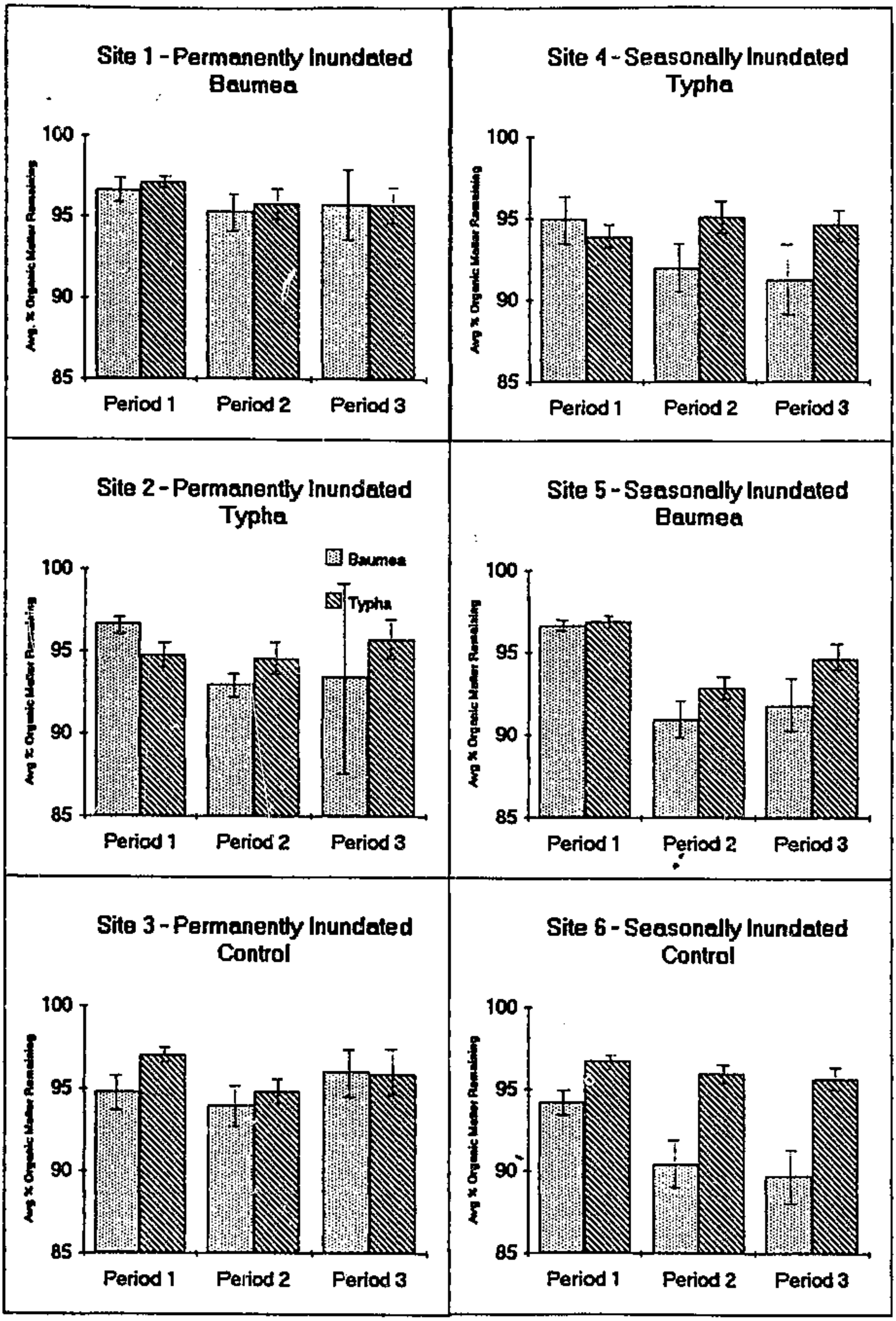


Figure 4.3. Average organic matter content of *Baumea* and *Typha* leaf packs from sites 1 to 6.

TIME PERIOD 1

Source of Variation	Degrees of Freedom	F value	Significance of F
Main Effects			
SPECIES	1	0.219	N/S
INUNDATION	1	0.344	N/S
VEGETATION COMMUNITY	2	7.141	###
2-Way Interactions			
SPECIES x INUNDATION	1	10.839	###
SPECIES x VEG. COMMUNITY	2	31.694	###
INUNDATION x VEG. COMMUNITY	2	12.884	###
3-Way Interactions			
SPECIES x INUNDATION x VEG. COMMUNITY	2	3.478	#

TIME PERIOD 2

Source of Variation	Degrees of Freedom	F value	Significance of F
Main Effects			
SPECIES	1	59.137	###
INUNDATION	1	34.549	###
VEGETATION COMMUNITY	2	0.333	N/S
2-Way Interactions			
SPECIES x INUNDATION	1	17.339	###
SPECIES x VEG. COMMUNITY	2	4.154	#
INUNDATION x VEG. COMMUNITY	2	17.339	###
3-Way Interactions			
SPECIES x INUNDATION x VEG. COMMUNITY	2	3.663	#

TIME PERIOD 3

Source of Variation	Degrees of Freedom	F value	Significance of F
Main Effects			
SPECIES	1	19.271	###
INUNDATION	1	66.841	###
VEGETATION COMMUNITY	2	0.092	N/S
2-Way Interactions			
SPECIES x INUNDATION	1	28.761	###
SPECIES x VEG. COMMUNITY	2	1.824	N/S
INUNDATION x VEG. COMMUNITY	2	0.266	N/S
3-Way Interactions			
SPECIES x INUNDATION x VEG. COMMUNITY	2	3.478	N/S

N/S - Not Significant
- $P < 0.05$ (significant)
- $P < 0.01$ (highly significant)
- $P < 0.001$ (very highly significant)

Table 4.2 ANOVA results for the percentage of organic matter remaining in leaf packs after each time period for sites 1 to 6.

permanently inundated sites, site 2 had the highest combined loss of organic matter from both species of leaf packs of 5.5 % by the end of the third period.

Patterns of organic matter loss from leaf packs in seasonally inundated sites were not as distinct. *Baumea* leaf packs generally exhibited constant losses of organic matter over each of the time periods, resulting in these leaf packs having substantially higher losses of organic matter compared to those of the same species in the field. *Typha* leaf packs in seasonal sites did not exhibit any patterns of organic matter loss similar to all three sites. Overall, the loss of organic matter from leaf packs at sites 4 and 6 remained relatively constant at around 5 % throughout the length of the experiment.

Both *Baumea* and *Typha* leaf packs at site 5 followed the pattern of organic matter loss experienced by the permanently inundated sites with an increase in organic matter content of leaf packs from the second to third periods. This suggests that as was the case in the permanently inundated sites, microbial biomass may be effecting the organic matter content of leaf packs.

Site 6 (seasonally inundated control) had the highest combined loss of organic matter from both species of leaf pack of 7.6 % by the end of the third period. Following exposure to their respective water regimes, the leaf packs in the seasonally inundated sites had higher losses of organic matter from leaf packs, indicating the benefit of aerobic conditions to leaf litter processing.

4.1.1.3 Organic Matter Loss - Species Differences

Similar trends were apparent when examining the difference in the amount of leaf litter processing between the two species of leaf pack, *Baumea* and *Typha*. The first time period revealed no difference in the amount of organic matter loss between the two species. By the end of the second period when the difference in water regime was apparent, a significant difference ($P<0.001$) between species was evident. As with the difference between water regimes, the significant difference of organic matter loss between *Baumea* and *Typha* leaf packs continued to the end of the third period when the leaf packs had been exposed to the seasonal hydrological cycle.

The difference in the loss of organic matter between *Baumea* and *Typha* leaf packs was more pronounced in the seasonally inundated sites than in the permanently inundated sites suggesting that the exposure to seasonal wetting and drying favours the processing of *Baumea*. Permanently inundated sites 1 and 3 show *Baumea* leaf packs with higher losses of organic matter in the first two periods, with a negligible difference in the final time period. Site 2, possessing the highest overall loss of organic matter, showed *Typha* leaf packs with the higher initial loss, with *Baumea* leaf packs reversing this for the second and final periods, with the greatest difference being in the latter period.

Baumea leaf packs in the three seasonal sites consistently demonstrated greater losses of organic matter than *Typha* leaf packs in the same site and the same time period, the difference becoming progressively greater with increased length of exposure. An initial analysis of the two species found *Baumea* to have a more rigid structure and therefore more resistant to decay. These results are contrary to those expected, suggesting other factors, such as leaf pack design may be altering the loss of organic matter from leaf packs.

4.1.1.4 Organic Matter Loss - Vegetation Community Differences

Leaf packs in the three vegetation communities (*B.articulata, T.orientalis* and no vegetation community) did not follow the same patterns of organic matter loss displayed by the previous two factors. By the end of the first time period, with the leaf packs in the water for only eight weeks, there was a significant difference ($P<0.001$) in the loss of organic matter between the three sites. However, at the end of the second and third time periods, the difference in the amount of organic matter loss from leaf packs between the vegetation communities was no longer significant.

Within the first time period where the vegetation community was shown to be the only factor displaying a significant difference in the processing of leaf packs, the leaf packs in the *Typha* community had the highest loss of organic matter, 4.5 %, the control site next with a 4.3 % loss and the *Baumea* community the slowest to process leaf litter with an average loss of only 3.2 % at the end of the first period. Although not statistically significant, the leaf packs in the *Typha* community exhibited higher losses of organic matter than those in *Baumea* communities throughout the experiment. This suggests that each of these communities may possess intrinsic characteristics that influence the amount of leaf litter processing.

4.1.1.5 Organic Matter Loss - Combined Effects.

The significance of the 3-way interactions ($P<0.05$), and therefore all 2 way interactions between species, inundation and vegetation community in the first and second periods demonstrates that despite some factors being not significant as main effects, the combined influence on decomposition from the interaction of factors is present in the first sixteen weeks.

In the final period of the experiment theANOVA main effects again showed species and inundation as the main effects being very highly significant ($P<0.001$). However, the 3-way interaction is no longer significant. The 2-way interactions show no significance of any factor when interacting with site. The only significant interaction is that between species and inundation ($P<0.001$). This demonstrates that by the third period, after the leaf packs had been in the field 24 weeks, the vegetation community no longer has any direct or indirect effect on the loss of organic matter; species and water regime are the only influences.

4.1.1.6 Organic Matter Loss in Naturally Fallen Leaf Litter

On completion of the experiment, the loss of organic matter from leaf packs was much lower than expected. It needed to be determined if this low amount of organic matter loss from leaves was 'normal' for these species in natural conditions. In order to determine the loss of organic matter from naturally occurring leaf packs, leaf litter was collected (using the same methods as described in Section 3.1.3) from the north west corner of the lake from the same stands of emergent macrophytes from which the initial leaf packs were constructed. The leaves were taken from plants in different stages of decay and the organic matter content determined using the methods described in Section 3.1.7. The results in Table 4.3 show that the loss of organic matter was higher when forming naturally occurring leaf packs than in those artificially constructed.. Leaves that

Baumea articulata

	Leaves still attatched to standing plant	Leaves still attatched but fallen into the water	Leaves unattatched and floating	Leaves unattatched and sunk to benthos
% Organic Matter Remaining (Avg of 5 replicates)	96.60	97.60	95.80	93.60

Typha orientalis

	Leaves still attatched to standing plant	Leaves still attatched but fallen into the water	Leaves unattatched and floating	Leaves unattatched and sunk to benthos
% Organic Matter Remaining (Avg of 5 replicates)	97.80	97.60	95.80	92.00

Table 4.3. The percentage of organic matter remaining in naturally fallen *Baumea* and *Typha* leaf litter in different stages of decay.

had sunk to the bottom had similar losses of organic matter after eight weeks to those of artificially placed leaf packs that had been in the field for 24 weeks. There was negligible difference between species evident at any stage of degradation. These results provide further evidence that the design of the leaf packs may have altered the amounts of leaf litter processing.

4.1.1.7 Soil Organic Matter

The determination of the percentage of organic matter in soil core samples taken from each site clearly demonstrate much higher levels in the permanently inundated sites as shown in Figure 4.4. The values ranged from around 40 % in site 1 (permanently inundated *Baumea* stand) to just 2 % in site 6 (seasonally inundated control). In both the permanent and seasonally inundated sites the amount of organic matter loss from leaf packs corresponded to the amount of organic matter present in the soil. Site 1 had the lowest amount of leaf litter processing of the permanently inundated sites which corresponded to site 1 having the highest soil organic matter content. At the other end of the scale, site 6 which had the highest amount of organic matter loss also had the lowest amount of organic matter present in the soil. This relationship between the low rates of organic matter processing and the presence of peaty soils suggests that the slower rate of leaf litter processing in the permanently inundated sites found in this study have been occurring for some time.

4.1.2 Laboratory Treatments 1 and 2

4.1.2.1 Leaf Pack Wet Weights and Dry Weights

Figure 4.5 shows the average wet weight and dry weight for all laboratory treatments. The average wet weights of leaf packs in treatment 1 (seasonally inundated) and treatment 2 (permanently inundated) are comparable to those found in the respective field sites. *Typha* leaf packs again had average wet weights almost double those of *Baumea* leaf packs, adding almost 600 % to their initial average wet weight. *Baumea* leaf packs had substantially higher values than those found in the field sites at the end of the experiment. Although the trends of organic matter loss in the laboratory treatments are

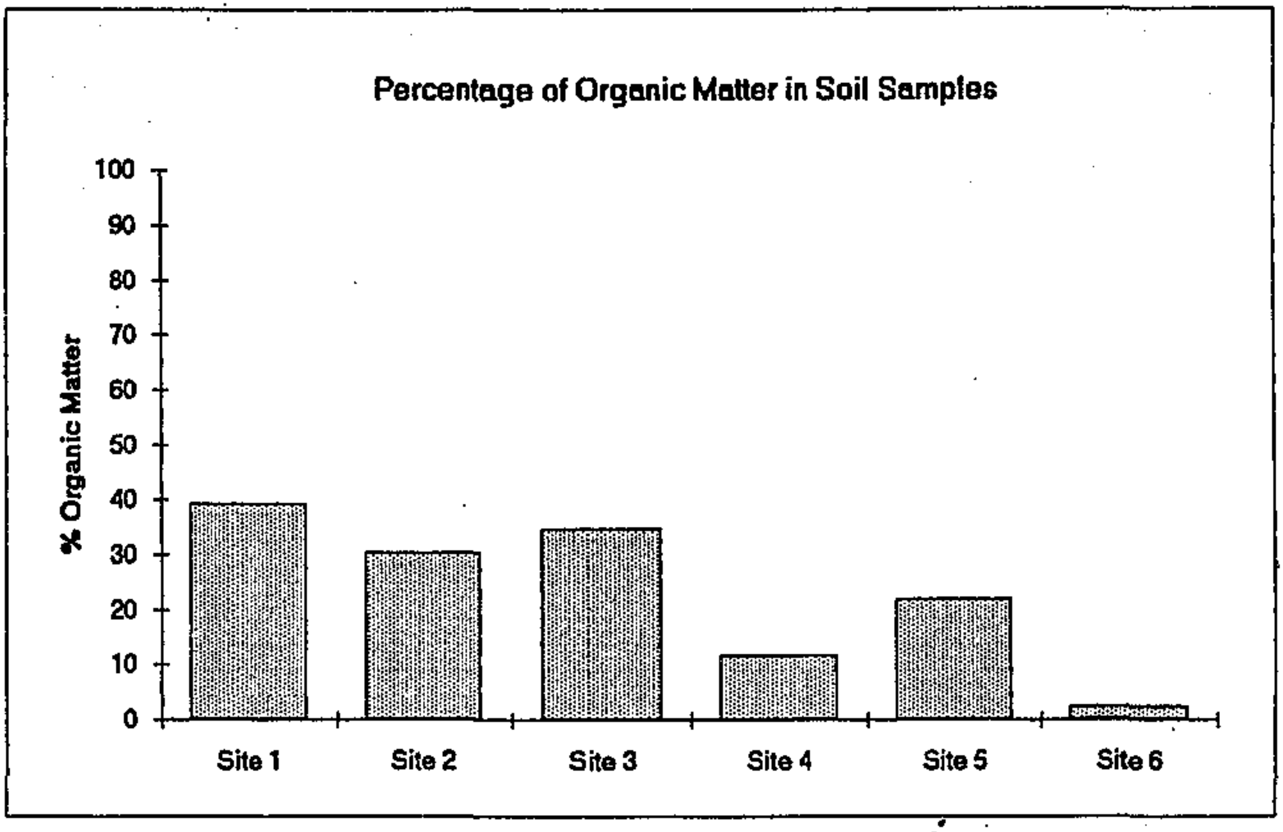
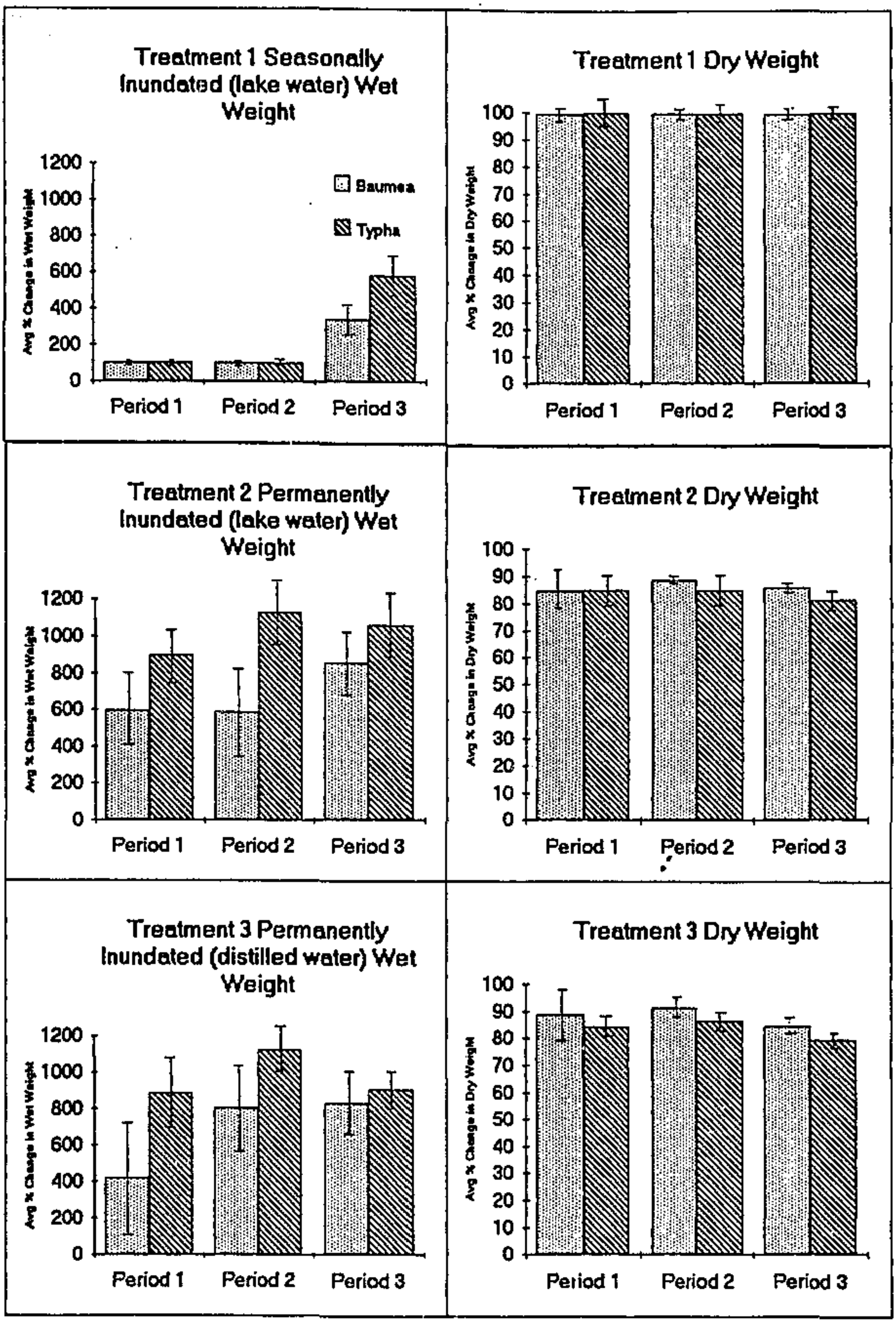


Figure 4.4. The percentage of organic matter in soil samples taken from each field site.



Treatment 1 Seasonally Inundated (lake water) Wet Weight

Treatment 1 Dry Weight

Treatment 2 Permanently Inundated (lake water) Wet Weight

Treatment 2 Dry Weight

Treatment 3 Permanently Inundated (distilled water) Wet Weight

Treatment 3 Dry Weight

Figure 4.5Average change in wet weight and dry weight for *Baumea* and *Typha* leaf packs from laboratory treatments 1, 2 and 3.

comparable, the values are substantially higher than those found in the field. For example, *Typha* leaf packs in treatment 2 increase their initial average wet weight by nearly 1200 %, an increase of wet weight of over 350 % higher than any value obtained in the field.

The loss of average dry weight in the permanently inundated treatment, as was the case in field sites, was much higher than in the seasonally inundated treatment where the loss of organic matter was negligible after 24 weeks of exposure. As with the field sites these values did not correspond to losses of organic matter in any of the time periods or inundation regimes.

4.1.2.2 Organic Matter Loss - Water Regime

The patterns and amounts of leaf litter processing from all the laboratory treatments are shown in Figure 4.6. The leaf packs in treatment 2 (permanently inundated) had lost the greatest overall amount of organic matter by the end of the third period, although the overall amount of organic matter loss was low and comparable to those obtained in the field. Table 4.4 shows the results of the Anova with a significant difference ($P<0.001$) between leaf packs exposed to the different water regimes in period one, with the greatest loss in Treatment 1 where the leaf packs were not inundated. Period two also saw the leaf packs in treatment 1 free from water, however, the difference in amount of organic matter loss between the two regimes was no longer significant. By the conclusion of the experiment when the leaf packs in treatment 1 had been artificially inundated for eight weeks, there was again a very highly significant difference ($P<0.001$) in the amount of organic matter loss from leaf packs between the two water regimes, with Treatment 2 having lost substantially more organic matter.

Baumea and *Typha* leaf packs did not exhibit the same pattern or amount of organic matter loss within or between the treatments. In treatment 1 (seasonally inundated) both *Baumea* and *Typha* leaf packs exhibited trends in organic matter loss similar to those of the permanently inundated field sites, with an increase in their organic matter content by the end of the experiment. The inundation of this treatment with lake water containing a diversity of microorganisms may have resulted in the increase of the

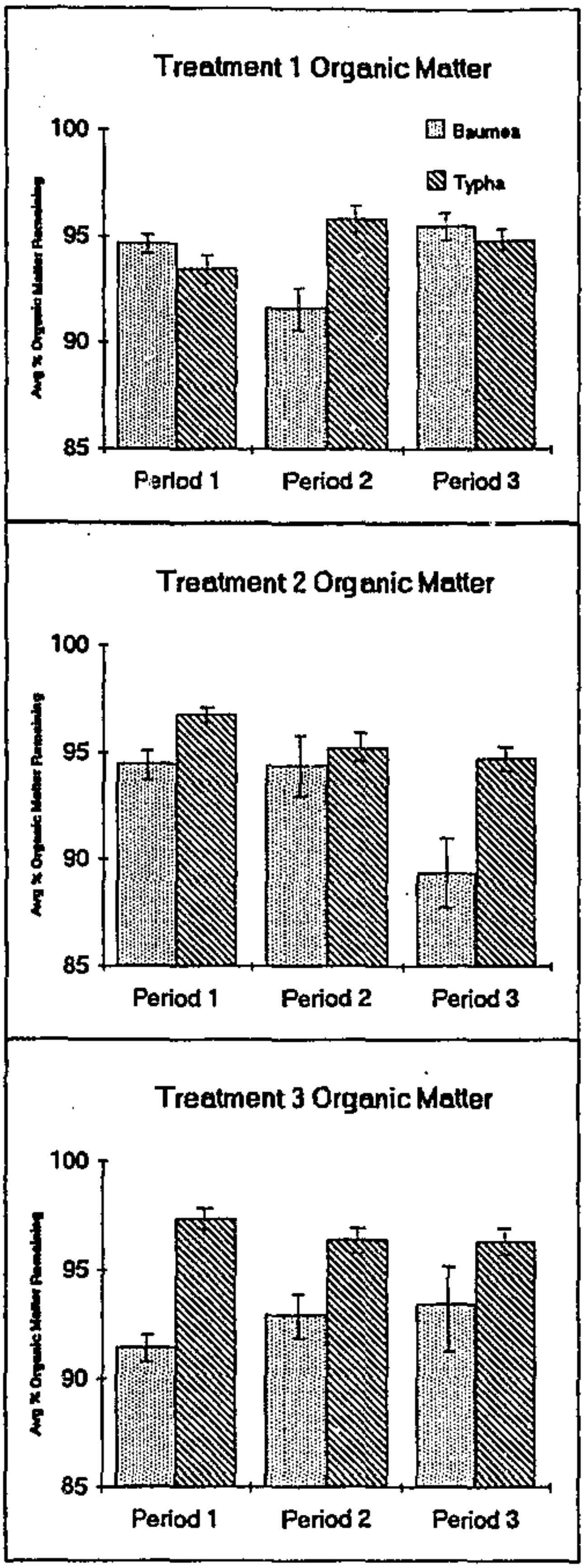


Figure 4.6 Average organic matter content of *Baumea* and *Typha* leaf packs from laboratory treatments 1, 2 and 3.

TIME PERIOD 1

Source of Variation	Degrees of Freedom	F value	Significance of F
Main Effects			
SPECIES	1	2.423	N/S
INUNDATION	1	18.508	###
2-Way Interactions			
SPECIES x INUNDATION	1	20.192	###

TIME PERIOD 2

Source of Variation	Degrees of Freedom	F value	Significance of F
Main Effects			
SPECIES	1	14.502	###
INUNDATION	1	1.978	N/S
2-Way Interactions			
SPECIES x INUNDATION	1	10.839	#

TIME PERIOD 3

Source of Variation	Degrees of Freedom	F value	Significance of F
Main Effects			
SPECIES	1	5.089	#
INUNDATION	1	11.882	###
2-Way Interactions			
SPECIES x INUNDATION	1	16.277	###

N/S - Not Significant
- $P < 0.05$ (significant)
- $P < 0.01$ (highly significant)
- $P < 0.001$ (very highly significant)

Table 4.4. ANOVA results for the percentage of organic matter remaining in each time for laboratory treatments 1 and 2.

microbial biomass of the leaf packs. As this water was filtered, the absence of invertebrates feeders would allow the microbial biomass to continue to rise. Treatment 2 (permanently inundated) featured a pattern of leaf litter processing similar to the seasonally inundated field sites. Both *Baumea* and *Typha* leaf packs followed a constant loss of organic matter over the three periods, the loss being much greater in *Baumea* leaf packs, especially in the third period.

4.1.2.3 Organic Matter Loss - Species Differences

The difference in the amount of organic matter loss between *Baumea* and *Typha* leaf packs followed the same trends as the field sites. The difference between species did not become significant until the second time period ($P<0.001$) continuing to be significant in the final period ($P<0.05$). In treatment 1 the greatest difference in the organic matter content of the leaf packs of 3.2 % is in period two, with the difference being negligible following inundation in the third period. In treatment 2 *Baumea* leaf packs show a higher loss of organic matter from leaf packs throughout the experiment. By the end of the final period *Baumea* leaf packs had lost 10.6 % compared to a 5.5 % loss for *Typha* leaf packs.

4.1.2.4 Organic Matter Loss - Combined Effects

Two way interactions between species and inundation prove to be significant ($P<0.05$) throughout each of the time periods. This demonstrates that despite species or inundation having no significance in certain time periods, their effects combine in all three time periods indirectly to enhance the loss of organic matter from leaf packs in a laboratory environment.

4.1.3 Laboratory Treatment 3 Distilled Water

4.1.3.1 Leaf Pack Wet Weights and Dry Weights

The wet and dry weights in Treatment 3 were very similar to those obtained in treatment 2, the other permanently inundated laboratory treatment. The initial average wet weight of *Typha* leaf packs was nearly double those of *Baumea* leaf packs, with an average difference of around 500 % increase in wet weight found between species. The average increase in wet weight of *Typha* leaf packs peaked at 1100 % in period two, some 300 % higher than Baumea. Due to a steady increase in the average wet weight of *Baumea* leaf packs the difference between species in the final period is negligible.

The average loss of dry weight from both species of leaf pack did not correspond with changes in the organic matter content in any time period. The average loss of organic matter stay relatively constant around 10 % throughout the experiment with no discernible difference apparent between species.

4.1.3.2 Organic Matter Loss - Species Differences

Table 4.5 shows the difference in leaf litter processing between *Baumea* and *Typha* leaf packs in treatment 3 (distilled water) was found to be very highly significant ($P<0.001$) in the first time period, reducing in significance in the second period and by the end of the third period was no longer significant. This is opposite to trends in all the other field sites and laboratory treatments where the difference in organic matter loss became more significant as the experiment progressed.

Baumea leaf packs displayed a high initial loss of organic matter, around 9 %, but from then on the organic matter content of the leaf packs steadily increased until by the end of the third period they had only lost 6 % organic matter. As previously suggested, an increase in organic matter of leaf packs may be due to increased microbial biomass. However, this treatment was inundated with distilled water indicating any microorganisms found in the leaf packs were present on the leaf material when the leaf packs were constructed. *Typha* leaf packs organic matter remained relatively constant throughout the experiment at around 96 %. Due to *Baumea* leaf packs increasing their organic matter content over time, the difference between the species had lessened by the final period .

