

**SPATIAL AND TEMPORAL DYNAMICS OF FRESHWATER WETLANDS
ON THE EASTERN SHORES OF ST LUCIA, AS REFLECTED BY THEIR
MACROFAUNAL COMPOSITION AND DISTRIBUTION.**

by

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ABSTRACT

The wetlands on the Eastern Shores of Lake St Lucia are primarily groundwater fed and exhibit a variety of hydrological regimes that give rise to a high degree of habitat and species diversity. Hydrologically unstable systems experience ecophasal shifts that can disrupt an established steady state within the wetland ecosystem. Communities of both plants and animals can accordingly disintegrate into more or less isolated populations, open to re-invasion by preceding or "new" species when conditions change again. Given the ephemeral and episodic nature of much of the surface water on the Eastern Shores, ecological dynamics of this type are likely. Fish and aquatic invertebrates were sampled from a number of routine and other sites between May 2002 and April 2003. Measurements of various environmental and abiotic factors (including pH, ionic conductivity and dissolved oxygen levels) were taken with each sample in order to establish relationships between environmental changes and the assemblages of aquatic fauna occurring within the Eastern Shores wetlands. Conditions on the Eastern Shores during the study were somewhat anomalous, as the region experienced drought conditions during this period. The Eastern Shores wetlands support a diversity of aquatic fauna, including at least four species of freshwater fish listed as rare or threatened by the IUCN. The aquatic organisms existing within this dynamic system exhibited changes in abundance and distribution that reflected the spatial and temporal changes in their environment. The relationships between aquatic organisms and their environment were complex, with assemblages being affected by combinations of changing environmental and habitat variables as well as other factors such as the environmental stability of habitats and stochastic effects. Given the complex nature of these interactions, aquatic macrofauna on the Eastern Shores are likely to be best conserved through the preservation a heterogeneous mix of wetland habitats, maintaining the diversity of wetland structure and function on the Eastern Shores that can facilitate an element of lottery in the development and structure in biotic assemblages.

PREFACE

The work described in this dissertation was carried out on the Eastern Shores of Lake St Lucia, KwaZulu-Natal, South Africa and in the School of Botany & Zoology, University of Natal, Pietermaritzburg, from February 2002 to December 2003, under the supervision of Professor Rob C. Hart and Professor William N. Ellery

The project forms part of an integrated programme funded by the Norwegian University Fund (NUFU), entitled "**NATURE CONSERVATION AND MANAGEMENT: Biodiversity in coastal Maputaland (northern KwaZulu-Natal and southern part of Mozambique): links between geology and ecology**" comprising a suite of projects examining the hydrology, vegetation and ecology of this region. Collectively these projects will provide significant insight into the functioning of the Eastern Shores wetlands.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others it is duly acknowledged in the text.



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TABLE OF CONTENTS

ABSTRACT	II
PREFACE	III
TABLE OF CONTENTS	IV
LIST OF TABLES	VI
LIST OF FIGURES	VII
ACKNOWLEDGEMENTS	XII
INTRODUCTION	1
DESCRIPTION OF STUDY SITE	6
STUDY AREA	6
GENERAL TOPOGRAPHY	8
HYDROLOGY	9
VEGETATION TYPES	11
CLIMATE AND RAINFALL	13
SAMPLE SITES	15
THE PHYSICAL ENVIRONMENT	17
VEGETATION AND HABITAT TYPES	18
RELATIONSHIPS BETWEEN BIOTIC AND ABIOTIC VARIABLES	20
GENERAL CHARACTERISTICS OF THE SURFACE WATERS ON THE EASTERN SHORES.	23
ENVIRONMENTAL STABILITY	30
SOME NOTES ON THE EFFECT OF HIPPOPOTAMUSES ON THEIR ENVIRONMENT.	31
FRESHWATER FISHES	34
METHODS	38
Collection	38
Data Analysis	39
RESULTS	41

RED DATA SPECIES	46
DISCUSSION	46
AQUATIC MACROINVERTEBRATES	50
METHODS	51
Collection	51
Data Analysis	52
RESULTS	53
DISCUSSION	62
CONCLUSIONS AND IMPLICATIONS FOR BIODIVERSITY CONSERVATION ON THE EASTERN SHORES	64
REFERENCES	71
APPENDICES	84
APPENDIX I	86
APPENDIX II	87
APPENDIX III	95

LIST OF TABLES

Table 1: Classification of water regimes of temporary wetlands (from Brock <i>et al.</i> , 2003)	10
Table 2: Rainfall statistics for the St Lucia Region. Mount Tabor is located on the Eastern Shores of Lake St Lucia, and Fanies island on the western shore. (From Kelbe & Rawlins, 1992)	13
Table 3: Description of Eastern Shores sample sites. The degree of permanence is coded according to the classification of Brock <i>et al.</i> (2003): NP – Near permanent; SP – Semi permanent; S – Seasonal; I – Intermittent.	16
Table 4: Broad physiognomic classification of wetland habitats and biotopes on the Eastern Shores.	19
Table 5: Environmental and habitat variables measured for each sample.	20
Table 6: Summary statistics for RDA of habitat and environmental variables on the Eastern Shores.	23
Table 7: Summary statistics for four abiotic variables measured at collection sites on the Eastern Shores, between May 2002 and April 2003.	28
Table 8: Multivariate stability scores based on physicochemical variables recorded on each sampling occasion at each site.	30
Table 9: Freshwater fish species occurring or thought to occur on the Eastern Shores of Lake St Lucia. Information compiled from a number of sources: Bruton, 1980; Coke, 1991, 1993; Froese & Pauly, 2003; unpublished EKZNW records; and other references where indicated.	36
Table 10: Summary statistics for db-RDA based on Bray Curtis distances of $\sqrt{}$ transformed fish abundance data from sites on the Eastern Shores.	45
Table 11: Aquatic associations and habitats of insect orders with aquatic or semiaquatic representatives. (Ward, 1992)	51
Table 12: Summary statistics for db-RDA based on Bray Curtis distances of $\sqrt{}$ transformed invertebrate abundance data (aggregated at family level) from sites on the Eastern Shores.	59

LIST OF FIGURES

- Figure 1: General metapopulation models a) Mainland-island model. b) Intermediate model with variable patch size and no mainland. c) Levins's model of equal patch size. Dashed lines indicate limits of the system of patches inhabited by the metapopulation. Arrows indicate the movement of individuals between patches. (After Hanski & Gyllenberg, 1993) 3
- Figure 2: Schematic representation of how environmental processes may drive the patterns observed in wetland faunal distributions. Water table fluctuations drive changes in various environmental parameters (indicated in italics), which in turn affect the spatial and temporal distributions of aquatic macrofauna. 5
- Figure 3- Map of the Eastern Shores, showing wetland areas and areas under pine plantations in 1998. A large proportion of the pine plantations had subsequently been removed at the time of writing (mapped from 1998 aerial photography). 7
- Figure 4: Location of routine sample site on the Eastern Shores. Site descriptions are given in Table 3. 8
- Figure 5: Section of rectified orthophoto (1998) showing the mosaic of some wetland and dry land habitats on the Eastern Shores. Arrows show direction of surface flow and linkages and letters denote different habitat types: DrF- dry forest; E- endorheic pan; L – linked wetlands; Nk – Nkazana stream (main drainage out of Mfabeni Depression); P- *Pinus eliotti* plantation; SwF- swamp forest. 10
- Figure 6: Schematic profile (dune heights exaggerated) showing the main vegetation types along a west- east transect of the Eastern Shores (after Taylor, 1991). Vegetation types are designated as follows A – sedge swamp; Gh – hygrophilous grassland; Ga – dry grassland; Gf – forest; Ff – swamp forest; Fe – pine plantations; Fc – dune forest. 11
- Figure 7: Schematic representation of zonation of vegetation within a generalized Eastern Shores wetland. Letters represent different ecotones: A – Hygrophilous grasses; B – sedges and sedge type aquatic plants; C –

- emergent aquatic plants; D - Open water with submerged and floating leaved plants. 12
- Figure 8: Monthly rainfall figures from UNIZUL weather station on the Eastern Shores, observed during this study period compared with 20 year monthly medians and means from Mount Tabor weather station (Kelbe & Rawlins, 1992). Error bars represent 1 standard deviation from monthly means. 14
- Figure 9 : Relative frequency distribution for rainfall at St Lucia between April 2002 and May 2003. Data from UNIZUL weather station on the Eastern Shores. 15
- Figure 10: Conceptual diagram of the relationship between the effects of hydrology on wetland function and biotic feedback loops that affect wetland hydrology. Pathways A and B are feedback loops to hydrology and physicochemistry of the wetland. Solid arrows represent direct effects and dashed arrows represent biotic feedback (After Mitsch & Gosselink, 2000). 18
- Figure 11: Scatterplots of samples along the first two axes of an RDA of habitat type and physico-chemical variables. Envelopes enclose samples taken from each of the four habitat types indicated in the legend. Summary statistics are given in Table 6. 21
- Figure 12: Plot of first two axes of RDA of habitat and environmental variables measured at sites on the Eastern Shores. Codes are listed in Table 4. Summary statistics are given in Table 6. 22
- Figure 13: Variation in pH values recorded at routine sample sites on the Eastern Shores between May 2002 and April 2003. For clarity, sites are separated into the groups determined by redundancy analysis of habitat and environmental variables in Figure 11. 25
- Figure 14: Variation in dissolved oxygen levels recorded at routine sample sites on the Eastern Shores between May 2002 and April 2003. For clarity sites are separated into groups determined by redundancy analysis of habitat and environmental variables. The gaps in the data between days 160-250 and for some sites, 300-350 are due to instrument failure. 27

- Figure 15: Variation in ionic conductivity recorded at routine sample sites on the Eastern Shores between May 2002 and April 2003. For clarity sites are separated into groups determined by redundancy analysis of habitat and environmental variables. 29
- Figure 16: Topographic profile across Site 2 taken in February 2003 showing the effect of hippo trails on the bottom topography of a pan on the Eastern Shores. 31
- Figure 17: Groundwater seepage concentrated by a hippo trail to form a sandy bottomed stream near the Lake St Lucia shoreline. The stream has become incised through a layer of peat and mud to the sandy substrate below. Streams were persistent and flowed strongly all year round. The arrows represent a width of approximately 50cm. Depth varied from 5-10cm. 33
- Figure 18: Analysis scheme for db-RDA of fish abundance data. 40
- Figure 19: Relative contributions of fish families to overall percentage occurrence of fishes in samples. Numbers in parentheses indicate the number of species collected per family. 41
- Figure 20: MDS plots from Bray Curtis similarities of $\sqrt{}$ transformed abundance data from Eastern Shores. The four main fish families, Cichlidae, Clariidae, Cyprinidae and Poeciliidae, are illustrated on separate plots with bubble sizes representing the relative importance of the family per sample (Stress for all plots = 0.1). 43
- Figure 21: Results of a hierarchical cluster analysis, using group average linking on Bray-Curtis similarities between $\sqrt{}$ transformed abundance data. Letters in bold represent groups discussed in text. A – Rare species; B – Pond and Channel Species ; C – Hardy species; D – Marginal Estuarine species. 44
- Figure 22: Plot of first two axes of a db-RDA showing relationships between fish-plotted as points and measured environmental variables-plotted as arrows. Summary statistics are given in Table 10. 45

Figure 24: MDS plots from Bray Curtis similarities of $\sqrt{\text{transformed}}$ invertebrate abundance data from Eastern Shores. Zygoptera, Coleoptera, Heteroptera and Anisoptera are illustrated on separate plots with bubble sizes representing the relative importance of the order per sample. Stress value = 0.19 for all plots.

54

Figure 25: Heirarchical cluster analysis from Bray-Curtis similarities of $\sqrt{\text{transformed}}$ invertebrate abundance data aggregated at order level. (Terrestrial groups excluded).

55

Figure 26: Vector plots showing the relative degree and direction of change in invertebrate assemblages from selected sites on the Eastern Shores. Start points in each sequence are represented by a closed circle and end points by a square. Plots are based on scores from 2 dimensional MDS analysis of Bray Curtis similarities between $\sqrt{\text{transformed}}$ invertebrate abundance data. Stress value for all plots is 0.19.

56

Figure 27: Plot of first two axes of a db-RDA showing relationships between invertebrate families^a, plotted as points and measured environmental variables^b, plotted as arrows. Summary statistics are given in Table 12. Key: ^a Clusters of invertebrates: i – Tabanidae, Curculionidae, Buprestidae; ii – Belastomatidae, Naucoridae, Dystiscidae, Culicidae; iii – Nepidae, Cicadellidae, Cerambycidae, Pleidae, Baetidae, Tettigogonidae; iv – Lestidae, Cleridae, Coenagrionidae, Notonectidea, Gyridae Planorbidae; v – Aeshnidae, Mesovelidae. ^b Clusters of environmental variables: 1 – FLOG, MUD, PEAT, ELIO1 NYM2. Other environmental variables are labelled individually.