TIME PERIOD 1

Source of variation	Degrees of Freedom	F value	Significance of F
Main Effect			
SPECIES	1	183.7	###

TIME PERIOD 2

Source of variation	Degrees of Freedom	F value	Significance of F
Main Effect			
SPECIES	1	10.08	##

TIME PERIOD 3

Source of variation	Degrees of Freedom	F value	Significance of F
Main Effect			
SPECIES	1	1.945	N/S

N/S - Not Significant
- $P < 0.05$ (significant)
- $P < 0.01$ (highly significant)
- $P < 0.001$ (very highly significant)

Table 4.5. ANOVA results for the percentage of organic matter remaining in each time for laboratory treatment 3.

4.2 PHYSICO - CHEMICAL CHARACTERISTICS OF THE WATER COLUMN

4.2.1 Field Sites

4.2.1.1 Water Depth

A distinct seasonal water regime is present at Lake Jandabup as is evident by the water levels in Figure 4.7. Water level raw data is in Appendix 2. The depth, AHD, at the beginning of the experiment in January was 44.85m, steadily declining to 44.48m by the end of April when lake water levels increased quite rapidly with the onset of the winter rains, returning to 44.87m on the last recording date in July.

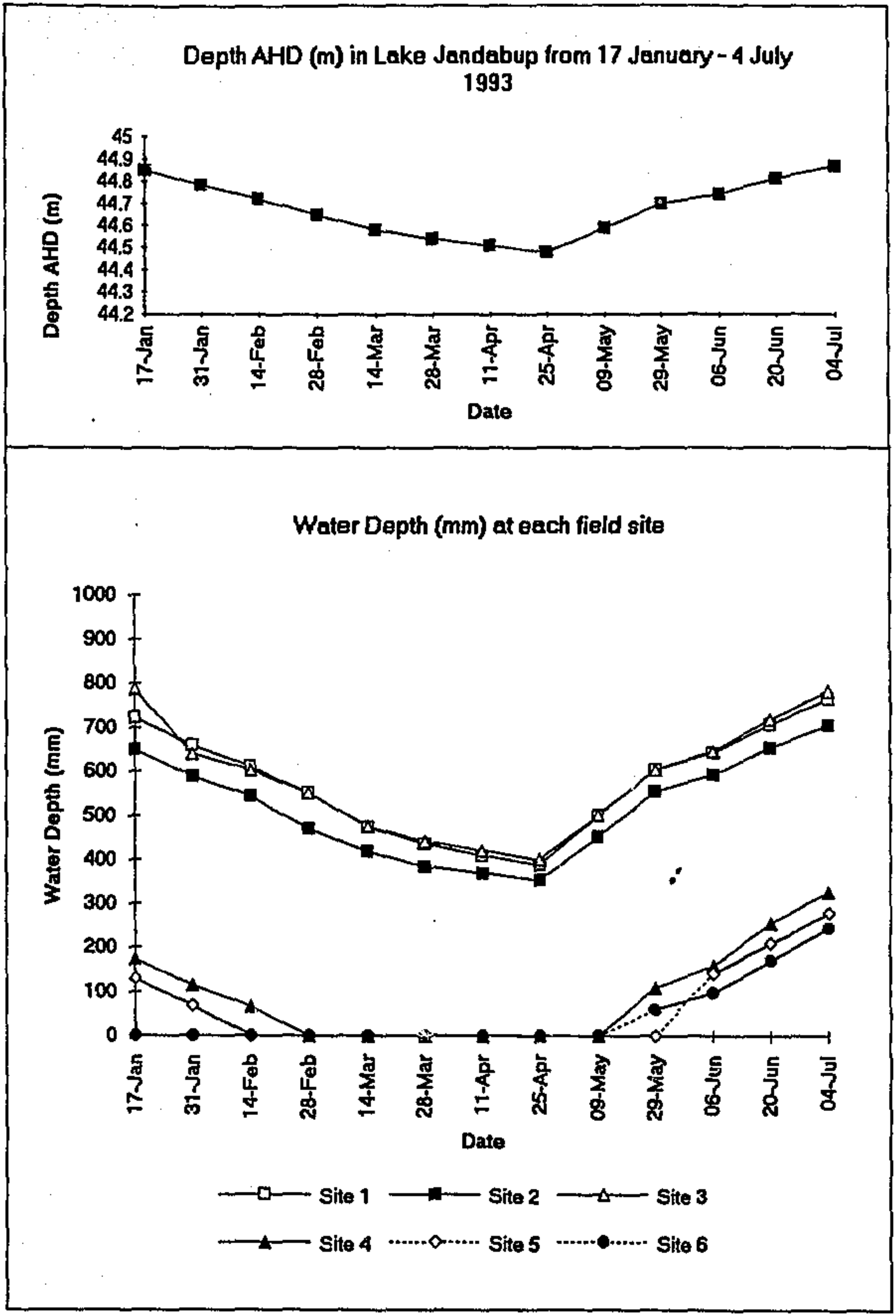
The three permanently inundated sites followed this pattern of reduced water depth over the summer months with a rapid increase with winter rainfall returning levels similar to those recorded at the beginning of the experiment. Site 3 had the greatest loss of water depth of over 400mm, with site 2 having the lowest fall in water depth of only 300mm returning to a value slightly higher than the depth recorded in January.

Of the seasonal sites, site 5 remained inundated for only four weeks and site 4 for six weeks before a reduction in lake water levels resulted in the leaf packs becoming exposed. Sites 4 and 5 remained exposed for ten and fourteen weeks respectively before a rise in water levels reflooded the leaf packs. All three sites had greater water depths at the end of the experiment in July than those recorded in January. The leaf packs at site 4 were reflooded before the other two sites as this community were influenced by surface drainage from surrounding abandoned market gardens, whereas the leaf packs in sites 5 and 6 were reliant on the groundwater levels for inundation.

Groundwater levels did not return to levels predicted near the end of the experiment resulting in the leaf packs at sites 5 and 6 being carefully moved to areas within the same community where inundation was guaranteed. As a result there was a rapid rise in water levels for site 5 on May 29.

4.2.1.2 Site 1 Permanently Inundated *Baumea*

Figure 4.8 shows the physico-chemical data for site 1, the raw data for all sites is in Appendix 3. The temperature of the water in site 1 followed a predictable trend of progressively lower values as the experiment proceeded, reflecting the ambient air



Depth AHD (m) in Lake Jandabup from 17 January - 4 July 1993

Water Depth (mm) at each field site

Figure 4.7. Fluctuations in water levels at Lake Jandabup

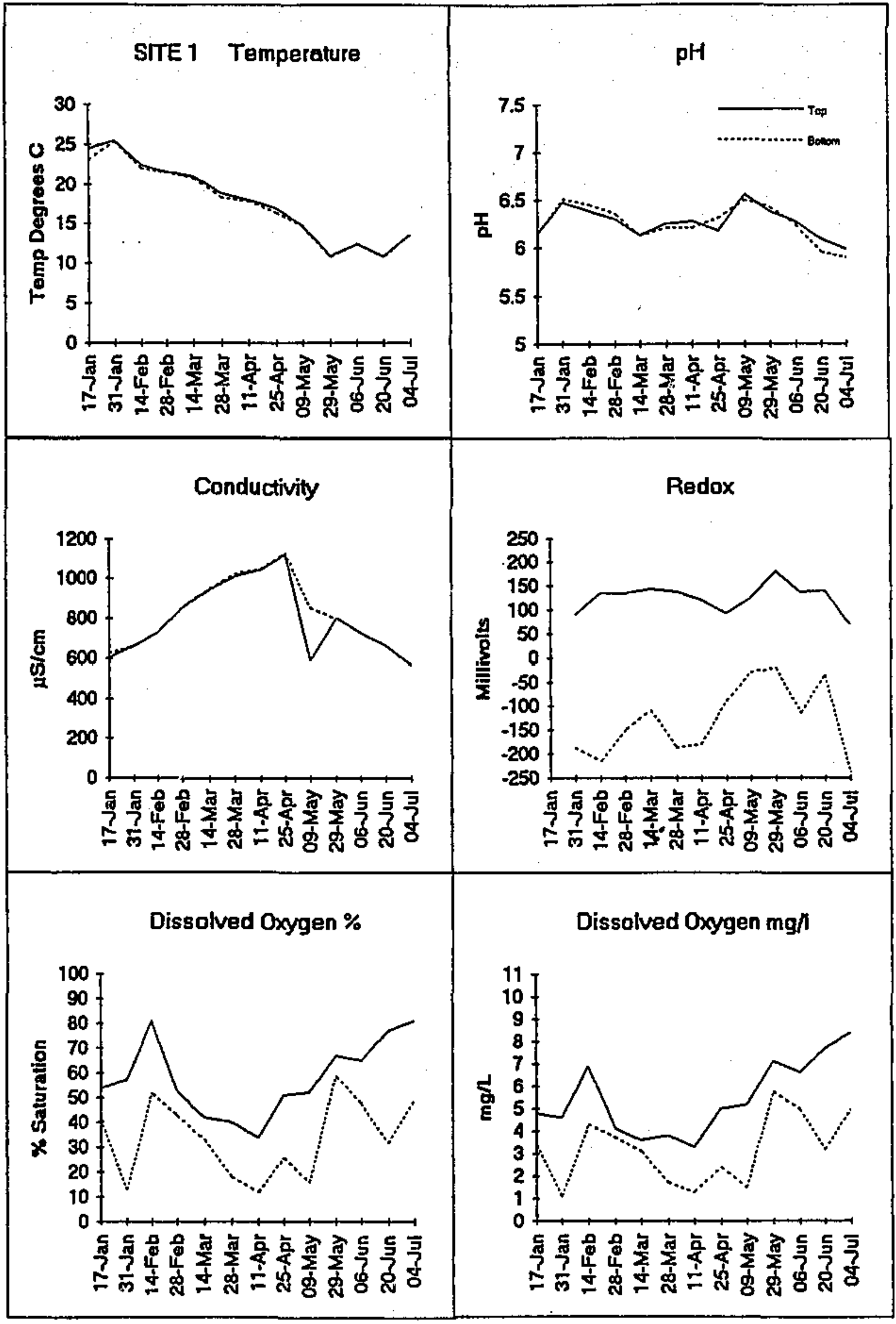


Figure 4.8. Physico-chemical characteristics of the water column for site 1, permanently inundated *Baumea*

temperature. There was minimal difference between the top and bottom of the water column. Water temperature peaked at 25.5 °C on January 31, with the lowest temperature of 10.9°C recorded on May 29 and June 20. The pH remained between 6.0 and 6.5 throughout the experiment. The pH at the bottom of the water column remained slightly higher than at the surface. With the first major rainfall event on April 25 the pH rose by half a unit resulting in the bottom of the water column being slightly more acidic than the top. Conductivity fluctuated markedly throughout the experiment, peaking at 1116 µS/cm on April 25 followed by a dramatic drop in conductivity to 584 µS/cm in two weeks. At the same time the difference between the top and bottom of the water column increased to 270 µS/cm; strong evidence for the stratification of the water column under these conditions. The redox potentials were consistently highly positive at the surface and highly negative at the bottom, with maximum and minimum levels of +180mv and -238mv respectively, with the greatest difference between the top and the bottom corresponding to the highest water temperature. The negative bottom readings indicate the presence of strongly reducing substances, such as peat. This supports the potential for stratification under these conditions. The dissolved oxygen percentage and mg/L followed identical patterns in all sites indicating that the percentage saturation represents the available oxygen in the water column. The fluctuations in levels corresponded to the presence of external variables such as high temperatures or windy conditions. The difference between the top and bottom of the water column also reflected environmental conditions with the greatest difference corresponding to the highest temperatures.

4.2.1.3 Site 2 Permanently Inundated *Typha*

Figure 4.9 shows the fluctuations in physico-chemical parameters. Water temperature followed the same pattern as described in site 1, peaking slightly higher at 26.5°C on January 31. The pH at site 2 steadily rose to 6.8 on April 25, but an increase in water depth from this date resulted in a sudden drop in pH of 1 unit, with the levels remaining consistently lower at the bottom. The conductivity, as in site 1 steadily increased with decreasing water depth. The highest level of all the permanently inundated sites of 1162 µS/cm was recorded on April 25. With the increase in water

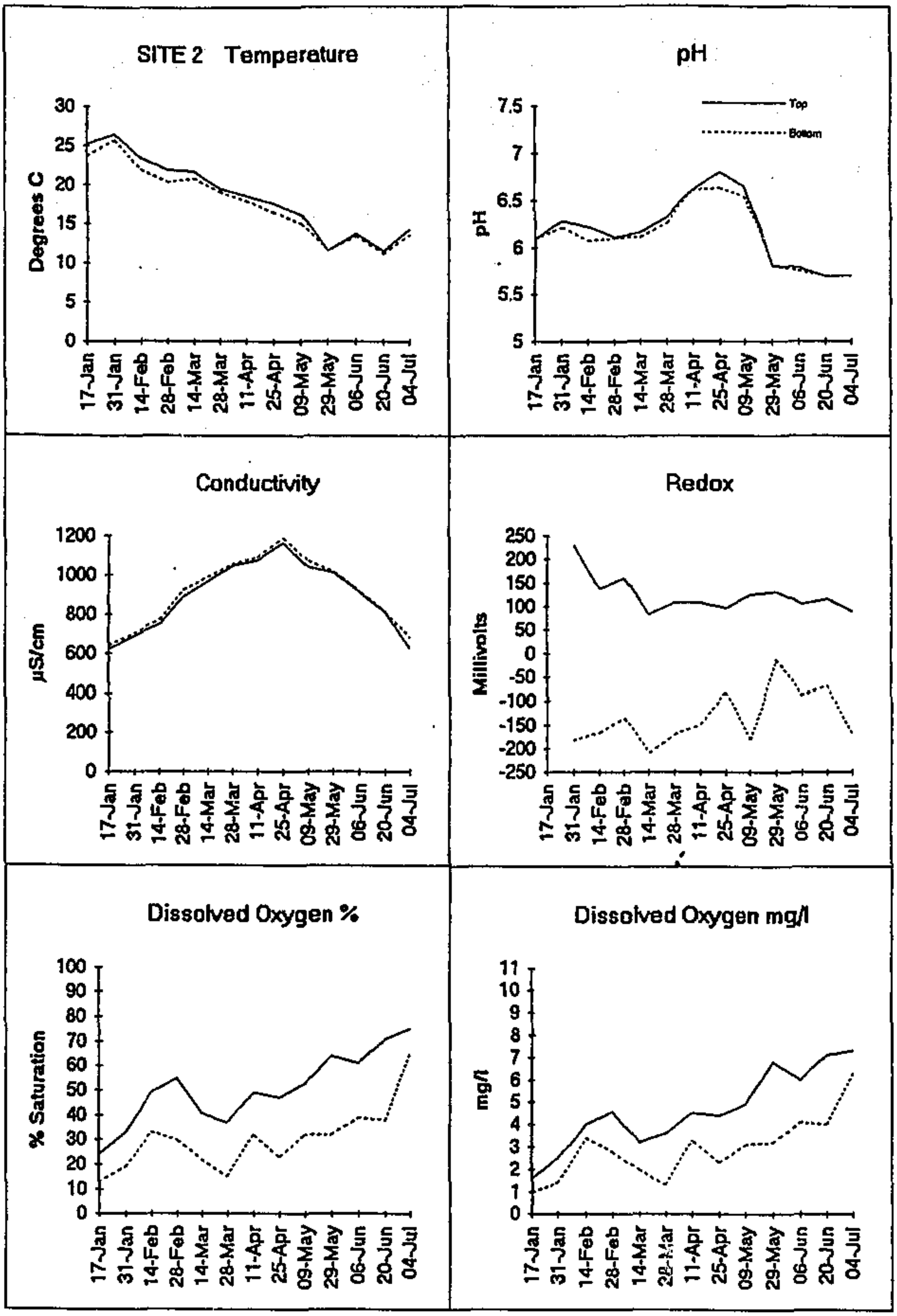


Figure 4.9. Physico-chemical characteristics of the water column for site 2, permanently inundated *Typha*

depth the conductivity continued to decline for the rest of the experiment. The difference between the top and bottom of the water column remained constant with the surface waters having slightly lower levels. The dramatic drop in conductivity and the resulting difference between the top and bottom displayed in site 1 was not present in site 2. The redox followed similar trends to site 1 with highly positive surface readings and highly negative bottom readings. The greatest difference between the top and the bottom again corresponded to the highest temperatures, indicating the potential for stratification at this site also. The dissolved oxygen in site 2 was much lower than the other two permanently inundated sites, steadily increasing as the temperature decreased with the difference between the top and the bottom much less than the other sites. The low dissolved oxygen may be attributable to the site being located in a channel off the main body of water and with a longer retention time and less mixing.

4.2.1.4 Site 3 Permanently Inundated Control

Figure 4.10 shows the fluctuations in the physico-chemical parameters. The temperature followed the same pattern as previously described for the permanently inundated sites, peaking at 25.9°C on January 31. The pH in this site was much higher than in sites 1 and 2, ranging from 6.11 to 7.48. The pH steadily increased, reaching a maximum on April 25 and rapidly falling by 1.2 units after the first rains. The pH on the bottom alternated between being higher and lower than the top, appearing to follow the same trends only two weeks in lag. The conductivity followed the same patterns as those in sites 1 and 2, although the severe drop with the increase in water depth did not occur. Conductivity peaked on April 25 at 1072 µS/cm, the lowest of all the permanently inundated sites indicating the incoming water is well mixed at this site. The redox potential at site 3 exhibited values closer to 0mv, although the top and bottom readings were still positive and negative receptively. The lower redox potential may reflect a lack of emergent vegetation and therefore less decomposition on the bottom, decreasing the reducing ability of the sediments. The dissolved oxygen at site 3 was much higher than the other two permanently inundated sites indicating increased mixing as a result of a lack of emergent vegetation providing shelter.

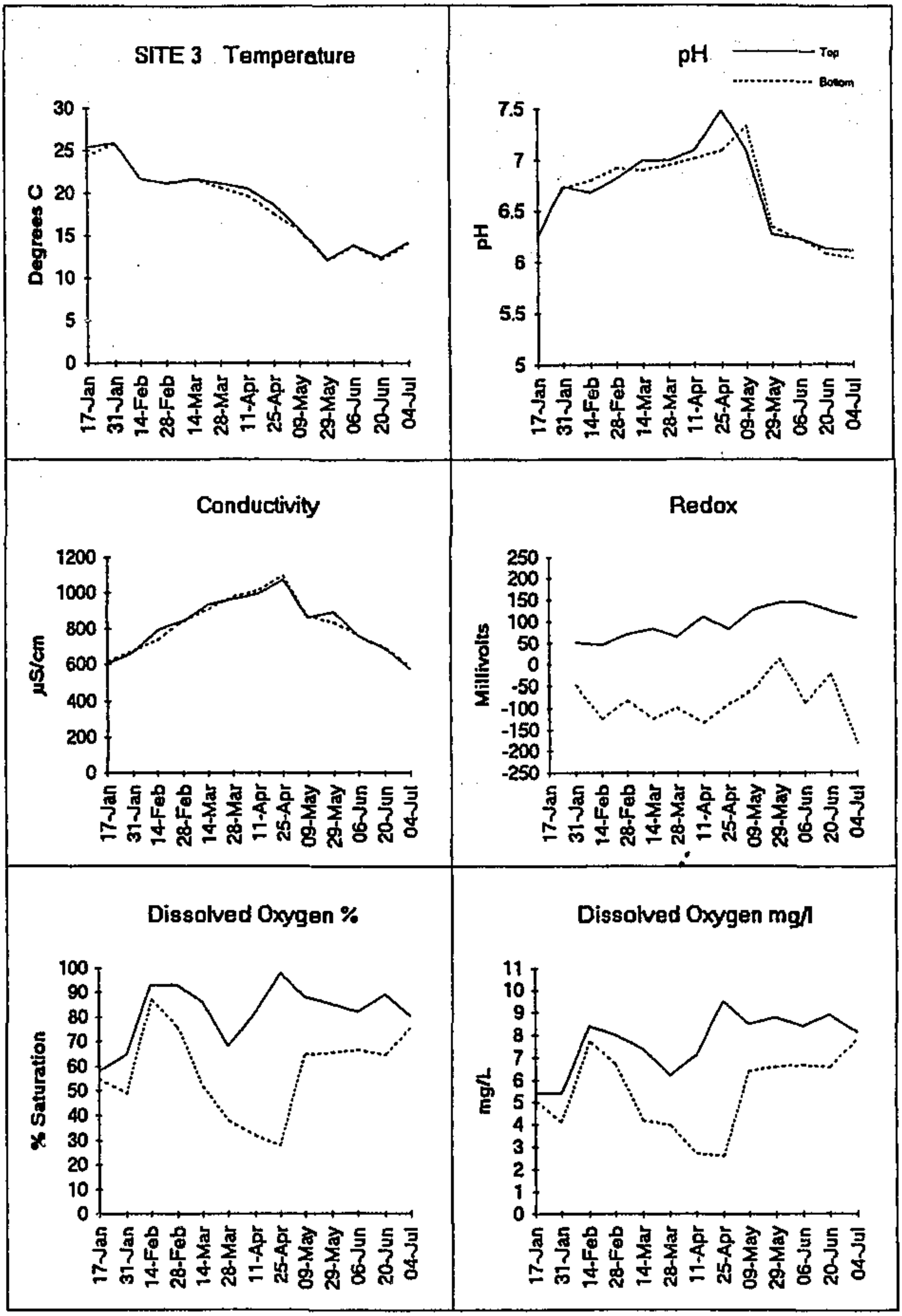


Figure 4.10. Physico-chemical characteristics of the water column for site 3, permanently inundated control.

4.2.1.5 Site 4 Seasonally Inundated *Typha*

Figure 4.11 shows the fluctuations in physico-chemical parameters. The water temperature at site 4 was higher than any of the permanently inundated sites for the same time period, with a maximum of 27.7°C reflecting the shallowness of the water. Site 4 had the lowest temperature of all sites, 9.1°C on May 29. Upon reflooding the pH was higher than the level recorded before it dried, with the pH lower on the bottom, whereas before inundation it was lower on the top. The pH dropped quickly once reflooded from 6.70 to 5.64. Conductivity levels of 1131 µS/cm following reflooding were the highest of all field sites in the same period, gradually falling as water depth increased. Before exposure the redox potential was positive on the top and negative at the bottom of the water column, however, after reflooding both readings were positive. This suggests that the higher temperatures at the beginning of the experiment resulted in increased biological activity at the sediment causing a high reducing potential, supported by the corresponding low dissolved oxygen levels.

4.2.1.6 Site 5 Seasonally Inundated *Baumea*

Figure 4.12 shows the fluctuations in physico-chemical parameters. Site 5 consistently had lower values for all parameters (except temperature) than all other field sites. The temperature was the highest of all field sites peaking at 28.2°C on January 17. The pH values were all below neutral ranging from 6.48 to 5.12. Following the reflooding of this site the pH was lower than before exposure, and rapidly fell to 5.12 over the final two weeks. The conductivity remained relatively constant around 600 µS/cm, far less than all the other sites in the same period. As in site 4, this site had a positive redox on both the top and bottom of the water column following reflooding. There were large differences in the dissolved oxygen between the top and the bottom in the summer months with dissolved oxygen levels falling to 13 % on January 31.

4.2.1.7 Site 6 Seasonally Inundated Control

Figure 4.13 shows the fluctuations in physico chemical parameters. Site 6 was not exposed to water prior to May 29 and as such there is only data for the period following reflooding. Water temperatures reflected the ambient air temperature and were therefore

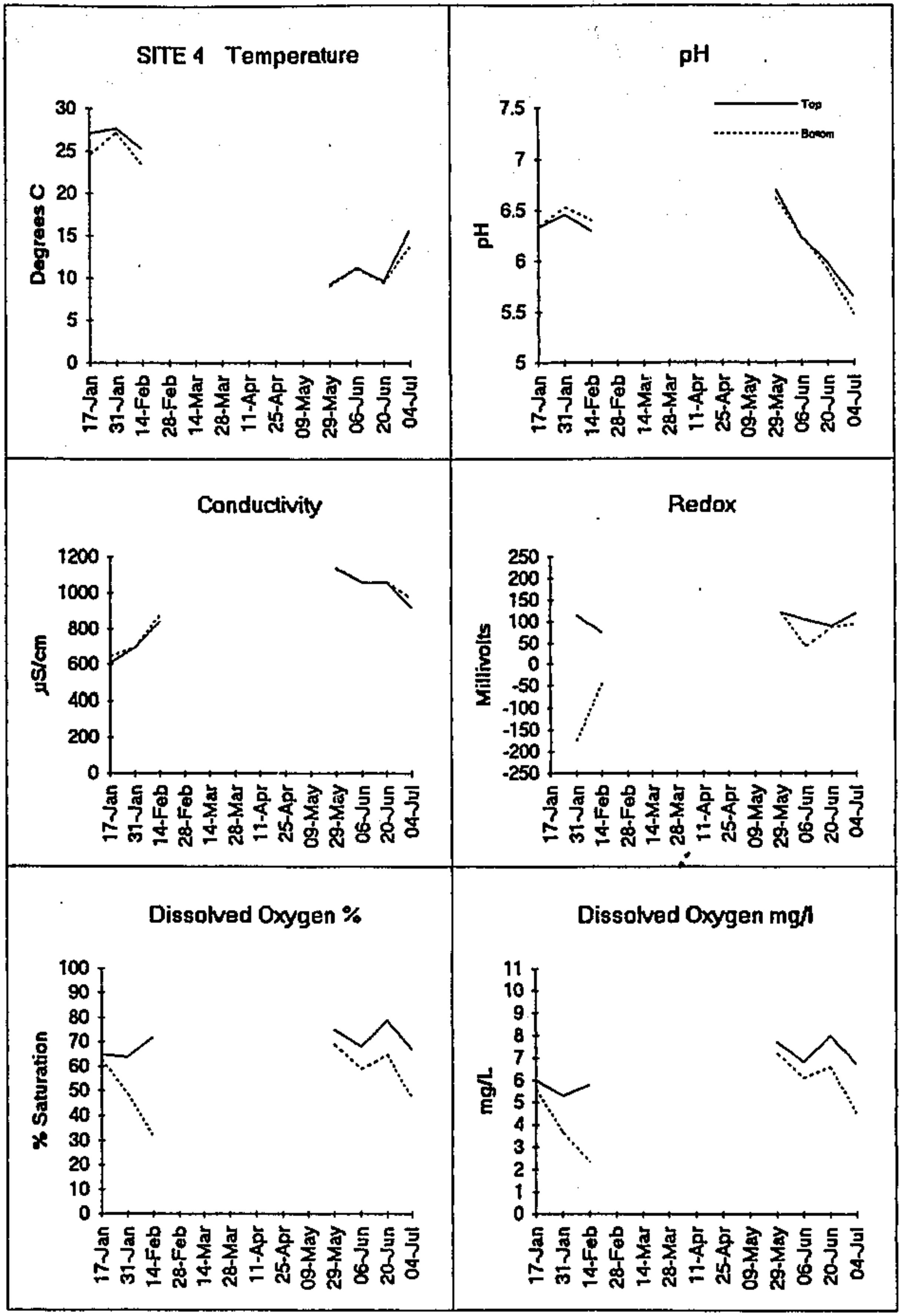


Figure 4.11. Physico-chemical characteristics of the water column for site 4, seasonally inundated *Typha*.

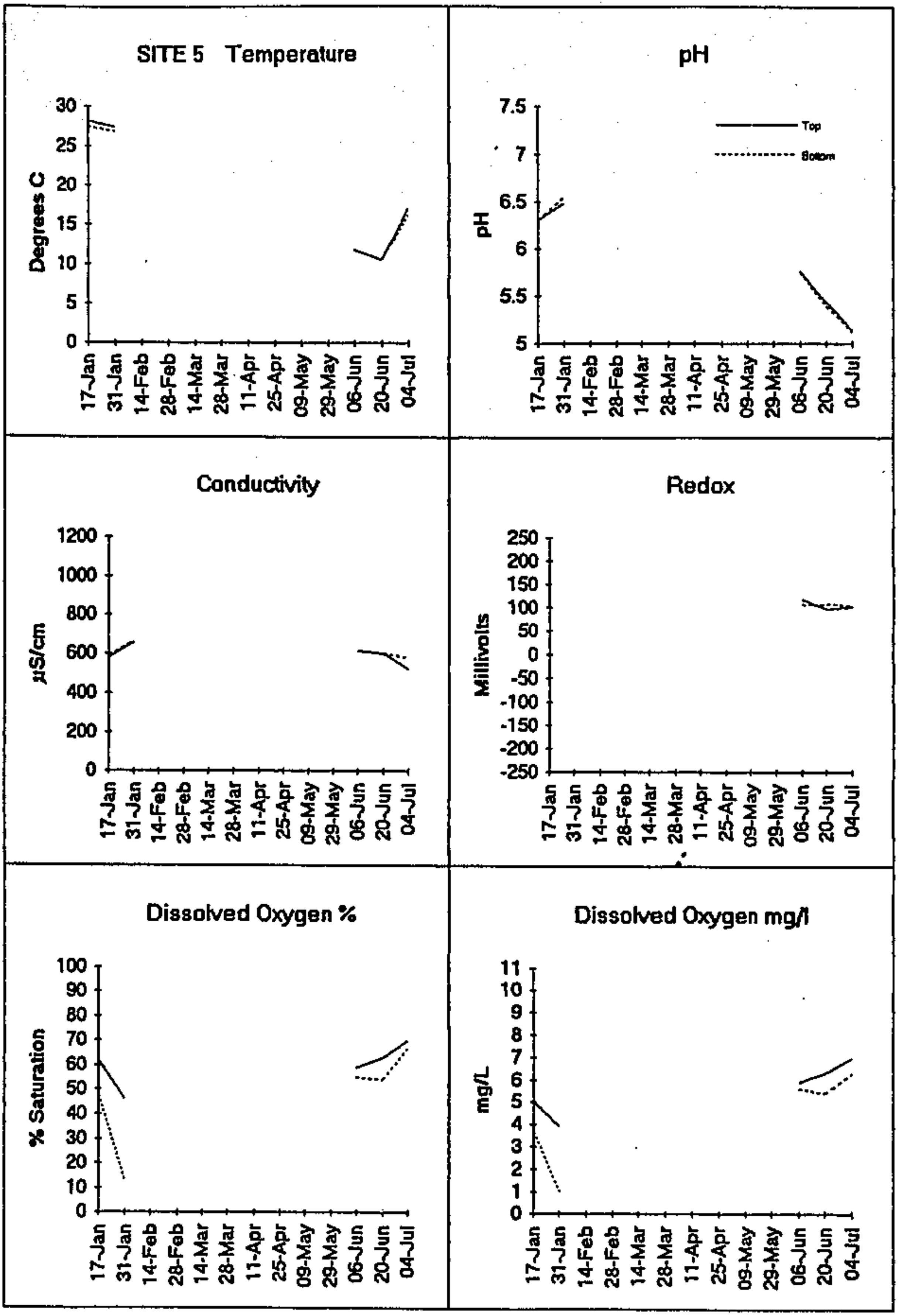


Figure 4.12. Physico-chemical characteristics of the water column for site 5, seasonally inundated *Baumea*.