58

Figure 28: Scatterplot showing relative distributions of samples on the first two axes of db-RDA based on Bray Curtis distances of $\sqrt{\text{transformed}}$ invertebrate abundance data (aggregated at family level) from sites on the Eastern Shores. Envelopes enclose samples taken from each of the four habitat types indicated in the legend. Summary statistics are given in Table 12.

60

Figure 29: Relative composition of invertebrate assemblages by family for the four groupings of samples in Figure 28. Key: a= Isopoda, Hymenoptera, Lepidoptera, Nematoda & Orthoptera, Arachnida, Decapoda, Ephemeroptera (All occurring at 1%) b= Isopoda, Diptera, Homoptera, Hymenoptera, Lepidoptera, Pulmonata, Zygoptera. (All occurring at 2%). 61

Figure 30: Frequency histograms of habitat specificity for the four groupings of samples shown in Figure 28. Habitat specificity is the number of occurrences of a taxon in a particular habitat as a percentage of the total occurrences of that taxon in the entire dataset. Bars represent the proportions of taxa occurring in 5% classes of habitat specificity, lines represent cumulative frequency of taxa collected. 61

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“...never was Rum, that cordial of Life, found more necessary than in this Dirty Place.”

– Colonel William Byrd III (1674-1744)

This dissertation is dedicated to my parents, for their love and support in allowing me to follow my interests and for giving me the gift of education.

Sven Vrdoljak, 2004

INTRODUCTION

Lake St Lucia and its surrounding wetlands are recognized as being a valuable and unique natural system in terms of their biophysical diversity as well as hydrological and ecological functioning. The Greater St Lucia Wetland Park (GSLWP) was inscribed as a World Heritage site in 1999 (World Heritage Center, 2002) as well as being declared a wetland of international importance under the Ramsar convention in October 1986 (Cowan, 1995). In order to effectively conserve and manage such a site it is important to understand the ecological processes at work in the area.

The wetlands on the Eastern Shores of St Lucia (hereafter referred to as the 'Eastern Shores') are putatively understood as being maintained by groundwater (Kelbe & Rawlins, 1992). Although this groundwater flow is variable, it does provide a sustained input of fresh water into the system, allowing certain areas to persist as wetland during the annual dry season as well as through periods of extended drought. Within the wetlands a variety of hydrological regimes results in high habitat diversity and species richness, both spatially and temporally. Hydrologically unstable (polyperiodic) systems experience shifts of ecophase that can disrupt an established steady state within the wetland or terrestrial ecosystem (Hejný & Segal, 1998). In this type of system, communities of both plants and animals can disintegrate into more or less isolated populations, open to invasions when conditions change again. Species existing in transient habitats have to be able to cope with an ever changing number and spatial arrangement of habitat patches that vary in quality over time (Fahrig, 1992). This type of situation is likely on the Eastern Shores given the ephemeral and episodic nature of much of its surface water. Two general strategies for rapid colonization after inundation are exhibited by aquatic invertebrates (and other organisms) in wetlands (Batzer & Wissinger, 1996; McPeck & Kalisz, 1998). The first is desiccation resistance in the eggs, larvae or even adult stages that facilitates survival, often in a state of diapause until the next inundation. This strategy is common amongst plants and zooplankton (Brock *et al.*, 2003) that lack strong dispersal ability, but are able to produce desiccation resistant propagules. It occurs less frequently in other groups

such as the fish, with the exception of annual killifishes (Aplocheilidae) that produce desiccation resistant eggs and lungfish (*Protopterus* spp.) that are able to estivate during dry periods. The second strategy is colonization through adult immigration and oviposition. This strategy is common in taxa such as Odonata, many Coleoptera and Heteroptera, that are able to fly and can easily disperse beyond their natal habitat. Those taxa that are unable to utilise any of these options (for example most wetland fish) will be dependent on maintaining viable populations in small pockets of suitable habitat (refugia). These refugia will form a core population from which expansion and colonization can occur once these refugia are reconnected and new habitat becomes available. Aquatic refugia, by default, require water, but water quality is also important (Magoulick & Kobza, 2003). Water temperature, pH, dissolved oxygen, and mineral content (conductivity) all need to remain within the tolerance of the organisms that use the refugia.

Given the fragmented and dynamic nature of aquatic habitats on the Eastern Shores it is possible that many taxa may exist in the form of metapopulations, defined by Levins (1970) as an assemblage of local populations connected by migration. Two main conceptual models exist to explain metapopulations. The mainland-island model assumes a large invulnerable source population with outlying 'island' populations, whereas Levins's model envisages a set of equally large habitat patches or islands (Figure 1). These theoretical models represent two ends of a continuum (Hanski & Gyllenberg, 1993). In reality, most species in nature will occur in environments that are intermediate between the two extremes with variable patch size, even if there is no true 'mainland' (Harrison, 1991). On the Eastern Shores, patch size could be equated to persistence of wetland patches within the mosaic of terrestrial and aquatic habitats and the system would probably follow the model outlined in Figure 1b. Implicit in this model is the importance of migration between patches, something that is only possible for obligate aquatic organisms when the wetlands are connected (either frequently or sporadically). Over-land dispersal by non-obligate aquatic taxa effectively obviates the need for direct connectivity.

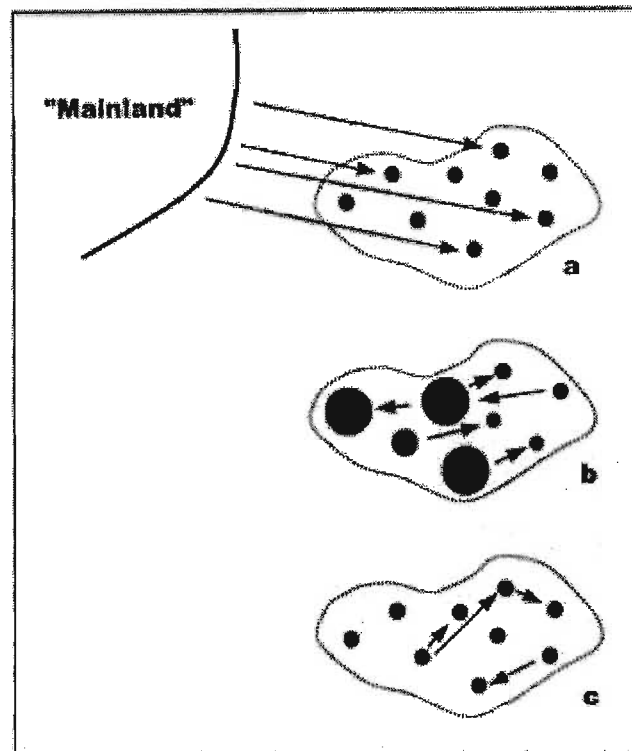


Figure 1: General metapopulation models a) Mainland-island model. b) Intermediate model with variable patch size and no mainland. c) Levins's model of equal patch size. Dashed lines indicate limits of the system of patches inhabited by the metapopulation. Arrows indicate the movement of individuals between patches. (After Hanski & Gyllenberg, 1993)

Which of these models most closely approximates reality is less important than the underlying basis of metapopulation theory. As with any model, what is observed in the real world very seldom exactly fits the assumptions made by the model. Panell and Obbard (2003) address the issue that the usage of the term 'metapopulation' has broadened considerably since its inception. In the process the term has arguably lost some of its precision and come to describe a number of different types of subdivided populations that may not meet all the original criteria of the model. The original metapopulation models also assume the existence of static patches and mobile populations. Most landscapes exhibit some state of dynamism, with some, like seasonal wetlands, exhibiting far greater variability than others. Johst *et al.* (2002) defined a dynamic landscape as "an ensemble of habitat patches whose quality was allowed to change across time." Patches can be destroyed, but in contrast to habitat loss (Bascompte & Solé, 1996; Tilman *et al.*, 1997) patches can regenerate to regain their former quality. Aquatic habitats on the Eastern Shores fit this definition well, and the idea of metapopulations existing

in a dynamic landscape form a useful conceptual framework for considering aquatic faunal assemblages in these wetlands.

The overall environmental processes at work in the wetlands will drive the patterns observed in the distributions of wetland fauna on the Eastern Shores (Figure 2), either directly by creating suitable habitat for aquatic organisms, or indirectly by affecting competitive and other interactions between wetland animals or triggering biological processes such as spawning or emergence events (Junk, 2002). These water table fluctuations also play an important role in the functioning and maintenance of metapopulations on the Eastern Shores. In order for metapopulations to be maintained, colonists need to migrate through the landscape matrix (Levins, 1970). For organisms such as fish, this would require a direct connection between habitat patches, as would occur during periods of high water or flooding. The importance of direct connection diminishes somewhat as dispersal ability increases and reliance on a strictly aquatic existence is reduced. This is exemplified by many aquatic invertebrates that have highly mobile, aerial stages in their life histories and are able to disperse to new but more isolated habitats, as exhibited by insects in particular.

These interactions can occur over a number of spatial and temporal scales. Spatial scales can range from ecotones within the vegetation of a single water body to the broader landscape level heterogeneity observed on the Eastern Shores. Temporal changes are of variable scale, ranging from a few months, as with the seasonal wetting and drying of the pans, through longer temporal scales, several years, as during periods of drought such as those observed in the 1980's (and possibly at present) to scales of hundreds of years as the effects of global climate change, such as changes in hydrological regime, increased fire and drought stress, or flooding of coastal wetlands (Junk, 2002) become apparent. The fact that these processes may occur over a number of temporal scales may be a confounding factor when attempting to explain their observed effects upon wetland fauna. However, in spite of their temporal incongruity the underlying processes at work are likely to be the same.

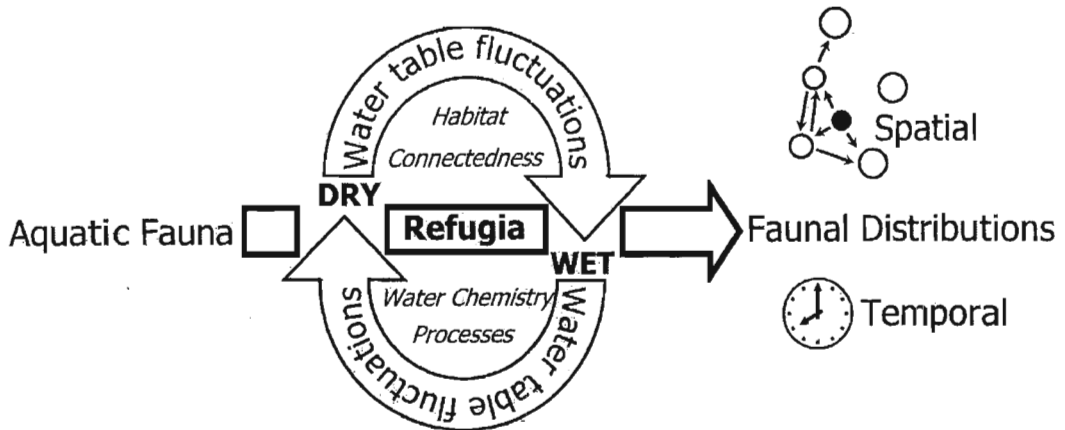


Figure 2: Schematic representation of how environmental processes may drive the patterns observed in wetland faunal distributions. Water table fluctuations drive changes in various environmental parameters (indicated in italics), which in turn affect the spatial and temporal distributions of aquatic macrofauna.

The main objectives of this project were to discern any spatial and temporal patterns in the fish and aquatic macroinvertebrates assemblages in the Eastern Shores wetlands, and attempt to determine the causal factors underlying these patterns. Secondary objectives included performing baseline surveys of fish species and certain groups of aquatic macroinvertebrates, in particular Coleoptera and Heteroptera that appear to be largely unknown on the Eastern Shores, as well as identification of conservation 'hotspots' on the Eastern Shores. To these ends, fish and aquatic macroinvertebrates were surveyed extensively from a number of fixed and *ad hoc* sample sites across the Eastern Shores between May 2002 and April 2003. It can be recognised that the distributions of fish and aquatic macroinvertebrates are likely to be closely related and links between these taxa have been made by other authors (Diehl, 1992; Mallory *et al.*, 1994; Wong *et al.*, 1998 and other more extensive examples cited in Batzer and Wissinger, 1996). However, disparities between collecting methods used for the taxa in this study and the subsequent datasets generated meant that the distributions of fish and aquatic macroinvertebrates required independent assessment and as such they are discussed separately. This does not mean that the relationship between these faunal groups has been ignored; the presence of fish as an environmental parameter is included in the assessment of invertebrate assemblages.

DESCRIPTION OF STUDY SITE

STUDY AREA

The St Lucia system is located on the north eastern coast of South Africa, in northern KwaZulu Natal (28°04'S 032°28'E) approximately 200km North of Durban. The system contains an outstanding diversity of wetland and terrestrial habitats. Wetlands range from saline to fresh water and from oligotrophic to eutrophic, encompassing swamps, hygrophilous grasslands, salt marsh, mangroves, swamp forests and riparian forest habitats¹.

The freshwater wetlands on the Eastern Shores lie between the eastern shoreline of Lake St Lucia and the high coastal dune cordon that separates the contiguous coastal plain from the Indian Ocean (Figure 3). The area is a spatially heterogeneous mosaic of different wetland and dry land habitats, the location and extent of which are determined by topography, hydrology, vegetation, and in some areas historical land use. The wetlands on the Eastern Shores have been recognised as an integral part of the estuary system and should be included in the total picture of the system if Lake St. Lucia is to be preserved as a holistic system for studying estuarine processes, geomorphology, stratigraphy and Quaternary history (Smart, 1992).

Since the freshwater wetlands of the Eastern Shores were the object of this study, the study area was focused on the low lying areas of the coastal plain. The study area extended from iPhiva pan in the south to the southern end of Lake Bhangazi in the north. The eastern and western boundaries were delineated by the dune cordon and the Lake St Lucia shoreline respectively.

Although samples were taken extensively over this area during the course of the study period, the sampling was focused on 16 routine sites (Figure 4) scattered between the lower end of the Mfabeni depression to the southernmost entrance to the GSLWP.

¹ Ramsar information sheet 1ZA006. 1998. The Bureau of the Convention on Wetlands. Gland, Switzerland.

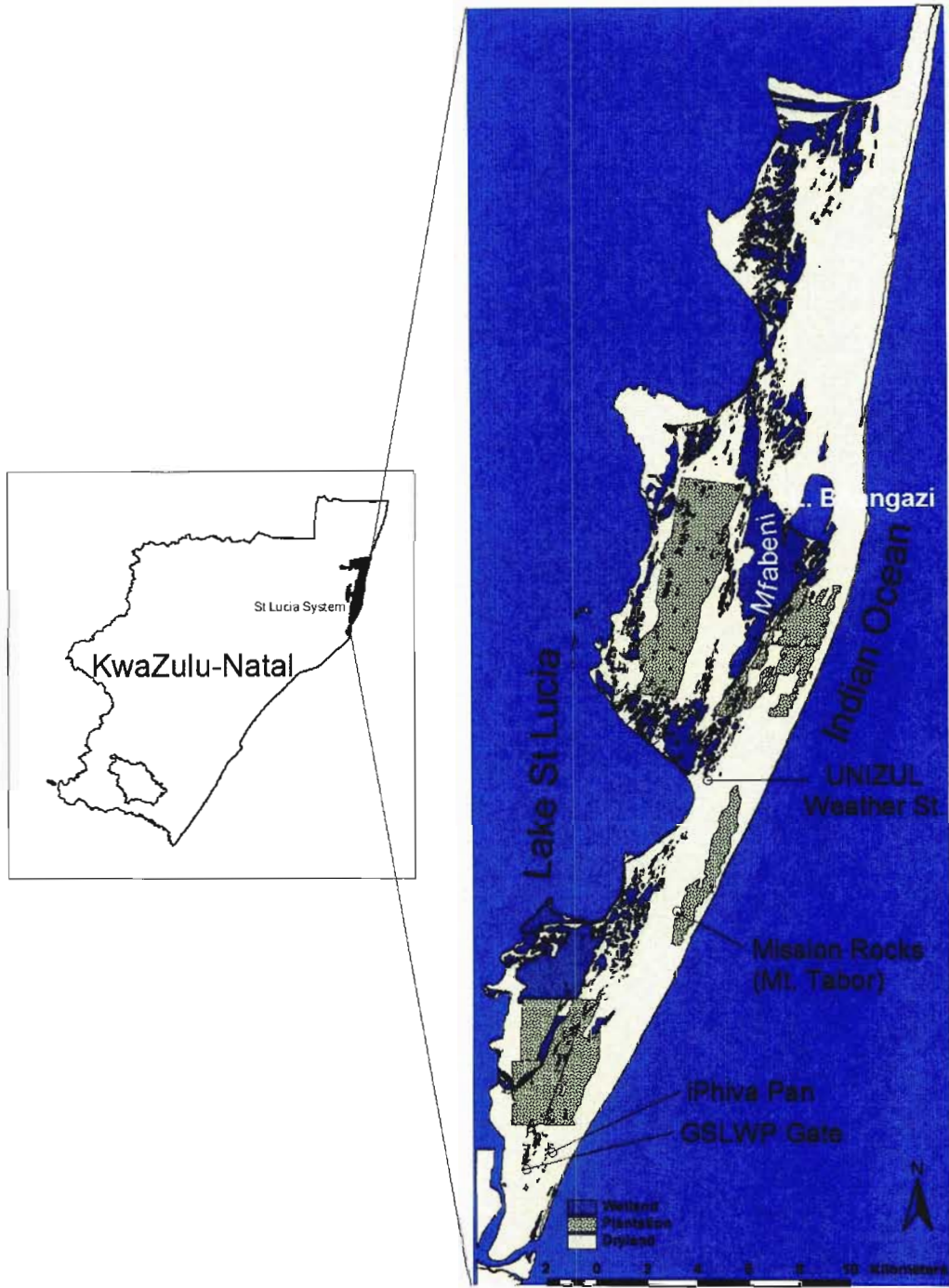


Figure 3- Map of the Eastern Shores, showing wetland areas and areas under pine plantations in 1998. A large proportion of the pine plantations had subsequently been removed at the time of writing (mapped from 1998 aerial photography).

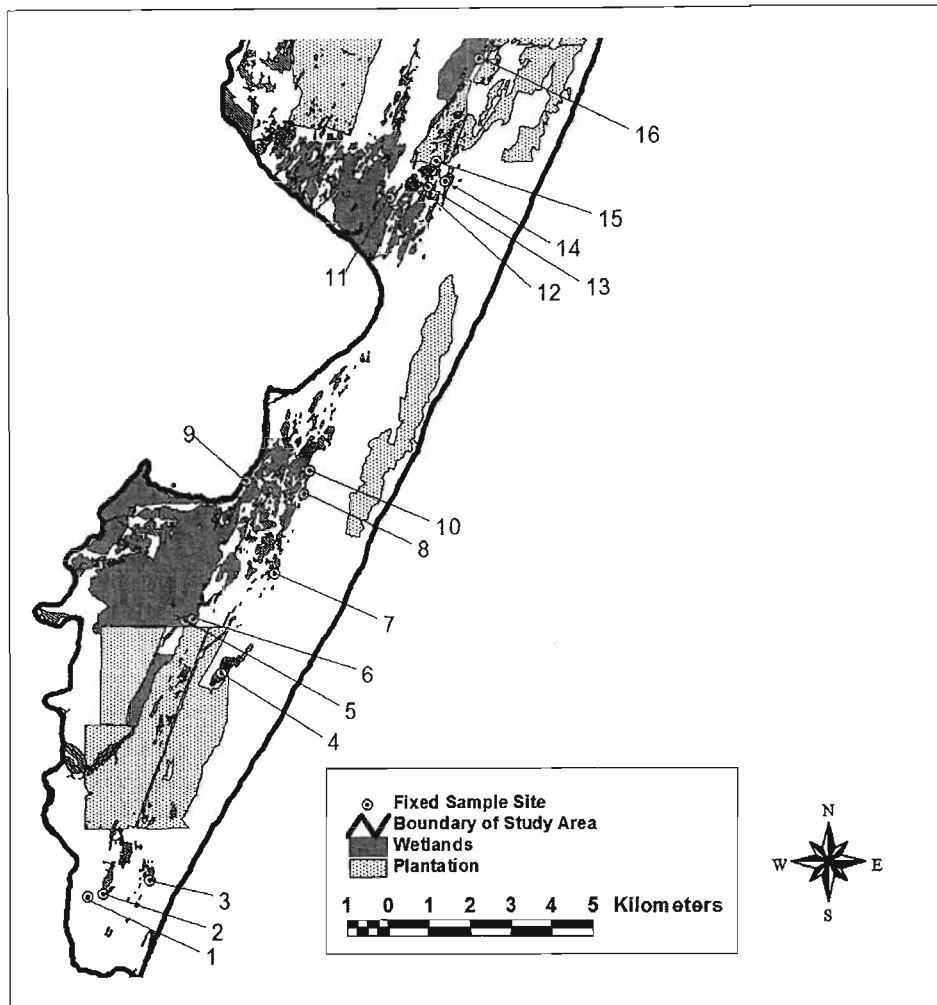


Figure 4: Location of routine sample site on the Eastern Shores. Site descriptions are given in Table 3.

GENERAL TOPOGRAPHY

The general topography of the Eastern Shores can be divided broadly into four main units (Davies Lyn & Partners, 1992):

1. Coastal Dune Cordon, 1 – 2km wide with an elevation of between 80 and 131 metres above mean sea level (AMSL).
2. Low lying coastal plain (<15m AMSL) varying in width between 0.5 and 7km, the narrowest point being opposite the Mission Rocks area.
3. Drainage depressions (<8m AMSL) the largest of which is the Mfabeni Depression. The depression is oriented parallel to the coast and drains partly northwards into Lake Bhangazi, but predominantly southwards into lake St Lucia.

4. Eastern Shore Plain, an extensive coastal plain to the west of the Mfabeni depression. Elevation ranges from approximately 15m AMSL to 70m AMSL on fossil dune ridges. Drainage is to the east into the Mfabeni Depression and to the west into Lake St Lucia.

HYDROLOGY

Kelbe and Rawlins (1992) provide a detailed description of the functioning of the Eastern Shores wetlands in relation to the underlying hydrology of the area. The salient points are outlined briefly here. The system is largely dependent upon rainfall, which shows considerable regional and annual fluctuation, for recharge. Highly permeable coastal dune cover sands in the region allow most of the rainwater not lost to evapotranspiration to percolate to the water table and recharge the unconfined aquifer that covers the entire region. There is usually very little surface flow, except during extreme rainfall events. Due to annual variation in rainfall and the subsequent recharge of the aquifer, the groundwater table level can vary as much as three metres between years.² Pans and wetlands exist where the groundwater table reaches the land surface to form a mosaic of wetlands that vary in size, type and permanence within the landscape matrix (Figure 5).

The pans fluctuate in size and water depth in response to groundwater table fluctuations following natural seasonal variation, falling during drier periods and rising following significant rainfall events (Kelbe & Rawlins, 1992). Only the largest and very lowest-lying pans appear to be permanent or near permanent. The others are generally seasonal or intermittent (see Table 1 for explanation of water regimes). The Mfabeni depression forms a more permanent shallow swampy area, consisting of low lying, usually water logged grassland that connects Lake Bhangazi with Lake St Lucia. Afforestation in wetland areas has significantly reduced both the number and size of wetlands situated within plantations, due to high rates of evapotranspiration associated with pine plantations. Rawlins and Kelbe (1988) suggest that the pine plantation located to the west of the Mfabeni

² Unpublished data from EKZNW/UNIZUL borehole monitoring on the Eastern Shores

Swamp transpires water at a rate exceeding the surrounding vegetation by 450mm/year.

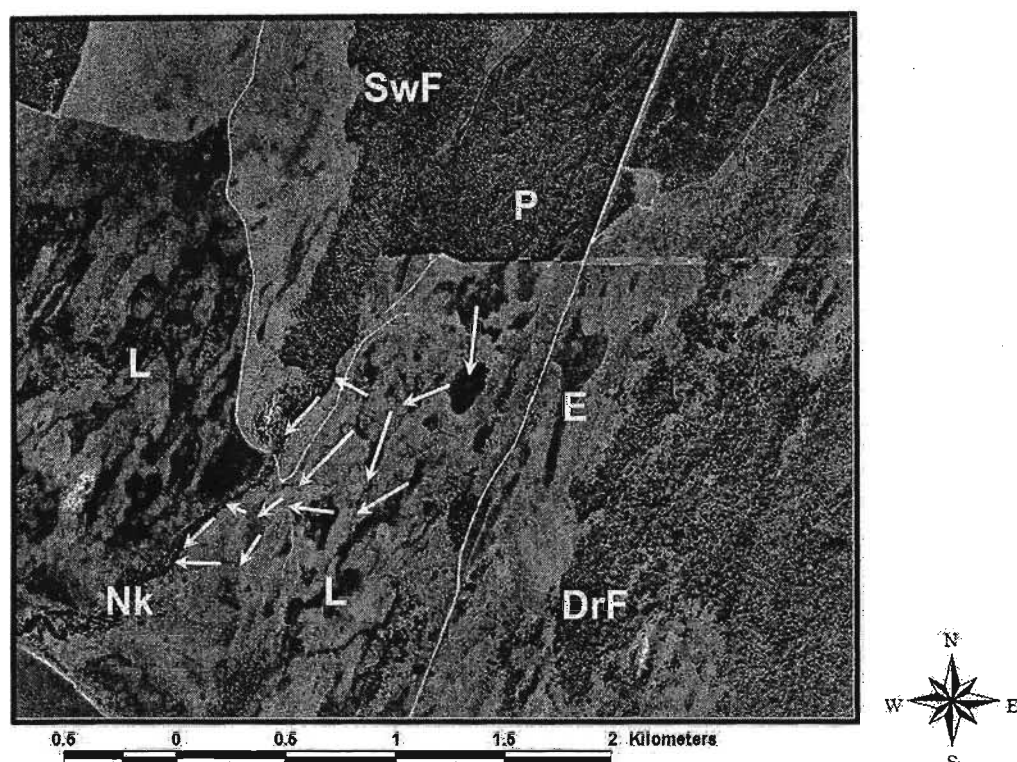


Figure 5: Section of rectified orthophoto (1998) showing the mosaic of some wetland and dry land habitats on the Eastern Shores. Arrows show direction of surface flow and linkages and letters denote different habitat types: DrF- dry forest; E- endorheic pan; L – linked wetlands; Nk – Nkazana stream (main drainage out of Mfabeni Depression); P- *Pinus eliotti* plantation; SwF- swamp forest.