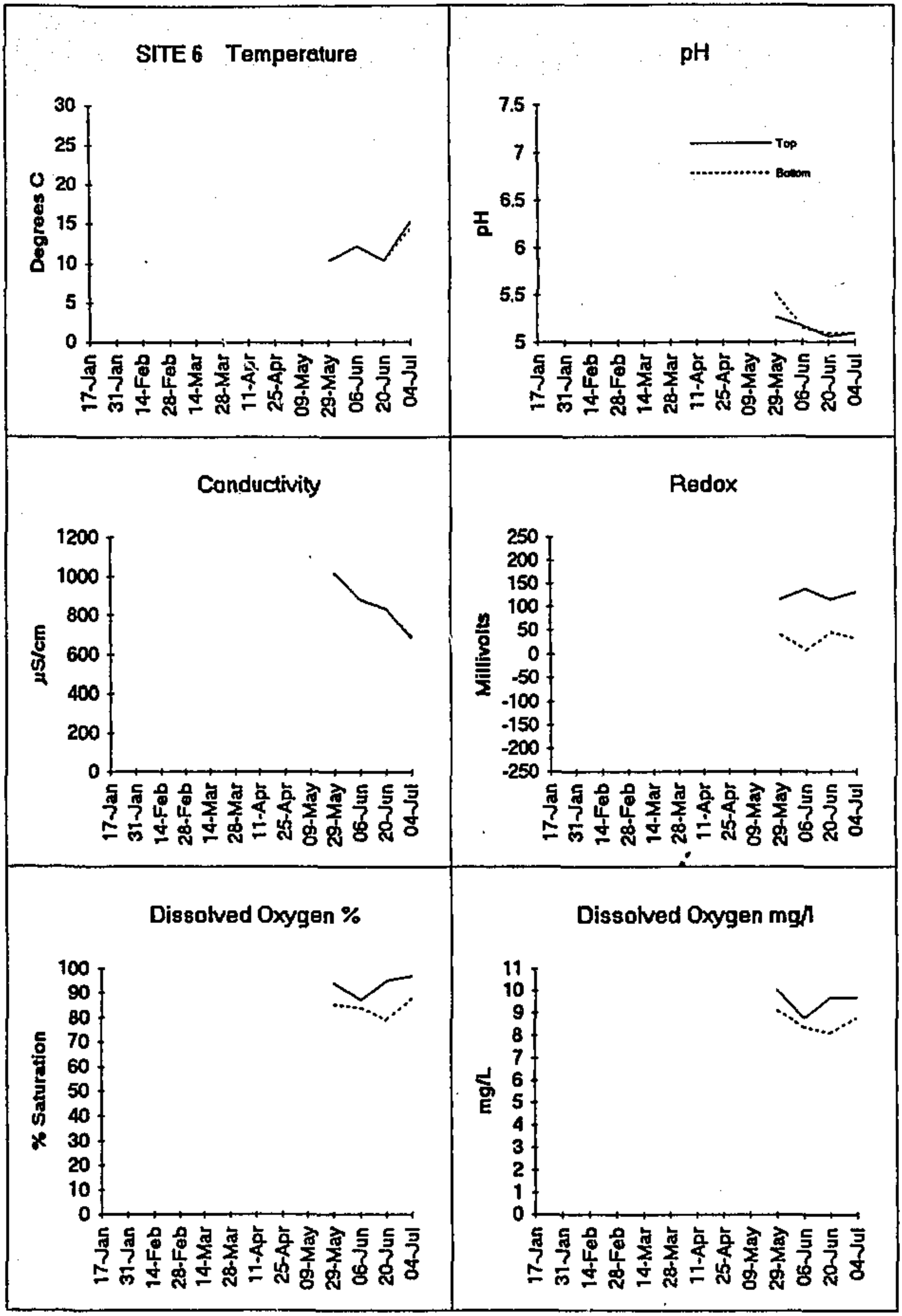


Figure 4.13. Physico-chemical characteristics of the water column for site 5, seasonally inundated control.

relatively low. The pH was very low, around 5.0, the most acidic of all the field sites yet there was no vegetation present. Conductivity was high in comparison to the other sites in this period, with a maximum of 1016 μS/cm on May 29, gradually falling as the water depth increased. The redox potential was again positive on the top and bottom of the water column, however, the readings at the top were around 100 mv higher indicating that although there is little organic matter in the sediments, reducing elements are still present. Dissolved oxygen was higher in this site in comparison to the other seasonally inundated sites perhaps due to a lack of emergent vegetation allowing more complete mixing.

4.2.1.8 Gilvin

Gilvin levels in Lake Jandabup show variability firstly between vegetation communities and more importantly within the seasonal water cycle. In both the permanently inundated and the seasonally inundated sites the *Typha* community had the highest gilvin levels, indicating its ability to readily leach the soluble components within its leaves. In each of the permanently inundated sites, gilvin levels increased as the water levels decreased reaching a maximum in March followed by a rapid decline with increasing water levels. This was most apparent in site 2 which has the highest gilvin of 21.99 in March dropping to 12.06 just eight weeks later when the lake water levels had increased significantly (Table 4.6). Upon reflooding, the seasonal sites increased their gilvin levels, opposite to trends in the permanently inundated sites, with levels higher in these sites than in those recorded for the same period in the sites with permanent water. The breakdown of leaf litter was found to be higher in seasonally inundated sites. As the groundwater percolates through the sediment to recharge the lake water levels, the soluble humic substances produced as a result of the decomposition of leaf material are incorporated into the water column. The result is an increase in the gilvin in these sites following reflooding.

GILVIN (abs/m)

DATE	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6
17-Jan	10.40	14.62	13.82	10.94	10.59	
14-Mar	14.74	21.99	17.50			
09-May	8.98	12.06	11.05			
04-Jul	6.33	10.13	7.37	13.82	10.82	9.90

Table 4.6. Gilvin levels (abs/m) for each time period and fiels site from Lake Jandabup.

4.2.2 Laboratory Treatments

4.2.2.1 Treatment 1 - seasonally inundated

The physico-chemical data for the laboratory treatments are shown in Table 4.7. Treatment 1 was artificially inundated on June 23 with water from field site 6 collected on the June 20 to imitate the same period of flooding as the field seasonally inundated control. Temperature and redox remain relatively constant in both species. The pH in the treatment containing the *Typha* leaf packs rose half a unit over the length of the experiment to 6.07.Conductivity in the *Typha* treatment increased by 100 µS/cm in the eight weeks of inundation compered to an increase of 40 µS/cm in the *Baumea* treatment. Dissolved oxygen percentage rose slightly in both species, but unlike the field sites the available dissolved oxygen (mg/L) declined over the same period. The gilvin level rose sharply from 9.90 to over 30 in both species over the eight week period to values much higher than those found in the field.

4.2.2.2 Treatment 2 - Permanently Inundated (Lake Water)

The water temperature and pH did not change greatly from those values obtained at the beginning of the experiment. Conductivity in the *Typha* rose dramatically from 680 us/cm to1632 µS/cm. The conductivity of *Baumea* in this treatment rose by 360 µS/cm to 1040 µS/cm. The redox potential remained relatively constant in the treatment with *Typha* leaf packs, but plummeted from 235 to just 7 millivolts after 24 weeks in the treatment with *Baumea* leaf packs. Dissolved oxygen saturation and mg/L declined slightly in the case of *Baumea*, however in the treatment with *Typha* leaf packs the dissolved oxygen declined from 58 % to 18 % and 5.4 mg/L to 1.3 mg/L. Gilvin rose dramatically in this treatment. It was artificially inundated with water from site 3 (open water control) collected on February 28 which had a gilvin of 10.82. After the water had been exposed to leaf packs for 24 weeks, the gilvin in the treatment with *Typha* had increased nearly twenty times to 205.43 with the *Baumea* recording a gilvin of 119.76 by the end of the experiment.

Baumea articulata

	26-Jun Treatment 1	18-Aug Treatment 1	03-Mar Treatment 2	18-Aug Treatment 2	03-Mar Treatment 3	18-Aug Treatment 3
Temperature Degrees C	18.6	18.1	21.8	18.1	21.8	18.0
pH	5.55	5.63	6.26	5.51	6.99	5.75
Conductivity µS/cm	826	864	680	1640	497	557
Redox mV	155	245	235	7	212	125
Dissolved Oxygen % Saturation	69	77	58	43	98	46
Dissolved Oxygen mg/l	66	6.3	5.4	3.1	9.3	3.6
Gilvin - abs/m	9.9	32.47	10.82	119.76	0.00	153.61

Typha orientalis

	26-Jun Treatment 1	18-Aug Treatment 1	03-Mar Treatment 2	18-Aug Treatment 2	03-Mar Treatment 3	18-Aug Treatment 3
Temperature Degrees C	18.6	16.9	21.8	17.5	21.9	17.2
pH	5.55	6.07	6.26	6.04	7.01	6.03
Conductivity µS/cm	826	930	680	1632	497	679
Redox mV	155	202	235	191	209	202
Dissolved Oxygen % Saturation	69	74	58	18	99	32
Dissolved Oxygen mg/l	6.6	6.1	5.4	1.3	9.3	2.4
Gilvin - abs/m	9.9	35.46	10.82	205.43	0.00	122.63

Table 4.7. Physico-chemical characterictics of the water in laboratory treatments 1 to 3.

4.2.2.3 Treatment 3 - Permanently Inundated (Distilled Water)

The water temperature and redox potentials did not change greatly from those values obtained at the beginning of the experiment. For both species lower pH values were recorded on August 18 than on March 3, *Baumea* decreasing the most losing around one pH unit in both cases. As in treatment 1, the *Typha* in treatment 3 increased its conductivity by 180 μS/cm to 679 μS/cm, three times the increase found in the *Baumea* in treatment 3. Both species showed substantial decreases in both dissolved oxygen percentage and mg/L in treatment 3, the loss being slightly greater in the case of *Typha*. As these treatments were artificially inundated using distilled water the initial gilvin was 0. After the leaf packs had been in the treatments for 24 weeks, the gilvin had risen dramatically to 153 and 122 for *Baumea* and *Typha* respectively.

4.2.3 Diurnal Fluctuations

4.2.3.1 Site 1 - Permanently Inundated *Baumea*

Figure 4.14 shows the diurnal fluctuations in the physico-chemical parameters. There is strong evidence for the stratification of the water column at site 1. Temperature peaked at 23.9°C at 1300 hours resulting in a difference of 6.6°C between the top and bottom of the water column. The Dissolved oxygen percentage reached 0 % with an available oxygen of 0.1 mg/L on the bottom while the top of the water column was well oxygenated. The redox potential was also highly negative on the bottom and positive on the top indicating that oxygen is being used in decomposition with the resulting products having strong reducing potentials. This is backed up by a high difference in pH between the top and bottom of the water column. The bottom was more acidic by as much as one pH unit indicating the production of acids, such as humic acid, a product of decomposition. The conductivity completes the picture of stratification with the surface waters being more saline by as much as 140 μS/cm. In general the values between the top and bottom became closer during the night indicating that stratification is only short lived.

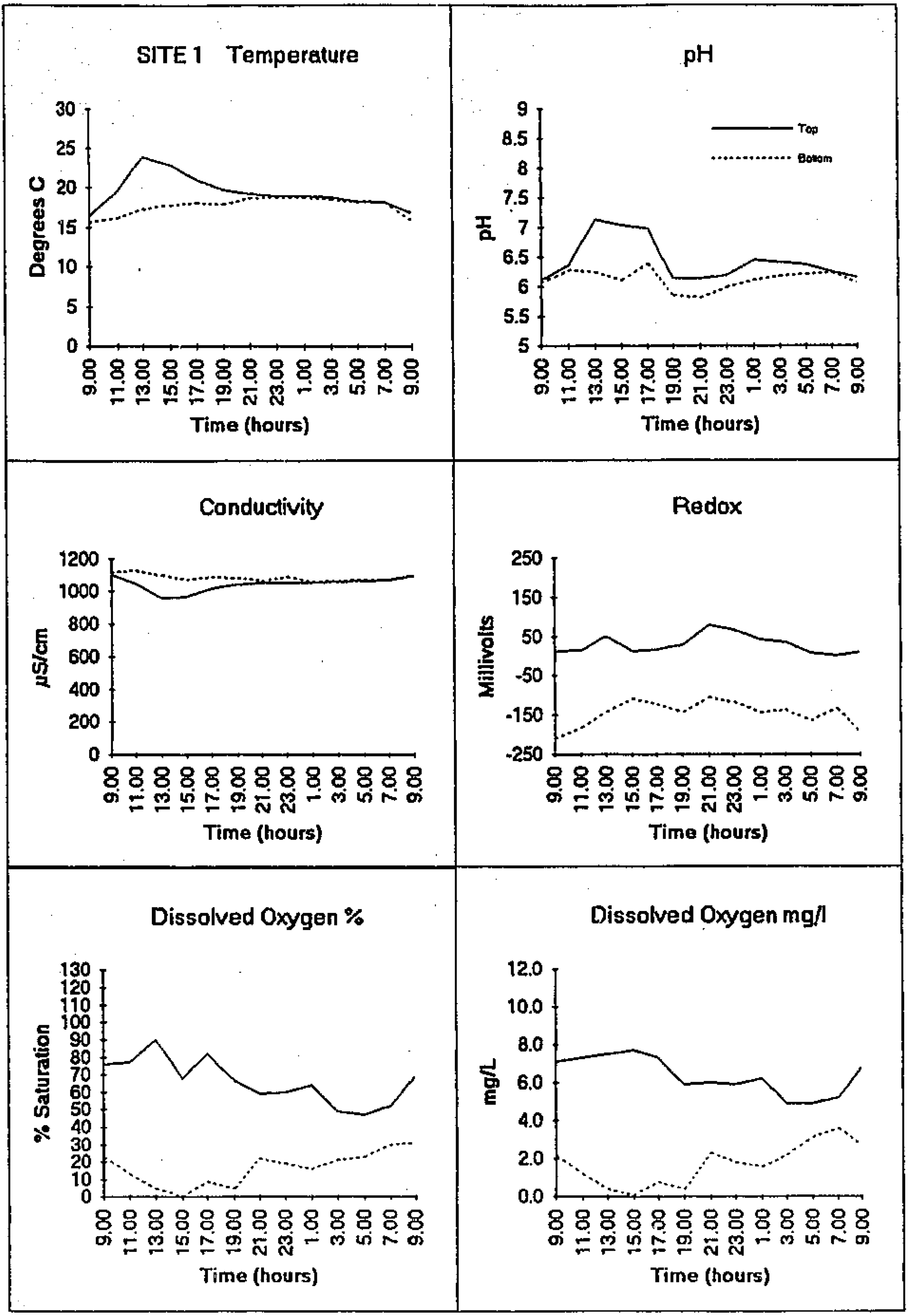


Figure 4.14. Diurnal fluctuations in the physico-chemical characterictics of the water column in site 1, permanently inundated *Baumea*.

4.2.3.2 Site 2 Permanently Inundated *Typha*

Figure 4.15 shows the fluctuations in physico-chemical parameters. There is strong evidence for the stratification of the water column in site 2 as well, however, it appears to be later in the day than at site 1. Temperature peaked at 23.7°C at 1500 hours resulting in a difference of 6°C between the top and bottom of the water column. Dissolved oxygen percentage saturation fell to 4 % with an available oxygen of 0.3 mg/L at the bottom while the top of the water column remained well oxygenated. As with site 1 the redox potential was highly negative on the bottom and positive on the top and the pH showed more acidic conditions at the bottom, the explanations for which are the same as for site 1. Again the conductivity was higher at the bottom, with the greatest difference of 130 µS/cm occurring at 1500 hours.

4.2.3.3 Site 3 Permanently Inundated Control

Figure 4.16 shows the fluctuations in physico-chemical parameters. Site 3 had no emergent vegetation resulting in the diurnal fluctuations differing from the other two sites, but there is still evidence of stratification even in the supposedly well mixed parts of the lake. The temperature peaked at 24.1°C (the highest of all three sites) at 1500 hours resulting in a difference of 3.4°C between the top and bottom of the water column. Site 3 was more exposed to the influences of wind far more than the other two sites as a result of no emergent vegetation. As a consequence the surface oxygen levels were much higher, peaking at 128 % at 1700 hours. Despite this high reading, dissolved oxygen levels of 11 % and 2.0 mg/L were recorded at the bottom, indicating that despite the presence of strong wind conditions severe oxygen depletion in benthic habitats can still occur. As with the other two sites the redox potential was highly negative on the bottom and positive on the top of the water column. The pH also showed a distinct difference between the top and bottom of the water column with the pH at the bottom being consistently lower. The fluctuations in pH were in the alkaline range, whereas the other two sites remained below neutral. The conductivity did not show definite signs of stratification as the topandbottom followed similar trends, with the bottom of the water column remaining slightly higher.

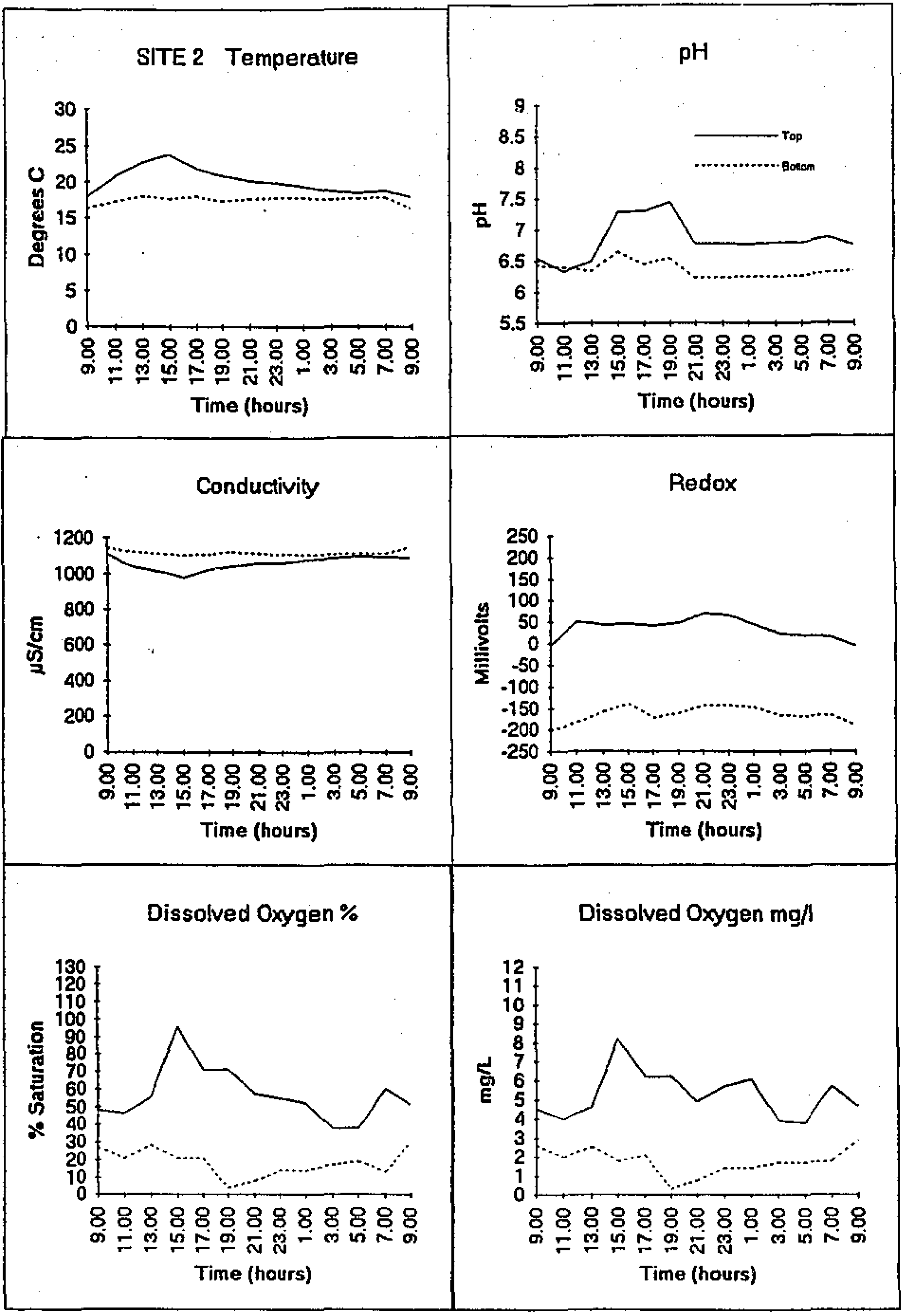


Figure 4.15. Diurnal fluctuations in the physico-chemical characterictics of the water column in site 2, permanently inundated *Typha.*

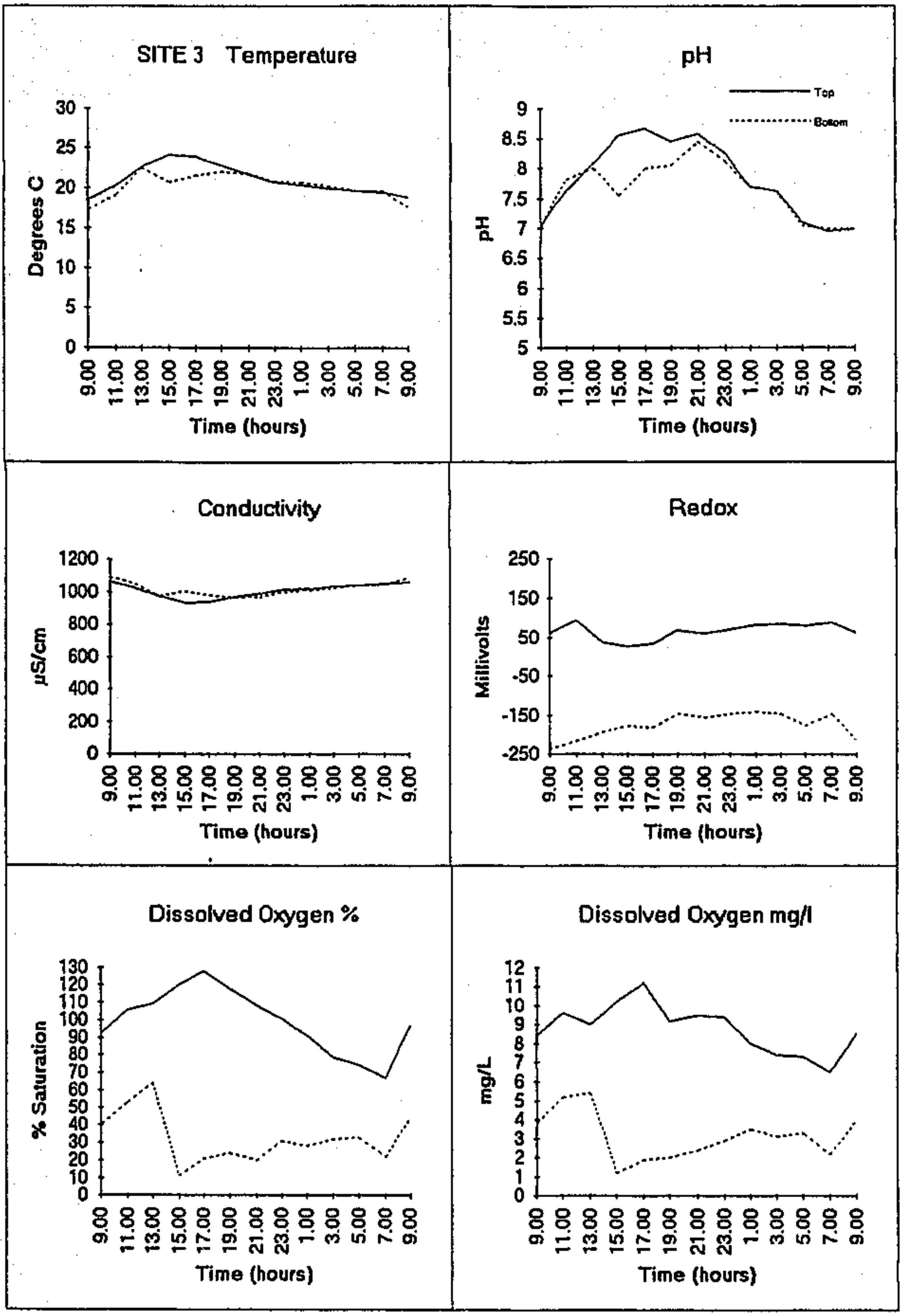


Figure 4.16. Diurnal fluctuations in the physico-chemical characterictics of the water column in site 3, permanently inundated control.

4.3 MICROBIAL BIOMASS

4.3.1 Field Sites

The microbial biomass of an average leaf pack before it was placed in the field was 0.00 mg/L P in both species. Samples of leaf packs of each species that were treated with fungicide also returned a microbial biomass of 0.00 mg/L P.

The results of the microbial biomass analysis are shown in Table 4.8. The variation between the permanently inundated and seasonally inundated sites is evident being up to twenty times higher in the *Baumea* leaf packs in the permanently inundated sites. The permanently inundated sites had levels ranging from 6.0 x 10 ^{3}mg/L P to 0.4 x 10 ^{3}mg/L P in *Baumea* leaf packs and from 4.84 x 10 ^{3}mg/L P to 0.6 x 10 ^{3}mg/L P in the *Typha* leaf packs. The highest levels of microbial biomass in the permanently inundated sites were generally in the second time period. The seasonally inundated sites had a much higher range of microbial biomass from 7.85 x 10 ^{3}mg/L P to 0.32 x 10 ^{3}mg/L P in *Baumea* leaf packs and from 14 x 10 ^{3}mg/L P to 0.28 x 10 ^{3}mg/L P in the *Typha* leaf packs. The highest levels of microbial biomass in the seasonally inundated sites were generally in the third period following reflooding. The highest levels recorded in the field sites were at site 6 (seasonally inundated control) following reflooding in period 3 of 7.85 x 10 ^{3}mg/L P and 14.00 x 10 ^{3} mg/L P in *Baumea* and *Typha* leaf packs respectively.

In the permanently inundated sites a trend was evident indicating a preference for *Typha* leaf packs when they were first placed in the water. In all three sites the microbial biomass was higher in *Typha* leaf packs in the first period yet by the end of the experiment this had reversed with a distinctly higher microbial biomass on the *Baumea* leaf packs. This reflects the lower organic matter content and the resulting higher structural components found in *Baumea* making it more resistant to breakdown and as shown by these results a less preferred substrate for microbial colonisation.

4.3.2 Laboratory treatments

The leaf packs in laboratory treatment 1 (seasonally inundated) followed the same trend of microbial biomass as the seasonally inundated field sites with levels peaking in

Baumea articulata

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Treatment 1	Treatment 2	Treatment 3
Time Period 1	2.56	0.40	0.56	0.52	0.96	2.24	0.20 x 10	1.60	0.80
Time Period 2	6.00	4.00	2.40	0.84	1.00	0.32	1.92 x 10	1.40	1.56
Time Period 3	3.96	3.20	1.20	2.52	3.08	7.85	1.56 x 10	0.40	1.20

Typha orientalis

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Treatment 1	Treatment 2	Treatment 3
Time Period 1	3.20	3.52	1.60	2.80	1.60	0.28	0.00	0.00	3.08
Time Period 2	3.36	1.40	4.84	0.40	0.96	0.64	1.40	0.72	1.20
Time Period 3	0.80	0.60	1.60	2.00	1.92	14.00	3.96	7.20	1.08

Table 4.8. Measurements of microbial biomass in mg/L P x 10^{-3} of leaf packs from field sites 1 to 6 and laboratory treatments 1 to 3.

period 3 following reflooding. *Baumea* leaf packs in this treatment had a maximum microbial biomass of 1.2 x 10 ^{3}mg/L P, far less than those recorded from field sites. *Typha* leaf packs in Treatment 1 had a maximum microbial biomass of 3.96 x 10 ^{3}mg/L P a level much closer to those obtained in the field.

In treatment 2, *Baumea* leaf packs had a substantially higher microbial biomass in the first two periods however, by the last time period the *Typha* leaf packs had a microbial biomass of 7.2 x 10 ^{3}mg/L P, nearly 20 times that found in the *Baumea* leaf packs. This is opposite to the trends found in the field where *Baumea* leaf packs had the highest microbial biomass in the final time period in all of the permanently inundated sites.

When placed in Treatment 3 (distilled water) the *Typha* leaf packs had a microbial biomass of 3.08 x 10 ^{3}mg/L P by the end of the first time period, some four times that found in *Baumea* leaf packs in the same period. However, by the end of the second period the microbial biomass of *Baumea* leaf packs had increased to levels similar to those in the *Typha* leaf packs, remaining similar for the duration of the experiment.

4.4 MACROINVERTEBRATES

4.4.1 Species Collected

Forty-four taxa were collected from leaf pack samples with abundances ranging from 0 (no invertebrates in the sample) to over 100 individuals (Table 4.9). Species of invertebrates deemed to be terrestrial include seven species of spider, three of Collembola and one species of Coleoptera. Of the forty four taxa collected, two species might be regarded as common, occurring in the majority of sites; the amphipods and chironomids being present in all inundated sites. One species of Coleoptera larvae, Helodidae, had very high abundances in the reflooded seasonally inundated sites.

Total invertebrate abundance in seasonally inundated and permanently inundated sites in the final time period following reflooding had similar numbers of individuals. The species richness between the two water regimes in this time period were similar in

CLASS / ORDER Common Names	Family	Species	*Baumea articulata*																		*Typha orientalis*																	
			1st Collection Site						2nd Collection Site						3rd Collection Site						1st Collection Site						2nd Collection Site						3rd Collection Site					
			1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
OLIGOCHAETA Worms	?Phreodrilidae	sp.1		8			3			5	2		2									3		1			4	31						3				
		Unidentified sp.2																2																				
HIRUDINEA	?Glossiphoniidae	sp.1																			1																	
		Unidentified sp.2															1																					
GASTROPODA Snails	Ancylidae	sp.1		1	4	5	1		4	18					4	24		8	5			2		5	2		3	43					15	43	16	13	5	6
	Physidae	*Physastra sp.*	1		1				2		1				2	1	7			2	1		5				1		12				1		6		2	
	Planorbidae	sp.3																				1																
ARACHNIDA / ACARINA Water Mites		sp.1																														6						
ARACHNIDA / ARANEA Spiders (terrestrial)		sp.1																						1						2	1							
		sp.2													2									1						3						1		
		sp.3				1																																
		sp.4				1		1							1											1										1		
		sp.5										2																					1					
		sp.6												2																		2						
		sp.7														1																					1	
CRUSTACEA / ISOPODA Crustaceans / Shrimps	Phreatoicidea	sp.1		2						4	4					2	2			1		7	6				1	9	4				3	5	5		2	
CRUSTACEA / OSTRACODA Crustaceans / Seed - Shrimps		*Cypretta sp.* /							2								1										3		15									
		Ilyodromus		3		1				23						35						5		1	1			54					1					15
		Unidentified sp.3																																		8		
		Unidentified sp.4		3			1		8	3							2			7		6			1			3						18		2		
CRUSTACEA / CLADOCERA Crustaceans / Water Fleas	Daphniidae	sp.1														2	2											1										
	?Chydoridae	sp.2																																		5		
CRUSTACEA / AMPHIPODA Crustaceans / Shrimps	Ceinidae	*Austrochiltonia sp.*	18	22	83		1		11	6	100+				100+	39	100+	3	1	21	1	20	67				4	25	100+				30	4	55	4	16	22
INSECTA / BLATTODEA Cockroach		sp.1												1																								
INSECTA / COLLEMBOLA Springtails (terrestrial)		sp.1																												10								
		sp.2										2		2												2				1		12						
		sp.3																4																			6	
INSECTA / LEPIDOPTERA		sp.1												1																								
INSECTA / HEMIPTERA Water Bugs	?Saldidae	sp.1																												2								
INSECTA / COLEOPTERA Water Beetles	Hydrophilidae	sp.1															1	10	2	7		1															1	4
	Helodidae	sp.2													9			100+	100+	7										2			1			100+	100+	3
	Curculionidae	sp.3																		2																	3	
		sp.4																	1																			2
INSECTA / DIPTERA Fly Larvae	Tabanidae	sp.1							1																													
	Ceratopogonidae	sp.2														3		3	2			1														8	14	5
	?Stratiomyid	sp.3														1				2														1				
		Unidentified sp.4	2																	1																		
		Undifferentiated larvae sp.5			27						1												3															
	Chironomidae	spp	38	100+	23		6		52	100+	41		3		39	100+	37	100+	25	100+	100+	100+	40	3			100+	100+	100+	1			100+	100+	36	46	100+	100+
INSECTA / EPHEMEROPTERA Mayflies	Caenidae	*Tasmanocoenis sp*								4	2									1			3					1	4									1
INSECTA / ODONATA Damselflies	Lestidae	sp.1														1																						
INSECTA / TRICHOPTERA Caddis Flies	Ecnomidae	*Ecnomus turgidus*	11						20	1					31	13		3	7	1	5						10						61			11		
	Leptoceridae	*Oecetis lacustra*	5		2				3		16						3	1			5	1	13						38				6		10		1	
	Hydroptilidae	*Hellyethira litua*		3						6	2					3												4						2			1	
	TOTAL NUMBER OF INDIVIDUALS		75	142+	140	8	12	1	103	170+	169+	4	5	6	188+	225+	156+	234+	134+	152+	113+	147+	137	12	4	3	126+	271+	273+	21	1	20	219+	176+	128	199+	252+	158+
	SPECIES RICHNESS		6	8	6	4	5	1	9	10	9	2	2	4	8	13	10	10	8	12	6	11	7	5	3	2	8	10	7	6	1	3	10	8	6	11	13	9

Table 4.9. Species and relative abundance data for macroinvertebrates found in leaf packs in sites 1 to 6.

the *Baumea* leaf packs, but markedly higher in the seasonally inundated *Typha* leaf packs, with thirteen taxa collected from site 5. In both species of leaf pack in the final time period the *Typha* community had the highest species richness. *Baumea* leaf packs had the lowest species richness when in their own vegetation community while *Typha* leaf packs had the lowest species richness in the open water site. The majority of taxa found in Lake Jandabup were present in all sites, however, the relative abundances varied considerably.

4.4.2 Invertebrate Abundance and Functional Feeding Groups

The classification of invertebrates into functional feeding groups is given in Table 4.10. Figures 4.17 to 4.22 displays graphically, for sites 1 to 6 respectively, the proportion of each sample represented by each of the groups and the total abundance for each species of leaf pack and each time period.

4.4.2.1 Permanently Inundated Sites (Sites 1-3)

Within the three permanently inundated sites the abundance of each group varied considerably. The relative abundance of invertebrates in each species of leaf pack in site 1 (permanently inundated *Baumea* community) steadily rose each time period, with numbers slightly higher in the *Typha* leaf packs. Site 1 had the highest percentage of predatory animals of the permanently inundated sites dominated by *Ecnomus turgidus*, a predacious free living trichopteran. *Baumea* leaf packs in this site were dominated by collector-filterers (mainly Diptera) in the first two time periods followed by a marked shift to an invertebrate fauna of over 50 % shredders, mainly amphipods. *Typha* leaf packs in the same community had over 90 % dipterans in the first two time periods before an increase in the abundance of *E.turgidus* reduced the numbers to around 50 %. An increase in the shredder abundance also occurred in these leaf packs in the last time period.

The *Baumea* leaf packs in site 2 (permanently inundated *Typha* community) again showed a steady increase in invertebrate numbers over the three time periods however, the total abundance of invertebrates in *Typha* leaf packs peaked in period 2 with 271

SHREDDERS

- Isopoda
- Amphipoda
  - Ceinidae
- Lepidoptera
- Coleoptera
  - Helodidae
- Trichoptera
  - Leptoceridae

SCRAPERS

- Gastropoda
  - Ancylidae
  - Physidae
  - Planorbidae
- Diptera
  - Tabanidae

COLLECTORS - FILTERERS

- Oligochaeta
- Ostracoda
- Cladocera
- Collembola
- Diptera
  - Ceratopogonidae
  - Chironomidae
  - Stratiomyidae
- Ephemeroptera
- Trichoptera
  - Hydroptilidae

PREDATORS

- Hirudinea
- Acarina
- Araneae
- Hemiptera
  - ?Saldidae
- Coleoptera
- Odonata
- Trichoptera
  - Ecnomidae

Table 4.10. Classification of invertebrates found in Lake Jandabup into functional feeding groups (after Cummins, 1973)

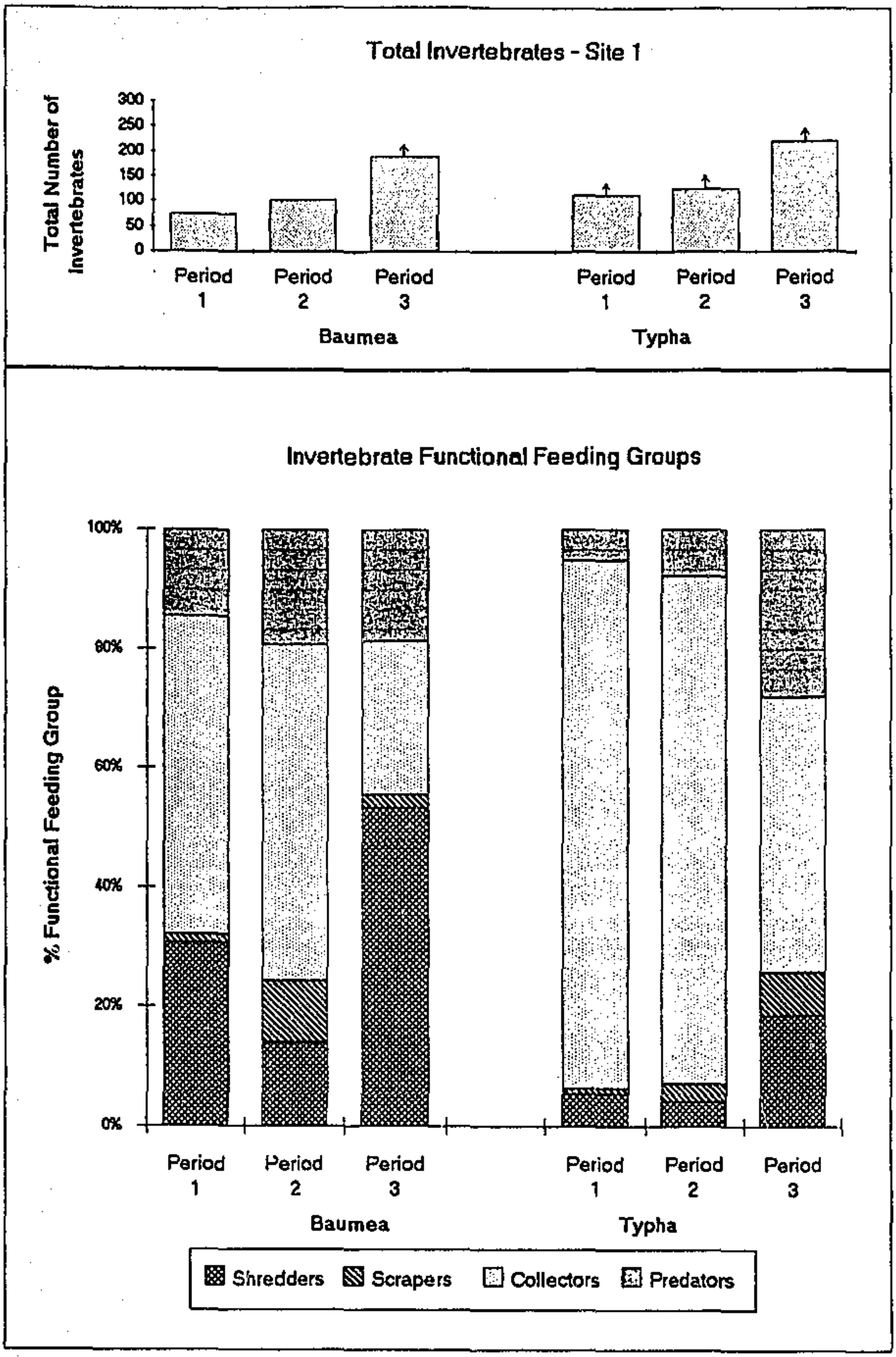


Figure 4.17. Macroinvertebrate relative abundance and percentage occurrence of each functional feeding group in site1. ↑ indicates abundances of 100+ were collected.

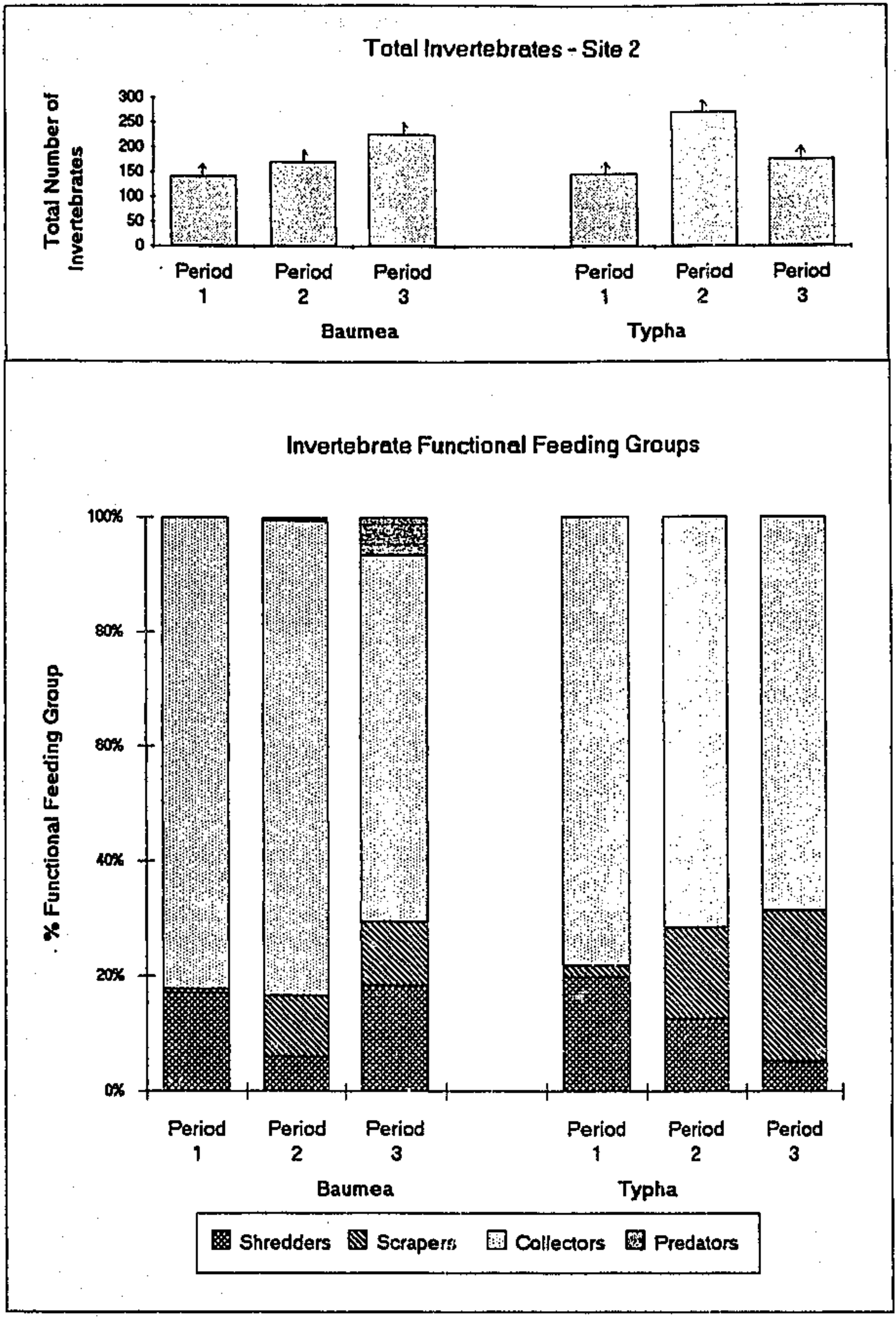


Figure 4.18. Macroinvertebrate relative abundance and percentage occurrence of each functional feeding group in site 2. ↑ indicates abundances of 100+ were collected.

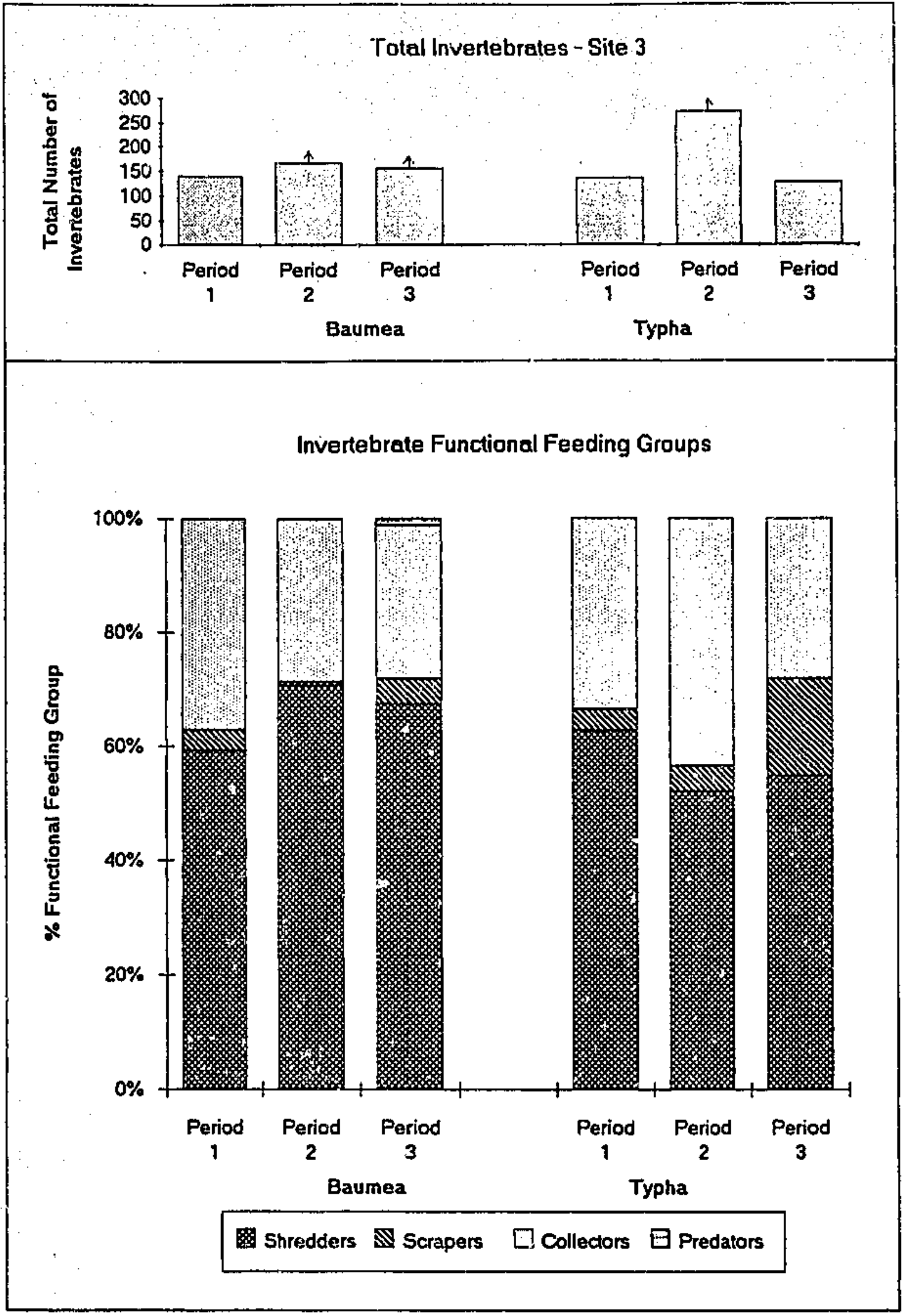


Figure 4.19. Macroinvertebrate relative abundance and percentage occurrence of each functional feeding group in site 3. ↑ indicates abundances of 100+ were collected.

individuals the highest level recorded in all sites before falling to a lower total abundance in the final period. Both species of leaf pack contained 70 % to 80 % collector filterers throughout the 24 weeks, the most notable feature was an almost complete absence of predators in this site. Both species saw the number of scrapers (mainly gastropods) increase in each time period. In the *Typha* leaf packs this also corresponded to a decrease in the number of shredders.

Both *Baumea* and *Typha* leaf packs in site 3 (permanently inundated control) exhibited a peak in invertebrate numbers in the second time period, the peak being far more pronounced in the *Typha* leaf packs. Shredders comprising mainly Amphipods dominated both species of leaf pack in all three time periods, with a noticeable lack of predators in this site. Again gastropod scrapers had increased in numbers by the end of the third time period, with the low number of collector filterers remaining fairly constant.

4.4.2.2 Seasonally Inundated Sites (Sites 4 - 6)

All seasonally inundated sites exhibited the same pattern of invertebrate abundance, being far greater in the third period following reflooding. By the end of the first and second time periods the seasonally inundated sites had conditions similar to those in a terrestrial environment. As a result, the invertebrate fauna in these two time periods were dominated by terrestrial species of remains of desiccated aquatic species that did not retreat with the lowering water table.

Invertebrate abundances in site 4 (seasonally inundated *Typha* community) were higher in *Baumea* rather than *Typha* leaf packs following reflooding. In this final time period both species of leaf pack were dominated by collector-filterers (mainly Diptera) and by a larvae of Helodidae a Coleopteran that dominates the invertebrate communities in the reflooded seasonal sites. Predator species were low, comprised of the predacious free living Trichopteran.

Total invertebrate abundance in site 5 (seasonally inundated *Baumea* community) was greater in *Typha* rather than *Baumea* leaf packs in the third period with 252+ individuals the highest of the seasonally inundated sites. In this site a distinct difference in feeding group percentages is apparent. The invertebrate fauna of the *Baumea* leaf

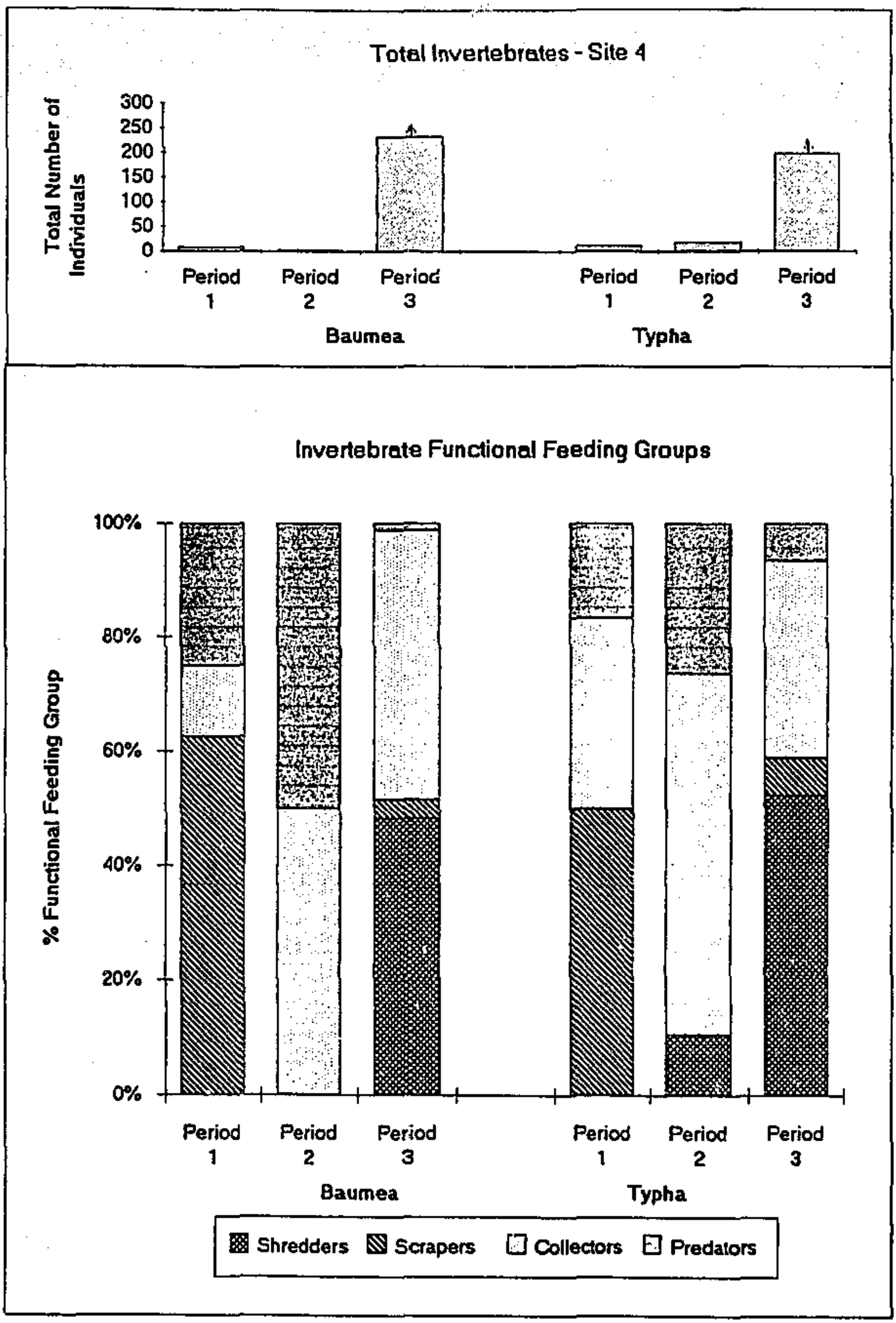


Figure 4.20. Macroinvertebrate relative abundance and percentage occurrence of each functional feeding group in site 4. ↑ indicates abundances of 100+ were collected.

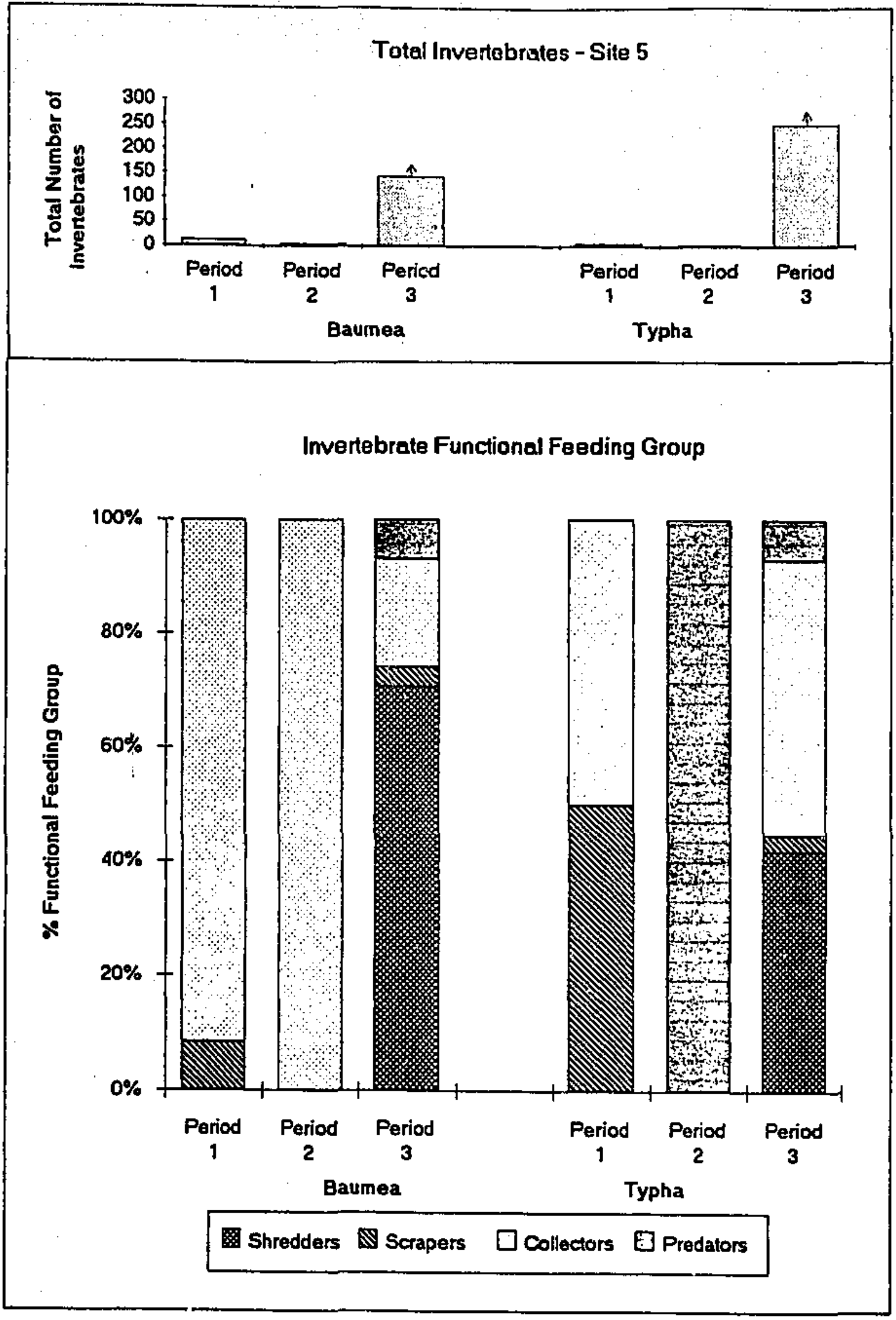


Figure 4.21. Macroinvertebrate relative abundance and percentage occurrence of each functional feeding group in site 5. ↑ indicates abundances of 100+ were collected.