Table 1: Classification of water regimes of temporary wetlands (from Brock *et al.*, 2003)

Drying Pattern	Predictability and duration of filling
Semi permanent or near permanent.	Usually holds some water Annual inflows are greater than minimum loss in 90% of years May dry during extreme drought events
Seasonal	Alternately wet and dry every year according to season Fills during wet season and dries annually Surface water persists for months
Intermittent	Alternately wet and dry but less frequently and regularly than seasonal wetlands Surface water may persist for months to years
Episodic	Annual inflow is less than loss in 90% of years Dry for most of the time Only rarely or irregularly flooded when water may persist for months
Ephemeral	Only fills for a few days after unpredictable rainfall and runoff

Wetlands altered by afforestation will only exist for short periods following heavy rainfall events. It is likely that these wetlands will return to their natural hydrological regime once the plantations are removed, although whether or not they will regain their original ecological functioning remains to be seen.

VEGETATION TYPES

The distribution of major plant communities on the Eastern Shores is shown schematically in (Figure 6). Three of the seven communities shown, namely sedge swamp (A), hygrophilous grassland (Gh) and swamp forest (Ff) are of relevance to this study. Hygrophilous grasslands and sedge swamps are abundant on the Eastern Shores, covering 18 and 17 percent of the total area respectively (Lubke, Avis & Phillipson, 1992). Large proportions of this hygrophilous grassland have been planted with pines (*Pinus elliotii*). In many areas the pines have been able to invade hygrophilous grassland and pans (Taylor 1980) due to the progressive drying due to the high evapotranspiration rates of the plantations. In the 1992 survey (Lubke *et al.*, 1992) pines covered 33 percent of the Eastern Shores. Removal of the pine plantations is currently underway and at time of writing the proportion of land cover by pines was estimated to be considerably less than 30%.

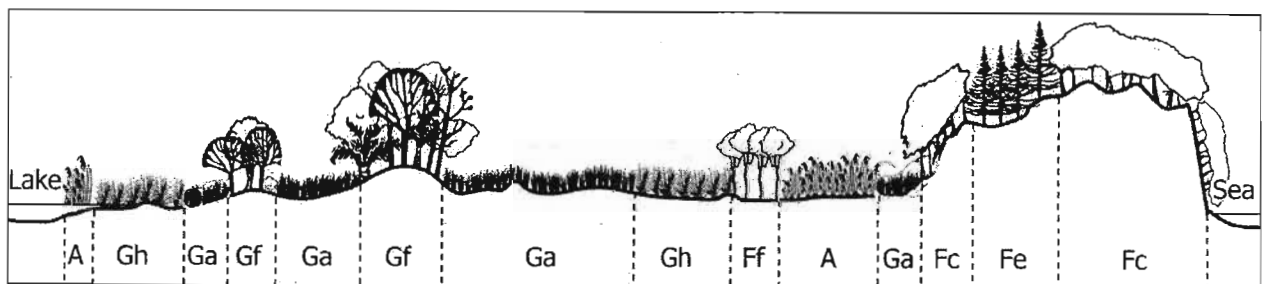


Figure 6: Schematic profile (dune heights exaggerated) showing the main vegetation types along a west- east transect of the Eastern Shores (after Taylor, 1991). Vegetation types are designated as follows A – sedge swamp; Gh – hygrophilous grassland; Ga – dry grassland; Gf – forest; Ff – swamp forest; Fe – pine plantations; Fc – dune forest.

In the vegetated pans and reed/sedge swamp areas, the plant species composition seems to depend on water depth and the regularity of drying up resulting in the zonation of vegetation or hydrosere (Denny, 1985; Hejný & Segal, 1998) shown in Figure 7.

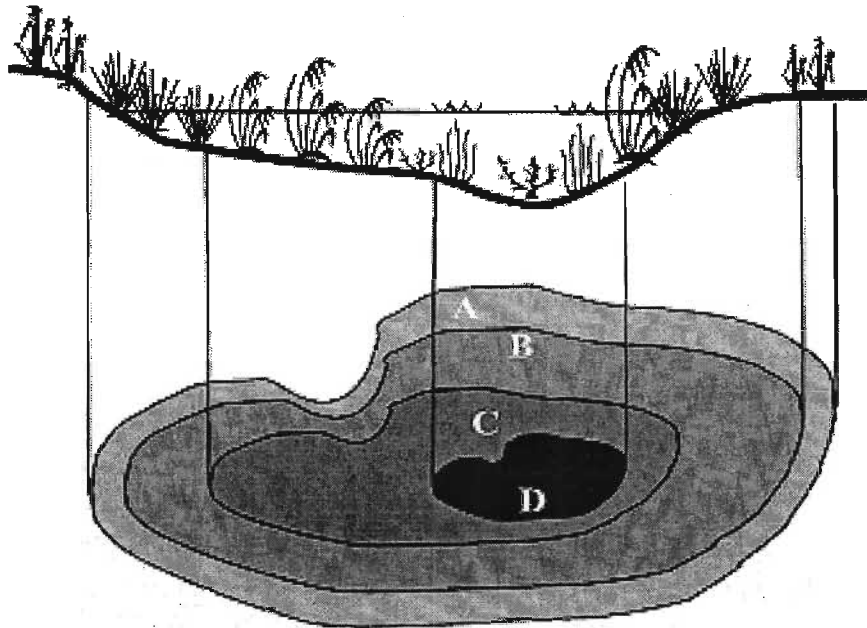


Figure 7: Schematic representation of zonation of vegetation within a generalized Eastern Shores wetland. Letters represent different ecotones: A – Hygrophilous grasses; B – sedges and sedge type aquatic plants; C – emergent aquatic plants; D - Open water with submerged and floating leaved plants.

Backeus (1993) distinguishes two types of border zones between ecosystems: ecotones and ecoclines. Ecotones, as characterised by van Leeuwen (1966, cited in Backeus, 1993) are driven by a fluctuating environmental variable, have sharp lines of demarcation, unstable conditions inside and low variability in space. Ecoclines on the other hand are gradient zones with faint lines of demarcation, stable conditions inside and high variability in space. Following these descriptions, vegetation at the landscape level on the Eastern Shores is ecoclinal in nature, whereas within individual wetlands it is more ecotonal in nature.

The vegetation that occurs within the pans provides a variety of heterogeneous habitats that are likely to have a marked effect on the faunal assemblages. Aquatic organisms have a close relationship with vegetation, substrate and other habitat characteristics. Such relationships have been established by several authors for aquatic macroinvertebrates (Minshall, 1984; Olson *et al.*, 1995; Hoffman *et al.*, 1996) and fishes (Brazner & Beal, 1997; Weaver *et al.*, 1997; Grenouillet & Pont, 2001).

CLIMATE AND RAINFALL

The northeast coast of South Africa experiences a subtropical climate characterized by warm, moist summers and mild dry winters, with a significant warming influence exerted by the Agulhas current. Mean annual temperature exceeds 21 °C. There is an east-west climate gradient with the coast experiencing moist, subtropical conditions and high precipitation relative to the area inland which is moderately dry and subtropical. Rainfall is temporally and spatially highly variable. Rainfall at the coast in northern KwaZulu-Natal varies from 1200 to 1300 mm per annum with 60% of the rainfall in summer (November to March). St Lucia experiences a definite annual cycle in rainfall. The wettest months on the Eastern Shores are usually from January to March with slightly lower mean rainfall in February (Table 2).

Table 2: Rainfall statistics for the St Lucia Region. Mount Tabor is located on the Eastern Shores of Lake St Lucia, and Fanies Island on the western shore. (From Kelbe & Rawlins, 1992)

	Fanies Island (WB 0339756)					Mount Tabor (WB 0339856)				
	Mean	Median	St Dev	CV	Skew	Mean	Median	St Dev	CV	Skew
Annual	943.1	947.5	287	30	0.7	1340.2	1334.3	382	28	1.2
January	125.8	103.1	115	92	1.8	156.9	127	134	86	1.9
February	119.5	100.5	102	85	1.7	152.5	137.4	106	70	1.1
March	108.2	87.5	91	84	2.2	154.5	114.2	117	76	1.5
April	79.6	70	49	62	1	120	109	177	64	1.3
May	46.8	39.5	41	88	1.7	91.9	69.4	71	78	1.9
June	39.4	32.5	42	107	1.7	67.2	63.5	52	78	1.1
July	40.5	14	61	151	2.8	69.1	53.5	56	81	1.7
August	43.1	29.5	52	121	1.9	77.1	58.5	78	102	1.8
September	67.5	45.5	67	100	1.5	86.4	78.7	67	78	1.9
October	85.6	83.7	48	57	0.4	127.7	121.2	71	56	0.5
November	91	72.5	66	73	1.6	113.4	96.7	73	64	0.9
December	96.1	79	72	75	1.8	123.5	84.7	100	81	1

For the duration of this project, rainfall seemed somewhat anomalous (Figure 8), being on the whole being somewhat lower than the expected average in most months, except the winter months of June to August where rainfall was much higher than average. Rainfall in February 2003 was also notably higher than average, but markedly below average in March 2003. In spite of these above average figures, 'drought' conditions were still observed in the region. Perhaps of greater importance than the monthly rainfall figures is the distribution of daily rainfall figures, which more directly determine groundwater recharge rates.

Between April 2002 and May 2003 daily rainfall was less than 10mm on 89% of days, only accounting for 16 percent of the total rainfall for that period. Kelbe and Rawlins (1992) suggest that a rainfall event is unlikely to have any recharge effect on the Eastern Shores groundwater aquifer unless it exceeds 10mm, depending upon the depth of the groundwater and antecedent conditions. This seems to be supported by the fact that water levels in both the Eastern Shores wetlands, as well as Lake St Lucia itself were observed to be exceptionally low in 2002 and 2003 with the lake surface area being reduced by 30% by the end of 2003³, suggesting that there had been very little groundwater recharge during this period.

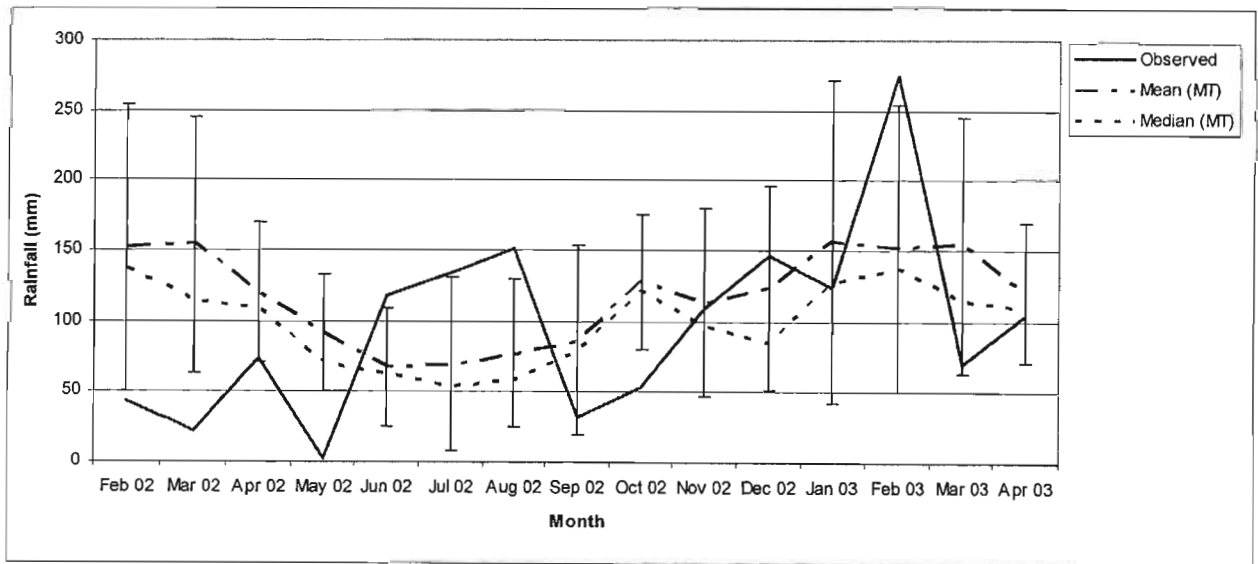


Figure 8: Monthly rainfall figures from UNIZUL weather station on the Eastern Shores, observed during this study period compared with 20 year monthly medians and means from Mount Tabor weather station (Kelbe & Rawlins, 1992). Error bars represent 1 standard deviation from monthly means.