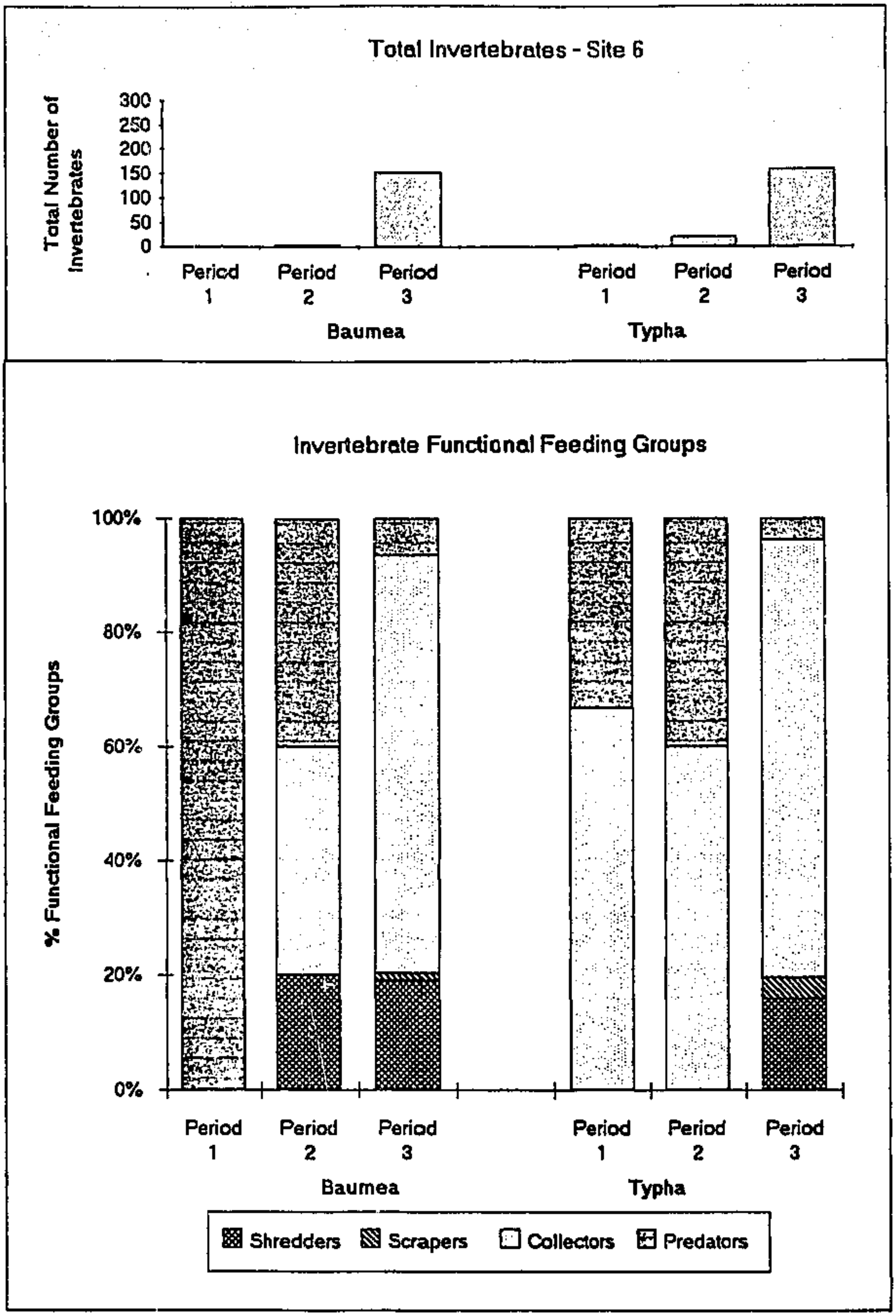


Figure 4.22. Macroinvertebrate relative abundance and percentage occurrence of each functional feeding group in site 6. ↑ indicates abundances of 100+ were collected.

packs comprised 75 % of the Coleoptera Helodidae while this species comprised only 45 % in the *Typha* leaf packs. The *Typha* leaf packs also had a higher percentage of collector-filterers and similar numbers of shredders to the *Baumea*.

The invertebrate numbers in site 6 are relatively equal in both species of leaf pack and the lowest of all the seasonally inundated sites. The proportion of each functional feeding group represented in each of the species is also relatively equal, dominated by collector-filterers (mainly Diptera) with low numbers of all other functional feeding groups.

4.4.3 Invertebrate Classification

The species collected in this experiment are shown in Table 4.9. A total of 44 taxa were collected from the two species of leaf pack at six sites on three sampling occasions on March 14, May 9 and July 4. Figure 4.23 shows the results of a TWINSPAN analysis using cut levels of 0,1,10,50,100 to incorporate the influence of the widely different abundances which occurred for some species. The result was ten groups of similar sites based on invertebrate relative abundance.

The absence of amphipods and chironomids and the presence of Collembola sp.2 resulted in the sites containing only terrestrial species being separated from all others in the first division. Invertebrates from the seasonally inundated leaf packs from the second period in site 5 were separated at the next division by the presence of Araneae sp.1, the only taxon found at that site in that time period. Two collection dates at site 4 in which the leaf packs were not inundated were separated at the third division by the presence of Araneae sp.1 a terrestrial spider. Further division saw the separation of the majority of the seasonally inundated sites from those permanently inundated. The result was collections from sites 4 and 5 following reflooding and *Baumea* leaf packs from the first time period being separated, with the latter being further separated from the inundated sites by the occurrence of Araneae sp.3 a terrestrial spider. The fifth division resulted in the permanent *Typha* community being separated from the other two permanently inundated sites by the presence of Ostracoda sp.2 and the absence of *Physastra* and

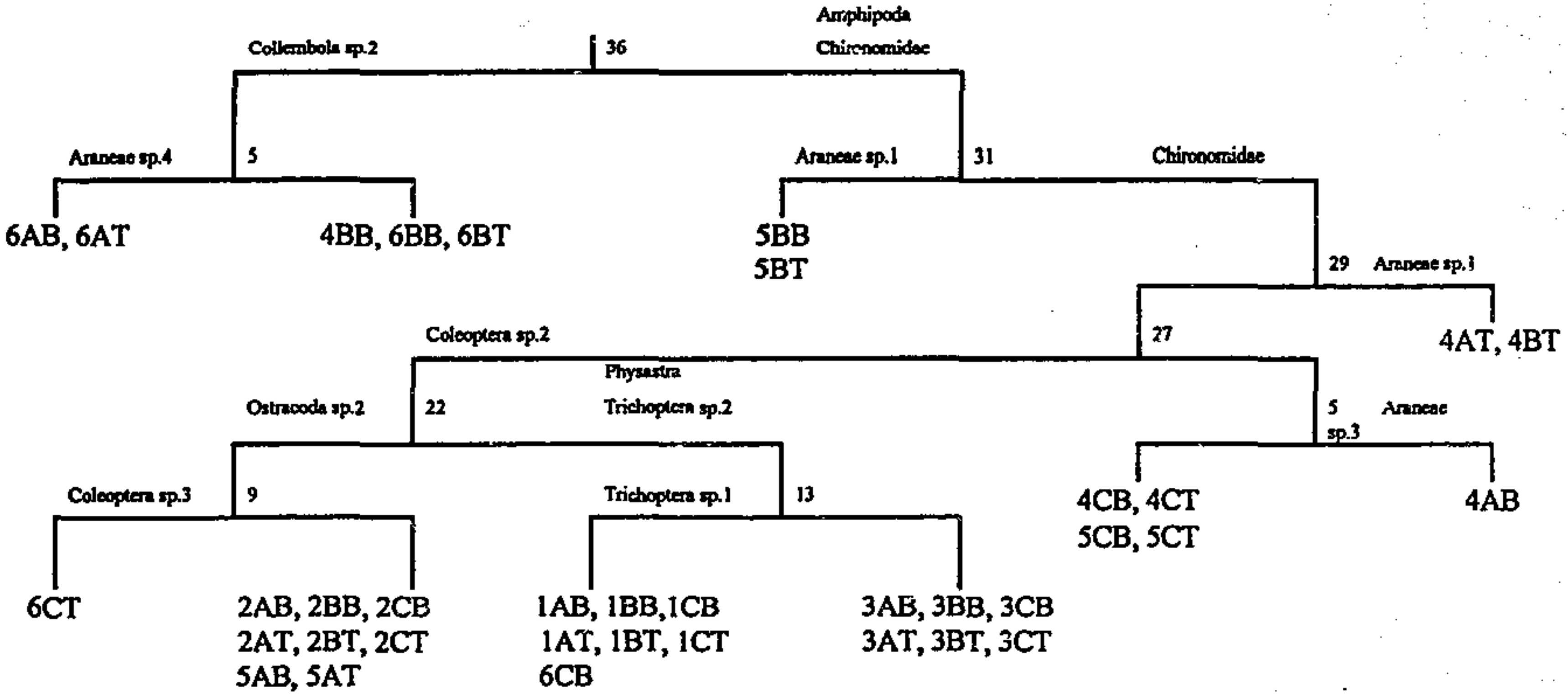


Figure 4.23. TWINSPAN results for macroinvertebrates collected from leaf packs using 0,1,10,50,100 cut levels. Indicator species and number of species are given at each division.

Trichoptera sp.2. The final division resulted in distinct invertebrate communities being present in each of the three permanently inundated vegetation communities. In one division, both the *Baumea* and *Typha* leaf packs and all of the collection dates in sites 1 and 3 were completely separated into two groups by the presence of Trichoptera sp.2 in site 1. The presence of this species in site 6 following reflooding resulted in this collection being grouped with the site 1 collections. The other division at this level saw both species and all collection dates from site 2 form a distinct group. Collections from site 5 were also included in this grouping as Ostracoda sp.2 was present, an indicator species in the previous division.

SECTION 5

DISCUSSION

5.1 Review of Major Findings

The aim of this study was to determine the effect of seasonal water regimes on the processing of leaf litter from two competitive emergent macrophytes, *Baumea articulata* and *Typha orientalis*. Three main hypotheses were generated in order to examine the processing of leaf litter after exposure of the leaf packs to the hydrological cycle :

1. There is no difference in the organic matter remaining for *B.articulata* leaf packs compared to leaf packs of *T. orientalis.*

2. There is no difference in the organic matter remaining in leaf packs between those found in *B.articulata* communities, *T.orientalis* communities and no vegetation community (open water).

3. There is no difference in the organic matter remaining in leaf packs between those sites that are permanently inundated and those seasonally inundated.

The first null hypothesis was rejected with a significant difference ($P<0.001$) in organic matter loss from leaf packs between species after they had been exposed to their respective water regime. Leaf packs constructed of *B.articulata* consistently had the highest loss of organic matter in each time period and in all sites. Site 6, the seasonally inundated control site showed *B.articulata* leaf packs lost almost double the organic matter of the *T.orientalis* leaf packs in the same site.

The second null hypothesis was accepted with no significant difference in the amount of leaf litter process between the different vegetation communities. Although not statistically significant, there were differences in the amounts of organic matter loss between the communities, particularly in those permanently inundated. *Baumea* as a vegetation community processed the lowest amount of organic matter with the *Typha* community processing the most. There is further evidence for this in the presence of peaty soils high in organic matter in site 1 and to a lesser extent in site 2. Despite the results showing that *B. articulata* leaf packs were processed faster than those of *Typha*, the *Baumea* community's overall slow rate of organic matter processing suggests that this community may have some intrinsic characteristics that result in reduced leaf litter processing.

The final null hypothesis was rejected, as statistical analysis showed a very highly significant difference ($P<0.001$) between the amount of organic matter loss in seasonally inundated as compared to permanently inundated sites. The leaf packs in the seasonally inundated sites lost higher amounts of organic matter following exposure to a full wet/dry hydrological cycle. The results of this study are supported up by the presence of peaty soils in the permanently inundated and not in the seasonally inundated sites. The formation of peat is encouraged by the presence of low oxygen concentrations as a result of prolonged flooding, indicating that the water regime of the seasonal inundation of the littoral vegetation currently experienced at Lake Jandabup has been in effect for some time.

In determining the loss of organic matter from leaf packs, other variables that contribute to the processes of decomposition were examined. These were physico-chemical characteristics of the water column and the role of microorganisms and macroinvertebrates.

An important outcome of this experiment was the potential for the stratification of the water column during the summer months. Stratification resulting in anaerobiosis, highly negative redox potentials and strong temperature differences between the top and bottom of the water column were found to occur in each of permanently inundated sites during the afternoon, the effect being most pronounced in the two vegetated communities. The presence of a stratified water column and the resulting limitations placed on the microorganisms and macroinvertebrates appears to be the driving force behind the low amount of leaf litter processing and subsequent accumulation of organic material.

Another significant determinant of water quality within the lake ecosystem was the influx of groundwater following the first substantial rains. On April 25, the date of the first rise in the water table after the summer drawdown features prominently in the results, as from this date all physico-chemical parameters were altered. The most noticeable of these was the salinity stratification of site 1, with a difference in conductivity between the top and the bottom of the water column of 532 µS/cm as a result of increased water levels.

The most interesting outcome of this experiment was the water quality of the laboratory treatments. At the end of the experiment, laboratory treatment 2 with *Typha* leaf packs had a rise in conductivity of nearly 1000 µS/cm and a gilvin that increased twenty fold to over 205 in the space of 24 weeks. These results were significantly higher than those in the same treatment containing *Baumea* leaf packs. This suggests that *Typha* may leach its soluble components more rapidly, with the high gilvin level indicating its potential to mobilise tannins stored in its leaves more readily.

The microbial biomass of leaf packs was found to be higher initially in *Typha* leaf packs but after 24 weeks this had reversed to be higher in the *Baumea* leaf packs. These results suggest that the softer structural components found in *Typha* leaves makes them a preferred food source for microorganisms initially with *Baumea* exhibiting delayed conditioning due to the more rigid structural component in its leaves.

The classification into groups of macroinvertebrates found in leaf packs using TWINSPAN resulted in a separation of the permanently inundated sites into distinct invertebrate communities, with no preference for Baumea or Typha leaf packs shown within established vegetation communities. The water quality data indicated that no substantial differences were present that may lead to such distinct differences in invertebrate community composition, indicating that other factors, perhaps vegetation community structure is a determining factor.

5.2 Organic Matter Loss

The processing of leaf litter has been described in Section 2.1 as following a predictable pattern of an initial weight loss due to leaching, followed by microbial colonisation and subsequent leaf conditioning and high invertebrate abundances corresponding to peaks in microbial biomass. Conditioning of leaf material by microorganisms increases its palatability and therefore make it a preferred food source for macroinvertebrates, increasing the amount of organic matter processed.

This pattern was apparent in some of the field sites however, there were many exceptions. In some instances a high microbial biomass actually resulted in an increase in the organic matter content of leaf packs. Site 5 is a noticeable example where an increase in the microbial biomass of leaf packs from the second to third time periods corresponded to an increase in their organic matter content. Microorganisms contain organic material and therefore an increase in the microbial biomass of leaf packs would also lead to an increase in their organic matter content. If the microbial biomass is not consumed by invertebrates and the increase of microorganisms is greater than the loss of organic matter from the leaf material then a rise in the organic matter content of leaf packs would occur.

In all permanently inundated sites, an increase in the organic matter of leaf packs from the second to third periods corresponded to a decrease in their microbial biomass over the same period. As previously mentioned, microorganisms contain organic matter and therefore can influence the organic matter content of leaf packs. The microbial biomass of leaf packs was measured using a phospholipid analysis in which only the viable microbial community was determined. The presence of viable microbial communities was found by Polunin (1984) to be influenced primarily by temperature, with microorganisms functioning best under higher temperatures. The steady decline in water temperature recorded at Lake Jandabup throughout the experiment may have contributed to a reduced viable microbial biomass. The presence of a higher microbial biomass in the previous period suggests that the microorganisms may still be present on the leaf packs, but due to the low water temperatures have become inactive and therefore no longer part of the viable microbial community measured in this experiment. As a result, microorganisms t[illegible]ere not measured may have been present on leaf packs and therefore, contributed to their organic matter content, resulting in a rise in organic matter content of leaf packs in the final period. These results suggest that microorganisms have contributed to the organic matter content of leaf packs and therefore the losses of organic matter from leaf packs may actually have been higher than those measured.

Following the exposure of leaf packs in the seasonally inundated sites to a seasonal wet / dry hydrological cycle, leaf packs in these sites lost more organic matter than those permanently inundated, indicating that aerobic exposure of leaf material over the summer months promotes increased leaf litter processing. These results suggest that the processing of leaf litter proceeds at a relatively slower rate in permanently inundated sites and an examination of the lake sediments found a higher proportion of plant material in these sites, suggesting an accumulation of organic material in the permanently inundated sites and the present distribution of the vegetation communities have been occurring for some time. This is supported by Allen (1979) who found peaty soils in Lake Jandabup, concluding that the process of organic matter accumulation was still occurring.

Three factors, species (*B.articulata* and *T.orientalis*), water regime (permanent or seasonal inundation) and vegetation community (*B.articulata* stand, *T.orientalis* stand and open water) were used to determine their significance in the process of leaf degradation. The vegetation communities in which the leaf packs were placed did not play a significant role in the processing of leaf litter after exposure to the seasonal hydrological cycle. A significant difference ($P<0.001$) was found between species and between water regimes in the final two periods, when the seasonal sites were exposed to aerobic conditions before being reflooded. The significance ($P<0.001$) of the interactions between factors affecting organic matter loss throughout the experiment highlights the complexity of the processes within a wetland ecosystem, and illustrates that this research is just a glimpse at the fate of organic matter in these environments.

The loss of organic matter from both species was much lower than expected for the 24 weeks of exposure. Hill (1985) found that *Typha* leaf packs in experimental mesh bags lost up to 55 % of their initial organic matter in the same period of time, over five times the maximum loss found in this experiment. In addition, *Baumea* leaf packs had a consistently higher loss of organic matter than from those made of *Typha*, the opposite to that expected as *Baumea* leaves were found to have a higher structural component, making leaf breakdown more difficult. These discrepancies are most likely attributed to the structure and composition of the leaf packs.

Riece (1974) demonstrated that the size and design of leaf packs had a significant effect on the rate at which they break down. Microclimatic differences between the external and internal leaves in leaf packs may differ substantially. While the external leaves may be freely supplied with oxygen and relatively accessible to microbial invasion, invertebrate feeding and physical abrasion, internal leaves might be protected from microbial invasion and therefore invertebrate feeding and could even be exposed to anaerobiosis. Riece (1974) also stressed that where leaf material may accumulate naturally, this differential processing could also occur such that external leaves would normally process faster while internal leaves may not be processed at all. As the outer leaves were degraded, those nearer the pack centre would become available to processing factors and would break down at or near their species specific rate. This may be partially true for Lake Jandabup, as the loss of organic matter from leaves naturally abscessed and not bound in leaf packs had similar losses of organic matter after eight weeks as those leaf packs exposed for twenty four weeks, indicating that the design of the leaf pack hindered the process of organic matter loss.

The laboratory treatments support this in that they were not exposed to the same diversity of microflora or invertebrates as the seasonal sites, yet the losses of organic matter were comparable, again indicating that the use of leaf packs may not represent true leaf litter processing. The dry weight loss from leaf packs did not correspond to the losses of organic matter, highlighting the need for the use of loss of organic matter in such studies, as mass loss from leaf packs does not accurately reflect leaf litter processing.

The design of the leaf pack may also be responsible for significant differences ($P<0.001$) in the loss of organic matter between *Baumea* and *Typha* leaf packs. *Baumea* is a cylindrical, bamboo shaped reed, whereas *Typha* has flattened, elongate leaves and therefore, the two species differ structurally and chemically. The result is that *Baumea* leaf packs could not be packed as tightly as those made of *Typha*, therefore exposing a larger surface area to aerobic conditions and enhancing the process of degradation. In addition the *Baumea* leaf packs floated on the waters' surface for the majority of the experiment whereas the *Typha* leaf packs had sunk by the end of the first time period, again exposing the *Baumea* leaf packs to more aerobic conditions. *Typha* leaf packs had consistently higher wet weights indicating that given optimum conditions they would possess a higher surface area for microbial colonisation and invertebrate feeding and therefore, more rapid leaf processing.

The leaf material used in the construction of the leaf packs was removed from standing plants. It is this factor that may also have contributed to the low rates of organic matter loss. When measured, the microbial biomass of the leaf material was consistently 0.0000 mg/L P, yet leaf material from the same plants in the same terrestrial environment when unattached had maximum microbial biomass of 0.0031 mg/L P. This suggests that when attached to the plant, a natural fungicide may be present preventing degradation, and as such may be present in the leaf material used in the construction of leaf packs.

The physical environment may also interact with the leaf material effecting the rates of leaf litter processing in different habitats. The most noticeable changes in the water quality were as a result of the influx of water with the onset of the winter rains. Conductivity decreased substantially after the first rains, resulting in large salinity differences between the top and bottom of the water column. This indicates the potential for chemical stratification to occur in some lake habitats under these conditions. Groundwater is the most probable source of freshwater, as the conductivity on the eastern side where the groundwater enters was consistently lower than that on the western side of the lake. The hydroperiod also effects pH, as the water became more acidic as water depth increased. Increased acid conditions may result in available phosphorus complexing to forms unavailable for plant growth, therefore, reducing macrophyte productivity (Day, 1982).

Riece (1974) concluded that seasonal temperature changes controlled the rate of leaf breakdown in Augusta Creek, Michigan, and Benfield, Paul and Webster (1979) demonstrated that breakdown rates of two species were strongly influenced by temperature differences in thermal discharge from a power plant. The effects of temperature appeared to be overshadowed by other controlling factors in this experiment. Oxygen concentration may have a significant effect and can often reverse the enhancing effect of temperature if increased respiration rates lead to oxygen depletion. The diurnal fluctuations in temperature and dissolved oxygen concentrations between the top and bottom of the water column and the consistent highly negative redox potentials present at the bottom of the water column suggest that in summer some habitats have the potential to stratify on a daily basis resulting in anaerobic conditions within the water column.

The presence of a stratified water column severely affects the ability of microorganisms and macroinvertebrates to process leaf litter. The continuous supply of organic matter to the lake food web by emergent macrophytes must either be utilised in secondary production or stored in the soil. Under stratified conditions, oxygen may not diffuse into the system as rapidly as it is used by microorganisms and macroinvertebrates. Prolonged deoxygenation severely limits the capacity for these organisms to decompose organic matter, limiting the supply of nutrition in the water column and favouring the accumulation of this material and the formation of peat.

Water quality appeared to influence the loss of organic matter and more specifically the leaching of soluble components from leaf packs. The loss of organic matter was higher from leaf packs placed in filtered lake water than from those placed in distilled water. Of particular interest is the substantially higher conductivity and gilvin levels recorded in the treatment with filtered lake water. The conductivity rose by nearly 1000 µS/cm and gilvin increased twenty fold to 205 in this treatment with *Typha* leaf packs, almost double the changes recorded for *Baumea* leaf packs in the same treatment. This indicates that both species leach more soluble components in water from which they originated and *Typha* leaches more of these components than *Baumea*. This is backed up by field data which shows the *Typha* communities in the field having the highest conductivity in their respective water regime.

There seems little doubt that quantitatively the physico-chemical characteristics of the water column exert a regulating influence on leaf litter processing and that leaf pack structure and composition may have modified both species specific processing rates and the effects of a seasonal hydrologic cycle on leaf litter processing. However, increased losses of organic matter from both species occurred as a result of being exposed to a seasonal wet/dry hydrological water regime, and differences in the amount of organic matter processing exists between species, with *Baumea* losing substantially more.

The presence of peaty soils in the sites permanently inundated and their absence in those seasonally inundated indicates that there has historically been a difference in leaf litter processing between the two sites. The formation of peat is a natural process in wetlands, central to their geological transition to terrestrial environments. There appears to be a deficiency in literature concerning the distribution and formation of peaty soils on the Swan Coastal Plain despite it being of great importance to wetland ecology, of which there is an abundance of literature. The presence of peat within some microhabitats and its absence in others can provide insights into past water levels and vegetation communities. As the peat experiences anaerobic conditions, it can act as a partial preservative of past vegetation and invertebrate assemblages, providing a unique window into the past.

Throughout the experiment *Baumea* leaf packs lost substantially more organic matter than *T.orientalis* leaf packs. *Typha* has been described by Froend *et al* (1993) as an aggressive coloniser, capable of out competing *Baumea* in the same environment. At present the distribution of *Typha* is limited to small pockets, occupying land that has been severely disturbed. The encroachment of *Typha* further into the wetland would, based on the results of this study, significantly alter many aspects of the wetland ecosystem. *Typha* leaves exhibited a much lower loss of organic matter than that found in *Baumea* leaf packs throughout the experiment. The result of an increase in the distribution of *Typha* within the wetland would be a decrease in the amount of organic matter available to secondary producers and subsequently increase the accumulation of partly decayed organic matter and formation of peaty soils. The formation of peat is a natural process in the biotic transition from a lake system to a terrestrial environment.

Increased accumulation of peat as a result of the slow rate of processing of *Typha* leaves may increase the rate of terrestrialisation and therefore the loss of an already rapidly decreasing habitat.

The presence of distinctly different invertebrate communities found to exist between *Baumea* and *Typha* stands may be responsible for the differences in the amounts of organic matter processing. These results indicate that a change in the dominant emergent macrophyte at Lake Jandabup from *Baumea* to *Typha* may change the proportions of organic matter processing through a change in the invertebrate composition within the lake.

One of the important findings of the laboratory treatments was the ability of the *Typha* leaf packs to dramatically increase the conductivity and gilvin of the water through the leaching of soluble components within its leaves. An increase in the distribution of *Typha* within Lake Jandabup has the potential to spread these characteristics that are now restricted to small areas to the rest of the lake and therefore altering many aspects of the current wetland ecosystem.

All of this information is relevant in the determination of a water regime that will maintain the existing processes within Lake Jandabup. The low amount of organic matter processing and the presence of peat in the permanently inundated sites suggests that these communities (regarded as experiencing a permanent water regime for the purposes of this study) have experienced this water regime for some time. Alternatively, the higher amounts of leaf litter processing and a lack of peaty soils in the seasonally inundated sites also suggests that these communities have experienced this water regime for a prolonged period. A water regime that would maintain the existing ecological process within lake Jandabup requires the seasonal exposure of areas of littoral vegetation and the permanent inundation of others. In other words, prolonged flooding or drawdown would result in the alteration of the processing of wetland vegetation and therefore disrupt the food web.

5.3 Microorganisms

The colonisation of leaf litter by microorganisms is described as part of the rapid phase of decomposition (Polunin, 1984), therefore, a more accurate assessment of maximum microbial biomass could be obtained if measurements were taken shortly after the initial placement or reflooding of leaf packs rather than at eight week intervals, as microorganisms do not operate within rigid timetables. The values recorded during this experiment provide a valuable insight into the fluctuations of microbial biomass under differing environmental conditions.

The colonisation of leaf litter by microorganisms and the conversion of this plant material to a form of organic material that is easily digestible by aquatic invertebrates is an important component in the processing of leaf litter. Barlocher *et al* (1978) found that the nutritional value of detritus, or at least its palatability is greatly increased when it is first colonised by microorganisms. This was evident in the seasonally inundated sites where the microbial biomass peaked in the third period following reflooding as did the invertebrate numbers. This presence of maximum microbial biomass and invertebrate numbers also occurred in sites 2 and 3 of the permanently inundated sites, while site 1 had maximum microbial biomass in period 2 with a lag in the peak of invertebrate numbers. The earlier peak in microbial biomass in permanent sites may be due to increased exposure time to aquatic microflora, but the benefits of a period of exposure to microbial biomass and therefore, leaf litter processing are shown by higher losses of organic matter in the seasonally inundated sites.

The diurnal fluctuations in site 1 indicated its potential for anaerobiosis under certain conditions at the bottom of the water column, and may have limited the access of microorganisms or invertebrates. Oxygen availability has a far reaching influence on microbial metabolism. With declining dissolved oxygen levels, oxidation processes become more and more incomplete until respiration is finally replaced by fermentation (Barlocher et al, 1978) leading to an accumulation of partly degraded substances and as a result less energy is available for microbial growth, evident in the high soil organic content in the permanently inundated sites. Efficient aerobic decomposition is generally paralleled by a higher microbial biomass, highlighted by the highest microbial biomass being found in the site exposed to aerobic conditions the longest.

Increases in microbial biomass may be kept at a lower level by successive waves of invertebrate consumers or, in their absence it may accumulate. Laboratory treatments where invertebrates were excluded showed comparable microbial biomass and loss of organic matter to those in the field. This suggests that again the design and composition of the leaf packs hindered microbial colonisation, as leaf packs in the field had a greater potential for microbial colonisation and subsequent invertebrate feeding as they were exposed to a wider microflora community capable of colonisation. Gaur, Singhal and Hasija (1992) found that the initial impregnation of leaf litter by dominant species of fungi and bacteria can prevent further succession of microorganisms on leaf litter. Therefore the microbial community composition may have been predetermined, affecting subsequent colonisation and limiting the processing of organic matter.

5.4 Macroinvertebrates

Invertebrate responses to microbial biomass have already been discussed with invertebrates displaying a preference for microbially conditioned food. Neckles *et al*, 1992) found a tendency for more invertebrates to be associated with litter that has been submersed for longer as it had been exposed to increased microbial conditioning and as a result was a more palatable food source. This was found to be true in the majority of the field sites at Lake Jandabup. The seasonal patterns of functional feeding groups provides some evidence of the influence of leaf conditioning on invertebrate distribution and abundance.

Shredders probably responded, as did scrapers, to microbial and algal conditioning of the leaf litter. Because scrapers feed primarily on the surface of leaves and shredders feed both on surface and within the leaf material, shredder populations generally peaked later. Amphipods and Trichopterans were the dominant shredders, with the latter using fragmented leaf material in case building as well as for nutrition. The scraper community was dominated by a freshwater gastropod, the limpet (Ancylidae).

Collector / filterers appeared to be abundant throughout all sites and are well suited to a wetland environment because of the abundance of fine particulate organic matter. However the quality of fine particulate organic matter declines as particles become refractory over time (Nelson, 1992). This group was dominated by the order Diptera, especially by chironomid larvae. As expected, predator populations did not respond to leaf litter quality, their distribution and abundance probably most influenced by prey abundance.

The seasonally inundated sites had largely terrestrial conditions in the first two time periods and their invertebrate assemblages reflected this. Upon reflooding in the third period, invertebrate populations in sites 4 and 6 were dominated by collector / filterers (Chironomid larvae) and Helodidae larvae, a shredder belonging to the order Coleoptera which dominated the invertebrate community in the seasonally inundated sites following reflooding. Helodidae adults were found by Williams (1980) to lay their eggs in littoral vegetation during period of exposure, with site 5 containing almost entirely chironomid larvae. The variation in the invertebrate assemblages between vegetation communities following reflooding suggests the invertebrate populations of seasonally inundated sites may be more opportunistic than preferential feeders.

The classification of invertebrate data using TWINSPAN firstly separated the majority of seasonally inundated sites from those permanently inundated, but more importantly completely separated the three permanently inundated sites into distinct invertebrate communities incorporating both species and all time periods. The presence of distinct invertebrate assemblages in the different vegetation communities may explain the differences in the representation of functional feeding groups between sites and therefore, the differences in the amount of organic matter processing. The physico-chemical data obtained indicated no substantial differences in water quality between the three sites, suggesting that other factors, such as the difference in the structure of the emergent macrophyte community may be influencing invertebrate community composition.

The presence of distinct invertebrate communities within microhabitats is evidence that members of different functional feeding groups will vary, as will the processing of leaf litter within a wetland ecosystem. The maintenance of these communities appears crucial, not only for invertebrate diversity but in order to maintain the proportions of organic matter processing and accumulation of organic matter in the sediments in these communities at Lake Jandabup.

Based on the data obtained from this research, the need for future work on the decomposition of emergent macrophytes is clear. The loss of organic matter from leaf packs provides only a superficial glimpse of the processes involved in the decomposition of leaf litter. What is the fate of organic matter ? Who eats what (or who) in successive trophic levels ? Do microorganisms or invertebrates contribute most to decomposition ? Are there factors not yet evident controlling decomposition ? Is there a better way of measuring decomposition ? These are but a few of a multitude of questions that arose in the course of the experiment, and as yet remain unanswered for Perth's wetlands.

5.5 Management Implications

Lake Jandabup is a seasonal wetland on the Swan Coastal Plain and is a surface expression of the Gnangara Mound. The lake experiences a seasonal water regime in which a reduction in the water level during summer and autumn exposes large areas of littoral vegetation to aerobic conditions. This is followed by an increase in water levels in winter and spring as a result of rainfall, increasing the level of the groundwater table resulting in the reflooding the littoral zone. Groundwater abstraction for public and private use has the potential to reduce wetland water levels, whereas a rise in the water levels are often a result of vegetation clearing and urbanisation. Lake Jandabup is highly susceptible to changes in groundwater levels as it has a maximum depth of two metres, is located near the Wanneroo borefields and is adjacent to the maturing Gnangara pine plantation. This research was concerned with the effect of permanent or seasonal inundation on the processing of leaf litter from two common emergent macrophytes, *B.articulata* and *T.orientalis*.

Plant litter forms an important energy source within wetland food webs. The slow rate of leaf litter processing and an accumulation of organic matter in lake sediments in the permanently inundated sites suggests that the potential energy entering the system is not being fully utilised. Aerobic conditions provided for the most rapid processing of leaf litter, with optimum conditions achieved when leaf litter was exposed to an aerobic, alternate wet/dry hydrologic regime.

The maintenance of a seasonal water regime that provides for the periodic flooding and exposure of the littoral zone seems paramount in sustaining the ecological processes of organic matter decomposition and formation of peat and species composition in certain wetland ecosystems. Not only does periodic drawdown of the water table maintain the benefits associated with this environment, it also provides the proximate cues by which aquatic organisms respond to those benefits.

A reduction in the water levels currently experienced at Lake Jandabup would result in the littoral vegetation not being exposed to seasonal inundation and therefore, depriving secondary producers of a major source of organic matter. However, Froend *et al* (1993) in the study of wetland littoral vegetation found emergent macrophyte communities to be 'dynamic', and capable of responding rapidly to changes in water levels. Of concern is one of the other findings of this study. It was found that exposed sediment or shallow water near the edge of a *Baumea* stand during the drier seasons, provide ideal conditions for the invasion of *Typha*. Given that the presence of *Typha* already exists at Lake Jandabup and as previously mentioned an increase in its distribution is capable of altering many aspects of the wetland ecosystem, the maintenance of current water levels which are limiting the spread of *Typha* is paramount.

An increase in the water levels in Lake Jandabup could result from the maturing Gnangara pine forest to the east of the lake requiring thinning in future years, and from urban development that continues its progress towards the area. An increase in water depth is of concern as the results of Froend *et al* (1993) indicated that prolonged flooding of emergent macrophytes led to the death of part or all a species population. Increased water levels may result in the shift of the littoral vegetation up gradient, but the gradient of the new littoral zone becomes much steeper, dramatically reducing the area available for the colonisation of emergent macrophytes, a major source of organic matter in wetland food webs. As with a reduction in water levels, an increase would also detrimentally effect the proportions of organic matter available within the wetland, by reducing the inputs of organic matter into the lake from emergent macrophytes and preventing peaks in organic matter availability as a result of the seasonal inundation of the littoral vegetation.

Artificial maintenance of wetland water levels should be employed to maintain the natural variation in water regime, used only to mitigate the effects of groundwater abstraction or increased inputs in maintaining the existing water regime. Artificial maintenance, as suggested by Balla & Davis (1993) should take place in spring when it would more closely resemble the natural water regime, as seasonal flooding of the littoral zone may not occur if the levels are merely topped up in summer.

This study provides an insight into the effect of seasonal water regimes on the processing of leaf litter within a wetland ecosystem, concluding that the alternate seasonal inundation and exposure of the littoral vegetation can provide a substantial food resource to aquatic food webs. Alterations to this cycle have the potential to irreversibly modify the functioning of these ecosystems, changing the very nature of the wetland. If wetlands are to be preserved as a resource for future generations to use and enjoy, continued research is needed to ensure the sustainability of the ecological processes within these habitats.

SECTION 6

REFERENCES

Allen, A.D. (1979). The Hydrogeology of Lake Jandabup Swan Coastal Plain, W.A. In Western Australian Geological Survey Annual Report 1979, 32-40.

Anderson, N.H., & Sedell, J.R. (1979). Detritus Processing by Macroinvertebrates in Stream Ecosystems. Annual Review of Entomology, 24, 351-377.

Arnold,J.A. (1990). Jenny Arnold's Perth Wetland Resource Book - Wetlands of the Northern and Eastern Gnangara Mound and Eastern Wanneroo Wetlands ; Chapters 5 & 6, (Bulletin 266) Perth : EPA and WAWA.

Ayre,D., Colreavy,M., Coster,P., Fisher,K., Hill,A., Lymbery,A., McShane,P & Threlfall,T. (1977). A Limnological Survey of Lakes Joondalup, Jandabup and Loch McNess, Honours Thesis : University of WA.

Balla,S.A., & Davis,J.A. (1993). Wetlands of the Swan Coastal Plain - Vol 5 - Managing Perth's Wetlands to Conserve the Aquatic Fauna, Perth : EPA and WAWA.

Barlocher,F., & Kendrick,B. (1975). Leaf Conditioning by Microorganisms, Oecologia, 20, 359-362.

Barlocher,F., Mackay,R.J., & Wiggins,G.B.,(1978). Detritus Processing in a Temporary Vernal Pool in Southern Ontario, Archiv für Hydrobiologie, 81, (3), 269-295.

Barlocher,F., & Schweizer.P. (1983). Effects on Leaf Size and Decay Rate on Colonisation by Aquatic Hyphomycetes, Oikos, 41, 205-210.

Benfield,E.F., Paul,R.w., & Webster,J.R. (1979). Influence of Exposure Technique on Leaf Breakdown Rates in Streams, OIKOS, 33, 386-391.

Benner,R., Moran,M.A., & Hodson,R.E. (1985). Effects of pH and Plant Source on Lignocellulose biodegredation rates in two wetland ecosystems, the Okefenokee Swamp and a Georgia Salt Marsh, Limnologer and Oceanographer, 30, 489-499.

Boulton,A.J. & Boon,P.I.(1991) A Review of Methodology Used to Measure Leaf Litter Decomposition in Lotic Environments : Time to Turn Over a New Leaf, Australian Journal of Marine and Freshwater Research, 42, 1-43.

Brady,N.C. (1990). The Nature and Properties of Soil, New York : Macmillan Publishers.

Briggs,S.V., & Mayer,M. (1985). Limnological Studies of Waterfowl Habitat in South-western New South Wales. II. Aquatic Macrophyte Productivity, Australian Journal of Marine and Freshwater Research, 36, 707-715.

Briggs,S.V.,Maher,M., & Carpenter,S.M. (1985). Limnological Studies of Waterfowl Habitat in South-western New South Wales. I. Water Chemistry, Australian Journal of Marine and Freshwater Research, 36,59-67.

Bunn,S.E. (1986). Origin and Fate of Organic Matter in Australian Upland Streams, In P.Deckker & W.D.Williams (Eds.) Limnology in Australia, Melbourne : CSIRO.

Bunn,S.E. (1988). Processing of Leaf Litter in a Northern Jarrah Forest Stream, WA - Seasonal Differences, Hydrobiologia, 162, 201-210.

Chambers,J.M., & Davis,J.A. (1989). How Wetlands Work, In G.Lowe (Ed.) Swan Coastal Plain Groundwater Conference, Perth : WA Water Resources Council.

Cranwell,P.A. (1976). Organic Compounds as Indicators of Allochthonous and Autochthonous Inputs to Lake Sediments. In Interactions Between Sediments and Freshwater, The Hague : Dr W Junk Publishers.

Cummins,K.W. (1973). Trophic Relations of Aquatic Insects, Annual Review of Entomology, 18, 183-206.

Cummins,K.W. (1974). Structure and Function of Stream Ecosystems, Bioscience, 24, 631-641.

Cummins,K.W., Klug,J.J., Wetzel,R.G., Petersen,R.C., Suberkropp,K.F., Manny,B.A., Wuycheck,J.C. & Howard,F.O. (1972). Organic Enrichment with Leaf Leachate in Experimental Lotic Systems, Bioscience, 22, 719-722.

Cummins,K.W.,Wilzbach,M.A.,Gates,O.M.,Perry,J.B. & Taliaferro,B.W. (1989). Shredders and Riparian Vegetation, Bioscience, 39 (1), 24-30.

Danell,K., & Sjoberg,K. (1979). Decomposition of *Carex* and *Equisetum* in a Northern Swedish Lake : Dry Weight Loss and Colonisation by Macroinvertebrates, Journal of Ecology, 67, 191-200.

Davis,J.A., Rosich,R.S., Bradley,J.S., Growns,J.E., Schmidt,L.G., & Cheal,F. (1993). Wetlands of the Swan Coastal Plain Vol 6 - Wetland Classification on the Basis of Water Quality and Invertebrate Community Data, Perth : EPA & WAWA.

Day,F.P. (1982). Plant Litter Decomposition Rates in the Seasonally Flooded Great Dismal Swamp, Ecology, 63 (3), 670-678.

Day,F.P.(1983). Effects of Flooding on Leaf Litter Decomposition in Microcosms, Oecologia, 56, 160-184.

Froend,R.H., Farrell,R.C., Wilkins,C.F., Wilson,C.C. & McComb,A.J. (1993). Wetlands of the Swan Coastal Plain Vol 4 - The Effect of Altered Water Levels on Wetland Plants, Perth : WA Water Authority and EPA.

Gardiner,A., & Davies,R.W. (1988). Decay Rates of Autumn and Spring Leaf Litter in a Stream and Effects on Growth of a Detritivore, Freshwater Biology, 19, 297-303.

Gaur,S., Singhal,P.K., & Hasija,S.K. (1992). Relative Contributions of Bacteria and Fungi to Water Hyacinth Decomposition, Aquatic Botany, 43, 1-15.

Godshalk,G.L., & Wetzel,R.G. (1976). The decomposition of Macrophytes and the Metabolism of Organic Matter in Sediments. In Interactions Between Sediments and Freshwater, The Hague : Dr W Junk Publishers.

Godshalk,G.L., & Wetzel,R.G. (1978). Decomposition in the Littoral Zone of Lakes, In R.Good, D.Whigham & R Simpson (Eds.) Freshwater Wetlands : Ecological Processes and Management Potential, New York : Academic Press.

Hach DR 2000 Spectrophotometer Water Analysis Handbook .(1989). Colarado : Hach Company.

Hanlon,R.D.G. (1982). The Breakdown and Decomposition of Allochthonous and Autochthonous Plant Litter in an Oligotrophic Lake, Hydrbiologia, 88, 281-288.

Hanson,J.M. (1990). Macroinvertebrate Distributions of Two Contrasting Freshwater Macroinvertebrate Communities, Freshwater Biology, 24, 481-491.

Hanson,B.J.,Cummins,K.W.,Barnes,J.R. & Carter,M.W. (1984). Leaf Litter Processing in Aquatic Systems : A Two Variable Model, Hydrobiologia, 111, 21-29.

Herbst,G & Reice,S.R.(1982). Comparitive Leaf Litter Decomposition in Temporary and Permanent Streams in Semi-Arid Regions of Israel, Journal of Arid Environments, 5, 305-318.

Hietz,P. (1992). Decomposition and Nutrient Dynamics of Reed *Phragmites australis* Litter in Lake Neusiedl, Austria, Aquatic Botany, 43, 211-230.

Hill,B.H. (1985). The Breakdown of Macrophytes in a Reservoir Wetland, Aquatic Botany, 21, 23-31.

Hollick,M. (1989). Some Perspectives on Groundwater Management in Perth. In G.Lowe (Ed) Swan Coastal Plain Groundwater Management, Perth : WA Water Resources Council.

Kadlec,J.A. (1962). Effects of a Drawdown on a Waterfowl Impoundment, Ecology, 43, 267-291.

Kirk,J.T.O. (1986) Optical Limnology - a manifesto. In P.DeDeckker and W.Williams Limnology In Australia, Melbourne : Dr W Junk Publishers

Kent,M., & Coker,P. (1992) Vegetation Description and Analysis - a practical approach, London : Belhaven Press..

Marchant,R. (1982). Seasonal Variation in the Macroinvertebrate Fauna of Billabongs along Magela Creek, Northern Territory, Australian Journal of Marine and Freshwater Research, 33, 329-342

Mason,C.F. (1976). Relative Contribution of Fungi and Bacteria in the Decomposition of *Phragmites* leaves, Hydrobiologia, 1, (50), 65-69.

Meyer,J.L., & Johnson,C.(1983). The Influence of Elevated Nitrate Concentrations on the Rate of Leaf Decomposirion in a Stream, Freshwater Biology, 13, 177-183.

Mitchell,D.S. (1980). Aquatic Weeds. In W.D.Williams (Ed.) An ecological Basis for Water Resource Management, Canberra : Aust. National University

Moss,B. (1980). Ecology of Fresh Waters, Melbourne : Blackwell Scientific Publishers.

Murkin,H.R. (1989). The Basis for Food Chains in Prarie Wetlands, In A.G.vander Valk (Ed.) Northern Prarie Wetlands, Ames : Iowa State University Press.

Neckles,H.A.,Murkin,H.R. & Cooper,J.A. (1990). Influences of Seasonal Flooding on Macroinvertebrate Abundance in Wetland Habitats, Freshwater Biology, 23, 311-322.

Nelson,J.W., Kadlec,J.A., & Murkin,H.R. (1990). Responses by Macroinvertebrates to Cattail Litter Quality and Timing of Litter Submergence in a Northern Prarie Marsh, Wetlands, 10, (1), 47-60.

Petersen,R.C., & Cummins,K.W. (1974). Leaf Processing in a Woodland Stream, Freshwater Biology, 4, 343-368.

Pinder,A.M. (1986). Ecology of Macroinvertebrates in Seasonal Wetlands, Honours Thesis, Murdoch University, Western Australia.

Plaster,E.J. (1985). Soil Science and Management, New York : Delmar Publishers.

Polunin,N.V. (1984). The Decomposition f Emergent Macrophytes in Fresh Water, Advances in Ecological Research, 14, 115-153.

Puriveth,P. (1980). Decomposition of Emergent Macrophytes in a Wisconsin Marsh, Hydrobiologia, 72, 231-242.

Reddy,K.R., & Patrick,W.H. (1975). Effect of Alternate Aerobic and Anaerobic Conditions on Redox Potential, Organic Matter Decomposition and Nirogen Loss in a Flooded Soil, Soil Biology and Biochemistry, 7, 87-94.

Reed,F.C. (1979). Decomposition of *Acer rulorum*, Hydrobiologia, 64, 195-197.

Riece,S.R. (1974). Environmental Patchiness and the Breakdown of leaf litter in a Woodland Stream, Ecology, 55, 1271-1282.

Riggert,T.L. (1966). A Study of Wetlands of the Swan Coastal Plain, Western Australia, Perth : Department of Fisheries and Fauna.

Satchell,J.E. (1974). Litter interface of animate / inanimate matter, In C.Dickinson & G.Pugh (Eds) Biology of Plant Litter Decomposition volume 1, Academic Press : London.

Semeniuk,C.A. (1987). Wetlands of the Darling System - A Geomorphic Approach to Habitat Classification, Journal of the Royal Society of Western Australia, 63 (3), 95-112.

Short,R.A., Smith,S.L., Guthrie,D., & Stanford,J.A. (1984). Leaf Litter Processing Rates in Four Texas Streams, Journal of Freshwater Ecology, 2, 469-473.

Storey,A.W., Vervest,R.M., Pearson,G.B., & Halse,S.A. (1993). Wetlands of the Swan Coastal Plain Vol 7 - Waterbird Usage of Wetlands on the Swan Coastal Plain, Perth : EPA and WAWA

Vestal,J.R., & White,D.C. (1989). Lipid Analysis in Microbial Ecology - Quantitative Approaches to the Study of Microbial Communities, Bioscience, 39 (8), 535-541.

Ward,G.M., & Cummins,K.W. (1979). Effects of Food Quality on Growth of a Stream Detritivore, *Paratendipes albimanus* (Diptera:Chironomidae), Journal of Ecology, 60, 57-64.

Water Authority of Western Australia. (1986). Gnangara Mound Groundwater Resources - Environmental Review and Management Programme (Report WM 4).

Water Authority of Western Australia. (1987). Perth Urban Water Balance Study, Perth : Water Authority of WA.

Water Authority of Western Australia. (1992). Environmental Management of Groundwater Abstraction on the Gnangara Mound - Triennial Report, Perth : Water Authority of WA

Webster,J.R. & Benfield,E.F. (1986). Vascular Plant Breakdown in Freshwater Ecosystems, Annual Review of Ecological Systematics, 17, 567-594.

Weete,J.D.(Ed). (1974). Fungal Lipid Biochemisry - Distribution and Metabolism, New York : Plenum Press.

Wetzel, R .(1975). Limnology, London : W.B Saunders Publishers

White,D.C.,Davis,J.M.,Nickels,J.S.,King,J.D. & Bobbie,R.J. (1979). Determination of the Sedimentary Microbial Biomass by Extractible Lipid Phosphate, Oecologia, 40, 51-62.

Williams,W.D. (1980). Australian Freshwater Life - the Invertebrates of Australian Inland Waters, Sydney : Macmillan Press.

Zar,J.H.(1984). Biostatistical Analysis, Sydney : Prentice Hall International Publishers.

APPENDIX 1

Raw data for leaf packs from field sites 1 to 6 and laboratory treatments 1 to 3, including means and standard deviations.

Baumea - Time Period 1

SITE 1

LEAF PACK #	DAY 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	8.62	24.89	288.75	8.13	7.82	96.19	0.034	96.60
7	6.40	49.49	773.28	5.91	5.54	93.74	0.026	97.40
8	7.86	70.84	901.27	7.37	6.93	94.03	0.057	94.30
9	7.30	42.52	582.47	6.81	6.59	96.77	0.032	96.80
10	14.32	52.85	369.06	13.83	10.17	73.54	0.031	96.90
11	18.75	56.39	300.75	18.26	12.32	67.47	0.047	95.30
12	11.54	34.40	298.09	11.05	9.17	82.99	0.025	97.50
13	9.29	14.52	156.30	8.80	6.77	76.93	0.037	96.30
14	11.11	64.33	579.03	10.62	8.81	82.96	0.024	97.60
15	9.66	45.33	469.25	9.17	8.52	92.91	0.019	98.10
Total	104.85	455.56	4718.25	99.95	82.64	857.52	0.333	966.80
Mean	10.49	45.56	471.83	10.00	8.26	85.75	0.033	96.68
St. Dev	3.71	17.33	236.20	3.71	1.99	10.49	0.011	1.15

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	14.32	73.28	511.73	13.83	7.94	57.41	0.050	95.00
7	10.31	67.31	652.86	9.82	8.09	82.38	0.079	92.10
8	13.40	79.81	595.60	12.91	8.44	65.38	0.022	97.80
9	13.19	74.93	568.08	12.70	8.07	63.54	0.037	96.30
10	9.49	47.76	503.27	9.00	7.43	82.56	0.035	96.50
11	10.79	70.92	657.28	10.30	7.07	68.64	0.044	95.60
12	10.36	84.29	813.61	9.87	7.49	75.89	0.063	93.70
13	14.03	60.26	429.51	13.54	8.28	61.15	0.026	97.40
14	13.18	44.77	339.68	12.69	8.57	67.53	0.059	94.10
15	10.00	71.35	713.50	9.51	8.52	89.59	0.052	94.80
Total	119.07	674.68	5785.11	114.17	79.90	714.07	0.467	953.30
Mean	11.91	67.47	578.51	11.42	7.99	71.41	0.047	95.33
St. Dev	1.87	12.94	139.44	1.87	0.51	10.63	0.018	1.76

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	6.67	47.67	714.69	6.18	4.88	78.96	0.046	95.40
7	11.27	80.87	717.57	10.78	7.90	73.28	0.036	96.40
8	13.93	54.45	390.88	13.44	8.05	59.90	0.050	95.00
9	13.85	59.88	432.35	13.36	8.45	63.25	0.023	97.70
10	14.03	51.64	368.07	13.54	8.40	62.04	0.132	86.80
11	11.45	95.02	829.87	10.96	7.28	66.42	0.027	97.30
12	12.57	30.01	238.74	12.08	5.51	45.61	0.031	96.90
13	15.11	88.98	588.88	14.62	11.12	76.06	0.028	97.20
14	10.12	24.32	240.32	9.63	4.58	47.56	0.027	97.30
15	14.46	74.65	516.25	13.97	7.69	55.05	0.021	97.90
Total	123.46	607.49	5037.62	118.56	73.86	628.13	0.421	957.90
Mean	12.35	60.75	503.76	11.86	7.39	62.81	0.042	95.79
St. Dev	2.56	23.89	205.44	2.56	1.96	11.34	0.033	3.30

Baumea - Time Period 1 **SITE 2**

LEAF PACK #	DAY 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	16.38	26.55	162.09	15.89	7.30	45.94	0.031	96.90
7	8.69	59.31	682.51	8.20	6.83	83.29	0.038	96.20
8	11.33	53.74	474.32	10.84	9.28	85.61	0.040	96.00
9	8.38	49.63	592.24	7.89	6.58	83.40	0.046	95.40
10	11.60	58.14	501.21	11.11	8.29	74.62	0.029	97.10
11	10.42	78.15	750.00	9.93	8.18	82.38	0.026	97.40
12	9.22	14.50	157.27	8.73	5.99	68.61	0.047	95.30
13	9.67	60.69	627.61	9.18	7.58	82.57	0.027	97.30
14	11.44	54.91	479.98	10.95	7.22	65.94	0.019	98.10
15	11.82	69.54	588.32	11.33	9.30	82.08	0.033	96.70
Total	108.95	525.16	5015.55	104.05	76.55	754.44	0.335	966.40
Mean	10.90	52.52	501.55	10.41	7.66	75.44	0.033	96.64
St. Dev	2.30	18.93	200.30	2.30	1.10	12.38	0.009	0.90

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	10.51	62.52	594.86	10.02	7.78	77.64	0.090	91.00
7	9.38	57.44	612.37	8.89	6.25	70.30	0.072	92.80
8	10.49	54.87	523.07	10.00	7.69	76.90	0.074	92.60
9	15.79	61.67	390.56	15.30	7.94	51.90	0.060	94.00
10	12.82	72.59	566.22	12.33	7.77	63.02	0.058	94.20
11	9.38	50.69	540.41	8.89	6.61	74.35	0.052	94.80
12	6.94	39.17	564.41	6.45	4.81	74.57	0.067	93.30
13	13.76	86.31	627.25	13.27	6.18	46.57	0.080	92.00
14	7.34	58.50	797.00	6.85	6.05	88.32	0.083	91.70
15	7.34	49.19	670.16	6.85	3.40	49.64	0.069	93.10
Total	103.75	592.95	5886.32	98.85	64.48	673.22	0.705	929.50
Mean	10.38	59.30	588.63	9.89	6.45	67.32	0.071	92.95
St. Dev	2.96	13.03	104.94	2.96	1.47	13.94	0.012	1.19

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	14.25	53.92	378.39	13.76	7.38	53.63	0.020	98.00
7	9.65	56.74	587.98	9.16	6.68	72.93	0.019	98.10
8	8.33	95.20	1142.86	7.84	5.68	72.45	0.032	96.80
9	9.71	38.51	396.60	9.22	7.60	82.43	0.050	95.00
10	9.25	40.77	440.76	8.76	8.47	96.69	0.047	95.30
11	7.88	59.02	748.98	7.39	5.75	77.81	0.068	93.20
12	12.68	65.49	516.48	12.19	7.45	61.12	0.044	95.60
13	6.61	54.24	820.57	6.12	4.20	68.63	0.028	97.20
14	11.20	79.32	708.21	10.71	8.13	75.91	0.034	96.60
15	11.43	58.78	514.26	10.94	8.04	73.49	0.028	97.20
Total	100.99	601.99	6255.10	96.09	69.38	735.08	0.370	963.00
Mean	10.10	60.20	625.51	9.61	6.94	73.51	0.037	96.30
St. Dev	2.31	16.86	235.95	2.31	1.35	11.62	0.015	1.52

SITE 3

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	11.74	68.96	587.39	11.25	7.97	70.84	0.062	93.80
7	12.42	92.47	744.52	11.93	8.76	73.43	0.067	93.30
8	14.40	60.31	418.82	13.91	8.10	58.23	0.041	95.90
9	11.32	38.13	336.84	10.83	8.97	82.83	0.029	97.10
10	8.80	49.48	562.27	8.31	6.52	78.46	0.040	96.00
11	11.40	63.41	556.23	10.91	8.74	80.11	0.046	95.40
12	9.10	38.27	420.55	8.61	6.43	74.68	0.050	95.00
13	8.93	44.22	495.18	8.44	6.91	81.87	0.060	94.00
14	4.55	43.22	949.89	4.06	7.47	183.99	0.079	92.10
15	14.40	110.14	764.86	13.91	10.19	73.26	0.045	95.50
Total	107.06	608.61	5836.56	102.16	80.06	857.70	0.521	948.10
Mean	10.71	60.86	583.66	10.22	8.01	85.77	0.052	94.81
St. Dev	2.97	24.14	187.55	2.97	1.20	35.23	0.015	1.49

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	10.50	87.39	832.29	10.01	7.77	77.62	0.028	97.20
7	12.11	68.21	563.25	11.62	8.40	72.29	0.039	96.10
8	9.13	39.53	432.97	8.64	6.58	76.16	0.067	93.30
9	13.42	78.97	588.45	12.93	8.62	66.67	0.068	93.20
10	10.70	74.61	697.29	10.21	8.41	82.37	0.069	93.10
11	10.38	73.42	707.32	9.89	7.07	71.49	0.078	92.20
12	10.54	69.10	655.60	10.05	7.73	76.92	0.083	91.70
13	10.08	52.10	516.87	9.59	6.06	63.19	0.053	94.70
14	9.14	45.81	501.20	8.65	6.41	74.10	0.059	94.10
15	9.63	53.62	556.80	9.14	4.36	47.70	0.061	93.90
Total	105.63	642.76	6052.04	100.73	71.41	708.50	0.605	939.50
Mean	10.56	64.28	605.20	10.07	7.14	70.85	0.061	93.95
St. Dev	1.32	15.62	118.17	1.32	1.33	9.82	0.017	1.69

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	13.17	60.05	455.96	12.68	6.61	52.13	0.024	97.60
7	14.59	96.24	659.63	14.10	11.34	80.43	0.038	96.20
8	10.76	55.54	516.17	10.27	6.93	67.48	0.019	98.10
9	6.12	22.94	374.84	5.63	3.31	58.79	0.050	95.00
10	11.13	79.77	716.71	10.64	7.25	68.14	0.078	92.20
11	10.72	51.62	481.53	10.23	6.05	59.14	0.029	97.10
12	11.52	60.94	528.99	11.03	7.81	70.81	0.025	97.50
13	17.15	94.59	551.55	16.66	9.96	59.78	0.024	97.60
14	15.23	105.37	691.86	14.74	10.12	68.66	0.063	93.70
15	8.45	69.27	819.76	7.96	5.55	69.72	0.048	95.20
Total	118.84	696.33	5797.00	113.94	74.93	655.08	0.398	960.20
Mean	11.88	69.63	579.70	11.39	7.49	65.51	0.040	96.02
St. Dev	3.27	24.90	137.31	3.27	2.41	8.07	0.020	1.95

SITE 4

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	13.35	12.48	93.48	12.86	11.12	86.47	0.030	97.00
7	13.50	21.69	160.67	13.01	10.77	82.78	0.016	98.40
8	9.81	8.89	90.62	9.32	7.99	85.73	0.049	95.10
9	10.37	9.71	93.64	9.88	8.76	88.66	0.039	96.10
10	11.00	9.62	87.45	10.51	8.63	82.11	0.071	92.90
11	9.94	9.32	93.76	9.45	8.28	87.62	0.056	94.40
12	9.97	9.04	90.67	9.48	8.02	84.60	0.064	93.60
13	13.36	10.68	79.94	12.87	9.59	74.51	0.092	90.80
14	11.19	10.60	94.73	10.70	9.68	90.47	0.041	95.90
15	8.07	7.40	91.70	7.58	6.58	86.81	0.046	95.40
Total	110.56	109.43	976.66	105.66	89.42	849.77	0.504	949.60
Mean	11.06	10.94	97.67	10.57	8.94	84.98	0.050	94.96
St. Dev	1.82	4.00	22.56	1.82	1.37	4.47	0.022	2.16