³ EKZNW Media Release 23/2003, 19 December 2003

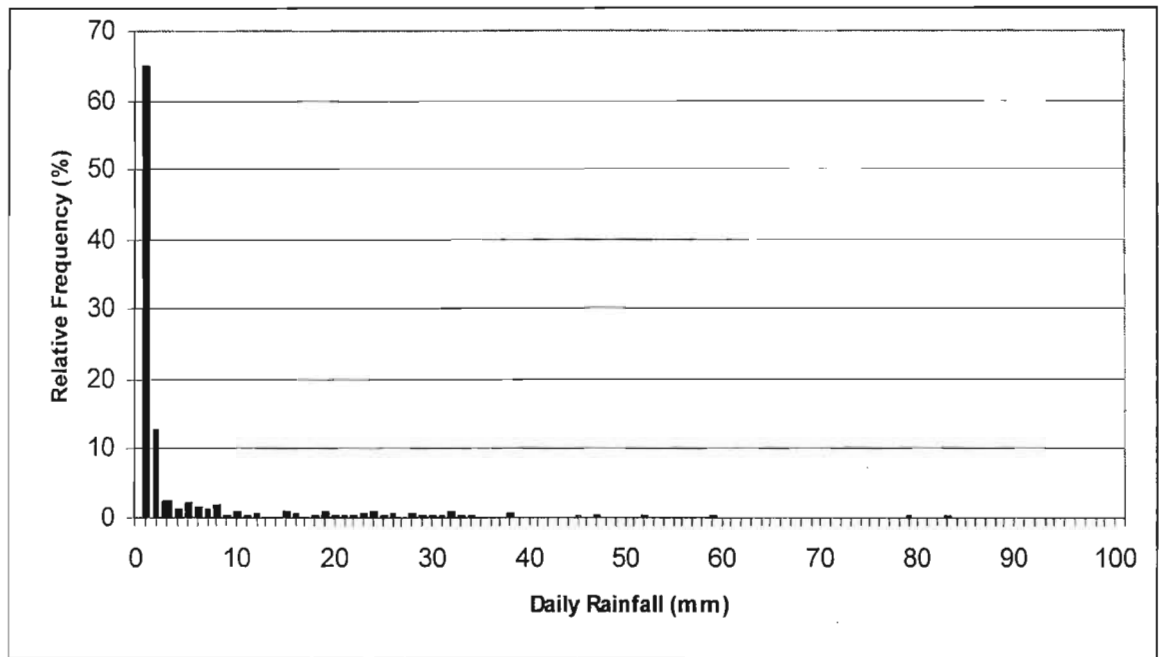


Figure 9 : Relative frequency distribution for rainfall at St Lucia between April 2002 and May 2003. Data from UNIZUL weather station on the Eastern Shores.

SAMPLE SITES

A total of 16 routine sites were selected on the Eastern Shores for repeated sampling (Figure 4). These sites were selected on the basis of a pilot survey of wetland fauna performed in February 2002. The 16 sites for the main study were selected with the intention to encompass a range of habitats, connectedness and persistence. Additional supplementary sites were also selected on an *ad hoc* basis during the sampling period, although these sites did not form part of the quantitative analyses. The water regime of the sites ranges from intermittent, to near permanent, following Brock *et al.*'s (1990) classification scheme. The connectedness and frequency of connection also varied between sites (Table 3). Although this is difficult to assess accurately within the space of a single year, estimations were made from examination of aerial photography from several different years (1981, 1993, 1998, 2000), as well as assessment in the field.

Table 3: Description of Eastern Shores sample sites. The degree of permanence is coded according to the classification of Brock *et al.* (2003): NP – Near permanent; SP – Semi permanent; S – Seasonal; I – Intermittent.

Site	Site Description	Permanence	Connected
1	Outflow and stream from base of slope below Crocodile Center.	NP	Seasonally
2	Pan at Crocodile center. Dense <i>Eliocharus</i> with hippo paths. Connected to the North. Fish present. Seasonal, with some near permanent pools.	S	Intermittently /rarely
3	iPhiva Pan. Endorheic, dominated by <i>Eliocharus</i> and <i>Nymphaea</i> . Deep in wet season.	SP	Endorheic
4	Large endorheic pan, densely vegetated with <i>Cyperus</i> species forming almost impenetrable root mat over water (4B). Some open water on western side (4A) heavily disturbed by hippos.	SP	Endorheic
5	Large, densely vegetated wetland (<i>Eliocharus</i> dominated), covering floodplain extending to lake. Fringed with swamp forest along eastern border.	S (SP)	Seasonally
6	Seepage at base of dune ridge. Persistent spring, supports swamp forest with <i>Ficus</i> spp. & <i>Barringtonia racemosa</i> .	SP	Seasonally
7	Kudu Pans. Open water with pine stumps, <i>Nymphaea</i> & <i>Utricularia</i> abundant. Tenuous/intermittent connection to North.	S	Seasonally
8	Well connected pan system with links to persistent water further North (Mfazana Pan).	S	Seasonally
9	Groundwater outflow at lake edge. Mixed habitat, of flowing streams, swamp forest pools and possibly some saline influence from lake. May form a refuge site for freshwater species.	NP	Seasonally (to lake)
10	Wetland south of old nursery weir, extensive, connected, <i>Eliocharus</i> dominated wetland with some <i>Nymphoides</i> ponds.	SP	Seasonally
11	Sand Quarry at Nkazana stream. Man made depressions that sometimes contain fish. Should be linked into Nkazana stream draining Mfabeni. Emergent <i>Eliocharus</i> on fringes of ponds, bare mud bottom with some <i>Nymphaea</i> .	NP	Seasonally
12	Deep, possibly persistent, relatively isolated but does contain fish. Open water, fringed with mixed emergent vegetation (<i>grasses/Cyperus/Eliocharus</i>)	SP	Rarely
13	Large pan in Nkazana area, connected, but may dry up completely. <i>Scleria</i> dominated with open water and some emergent grasses.	S (I)	Intermittently
14	Large endorheic pan, dense <i>Scleria</i> dominates vegetation, with open water in middle of pan.	S	Endorheic
15	Pan dissected by logging road, connected through to dry previously afforested section Mfabeni complex by culvert. Intermittent. Dries completely. Mixture of <i>Scleria</i> and <i>Eliocharus</i> .	I	Intermittently
16	Lower end of Mfabeni Swamp, deep persistent water with fish, <i>Eliocharus</i> and some <i>Phragmites</i> on fringes. Semi permanent.	NP	Permanent

THE PHYSICAL ENVIRONMENT

Wetlands possess unique physicochemical conditions that make them very different from both well-drained terrestrial systems and deepwater aquatic habitats. Hydrogeomorphology - hydrology combined with climate and basin geomorphology - is probably the most important determinant in the establishment and maintenance of wetland type and wetland processes. Hydrological regime will affect various physicochemical attributes of wetlands which in turn determine the composition of the wetland biota. Even slight changes in hydrological conditions can result in massive changes in species composition and richness (Mitsch & Gosselink, 2000). The biota themselves are not passive components of these systems and can in turn influence their environment through various biotic feedback loops (Figure 10). An example pertinent to this study is the hippopotamus (*Hippopotamus amphibius*), an animal able to exert a marked effect on water quality (Kilham, 1982; Wolanski & Gereta, 1999) and the physical attributes of the wetlands that they inhabit (Decampo, 2002; McCarthy, Ellery & Bloem, 1998). The Eastern Shores wetlands are spatially and temporally diverse with a wide range of habitat types available for aquatic organisms. Spatial diversity is manifested largely in the vegetation and wetland type, ranging from swamp forest to open wetlands. The temporal diversity is affected by the hydrology of the Eastern Shores and is manifested through changes in the physicochemical properties of the surface waters and changes in the extent and type of aquatic habitat. This chapter summarises the main physicochemical characteristics of the Eastern Shores wetlands and relates these characteristics to the various aquatic habitat types.

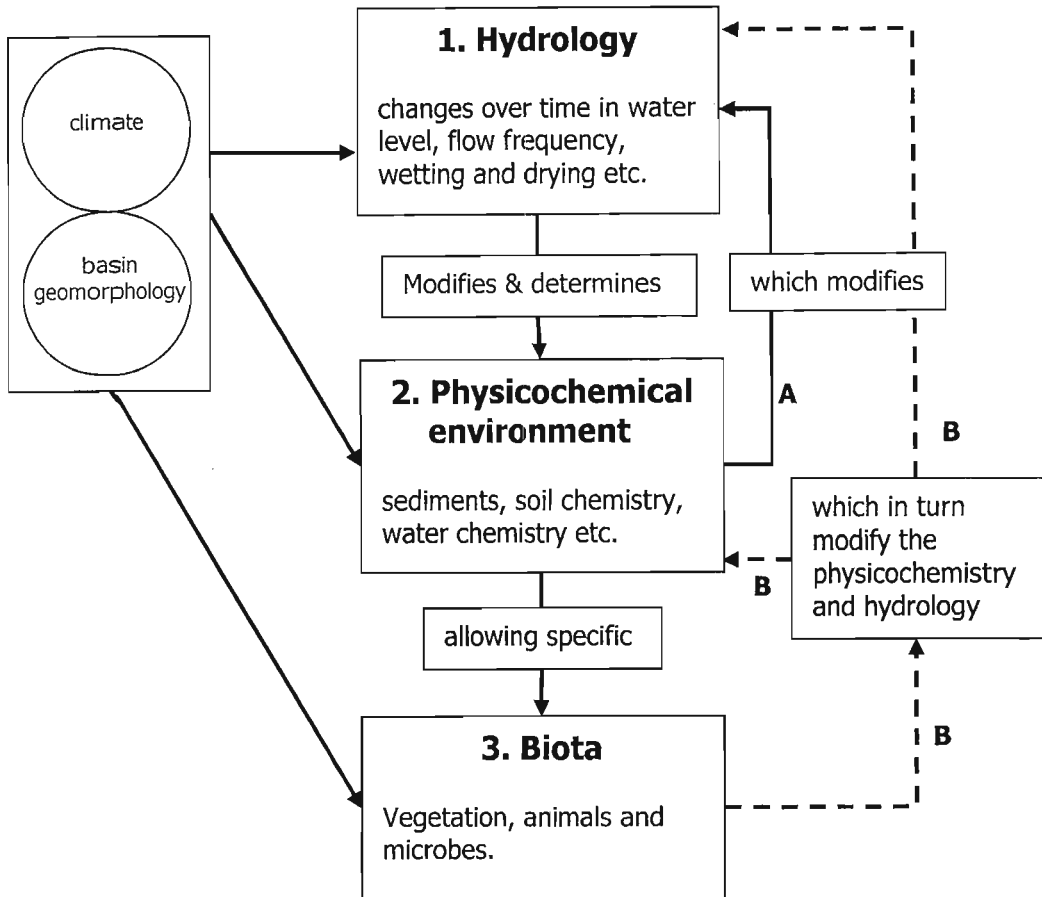


Figure 10: Conceptual diagram of the relationship between the effects of hydrology on wetland function and biotic feedback loops that affect wetland hydrology. Pathways A and B are feedback loops to hydrology and physicochemistry of the wetland. Solid arrows represent direct effects and dashed arrows represent biotic feedback (After Mitsch & Gosselink, 2000).

VEGETATION AND HABITAT TYPES

Apart from providing food for aquatic organisms, plants also provide important structural habitat for fish and invertebrates. Distributions of non-herbivorous invertebrate species can be predicted from the dominant plant types in wetlands (Batzer & Wissinger, 1996). Fish display preferences for certain aquatic macrophyte communities that variously provide a source of invertebrate prey (Keast *et al.*, 1978 in Crowder & Cooper, 1982), refuge from predation (Chapman *et al.*, 1996) or breeding and nursery habitat (Bruton & Jackson, 1985).

Habitat types (Table 4) were classified according to broad physiognomic characteristics of dominant plant species. This type of classification has the advantage of being based on easily observable properties and can be distinguished by relatively untrained observers (Goldsmith & Harrison, 1986). Each

sample site was then described in terms of the dominant habitat type or types present.

Table 4: Broad physiognomic classification of wetland habitats and biotopes on the Eastern Shores.