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	13.18	32.54	246.89	12.69	8.11	63.91	0.082	91.80
7	10.28	10.14	98.64	9.79	5.36	54.75	0.092	90.80
8	15.33	19.77	128.96	14.84	12.39	83.49	0.127	87.30
9	15.48	15.97	103.17	14.99	7.75	51.70	0.082	91.80
10	14.27	13.70	96.01	13.78	10.43	75.69	0.052	94.80
11	11.48	23.26	202.61	10.99	8.93	81.26	0.078	92.20
12	6.42	10.00	155.76	5.93	7.63	128.67	0.096	90.40
13	11.41	19.12	167.57	10.92	8.69	79.58	0.069	93.10
14	8.48	14.31	168.75	7.99	6.96	87.11	0.070	93.00
15	10.83	22.07	203.79	10.34	7.90	76.40	0.058	94.20
Total	117.16	180.88	1572.15	112.26	84.15	782.55	0.806	919.40
Mean	11.72	18.09	157.21	11.23	8.42	78.26	0.081	91.94
St. Dev	2.93	6.85	51.00	2.93	1.92	21.43	0.021	2.14

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	13.32	28.86	216.67	12.83	8.13	63.37	0.141	85.90
7	12.74	34.43	270.25	12.25	9.26	75.59	0.124	87.60
8	9.71	24.64	253.76	9.22	7.62	82.65	0.089	91.10
9	11.93	51.78	434.03	11.44	8.81	77.01	0.105	89.50
10	19.82	34.37	173.41	19.33	11.89	61.51	0.070	93.00
11	9.91	64.62	652.07	9.42	7.93	84.18	0.056	94.40
12	7.80	41.40	530.77	7.31	6.48	88.65	0.046	95.40
13	8.22	31.09	378.22	7.73	6.80	87.97	0.076	92.40
14	7.76	48.36	623.20	7.27	6.56	90.23	0.065	93.50
15	18.79	66.96	356.36	18.30	13.50	73.77	0.107	89.30
Total	120.00	426.51	3888.74	115.10	86.98	784.93	0.879	912.10
Mean	12.00	42.65	388.87	11.51	8.70	78.49	0.088	91.21
St. Dev	4.33	14.82	168.63	4.33	2.33	10.17	0.031	3.08

SITE 5

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	8.92	8.16	91.48	8.43	7.68	91.10	0.024	97.60
7	6.47	6.03	93.20	5.98	5.65	94.48	0.040	96.00
8	12.15	9.83	80.91	11.66	9.23	79.16	0.030	97.00
9	9.39	8.23	87.65	8.90	7.73	86.85	0.046	95.40
10	12.29	10.86	88.36	11.80	10.26	86.95	0.034	96.60
11	7.91	6.44	81.42	7.42	6.01	81.00	0.039	96.10
12	12.51	10.22	81.69	12.02	9.64	80.20	0.029	97.10
13	8.46	8.00	94.56	7.97	7.54	94.60	0.027	97.30
14	9.86	7.76	78.70	9.37	7.46	79.62	0.039	96.10
15	11.45	10.29	89.87	10.96	9.65	88.05	0.031	96.90
Total	99.41	85.82	867.84	94.51	80.85	862.01	0.339	966.10
Mean	9.94	8.58	86.78	9.45	8.09	86.20	0.034	96.61
St. Dev	2.08	1.66	5.69	2.08	1.57	6.00	0.007	0.69

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	13.43	11.54	85.93	12.94	10.21	78.90	0.077	92.30
7	15.61	11.92	76.36	15.12	10.15	67.13	0.099	90.10
8	11.78	11.25	95.50	11.29	10.22	90.52	0.120	88.00
9	13.75	12.19	88.65	13.26	10.12	76.32	0.096	90.40
10	8.53	7.37	86.40	8.04	6.76	84.08	0.072	92.80
11	11.82	11.81	99.92	11.33	10.77	95.06	0.087	91.30
12	9.84	8.12	82.52	9.35	7.52	80.43	0.080	92.00
13	8.55	7.99	93.45	8.06	7.16	88.83	0.106	89.40
14	13.04	10.97	84.13	12.55	9.98	79.52	0.088	91.20
15	17.48	11.80	67.51	16.99	10.73	63.15	0.085	91.50
Total	123.83	104.96	860.36	118.93	93.62	803.95	0.910	909.00
Mean	12.38	10.50	86.04	11.89	9.36	80.39	0.091	90.90
St. Dev	2.91	1.88	9.41	2.91	1.56	9.97	0.015	1.45

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	10.76	29.84	277.32	10.27	8.85	86.17	0.102	89.80
7	8.12	37.03	456.03	7.63	6.58	86.24	0.062	93.80
8	9.79	41.73	426.25	9.30	[illegible]	87.74	0.059	94.10
9	10.98	17.64	160.66	10.49	8.14	77.60	0.078	92.20
10	13.33	34.72	260.47	12.84	10.02	78.04	0.131	86.90
11	12.70	28.79	226.69	12.21	8.68	71.09	0.091	90.90
12	12.40	39.07	315.08	11.91	9.67	81.19	0.056	94.40
13	16.13	38.15	236.52	15.64	10.71	68.48	0.063	93.70
14	12.06	28.57	236.90	11.57	9.03	78.05	0.108	89.20
15	14.04	28.93	206.05	13.55	9.38	69.23	0.076	92.40
Total	120.31	324.47	2801.97	115.41	89.22	783.82	0.826	917.40
Mean	12.03	32.45	280.20	11.54	8.92	78.38	0.083	91.74
St. Dev	2.26	7.11	94.46	2.26	1.15	7.10	0.025	2.49

SITE 6

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	9.95	8.61	86.53	9.46	7.81	82.56	0.057	94.30
7	16.46	12.32	74.85	15.97	11.63	72.82	0.062	93.80
8	7.26	6.87	94.63	6.77	6.53	96.45	0.072	92.80
9	11.05	7.43	67.24	10.56	8.59	81.34	0.030	97.00
10	9.48	9.01	95.04	8.99	8.52	94.77	0.055	94.50
11	18.90	14.66	77.57	18.41	13.82	75.07	0.062	93.80
12	11.72	10.85	92.58	11.23	10.25	91.27	0.060	93.90
13	10.60	9.72	91.70	10.11	9.18	90.80	0.060	94.00
14	11.87	8.81	74.22	11.38	8.36	73.46	0.057	94.30
15	16.66	11.46	68.79	16.17	10.84	67.04	0.066	93.40
Total	123.95	99.74	823.14	119.05	95.53	825.60	0.582	941.80
Mean	12.40	9.97	82.31	11.91	9.55	82.56	0.058	94.18
St. Dev	3.71	2.37	10.95	3.71	2.12	10.34	0.011	1.11

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	12.54	12.24	97.61	12.05	10.81	89.71	0.094	90.60
7	12.69	13.06	102.92	12.20	10.36	84.92	0.086	91.40
8	16.02	11.79	73.60	15.53	10.27	66.13	0.079	92.10
9	12.50	10.72	85.76	12.01	9.73	81.02	0.141	85.90
10	7.24	6.96	96.13	6.75	5.81	86.07	0.090	91.00
11	12.36	9.40	76.05	11.87	7.36	62.01	0.112	88.80
12	9.91	10.07	101.61	9.42	8.07	85.67	0.075	92.50
13	6.59	9.47	143.70	6.10	8.32	136.39	0.089	91.10
14	12.55	11.59	92.35	12.06	10.24	84.91	0.081	91.90
15	12.05	11.09	92.03	11.56	9.78	84.60	0.112	88.80
Total	114.45	106.39	961.76	109.55	90.75	861.43	0.959	904.10
Mean	11.45	10.64	96.18	10.96	9.08	86.14	0.096	90.41
St. Dev	2.81	1.75	19.41	2.81	1.62	19.87	0.020	2.02

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	9.88	50.76	513.77	9.39	6.86	73.06	0.135	86.50
7	9.47	50.22	530.31	8.98	7.24	80.62	0.078	92.20
8	12.78	72.51	567.37	12.29	9.34	76.00	0.109	89.10
9	12.08	49.40	408.94	11.59	8.67	74.81	0.091	90.90
10	12.35	37.84	306.40	11.86	8.23	69.39	0.095	90.50
11	12.19	56.27	461.61	11.70	8.71	74.44	0.084	91.60
12	8.91	51.54	578.45	8.42	7.22	85.75	0.096	90.40
13	13.76	42.00	305.23	13.27	10.21	76.94	0.107	89.30
14	8.57	43.34	505.72	8.08	7.03	87.00	0.144	85.60
15	9.45	34.13	361.16	8.96	6.38	71.21	0.134	86.60
Total	109.44	488.01	4538.95	104.54	79.89	769.22	1.073	892.70
Mean	10.94	48.80	453.90	10.45	7.99	76.92	0.107	89.27
St. Dev	1.87	10.77	102.76	1.87	1.24	5.86	0.023	2.30

TREATMENT 1

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	21-Apr Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	21-Apr Dry Wt	% Change Dry Wt	21-Apr AFDW	21-Apr OM% rem.
6	7.63	7.96	104.33	7.14	7.17	100.42	0.053	94.70
7	5.95	5.72	96.13	5.46	5.13	93.96	0.055	94.50
8	6.56	6.85	104.42	6.07	6.01	99.01	0.061	93.90
9	6.51	6.80	104.45	6.02	6.16	102.33	0.070	93.00
10	7.25	7.57	104.41	6.76	6.81	100.74	0.043	95.70
11	7.44	7.83	105.24	6.95	7.00	100.72	0.048	95.20
12	7.92	8.27	104.42	7.43	7.33	98.65	0.049	95.10
13	6.05	6.33	104.63	5.56	5.43	97.66	0.065	93.50
14	8.17	8.57	104.90	7.68	7.68	100.00	0.040	96.00
15	6.45	6.72	104.19	5.96	6.09	102.18	0.052	94.80
Total	69.93	72.62	1037.12	65.03	64.81	995.67	0.536	946.40
Mean	6.99	7.26	103.71	6.50	6.48	99.57	0.054	94.64
St. Dev	0.79	0.92	2.68	0.79	0.84	2.46	0.009	0.95

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	16-Jun Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	16-Jun Dry Wt	% Change Dry Wt	16-Jun AFDW	16-Jun OM% rem.
21	9.83	10.19	103.66	9.34	9.30	99.57	0.101	89.90
22	5.95	6.15	103.36	5.46	5.64	103.30	0.057	94.30
23	6.47	6.69	103.40	5.98	6.06	101.34	0.060	94.00
24	8.39	8.68	103.46	7.90	7.87	99.62	0.076	92.40
25	6.67	6.89	103.30	6.18	6.03	97.57	0.103	89.70
26	7.83	7.98	101.92	7.34	7.31	99.59	0.074	92.60
27	6.36	6.59	103.62	5.87	6.03	102.73	0.081	91.90
28	8.50	8.78	103.29	8.01	7.99	99.75	0.058	94.20
29	8.28	8.58	103.62	7.79	7.33	94.09	0.124	87.60
30	7.40	7.54	101.89	6.91	6.85	99.13	0.070	93.00
Total	75.68	78.07	1031.52	70.78	70.41	996.69	0.804	919.60
Mean	7.57	7.81	103.15	7.08	7.04	99.67	0.080	91.96
St. Dev	1.22	1.26	0.67	1.22	1.19	2.60	0.022	2.23

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	11-Aug Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	11-Aug Dry Wt	% Change Dry Wt	11-Aug AFDW	11-Aug OM% rem.
36	6.48	26.20	404.32	5.99	6.02	100.50	0.024	97.60
37	6.82	30.11	441.50	6.33	6.40	101.11	0.044	95.60
38	7.41	27.19	366.94	6.92	7.02	101.45	0.070	93.00
39	7.19	18.52	257.58	6.70	6.72	100.30	0.064	93.60
40	8.38	21.53	256.92	7.89	7.71	97.72	0.035	96.50
41	8.33	28.59	343.22	7.84	7.45	95.03	0.038	96.20
42	7.11	25.77	362.45	6.62	6.60	99.70	0.059	94.10
43	7.43	15.56	209.42	6.94	7.03	101.30	0.048	95.20
44	6.06	28.52	470.63	5.57	5.47	98.20	0.035	96.50
45	7.34	22.21	302.59	6.85	6.86	100.15	0.035	96.50
Total	72.55	244.20	3415.56	67.65	67.28	995.44	0.452	954.80
Mean	7.26	24.42	341.56	6.77	6.73	99.54	0.045	95.48
St. Dev	0.72	4.78	84.89	0.72	0.66	2.01	0.015	1.48

TREATMENT 2

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	21-Apr Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	21-Apr Dry Wt	% Change Dry Wt	21-Apr AFDW	21-Apr OM% rem.
6	10.10	54.59	540.50	9.61	8.16	84.91	0.068	93.20
7	11.21	76.53	682.69	10.72	9.51	88.71	0.079	92.10
8	9.48	14.10	148.73	8.99	7.83	87.10	0.058	94.20
9	10.11	124.36	1230.07	9.62	8.70	90.44	0.048	95.20
10	11.75	44.94	382.47	11.26	9.33	82.86	0.084	91.60
11	11.96	64.78	541.64	11.47	6.83	59.55	0.050	95.00
12	10.83	69.28	639.70	10.34	8.72	84.33	0.046	95.40
13	8.91	57.58	646.24	8.42	7.77	92.28	0.053	94.70
14	7.80	71.81	920.64	7.31	6.38	87.28	0.030	97.00
15	11.57	25.92	224.03	11.08	9.55	86.19	0.036	96.40
Total	103.72	603.89	5956.71	98.82	82.78	843.65	0.552	944.80
Mean	10.37	60.39	595.67	9.88	8.28	84.36	0.055	94.48
St. Dev	1.35	30.17	317.88	1.35	1.09	9.17	0.017	1.74

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	16-Jun Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	16-Jun Dry Wt	% Change Dry Wt	16-Jun AFDW	16-Jun OM% rem.
21	9.71	96.69	995.78	9.22	8.28	89.80	0.023	97.70
22	11.80	72.35	613.14	11.31	9.84	87.00	0.047	95.30
23	9.68	100.65	1039.77	9.19	8.66	94.23	0.059	94.10
24	11.34	45.37	400.09	10.85	9.44	87.00	0.073	92.70
25	10.11	43.18	427.10	9.62	8.71	90.54	0.028	97.20
26	11.77	53.76	456.75	11.28	9.60	85.11	0.074	92.60
27	11.80	75.50	639.83	11.31	9.34	82.58	0.047	95.30
28	10.00	39.83	398.30	9.51	8.16	85.80	0.047	95.30
29	8.72	49.25	564.79	8.23	7.54	91.62	0.082	91.80
30	10.41	35.60	341.98	9.92	9.00	90.73	0.083	91.70
Total	105.34	612.18	5877.53	100.44	88.57	884.42	0.563	943.70
Mean	10.53	61.22	587.75	10.04	8.86	88.44	0.056	94.37
St. Dev	1.08	23.64	247.02	1.08	0.72	3.52	0.021	2.15

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	11-Aug Wet Wt	% Change Wet Wt	Estimated Day 0 Wet Wt	11-Aug Dry Wt	% Change Dry Wt	11-Aug AFDW	11-Aug OM% rem.
6	10.06	107.36	1067.20	9.57	8.66	90.49	0.109	89.10
7	8.52	98.65	1157.86	8.03	6.66	82.94	0.071	92.90
8	12.11	103.68	856.15	11.62	10.28	88.47	0.096	90.40
9	8.88	81.53	918.13	8.39	7.00	83.43	0.174	82.60
10	8.74	82.63	945.42	8.25	7.04	85.33	0.065	93.50
11	6.98	50.33	721.06	6.49	5.57	85.82	0.042	95.80
12	12.61	91.64	726.72	12.12	9.90	81.68	0.127	87.30
13	7.58	64.41	849.74	7.09	6.41	90.41	0.069	93.10
14	12.22	74.23	607.45	11.73	9.86	84.06	0.142	85.80
15	10.62	70.09	659.98	10.13	8.52	84.11	0.170	83.00
Total	98.32	824.55	8509.72	93.42	79.90	856.75	1.065	893.50
Mean	9.83	82.46	850.97	9.34	7.99	85.67	0.107	89.35
St. Dev	2.01	18.25	177.17	2.01	1.67	3.11	0.046	4.59

TREATMENT 3

Baumea - Time Period 1

LEAF PACK #	DAY 0 Wet Wt	21-Apr Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	21-Apr Dry Wt	% Change Dry Wt	21-Apr AFDW	21-Apr OM% rem.
6	9.12	52.01	570.29	8.63	7.84	90.85	0.090	91.00
7	7.81	17.06	218.44	7.32	7.04	96.17	0.082	91.80
8	11.66	20.29	174.01	11.17	10.44	93.46	0.074	92.60
9	10.89	59.74	548.58	10.40	9.37	90.10	0.068	93.20
10	8.49	23.92	281.74	8.00	6.49	81.13	0.085	91.50
11	9.30	64.20	690.32	8.81	8.04	91.26	0.118	88.20
12	10.18	17.07	167.68	9.69	7.78	80.29	0.073	92.70
13	7.78	55.13	708.61	7.29	6.62	90.81	0.094	90.60
14	13.07	56.35	431.14	12.58	9.74	77.42	0.078	92.20
15	8.03	31.97	398.13	7.54	7.12	94.43	0.094	90.60
Total	96.33	397.74	4188.94	91.43	80.48	885.92	0.856	914.40
Mean	9.63	39.77	418.89	9.14	8.05	88.59	0.086	91.44
St. Dev	1.79	19.38	205.48	1.79	1.37	6.53	0.014	1.45

Baumea - Time Period 2

LEAF PACK #	DAY 0 Wet Wt	16-Jun Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	16-Jun Dry Wt	% Change Dry Wt	16-Jun AFDW	16-Jun OM% rem.
21	10.14	76.65	755.92	9.65	9.01	93.37	0.083	91.70
22	9.16	94.26	1029.04	8.67	8.11	93.54	0.066	93.40
23	7.89	66.40	841.57	7.40	6.69	90.41	0.054	94.60
24	9.28	39.16	421.98	8.79	7.86	89.42	0.082	91.80
25	13.78	116.40	844.70	13.29	12.01	90.37	0.116	88.40
26	7.70	89.63	1164.03	7.21	6.54	90.71	0.043	95.70
27	9.09	35.50	390.54	8.60	7.94	92.33	0.124	87.60
28	8.74	68.77	786.84	8.25	7.55	91.52	0.038	96.20
29	8.47	89.78	1059.98	7.98	7.32	91.73	0.058	94.20
30	7.63	58.70	769.33	7.14	6.29	88.10	0.042	95.80
Total	91.88	735.25	8063.93	86.98	79.32	911.48	0.706	929.40
Mean	9.19	73.53	806.39	8.70	7.93	91.15	0.071	92.94
St. Dev	1.80	25.21	251.55	1.80	1.65	1.71	0.030	3.04

Baumea - Time Period 3

LEAF PACK #	DAY 0 Wet Wt	11-Aug Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	11-Aug Dry Wt	% Change Dry Wt	11-Aug AFDW	11-Aug OM% rem.
36	12.84	77.84	606.23	12.35	9.84	79.68	0.030	97.00
37	10.16	88.99	875.89	9.67	8.32	86.04	0.091	90.90
38	8.52	90.17	1058.33	8.03	6.91	86.05	0.064	93.60
39	11.14	84.36	757.27	10.65	8.82	82.82	0.118	88.20
40	11.78	128.25	1088.71	11.29	9.89	87.60	0.032	96.80
41	11.11	91.03	819.35	10.62	8.46	79.66	0.029	97.10
42	17.15	104.38	608.63	16.66	13.94	83.67	0.064	93.60
43	10.25	100.17	977.27	9.76	8.12	83.20	0.034	96.60
44	10.49	93.41	890.47	10.00	8.45	84.50	0.099	90.10
45	9.49	58.46	616.02	9.00	8.16	90.67	0.097	90.30
Total	112.93	917.06	8298.16	108.03	90.91	843.88	0.658	934.20
Mean	11.29	91.71	829.82	10.80	9.09	84.39	0.066	93.42
St. Dev	2.38	18.05	181.59	2.38	1.91	3.40	0.034	3.37

SITE 1

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	9.49	67.66	712.96	8.93	6.31	70.66	0.028	97.20
7	9.55	70.01	733.09	8.99	6.83	75.97	0.024	97.60
8	8.80	88.47	1005.34	8.24	6.97	84.59	0.037	96.30
9	6.60	60.75	920.45	6.04	5.74	95.03	0.033	96.70
10	7.64	69.91	915.05	7.08	5.87	82.91	0.029	97.10
11	11.55	84.95	735.50	10.99	8.01	72.88	0.024	97.60
12	9.62	77.00	800.42	9.06	7.14	78.81	0.026	97.40
13	10.25	83.32	812.88	9.69	7.31	75.44	0.027	97.30
14	8.68	70.19	808.64	8.12	7.15	88.05	0.029	97.10
15	11.61	87.61	754.61	11.05	8.40	76.02	0.026	97.40
Total	93.79	759.87	8198.94	88.19	69.73	800.37	0.283	971.70
Mean	9.38	75.99	819.89	8.82	6.97	80.04	0.028	97.17
St. Dev	1.57	9.63	96.88	1.57	0.85	7.55	0.004	0.41

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	11.19	82.28	735.30	10.63	7.32	68.86	0.029	97.10
7	7.82	98.48	1259.34	7.26	7.61	104.82	0.045	95.50
8	12.64	78.25	619.07	12.08	7.33	60.68	0.036	96.40
9	18.88	80.03	423.89	18.32	6.00	32.75	0.026	97.40
10	10.67	51.89	486.32	10.11	7.57	74.88	0.039	96.10
11	9.39	75.32	802.13	8.83	6.09	68.97	0.060	94.00
12	10.55	105.67	1001.61	9.99	7.54	75.48	0.067	93.30
13	7.11	63.45	892.41	6.55	5.49	83.82	0.037	96.30
14	13.94	97.83	701.79	13.38	7.08	52.91	0.043	95.70
15	8.67	77.68	895.96	8.11	6.51	80.27	0.035	96.50
Total	110.86	810.88	7817.81	105.26	68.54	703.44	0.417	958.30
Mean	11.09	81.09	781.78	10.53	6.85	70.34	0.042	95.83
St. Dev	3.45	16.35	247.77	3.45	0.77	19.24	0.013	1.29

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	8.93	79.88	894.51	8.37	6.78	81.00	0.072	92.80
7	10.30	82.04	796.50	9.74	6.53	67.04	0.023	97.70
8	10.38	75.58	728.13	9.82	7.57	77.09	0.023	97.70
9	9.17	110.89	1209.27	8.61	6.63	77.00	0.059	94.10
10	8.56	67.75	791.47	8.00	6.29	78.63	0.055	94.50
11	9.67	42.83	442.92	9.11	7.05	77.39	0.033	96.70
12	8.46	47.01	555.67	7.90	5.40	68.35	0.028	97.20
13	10.70	75.25	703.27	10.14	7.40	72.98	0.062	93.80
14	11.31	55.80	493.37	10.75	6.10	56.74	0.023	97.70
15	8.90	66.31	745.06	8.34	5.61	67.27	0.048	95.20
Total	96.38	703.34	7360.18	90.78	65.36	723.49	0.426	957.40
Mean	9.64	70.33	736.02	9.08	6.54	72.35	0.043	95.74
St. Dev	0.98	19.61	219.68	0.98	0.71	7.44	0.019	1.87

SITE 2

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	11.79	81.21	688.80	11.23	7.90	70.35	0.052	94.80
7	12.66	88.73	700.87	12.10	7.29	60.25	0.049	95.10
8	8.58	69.44	809.32	8.02	7.29	90.90	0.057	94.30
9	10.85	80.86	745.25	10.29	7.75	75.32	0.054	94.60
10	10.05	74.90	745.27	9.49	6.98	73.55	0.039	96.10
11	10.21	104.88	1027.23	9.65	8.33	86.32	0.045	95.50
12	13.49	68.13	505.04	12.93	5.52	42.69	0.066	93.40
13	7.92	70.78	893.69	7.36	6.11	83.02	0.037	96.30
14	7.60	89.33	1175.39	7.04	6.80	96.59	0.059	94.10
15	12.09	97.35	805.21	11.53	8.29	71.90	0.069	93.10
Total	105.24	825.61	8096.09	99.64	72.26	750.88	0.527	947.30
Mean	10.52	82.56	809.61	9.96	7.23	75.09	0.053	94.73
St. Dev	2.03	12.40	187.29	2.03	0.91	15.66	0.011	1.06

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	10.40	69.86	671.73	9.84	7.27	73.88	0.026	97.40
7	7.95	61.05	767.92	7.39	5.91	79.97	0.055	94.50
8	9.05	67.13	741.77	8.49	6.56	77.27	0.035	96.50
9	8.22	68.87	837.83	7.66	6.23	81.33	0.074	92.60
10	22.86	129.28	565.53	22.30	17.27	77.44	0.053	94.70
11	9.87	49.62	502.74	9.31	5.94	63.80	0.072	92.80
12	8.43	65.42	776.04	7.87	6.12	77.76	0.038	96.20
13	10.32	73.71	714.24	9.76	7.72	79.10	0.076	92.40
14	15.31	72.01	470.35	14.75	8.28	56.14	0.060	94.00
15	11.65	67.34	578.03	11.09	7.09	63.93	0.059	94.10
Total	114.06	724.29	6626.18	108.46	78.39	730.63	0.548	945.20
Mean	11.41	72.43	662.62	10.85	7.84	73.06	0.055	94.52
St. Dev	4.56	21.10	125.95	4.56	3.41	8.61	0.017	1.72

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	11.44	89.00	777.97	10.88	6.61	60.75	0.043	95.70
7	11.82	41.48	350.93	11.26	6.75	59.95	0.064	93.60
8	22.60	68.68	303.89	22.04	5.35	24.27	0.082	91.80
9	9.34	71.79	768.63	8.78	5.54	63.10	0.030	97.00
10	13.03	76.31	585.65	12.47	5.66	45.39	0.061	93.90
11	9.78	86.14	880.78	9.22	6.28	68.11	0.033	96.70
12	11.61	89.55	771.32	11.05	7.99	72.31	0.035	96.50
13	11.40	88.26	774.21	10.84	7.28	67.16	0.031	96.90
14	9.43	70.69	749.63	8.87	6.21	70.01	0.025	97.50
15	8.52	61.35	720.07	7.96	5.16	64.82	0.029	97.10
Total	118.97	743.25	6683.08	113.37	62.83	595.88	0.433	956.70
Mean	11.90	74.33	668.31	11.34	6.28	59.59	0.043	95.67
St. Dev	4.01	15.22	194.00	4.01	0.90	14.49	0.019	1.91

SITE 3

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	14.45	129.26	894.53	13.89	9.03	65.01	0.032	96.80
7	12.02	96.46	802.50	11.46	8.24	71.90	0.031	96.90
8	14.02	123.62	881.74	13.46	9.04	67.16	0.019	98.10
9	12.45	81.75	656.63	11.89	9.86	82.93	0.029	97.10
10	19.91	112.33	564.19	19.35	16.43	84.91	0.038	96.20
11	10.46	76.84	734.61	9.90	6.26	63.23	0.041	95.90
12	11.32	153.95	1359.98	10.76	11.52	107.06	0.031	96.90
13	7.26	79.05	1088.84	6.70	5.46	81.49	0.032	96.80
14	28.41	182.32	641.75	27.85	26.59	95.48	0.022	97.80
15	10.75	68.98	641.67	10.19	7.36	72.23	0.024	97.60
Total	141.05	1104.56	8266.44	135.45	109.79	791.40	0.299	970.10
Mean	14.11	110.46	826.64	13.55	10.98	79.14	0.030	97.01
St. Dev	6.01	37.18	244.06	6.01	6.29	14.13	0.007	0.68

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	10.63	122.22	1149.76	10.07	8.00	79.44	0.050	95.00
7	8.86	55.10	621.90	8.30	4.56	54.94	0.056	94.40
8	22.84	94.46	413.57	22.28	16.35	73.38	0.059	94.10
9	13.54	92.68	684.49	12.98	8.75	67.41	0.046	95.40
10	12.80	117.38	917.03	12.24	10.92	89.22	0.067	93.30
11	15.12	99.14	655.69	14.56	11.05	75.89	0.028	97.20
12	8.76	60.18	686.99	8.20	5.72	69.76	0.071	92.90
13	8.32	73.89	888.10	7.76	5.92	76.29	0.050	95.00
14	9.16	68.34	746.07	8.60	6.77	78.72	0.049	95.10
15	13.94	69.96	501.87	13.38	9.85	73.62	0.042	95.80
Total	123.97	853.35	7265.47	118.37	87.89	738.67	0.518	948.20
Mean	12.40	85.34	726.55	11.84	8.79	73.87	0.052	94.82
St. Dev	4.43	23.38	213.34	4.43	3.47	8.93	0.012	1.24

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	12.67	65.41	516.26	12.11	8.73	72.09	0.055	94.50
7	13.94	125.12	897.56	13.38	8.66	64.72	0.044	95.60
8	7.32	48.24	659.02	6.76	4.33	64.05	0.032	96.80
9	11.61	96.24	828.94	11.05	7.75	70.14	0.023	97.70
10	8.32	55.21	663.58	7.76	5.35	68.94	0.028	97.20
11	5.49	60.97	1110.56	4.93	4.61	93.51	0.080	92.00
12	9.75	57.81	592.92	9.19	5.64	61.37	0.018	98.20
13	8.49	101.68	1197.64	7.93	10.32	130.14	0.019	98.10
14	9.15	66.62	728.09	8.59	6.19	72.06	0.071	92.90
15	8.94	72.53	811.30	8.38	6.42	76.61	0.047	95.30
Total	95.68	749.83	8005.88	90.08	68.00	773.64	0.417	958.30
Mean	9.57	74.98	800.59	9.01	6.80	77.36	0.042	95.83
St. Dev	2.54	24.59	219.11	2.54	1.98	20.60	0.022	2.17