Category	Biotopes	Representative species	CODE
Swamp Forest		<i>Ficus</i> spp.; <i>Barringtonia racemosa</i>	
Emergent Vegetation	Swamp Forest		SWAF
	Open <i>Eliocharus</i>	<i>Scleria poaeformis</i> ; <i>Eliocharus limosa</i> ; <i>E. acutangularis</i> ; <i>Cyperus natalensis</i>	ELIO1
	Open <i>Scleria</i>		SCLE
	Dense Stems (<i>Eliocharus</i>)		ELIO2
	Open Stems (<i>Phragmites</i>)		PHRA
	Closed <i>Cyperus</i> mat		CYPE
	Emergent Grass		EMEG
Floating Leaved			<i>Nymphaea nouchali/lotus</i> ; <i>Nymphoides</i> sp.
	Open water, closed <i>Nymphaea</i>	NYM1	
	Open water, some <i>Nymphaea</i>	NYM2	
	Open water, no <i>Nymphaea</i>	NYM3	
Floating Grasses	Floating Grass	<i>Leersia hexandra</i>	FLOG
Submerged Plants	Submerged vegetation	(<i>Utricularia</i> spp.)	UTRIC
Other Habitats	Shoreline seepage		SHOR
	Slope seepage/streams		SEEP
	Manmade/altered habitat		MAN
	Hippo Channels		CHAN
	Pine Stumps/debris		PINE
	Bare mud		MUD
	Substrate	Hard Sand	
Clay/Mud			MUD
Peat/Organic Mud			PEAT
Leaf Litter (forest leaves)			LEAF
Fine particulate organic matter (hippo excreta)			FPOM
Coarse particulate organic matter (plant debris)			CPOM
Vegetation (floating root mat)			ROOT

For each sample a number of quantitative and descriptive environmental variables (Table 5) were recorded in addition to the habitat descriptions. These data provided a habitat and physicochemical profile for each sample that could later be linked to the macroinvertebrate and fish species composition for that sample.

Table 5: Environmental and habitat variables measured for each sample.

Variable	Method	Notes
Water Depth	Maximum depth encountered during sampling	Danger of hippopotamus/crocodiles in larger pans may prevent determining actual depth.
Substrate	Visual Assessment of dominant type of substrate.	May fall into one or more categories given in Table 4
Depth of Organic Matter Layer	Estimate from area worked in	
Conductivity	Conductivity meter	WTW conductivity/temperature probe
pH	pH meter	Eutech pH scan 2
Dissolved oxygen	Dissolved Oxygen meter	WTW dissolved oxygen meter
Water Temperature	Temperature probe	Measured at surface and bottom.
Habitat Type	Visual estimate of percentage cover of biotopes in pan.	For description of biotopes refer Table 4
Connectivity	Field Observation and remote sensing	Connected/not connected
Permanence	Likely water regime of the site	Based upon classification of Brock <i>et al.</i> (2003) given in Table 1
Hippo activity	Observation	Subjective rating given for each site: 0) None 1) Paths, occasional use 2) Paths, light disturbance 3) Paths, wallows & pools, medium disturbance. 4) Paths, wallows & pools, heavy disturbance 5) Very heavily disturbed, constant use.

RELATIONSHIPS BETWEEN BIOTIC AND ABIOTIC VARIABLES

To establish the relationship between the measured environmental variables and habitat types at the various sites, a centered and standardised redundancy analysis (RDA) was performed for the data collected using CANOCO Version 4.5 for Windows (ter Braak & Šmilauer, 2003). Habitat data were input as a sample data set ('site x habitat type' matrix) with the measured environmental variables as a corresponding environmental dataset ('site x physico-chemical variable' matrix). The results of the analysis were plotted along the first two axes of the ordination (Figure 11 and Figure 12). Samples form four distinct groups in the RDA ordination. The first and largest group consists of samples taken in open, vegetated wetlands of various types. The sites in this group show varying degrees

of change and overlap in their habitat composition and environmental conditions and this is reflected on the ordination plot (Figure 11).

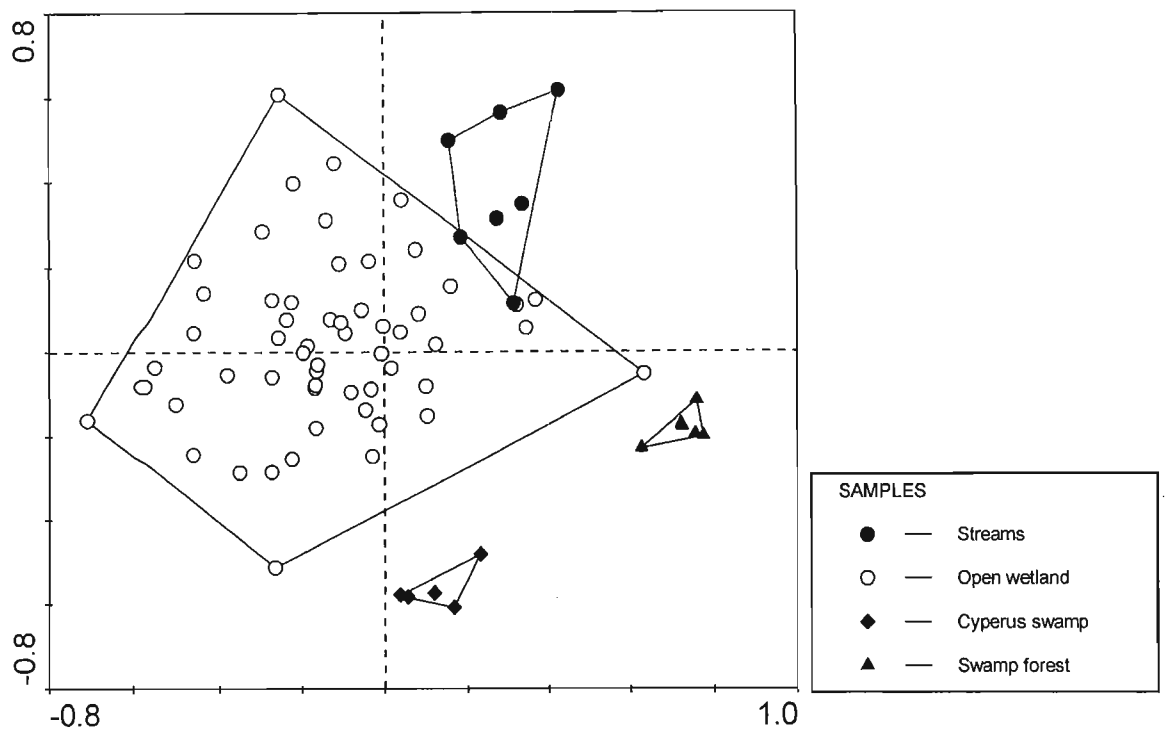


Figure 11: Scatterplots of samples along the first two axes of an RDA of habitat type and physico-chemical variables. Envelopes enclose samples taken from each of the four habitat types indicated in the legend. Summary statistics are given in Table 6.

Two smaller groupings consist of samples taken at single sites, namely Site 4A and Site 6 which are located in a dense *Cyperus* swamp and swamp forest respectively. Both of these sites are distinctive in terms of habitat and subsequently ordinate away from the other open wetlands and each other. Both of these sites were almost permanent and this is reflected in the smaller degree of variation (tighter clustering of points) compared to other sites in open wetlands. A fourth, although less distinct grouping can also be discerned and this is indicated as 'stream sites' on the plot and comprise a group of samples taken from Site 1, groundwater seepage at the base of the slope. Although this site is similar to the open wetland sites, it differs in possessing running water - small sandy bottomed streams formed in hippopotamus trails on the slope. These streams formed a rather distinctive habitat among sites that were dominated largely by standing or very slow moving water.

The ordination of habitat and substrate types (Figure 12) shows a similar pattern with the *Cyperus* (CYPE), swamp forest (SWAF) and groundwater seepage (SEEP) ordinating away from those categories found across the range of open wetlands. Although the first canonical axis was non significant, all of the canonical axes were significant when considered together. This indicates that it is the interaction of combinations of environmental variables rather than the effect of a few dominant variables (Leps & Šmilauer, 2003) that determine the distribution of wetland habitat types on the Eastern Shores.

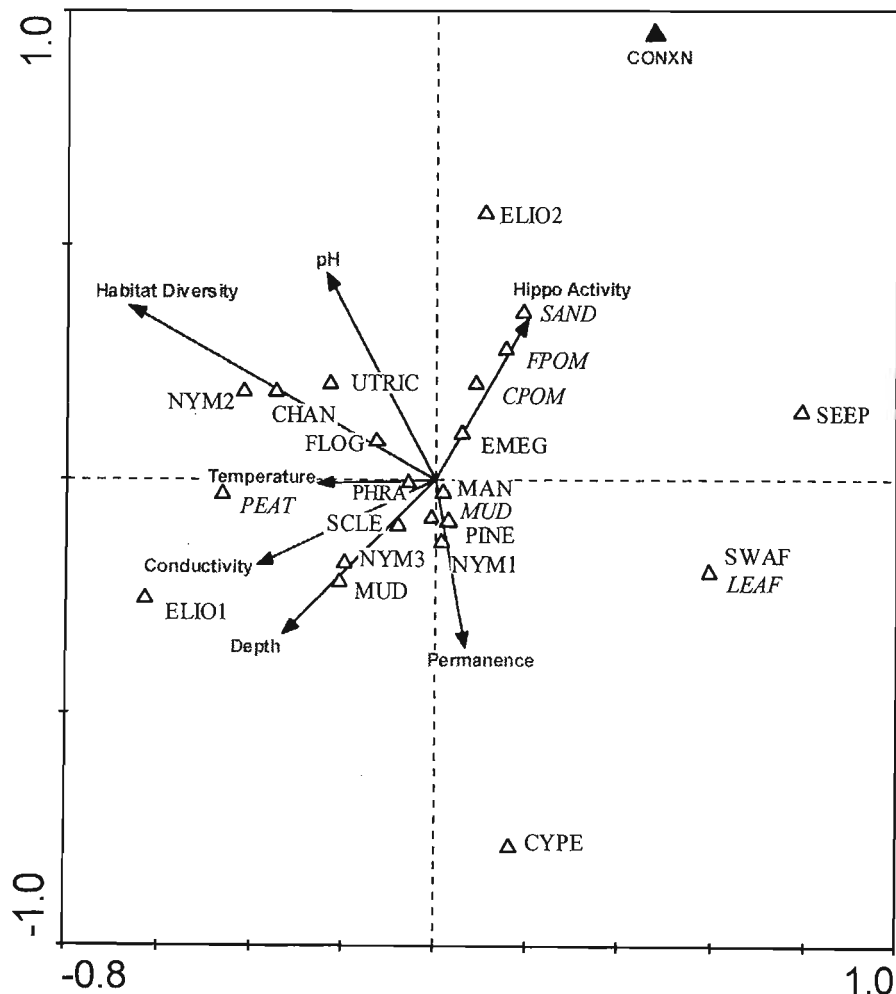


Figure 12: Plot of first two axes of RDA of habitat and environmental variables measured at sites on the Eastern Shores. Codes are listed in Table 4. Summary statistics are given in Table 6.

Among the environmental variables that do appear to have certain habitat types associated with them, increasing hippopotamus activity favours the hard sand substrate as well as increased occurrence of both fine and coarse particulate

organic matter. The channel biotope (CHAN) was associated with higher habitat diversity and floating and submerged leaved plants (NYM2, FLOG and UTRIC). Connectedness (CONXN) of the sites is not strongly associated with any particular habitat types. This is probably due to the fact that since the system is groundwater fed, sites do not necessarily have to be connected to have similar hydrological regimes.

Table 6: Summary statistics for RDA of habitat and environmental variables on the Eastern Shores.

Summary statistics for RDA						
Axes	1	2	3	4	Total variance	
Eigenvalues:	0.109	0.070	0.051	0.038	1.000	
Species-environment correlations:	0.819	0.783	0.699	0.662		
Cumulative percentage variance						
of species data:	11.2	18.3	23.6	27.4		
of species-environment relation:	33.4	54.8	70.5	82.0		
Sum of all eigenvalues:					0.974	
Sum of all canonical eigenvalues:					0.326	

Summary of Monte Carlo test		
Test of significance of first canonical axis:	eigenvalue=	0.109
	F-ratio=	8.310
	P-value=	0.2360 (NS)
Test of significance of all canonical axes:	Trace=	0.326
	F-ratio=	3.683
	P-value=	0.0040**

**Highly Significant (P<0.01)

GENERAL CHARACTERISTICS OF THE SURFACE WATERS ON THE EASTERN SHORES.