SITE 4

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	9.47	8.04	84.90	8.91	7.01	78.68	0.045	95.50
7	10.36	8.43	81.37	9.80	7.78	79.39	0.062	93.80
8	12.62	11.71	92.79	12.06	10.18	84.41	0.070	93.00
9	11.56	9.54	82.53	11.00	8.23	74.82	0.069	93.10
10	6.47	5.25	81.14	5.91	4.56	77.16	0.051	94.90
11	8.59	6.62	77.07	8.03	5.95	74.10	0.078	92.20
12	23.62	26.52	112.28	23.06	16.28	70.60	0.057	94.30
13	8.52	8.00	93.90	7.96	6.78	85.18	0.062	93.80
14	12.03	25.63	213.05	11.47	9.12	79.51	0.051	94.90
15	9.34	8.92	95.50	8.78	7.07	80.52	0.068	93.20
Total	112.58	118.66	1014.52	106.98	82.96	784.36	0.613	938.70
Mean	11.26	11.87	101.45	10.70	8.30	78.44	0.061	93.87
St. Dev	4.72	7.68	40.53	4.72	3.22	4.50	0.010	1.03

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	9.67	30.13	311.58	9.11	7.72	84.74	0.041	95.90
7	7.44	7.39	99.33	6.88	5.27	76.60	0.058	94.20
8	9.18	29.90	325.71	8.62	6.02	69.84	0.045	95.50
9	7.50	23.17	308.93	6.94	5.48	78.96	0.078	92.20
10	12.32	21.28	172.73	11.76	9.68	82.31	0.045	95.50
11	12.43	50.79	408.61	11.87	8.52	71.78	0.041	95.90
12	8.35	11.96	143.23	7.79	5.68	72.91	0.031	96.90
13	7.48	7.44	99.47	6.92	5.11	73.84	0.039	96.10
14	17.74	53.05	299.04	17.18	9.32	54.25	0.042	95.80
15	6.68	25.91	387.87	6.12	5.34	87.25	0.076	92.40
Total	98.79	261.02	2556.50	93.19	68.14	752.49	0.496	950.40
Mean	9.88	26.10	255.65	9.32	6.81	75.25	0.050	95.04
St. Dev	3.41	15.97	116.42	3.41	1.81	9.37	0.016	1.59

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	12.27	72.99	594.87	11.71	9.03	77.11	0.069	93.10
7	22.56	64.87	287.54	22.00	16.52	75.09	0.053	94.70
8	10.68	56.58	529.78	10.12	7.95	78.56	0.065	93.50
9	12.21	68.08	557.58	11.65	9.41	80.77	0.037	96.30
10	14.37	79.30	551.84	13.81	8.49	61.48	0.053	94.70
11	13.61	85.91	631.23	13.05	9.97	76.40	0.031	96.90
12	9.31	62.48	671.11	8.75	7.04	80.46	0.045	95.50
13	7.10	56.65	797.89	6.54	6.06	92.66	0.067	93.30
14	12.92	77.84	602.48	12.36	9.86	79.77	0.060	94.00
15	19.63	81.02	412.74	19.07	15.74	82.54	0.057	94.30
Total	134.66	705.72	5637.04	129.06	100.07	784.84	0.537	946.30
Mean	13.47	70.57	563.70	12.91	10.01	78.48	0.054	94.63
St. Dev	4.60	10.40	138.96	4.60	3.46	7.71	0.013	1.27

SITE 5

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	9.85	8.51	86.40	9.29	7.86	84.61	0.033	96.70
7	12.60	11.54	91.59	12.04	9.87	81.98	0.034	96.60
8	10.83	9.49	87.63	10.27	8.18	79.65	0.040	96.00
9	15.41	12.47	80.92	14.85	11.49	77.37	0.031	96.90
10	8.66	8.13	93.88	8.10	7.54	93.09	0.026	97.40
11	8.63	7.74	89.69	8.07	7.21	89.34	0.026	97.40
12	10.99	9.80	89.17	10.43	9.16	87.82	0.026	97.40
13	9.65	7.87	81.55	9.09	7.56	83.17	0.028	97.20
14	7.51	6.79	90.41	6.95	6.10	87.77	0.036	96.40
15	6.99	6.36	90.99	6.43	5.66	88.02	0.037	96.30
Total	101.12	88.70	882.23	95.52	80.63	852.82	0.317	968.30
Mean	10.11	8.87	88.22	9.55	8.06	85.28	0.032	96.83
St. Dev	2.51	1.97	4.22	2.51	1.74	4.80	0.005	0.51

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	7.17	6.39	89.12	6.61	5.65	85.48	0.086	91.40
7	12.58	11.67	92.77	12.02	10.48	87.19	0.068	93.20
8	8.96	7.96	88.84	8.40	7.22	85.95	0.064	93.60
9	9.95	10.00	100.50	9.39	9.02	96.06	0.059	94.10
10	8.54	7.21	84.43	7.98	6.58	82.46	0.062	93.80
11	8.31	6.33	76.17	7.75	6.71	86.58	0.072	92.80
12	10.73	9.67	90.12	10.17	8.81	86.63	0.076	92.40
13	7.66	6.67	87.08	7.10	6.30	88.73	0.089	91.10
14	9.75	9.37	96.10	9.19	8.43	91.73	0.085	91.50
15	11.45	8.72	76.16	10.89	7.90	72.54	0.054	94.60
Total	95.10	83.99	881.29	89.50	77.10	863.35	0.715	928.50
Mean	9.51	8.40	88.13	8.95	7.71	86.33	0.072	92.85
St. Dev	1.72	1.79	7.78	1.72	1.49	6.11	0.012	1.22

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	11.23	53.64	477.65	10.67	8.98	84.16	0.038	96.20
7	8.76	60.29	688.24	8.20	6.92	84.39	0.050	95.00
8	11.26	40.04	355.60	10.70	7.13	66.64	0.055	94.50
9	8.39	50.96	607.39	7.83	6.37	81.35	0.046	95.40
10	8.86	46.21	521.56	8.30	5.37	64.70	0.085	91.50
11	10.25	50.09	488.68	9.69	7.75	79.98	0.053	94.70
12	10.67	60.96	571.32	10.11	8.30	82.10	0.042	95.80
13	6.38	33.84	530.41	5.82	4.75	81.62	0.063	93.70
14	7.02	42.88	610.83	6.46	5.36	82.97	0.068	93.20
15	7.92	50.96	643.43	7.36	5.82	79.08	0.039	96.10
Total	90.74	489.87	5495.11	85.14	66.75	786.98	0.539	946.10
Mean	9.07	48.99	549.51	8.51	6.68	78.70	0.054	94.61
St. Dev	1.72	8.54	96.19	1.72	1.39	7.08	0.015	1.47

SITE 6

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	8.01	8.84	110.36	7.45	7.13	95.70	0.036	96.40
7	11.93	11.23	94.13	11.37	10.48	92.17	0.045	95.50
8	12.76	11.63	91.14	12.20	10.93	89.59	0.040	96.00
9	11.94	11.38	95.31	11.38	10.53	92.53	0.032	96.80
10	7.50	7.03	93.73	6.94	6.56	94.52	0.029	97.10
11	14.86	13.61	91.59	14.30	12.61	88.18	0.024	97.60
12	8.47	7.83	92.44	7.91	7.09	89.63	0.037	96.30
13	8.97	8.46	94.31	8.41	7.91	94.05	0.025	97.50
14	8.13	7.10	87.33	7.57	6.62	87.45	0.032	96.80
15	10.70	10.19	95.23	10.14	9.44	93.10	0.027	97.30
Total	103.27	97.30	945.59	97.67	89.30	916.94	0.327	967.30
Mean	10.33	9.73	94.56	9.77	8.93	91.69	0.033	96.73
St. Dev	2.48	2.21	6.05	2.48	2.14	2.82	0.007	0.68

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	09-May Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	09-May Dry Wt	% Change Dry Wt	09-May AFDW	09-May OM% rem.
6	8.41	7.81	92.87	7.85	6.88	87.64	0.060	94.00
7	12.70	11.97	94.25	12.14	10.29	84.76	0.038	96.20
8	5.86	6.41	109.39	5.30	5.78	109.06	0.031	96.90
9	14.84	14.14	95.28	14.28	12.46	87.25	0.036	96.40
10	7.68	7.48	97.40	7.12	6.70	94.10	0.035	96.50
11	10.87	10.28	94.57	10.31	9.05	87.78	0.052	94.80
12	12.86	12.72	98.91	12.30	11.21	91.14	0.044	95.60
13	8.65	8.54	98.73	8.09	7.55	93.33	0.035	96.50
14	6.72	6.56	97.62	6.16	5.79	93.99	0.030	97.00
15	24.81	22.29	89.84	24.25	19.49	80.37	0.042	95.80
Total	113.40	108.20	968.86	107.80	95.20	909.42	0.403	959.70
Mean	11.34	10.82	96.89	10.78	9.52	90.94	0.040	95.97
St. Dev	5.56	4.84	5.22	5.56	4.20	7.73	0.010	0.95

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	04-Jul Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	04-Jul Dry Wt	% Change Dry Wt	04-Jul AFDW	04-Jul OM% rem.
6	9.59	63.38	660.90	9.03	7.35	81.40	0.035	96.50
7	6.70	33.98	507.16	6.14	4.87	79.32	0.036	96.40
8	13.02	73.75	566.44	12.46	9.39	75.36	0.041	95.90
9	9.66	58.66	607.25	9.10	6.68	73.41	0.050	95.00
10	8.97	75.36	840.13	8.41	7.67	91.20	0.059	94.10
11	9.64	51.07	529.77	9.08	6.59	72.58	0.065	93.50
12	7.77	46.08	593.05	7.21	5.91	81.97	0.032	96.80
13	24.15	84.43	349.61	23.59	17.46	74.01	0.036	96.40
14	13.87	77.17	556.38	13.31	9.31	69.95	0.055	94.50
15	10.25	47.24	460.88	9.69	7.40	76.37	0.030	97.00
Total	113.62	611.12	5671.56	108.02	82.63	775.56	0.439	956.10
Mean	11.36	61.11	567.16	10.80	8.26	77.56	0.044	95.61
St. Dev	4.98	16.43	128.81	4.98	3.52	6.17	0.012	1.24

TREATMENT 1

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	21-Apr Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	21-Apr Dry Wt	% Change Dry Wt	21-Apr AFDW	21-Apr OM% rem.
6	6.95	7.26	104.46	6.39	6.40	100.16	0.053	94.70
7	5.09	5.15	101.18	4.53	4.63	102.21	0.050	95.00
8	7.04	7.47	106.11	6.48	6.48	100.00	0.066	93.40
9	5.25	5.56	105.90	4.69	4.70	100.21	0.065	93.50
10	5.96	6.22	104.36	5.40	5.61	103.89	0.062	93.80
11	4.95	5.16	104.24	4.39	4.66	106.15	0.081	91.90
12	7.42	7.82	105.39	6.86	6.76	98.54	0.093	90.70
13	5.48	5.81	106.02	4.92	5.18	105.28	0.048	95.20
14	4.95	4.33	87.47	4.39	3.88	88.38	0.073	92.70
15	5.54	5.66	102.17	4.98	4.72	94.78	0.062	93.80
Total	58.63	60.44	1027.31	53.03	53.02	999.61	0.653	934.70
Mean	5.86	6.04	102.73	5.30	5.30	99.96	0.065	93.47
St. Dev	0.94	1.14	5.61	0.94	0.97	5.27	0.014	1.41

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	16-Jun Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	16-Jun Dry Wt	% Change Dry Wt	16-Jun AFDW	16-Jun OM% rem.
21	6.31	6.48	102.69	5.75	5.77	100.35	0.044	95.60
22	6.73	7.03	104.46	6.17	6.05	98.06	0.053	94.70
23	5.72	5.97	104.37	5.16	5.42	105.04	0.030	97.00
24	8.64	8.98	103.94	8.08	8.01	99.13	0.033	96.70
25	8.14	8.57	105.28	7.58	7.64	100.79	0.031	96.90
26	4.96	4.78	96.37	4.40	4.24	96.36	0.037	96.30
27	5.81	6.09	104.82	5.25	5.44	103.62	0.033	96.70
28	7.88	8.23	104.44	7.32	7.19	98.22	0.071	92.90
29	4.68	4.88	104.27	4.12	4.29	104.13	0.029	97.10
30	7.57	7.38	97.49	7.01	6.50	92.72	0.061	93.90
Total	66.44	68.39	1028.14	60.84	60.55	998.42	0.422	957.80
Mean	6.64	6.84	102.81	6.08	6.06	99.84	0.042	95.78
St. Dev	1.37	1.47	3.18	1.37	1.29	3.80	0.015	1.47

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	11-Aug Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	11-Aug Dry Wt	% Change Dry Wt	11-Aug AFDW	11-Aug OM% rem.
36	5.09	26.33	517.29	4.53	4.54	100.22	0.048	95.20
37	5.86	36.83	628.50	5.30	5.38	101.51	0.062	93.80
38	7.64	41.22	539.53	7.08	6.82	96.33	0.031	96.90
39	4.86	19.05	391.98	4.30	4.22	98.14	0.037	96.30
40	6.26	24.84	396.81	5.70	6.00	105.26	0.041	95.90
41	8.28	54.20	654.59	7.72	7.62	98.70	0.059	94.10
42	5.26	35.37	672.43	4.70	4.60	97.87	0.060	94.00
43	5.64	43.03	762.94	5.08	5.08	100.00	0.058	94.20
44	5.48	36.45	665.15	4.92	4.98	101.22	0.074	92.60
45	6.66	40.91	614.26	6.10	6.02	98.69	0.049	95.10
Total	61.03	358.23	5843.47	55.43	55.26	997.95	0.519	948.10
Mean	6.10	35.82	584.35	5.54	5.53	99.79	0.052	94.81
St. Dev	1.12	10.21	121.40	1.12	1.08	2.49	0.013	1.31

TREATMENT 2

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	21-Apr Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	21-Apr Dry Wt	% Change Dry Wt	21-Apr AFDW	21-Apr OM% rem.
6	8.00	71.62	895.25	7.44	6.26	84.14	0.032	96.80
7	7.46	59.04	791.42	6.90	6.04	87.54	0.023	97.70
8	5.87	53.93	918.74	5.31	4.56	85.88	0.029	97.10
9	6.91	30.96	448.05	6.35	5.74	90.39	0.047	95.30
10	9.21	71.00	770.90	8.65	7.66	88.55	0.026	97.40
11	8.88	92.18	1038.06	8.32	6.95	83.53	0.021	97.90
12	8.69	90.25	1038.55	8.13	6.88	84.62	0.032	96.80
13	9.51	85.36	897.58	8.95	6.98	77.99	0.049	95.10
14	10.39	104.92	1009.82	9.83	8.10	82.40	0.033	96.70
15	6.84	79.23	1158.33	6.28	5.16	82.17	0.034	96.60
Total	81.76	738.49	8966.70	76.16	64.33	847.21	0.326	967.40
Mean	8.18	73.85	896.67	7.62	6.43	84.72	0.033	96.74
St. Dev	1.40	21.60	197.21	1.40	1.10	3.58	0.009	0.92

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	16-Jun Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	16-Jun Dry Wt	% Change Dry Wt	16-Jun AFDW	16-Jun OM% rem.
21	9.71	114.76	1181.87	9.15	7.88	86.12	0.056	94.40
22	9.13	101.97	1116.87	8.57	7.06	82.38	0.070	93.00
23	7.97	101.60	1274.78	7.41	6.39	86.23	0.044	95.60
24	5.82	70.59	1212.89	5.26	4.67	88.78	0.050	95.00
25	10.61	100.62	948.35	10.05	8.38	83.38	0.071	92.90
26	9.43	101.99	1081.55	8.87	7.69	86.70	0.038	96.20
27	7.03	86.46	1229.87	6.47	5.53	85.47	0.037	96.30
28	10.49	87.66	835.65	9.93	8.06	81.17	0.058	94.20
29	9.61	118.67	1234.86	9.05	7.82	86.41	0.031	96.90
30	7.47	89.11	1192.90	6.91	5.71	82.63	0.025	97.50
Total	87.27	973.43	11309.60	81.67	69.19	849.28	0.480	952.00
Mean	8.73	97.34	1130.96	8.17	6.92	84.93	0.048	95.20
St. Dev	1.58	14.24	140.47	1.58	1.27	2.40	0.016	1.58

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	11-Aug Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	11-Aug Dry Wt	% Change Dry Wt	11-Aug AFDW	11-Aug OM% rem.
36	11.07	121.82	1100.45	10.51	8.52	81.07	0.049	95.10
37	7.17	66.14	922.45	6.61	4.90	74.13	0.030	97.00
38	9.38	102.15	1089.02	8.82	6.64	75.28	0.031	96.90
39	11.01	114.43	1039.33	10.45	8.37	80.10	0.060	94.00
40	8.30	84.12	1013.49	7.74	6.48	83.72	0.039	96.10
41	10.05	90.51	900.60	9.49	7.83	82.51	0.067	93.30
42	9.21	111.95	1215.53	8.65	7.00	80.92	0.077	92.30
43	7.34	73.85	1006.13	6.78	5.84	86.14	0.066	93.40
44	10.22	106.17	1038.85	9.66	8.03	83.13	0.059	94.10
45	5.81	73.05	1257.31	5.25	4.43	84.38	0.052	94.80
Total	89.56	944.19	10583.16	83.96	68.04	811.37	0.530	947.00
Mean	8.96	94.42	1058.32	8.40	6.80	81.14	0.053	94.70
St. Dev	1.76	19.60	113.45	1.76	1.43	3.84	0.016	1.58

TREATMENT 3

Typha - Time Period 1

LEAF PACK #	Day 0 Wet Wt	14-Mar Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	14-Mar Dry Wt	% Change Dry Wt	14-Mar AFDW	14-Mar OM% rem.
6	9.18	82.99	904.03	8.62	7.28	84.45	0.026	97.40
7	4.96	53.11	1070.77	4.40	3.51	79.77	0.021	97.90
8	7.16	77.21	1078.35	6.60	5.66	85.76	0.024	97.60
9	11.20	104.06	929.11	10.64	8.77	82.42	0.025	97.50
10	7.43	70.35	946.84	6.87	6.21	90.39	0.027	97.30
11	7.46	67.75	908.18	6.90	6.09	88.26	0.021	97.90
12	4.84	45.14	932.64	4.28	3.47	81.07	0.037	96.30
13	8.06	49.76	617.37	7.50	6.52	86.93	0.030	97.00
14	6.46	41.77	646.59	5.90	5.18	87.80	0.033	96.70
15	7.30	60.36	826.85	6.74	4.99	74.04	0.022	97.80
Total	74.05	652.50	8860.73	68.45	57.68	840.90	0.266	973.40
Mean	7.41	65.25	886.07	6.85	5.77	84.09	0.027	97.34
St. Dev	1.87	19.33	153.72	1.87	1.62	4.87	0.005	0.53

Typha - Time Period 2

LEAF PACK #	Day 0 Wet Wt	16-Jun Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	16-Jun Dry Wt	% Change Dry Wt	16-Jun AFDW	16-Jun OM% rem.
21	10.98	126.69	1153.83	10.42	8.82	84.64	0.025	97.50
22	5.09	69.17	1358.94	4.53	4.33	95.58	0.056	94.40
23	6.35	65.85	1037.01	5.79	5.06	87.39	0.009	99.10
24	8.22	74.81	910.10	7.66	6.57	85.77	0.039	96.10
25	8.26	112.69	1364.29	7.70	6.14	79.74	0.045	95.50
26	7.69	81.84	1064.24	7.13	5.93	83.17	0.059	94.10
27	7.79	73.05	937.74	7.23	6.48	89.63	0.021	97.90
28	5.99	77.11	1287.31	5.43	4.72	86.92	0.039	96.10
29	5.91	70.53	1193.40	5.35	4.21	78.69	0.046	95.40
30	4.73	43.52	920.08	4.17	3.72	89.21	0.020	98.00
Total	71.01	795.26	11226.93	65.41	55.98	860.75	0.359	964.10
Mean	7.10	79.53	1122.69	6.54	5.60	86.08	0.036	96.41
St. Dev	1.87	23.76	175.90	1.87	1.51	4.95	0.017	1.65

Typha - Time Period 3

LEAF PACK #	Day 0 Wet Wt	11-Aug Wet Wt	% Change Wet Wt	Estimated Day 0 Dry Wt	11-Aug Dry Wt	% Change Dry Wt	11-Aug AFDW	11-Aug OM% rem.
36	5.91	44.81	758.21	5.35	4.29	80.19	0.048	95.20
37	7.40	64.77	875.27	6.84	5.54	80.99	0.035	96.50
38	9.05	59.63	658.90	8.49	6.53	76.91	0.024	97.60
39	6.58	67.43	1024.77	6.02	4.95	82.23	0.024	97.60
40	4.86	49.33	1015.02	4.30	3.48	80.93	0.029	97.10
41	7.36	81.84	1111.96	6.80	4.93	72.50	0.029	97.10
42	8.42	90.83	1078.74	7.86	5.95	75.70	0.038	96.20
43	5.71	59.98	1050.44	5.15	3.94	76.50	0.038	96.20
44	6.09	53.84	884.07	5.53	4.46	80.65	0.052	94.80
45	12.17	71.32	586.03	11.61	9.98	85.96	0.051	94.90
Total	73.55	643.78	9043.40	67.95	54.05	792.57	0.368	963.20
Mean	7.36	64.38	904.34	6.80	5.41	79.26	0.037	96.32
St. Dev	2.12	14.24	184.33	2.12	1.85	3.86	0.011	1.06

APPENDIX 2

Water level raw data for Lake Jandabup

WATER DEPTH (mm)

DATE	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6
17-Jan	723	651	789	175	130	
31-Jan	660	590	640	115	68	
14-Feb	612	545	605	67		
28-Feb	552	470	553			
14-Mar	474	419	477			
28-Mar	436	384	442			
11-Apr	409	369	420			
25-Apr	388	354	399			
09-May	499	452	501			
29-May	604	555	604	109		59
06-Jun	643	593	647	158	142	97
20-Jun	708	654	719	256	211	170
04-Jul	765	706	782	327	279	245

DEPTH AHD (m)

DATE	
17-Jan	44.85
31-Jan	44.78
14-Feb	44.72
28-Feb	44.65
14-Mar	44.58
28-Mar	44.54
11-Apr	44.51
25-Apr	44.48
09-May	44.59
29-May	44.70
06-Jun	44.74
20-Jun	44.81
04-Jul	44.87

APPENDIX 3

Raw data for physico-chamical characteristics of the water column field sites.

TEMPERATURE (Degrees Celcius)

	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6	
DATE	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
17-Jan	24.5	23.1	25.2	23.7	25.4	24.4	27.1	24.6	28.2	27.4		
31-Jan	25.5	25.4	26.5	23.7	25.9	25.8	27.7	27.2	27.4	26.9		
14-Feb	22.4	22.0	23.4	21.9	21.7	21.7	25.2	23.3				
28-Feb	21.6	21.5	22.0	20.4	21.2	21.2						
14-Mar	21.0	20.8	21.8	20.8	21.7	21.6						
28-Mar	18.9	18.4	19.5	19.1	21.2	20.7						
11-Apr	18.0	17.8	18.6	18.0	20.6	19.8						
25-Apr	16.9	16.4	17.7	16.5	18.7	17.7						
09-May	14.7	14.6	16.2	15.1	15.9	15.7						
29-May	10.9	10.8	11.7	11.7	12.2	12.1	9.30	9.10			10.5	10.5
06-Jun	12.4	12.4	13.8	13.5	13.9	13.8	11.3	11.2	11.8	11.8	12.3	12.3
20-Jun	10.9	10.8	11.5	11.2	12.5	12.2	9.70	9.50	10.6	10.6	10.5	10.5
04-Jul	13.6	13.6	14.4	13.7	14.3	14.1	15.7	13.8	17.2	16.3	15.4	14.6

REDOX (Millivolts)

	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6	
DATE	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
17-Jan	235	235	237	237	235	235	233	233	233	233		
31-Jan	90	-187	229	-181	52	-48	114	-174	45	-166		
14-Feb	135	-214	138	-166	45	-125	74	-44				
28-Feb	136	-150	159	-136	71	-82						
14-Mar	144	-108	83	-209	83	-122						
28-Mar	139	-186	109	-169	64	-98						
11-Apr	122	-179	109	-149	112	-134						
25-Apr	94	-89	97	-81	83	-88						
09-May	126	-28	126	-180	128	-56						
29-May	180	-18	130	-12	145	14	119	129			117	41
06-Jun	137	-112	106	-87	144	-85	103	41	118	107	139	8
20-Jun	140	-33	116	-69	125	-19	80	86	97	108	116	45
04-Jul	68	-238	90	-171	108	-181	120	94	102	106	132	32

pH

	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6	
DATE	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
17-Jan	6.15	6.15	6.09	6.09	6.26	6.26	6.33	6.33	6.30	6.30		
31-Jan	6.48	6.51	6.28	6.21	6.74	6.72	6.46	6.53	6.48	6.54		
14-Feb	6.39	6.45	6.22	6.07	6.68	6.8	6.29	6.40				
28-Feb	6.30	6.36	6.11	6.1	6.82	6.92						
14-Mar	6.14	6.13	6.16	6.11	7.00	6.90						
28-Mar	6.25	6.21	6.32	6.26	7.00	6.95						
11-Apr	6.28	6.21	6.61	6.61	7.09	7.01						
25-Apr	6.18	6.31	6.80	6.63	7.48	7.09						
09-May	6.56	6.50	6.64	6.54	7.09	7.33						
29-May	6.38	6.43	5.80	5.80	6.28	6.35	6.70	6.62			5.27	5.52
06-Jun	6.27	6.24	5.78	5.75	6.23	6.22	6.23	6.23	5.76	5.75	5.18	5.15
20-Jun	6.09	5.96	5.69	5.7	6.13	6.09	5.98	5.92	5.44	5.40	5.06	5.09
04-Jul	5.98	5.90	5.70	5.70	6.11	6.05	5.64	5.47	5.14	5.12	5.09	5.09

CONDUCTIVITY (us / cm) K20 Values

	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6	
DATE	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
17-Jan	604.3	622.8	617.4	638.0	606.6	620.2	612.7	648.3	576.0	587.0		
31-Jan	660.9	658.3	687.3	701.7	669.9	677.1	693.7	697.6	654.3	662.0		
14-Feb	727.3	728.6	746.5	770.6	789.0	739.0	841.4	877.0				
28-Feb	850.9	850.7	888.0	921.6	843.3	843.3						
14-Mar	942.8	944.6	965.9	987.9	933.2	914.0						
28-Mar	1010.8	1021.7	1044.3	1052.6	966.2	978.1						
11-Apr	1041.0	1045.1	1074.3	1088.9	996.9	1013.0						
25-Apr	1116.2	1124.5	1162.1	1188.8	1072.2	1095.2						
09-May	584.9	852.1	1037.3	1068.4	862.4	866.6						
29-May	795.5	796.8	1012.1	1015.6	888.1	839.6	1131.5	1135.2			1016.3	1016.3
06-Jun	720.0	720.0	908.2	915.3	754.0	753.1	1057.8	1058.4	608.8	608.8	877.7	877.7
20-Jun	657.2	653.6	807.3	811.4	688.9	693.6	1057.7	1061.2	598.8	596.4	830.6	830.6
04-Jul	560.6	560.6	622.7	681.2	570.4	585.8	912.2	964.4	517.4	576.3	680.3	690.3

DISSOLVED OXYGEN (%)

	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6	
DATE	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
17-Jan	54	41	24	13	58	55	65	63	62	48		
31-Jan	57	13	33	19	65	49	64	49	46	13		
14-Feb	81	52	49	33	93	87	72	32				
28-Feb	53	43	55	30	93	76						
14-Mar	42	33	41	22	86	52						
28-Mar	40	18	37	15	68	38						
11-Apr	34	12	49	32	82	32						
25-Apr	51	26	47	23	98	28						
09-May	52	16	53	32	88	65						
29-May	67	59	64	32	85	66	75	69			94	85
06-Jun	65	48	61	39	82	67	68	59	59	55	87	84
20-Jun	77	32	71	38	89	65	79	65	63	54	95	79
04-Jul	81	49	75	65	80	76	67	47	70	67	97	88

DISSOLVED OXYGEN (mg/l)

	SITE 1		SITE 2		SITE 3		SITE 4		SITE 5		SITE 6	
DATE	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM	TOP	BOTTOM
17-Jan	4.8	3.4	1.6	1.0	5.4	5.1	6.0	5.6	5.0	3.7		
31-Jan	4.6	1.1	2.5	1.4	5.4	4.1	5.3	3.7	3.9	1.0		
14-Feb	6.9	4.3	4.0	3.6	8.4	7.7	5.8	2.3				
28-Feb	4.1	3.7	4.6	2.8	8.0	6.7						
14-Mar	3.6	3.1	3.2	2.0	7.4	4.2						
28-Mar	3.8	1.7	3.6	1.3	6.2	4.0						
11-Apr	3.3	1.3	4.5	3.3	7.1	2.7						
25-Apr	5.0	2.4	4.4	2.3	9.5	2.6						
09-May	5.2	1.5	4.9	3.1	8.5	6.4						
29-May	7.1	5.8	6.8	3.2	8.8	6.6	7.7	7.2			10.1	9.1
06-Jun	6.6	5.0	6.0	4.1	8.4	6.7	6.8	6.1	5.9	5.6	8.8	8.4
20-Jun	7.7	3.2	7.1	4.0	8.9	6.6	8.0	6.6	6.3	5.4	9.7	8.1
04-Jul	8.4	5.0	7.3	6.3	8.1	7.9	6.7	4.5	7.0	6.3	9.7	8.8