The surface waters of the Eastern Shores were typically acidic, ranging from almost neutral (pH 6.8) to as low as pH 2.77 (Table 7). The low pH can probably be attributed to the abundance of organic matter in the wetlands and the presence of peat soils that tend to produce sulphuric and humic acids, thus maintaining a low pH (Mitsch & Gosselink, 2000). The swamp forest site consistently maintained the lowest pH (Figure 13b). For most sites, pH was relatively stable, with the exception of Site 11 (Figure 13d), the 'Old Quarry', a series of man made depressions adjacent to the Nkazana stream. The maximum and minimum pH recorded both occurred at this site and on one occasion pH values of 2.8 and 6.8 were recorded on the same day in adjacent pools. The cause of such wide fluctuations in pH at this site is not known. Hippos were frequently active in these pools, and the disturbance of bottom sediments could play a role in

altering the water chemistry between disturbed and undisturbed pools. The effects of extreme pH has been poorly studied both for aquatic invertebrates in lentic waters (Ward, 1992) and for African fish species (Lévêque, 1997). For fish, the most serious effect of acid waters is its effects on the gill tissues and subsequent respiratory problems. For invertebrates the direct effects of low pH may often be compounded with indirect effects such as oxygen and ion deficiencies; limited food resources; altered competitive and predation interactions that result in elimination of species and changes in community structures (Ward, 1992). Certain taxa may be more resistant to acid stress than others. For example, Gorham and Vodopich (1992) found that although low pH significantly affected predation rates and survivorship in *Enallagma* (Odonata: Coenagrionidea) these effects only became significant at pH 3.5. The acidic pools, at Site 11 frequently contained large numbers of Odonata, but often very few other taxa. These pools formed an ideal habitat for Odonata, with clear, shallow water, well vegetated edges and no insectivorous fish, that may have been limited by the acidic waters. In temperate latitudes, increasing acidification has been found to eliminate insectivorous fishes with a corresponding increase in the numbers of certain larger invertebrate predators, for example Odonata larva and corixids. (Eriksson *et al.*, 1980).

Although the pH values recorded in these pools and other habitats are well below those at which acidity may damage aquatic ecosystems (Gorham *et al.*, 1984) it is evident that certain taxa, such as the Odonata do well under these conditions. The direct effects of pH are often difficult to infer from field studies as it is often not the pH *per se* that affects the distribution of aquatic organisms but rather one or other of the physical and biotic factors that it reflects (Corbett, 1999). Aluminium has been found to enhance the survival of *Enallagma* at low pH (Havens, 1993). It is possible that at this particular site, some or other unknown factor may also be enhancing the survival of Odonata under these somewhat extreme conditions.

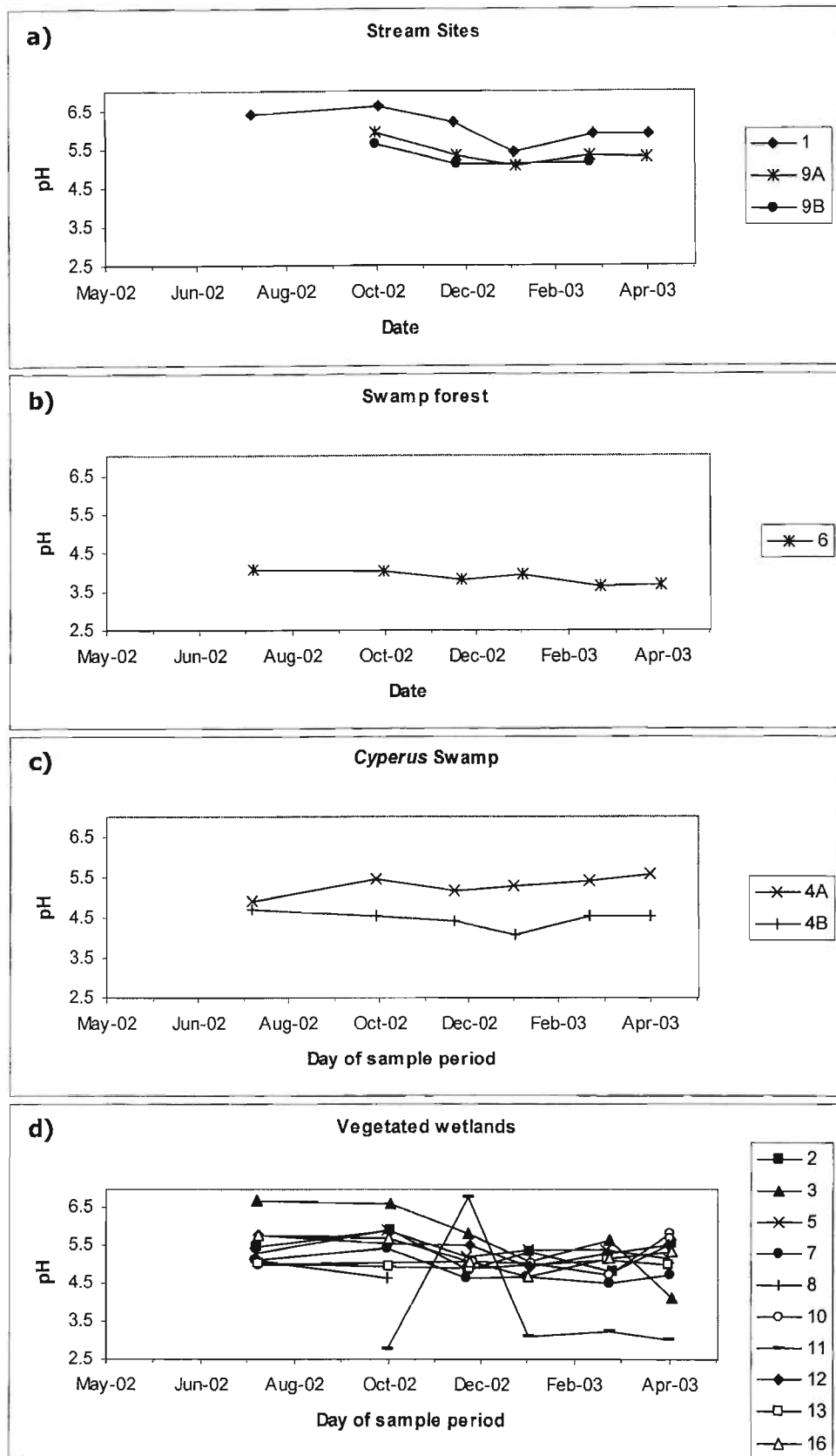


Figure 13: Variation in pH values recorded at routine sample sites on the Eastern Shores between May 2002 and April 2003. For clarity, sites are separated into the groups determined by redundancy analysis of habitat and environmental variables in Figure 11.

Dissolved oxygen was moderately to highly variable (Figure 14), both spatially and temporally, with sites ranging between anoxia and supersaturation (Table 7). Oxygen depletion can occur due to the decomposition of organic material, an abundant substrate in most Eastern Shores wetlands. Oxygen produced as a by-product of photosynthesis by aquatic plants can cause water to become supersaturated. This is more likely to occur with algae that produce oxygen that goes straight into solution, as opposed to higher plants that produce bubbles of oxygen (Macan, 1974). Given the relationship between oxygen solubility and water temperature it would be expected that oxygen levels would be low within the range of water temperatures measured (Table 7) making deoxygenation a potential problem for aquatic organisms. Many aquatic invertebrates, adult Coleoptera and Heteroptera and larva of the Coleoptera and Diptera are air breathers and thus independent of dissolved oxygen levels (Macan, 1974). Fish on the other hand, mostly depend on aerobic aquatic respiration. They have however, developed a range of physiological, behavioural and morphological adaptations for dealing with anoxia (Lévêque, 1997) and exhibit a variety of responses and tolerances to such conditions. The wide range of biotic and abiotic factors that affect the oxygen content of natural water bodies create a situation where even within a small water body there may be considerable local variation in dissolved oxygen content. Based on a number of datasets from Gameson and Griffith (1959), Macan (1974) makes the point that due to the inherent variability of the dissolved oxygen content of water, no reliable idea of the oxygen content of a water body can be obtained from a few spot samples. Under uncontrolled conditions, such as these, it is very difficult to determine clear links between the observed faunal composition and the measured dissolved oxygen level in a sample.

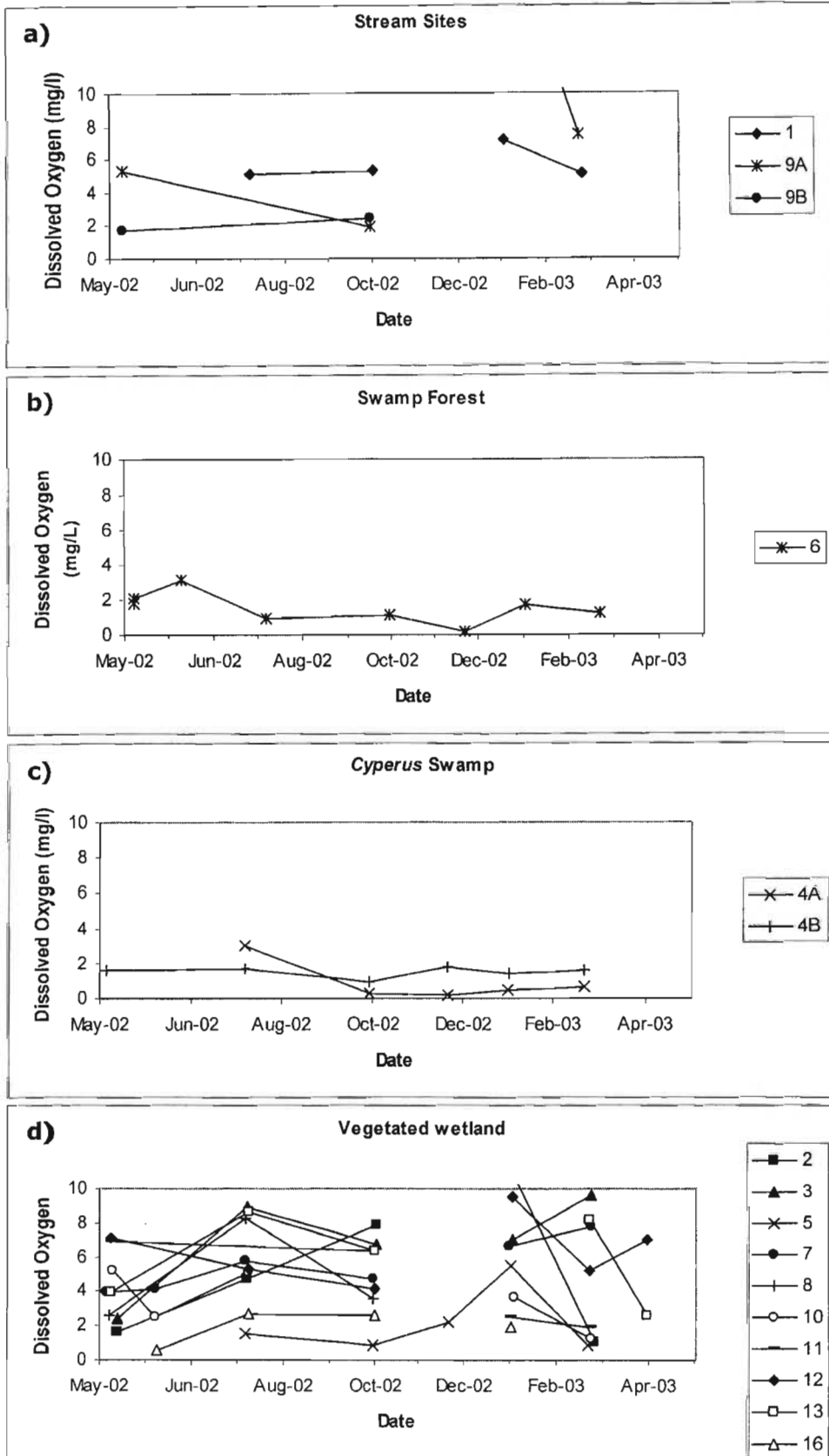


Figure 14: Dissolved oxygen levels recorded at routine sample sites on the Eastern Shores between May 2002 and April 2003. For clarity sites are separated into groups determined by redundancy analysis of habitat and environmental variables. The gaps in the data between days 160-250 and for some sites, 300-350 are due to instrument failure.

Ionic conductivity varied by location and time. (Figure 15). The highest conductivity was recorded at Site 9A on the shoreline of Lake St Lucia during May 2003. At this time, the lake level was still high and these readings were taken at the interface between fresh water flowing out from the shore seep and the saline water of the lake.

Notably, the stream sites (Sites 4A/B and Site 9A) and swamp forest site (Site 6) were among the sites with consistently lower conductivity (Figure 15a). These sites would appear to have a constant input of fresh water from the groundwater aquifer and as such are less prone to the concentrating effect that evaporation has on dissolved solids. Open, vegetated wetlands exhibited a range of conductivity values. Sites 13 and 11 (Figure 15), showed marked variation while others (shown in the same figure) varied within a much narrower range.

Water temperatures varied between 14 and 25 °C (Table 7). Much of the variation in temperature can however be attributed to the fact that measurements were made at different times of day and under a range of conditions. A number of factors including shading by vegetation, wind stirring, time of day and water turbidity will affect water temperature as well as the difference between surface and bottom temperatures, making it difficult to ascribe any seasonal trends to non standardised spot samples of temperature.

Table 7: Summary statistics for four abiotic variables measured at collection sites on the Eastern Shores, between May 2002 and April 2003.

	Minimum	Maximum	Median	Mean	Standard Error	n
Conductivity ($\mu\text{S}/\text{cm}$)	94.00	5820.00 ¹	356.00	526.57	670.32	138
pH	2.77	6.80	5.16	5.10	0.87	104
Dissolved Oxygen (mg/L)	0.00	21.30 ²	3.70	4.27	3.21	106
Surface Temperature (°C)	14.23	34.93	24.03	24.12	4.77	138
Bottom Temperature (°C)	14.23	33.06	23.64	23.35	4.19	138

1. Maximum conductivity recorded at site on shoreline of saline Lake St Lucia.
2. This figure is unusually high and may be erroneous.

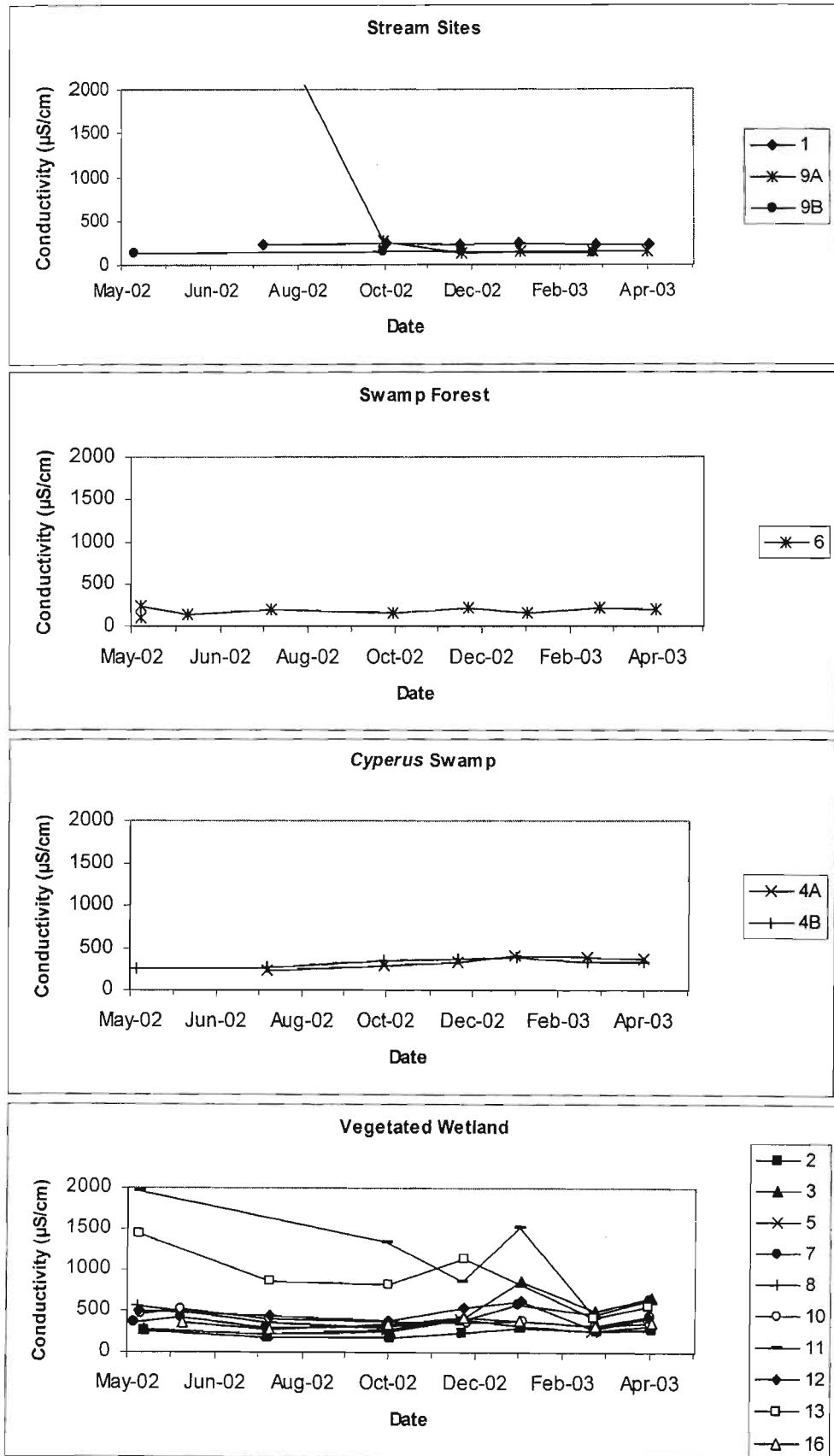


Figure 15: Variation in conductivity recorded at routine sample sites on the Eastern Shores between May 2002 and April 2003. For clarity sites are separated into groups determined by redundancy analysis of habitat and environmental variables.

ENVIRONMENTAL STABILITY

The environmental stability or constancy of sites – a measure of how much physico-chemical variables change over time – was estimated using a method similar to that applied by Death (1995). The range and standard deviation of five basic physicochemical variables (pH, conductivity, dissolved oxygen, surface temperature, bottom temperature and depth) were calculated for each site. These values were then combined into a single, multivariate index of instability using principal components analysis (PCA). Site scores on axis 1 of the analysis were adjusted (by multiplying by -1 and adding 5) so that an increase in the score indicates decreasing stability. The four most stable sites occurred in areas other than open, vegetated wetlands, generally characterised by standing water amongst less dense, emergent macrophytes. (Table 8). These were sites that were constantly wet, and in the case of the swamp forest and seepage streams especially, received a continual supply of fresh groundwater.

Table 8: Multivariate stability scores based on physicochemical variables recorded on each sampling occasion at each site.

Site	Habitat Type	Multivariate Instability Score
Stable sites		
6	Swamp forest	0.935
9B	Seepage stream	1.531
1	Seepage stream	3.24
4B	<i>Cyperus</i> swamp	4.102
Unstable sites		
12		4.257
13		4.698
5		4.887
2		5.321
10		5.416
7	Vegetated wetlands	5.879
9A		5.948
4A		6.344
16		6.455
3		7.797
11		10.264

SOME NOTES ON THE EFFECT OF HIPPOPOTAMUSES ON THEIR ENVIRONMENT.

Hippos are abundant on the Eastern Shores. According to Taylor (2003, pers. comm.⁴) there are approximately 800 resident animals in the St Lucia system. Of this number it is estimated that two thirds of the St Lucia hippo population will use the Eastern Shores for grazing. During wet periods, as many as 100 hippos will be resident in the larger bodies of fresh water on the Eastern Shores. These large animals, weighing between 1000 and 1500kg (Pienaar *et al.*, 1966) are able to exert a significant impact upon their environment. In fact there are very few places on the Eastern Shores, at least in the lower lying areas that do not exhibit some signs of hippo activity.

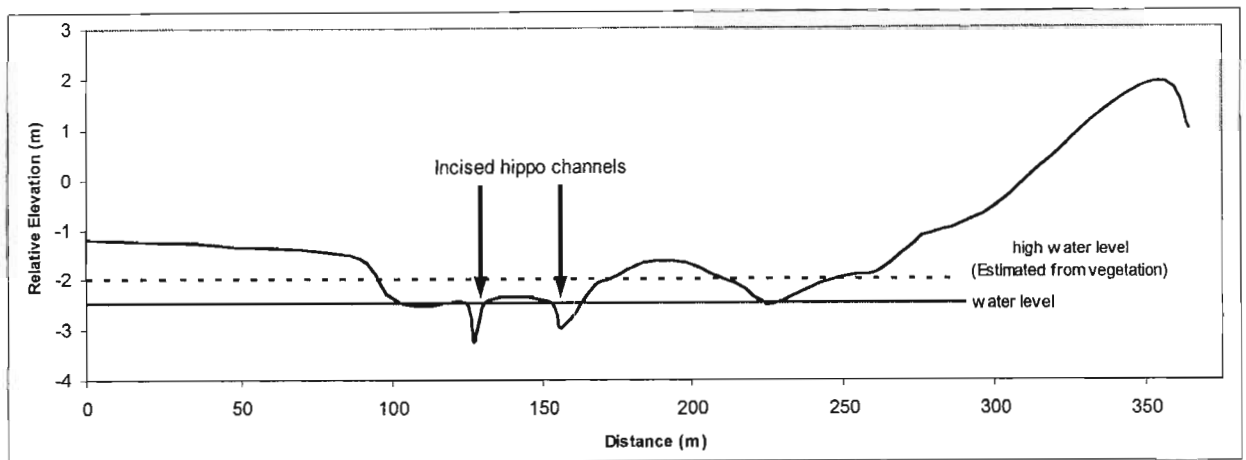


Figure 16: Topographic profile across Site 2 taken in February 2003 showing the effect of hippo trails on the bottom topography of a pan on the Eastern Shores.

The observed effects of hippos in the Eastern Shores wetlands were diverse, including extensive network hippo trails, usually 50cm to 1m wide, deeply incised channels through vegetated wetlands, extensive mud wallows and turbid, eutrophic pools used as daytime living space. Hippos also have the ability to transfer large amounts of organic matter from the land to water, as was observed in a section of the Nkazana stream heavily utilised by hippos as day-time living space, where the entire water surface was covered with a 30cm thick layer of floating hippo faeces. Although no water quality measurements were made at this site due to interruption by the resident hippos, such concentrations of these large animals will undoubtedly affect water quality (as observed by Wolanski & Gereta, 1999) and the subsequent utilisation of the habitat by other aquatic organisms.

⁴ Ricky Taylor, St Lucia Research Division, EKZNW, St Lucia.

There appears to be a correlation between the presence of channels and increased habitat diversity (Figure 12) with these channels, originally created by hippos, providing other habitats such as open water, floating and submerged vegetation in an otherwise homogenous area of dense emergent vegetation. The fine particulate organic matter that is deposited by hippo defaecation in the water also provides a substrate for bacteria, periphyton and algae, forming an important habitat for small fish and invertebrates, providing food and protection (Wallace, 1974). Deeply incised hippo trails may also assist in maintaining pockets of surface water in wetlands that may otherwise dry out completely during dry periods. Figure 16 shows a profile across a wetland (Site 2, The Crocodile Centre Pan) where hippo trails were the only places where deep water remained in the pan at the time of the survey. Apart from altering habitat, hippo activity can also create unique habitats that would not exist in the absence of hippopotamus. At two sites (Sites 1 and 9) hippo trails concentrated the flow of water from groundwater seepage at the toe of a slope to form small sandy-bottomed streams, usually 50cm wide and 5-10cm deep (Figure 17). The importance of these habitats as refugia for red data listed fish species is discussed further in Chapter 4. At least one location was observed where a hippo trail had become incised through a dune ridge separating two wetland complexes, and this could provide a linkage between otherwise separate wetlands during periods of high water. It is obvious that hippos are an integral biotic component in shaping both the structure and functioning of the Eastern Shores and their impact on this system warrants further investigation.



Figure 17: Groundwater seepage concentrated by a hippo trail to form a sandy bottomed stream near the Lake St Lucia shoreline. The stream has become incised through a layer of peat and mud to the sandy substrate below. Streams were persistent and flowed strongly all year round. The arrows represent a width of approximately 50cm. Depth varied from 5-10cm.

FRESHWATER FISHES

Let your hook always be cast; in the pool where you least expect it there will be fish.

Ovid

The freshwater fish fauna of Maputaland is particularly diverse for Southern Africa. The known fauna consists of 67 species in 42 genera and 23 families. The Maputaland region forms a tropical subtraction zone for a number of animal groups including fishes, with 29 species reaching the southern limits of their distributions there or only extending slightly further south (Bruton & Kok, 1980). The region is also home to a number of endemic species, as well as species listed under various categories of risk in the South African Red Data Book of Fishes (Skelton, 1987). The Eastern Shores wetlands provide a variety of suitable habitats for freshwater fishes that range from large water bodies such as Lake Bhangazi South, open pans, vegetated swamps, swamp forest, rivers and streams, to freshwater seepages on the shores of Lake St Lucia itself. It is therefore not surprising that freshwater ichthyofaunal diversity is relatively high, including more than 40% of the total diversity for the Maputaland region, on the Eastern Shores, including a number of endemic and rare species (Table 9). Historically, the larger waterbodies of Maputaland have been well collected (see Bruton & Kok, 1980). The more marginal habitats, like heavily vegetated swamplands appear to be less well known.

Wetlands and other shallow water bodies, with a high surface area-to-volume ratio will experience pronounced fluctuations in water temperature, conductivity, dissolved oxygen and other variables. Environmental variation also arises from changes in water levels, resulting in alternate flooding and desiccation of aquatic habitats. Wetland fish communities will be largely determined by these cycles of water level fluctuations. All organisms have defined physiological capacity and are only able to survive within limited ranges of abiotic gradients. When environmental conditions shift away from these optima for a species, the population of that species will decline and eventually disappear. After such local extinctions, fish are only able to recolonise aquatic systems if they are introduced, or when direct

connections exist between systems (Lévêque, 1997). The importance of seasonal fluctuations on the structure of tropical wetland fish communities has been well established (Lowe McConnell, 1975). Kushlan (1976, 1980) found seasonal water level fluctuations to be the most critical environmental factor affecting fish communities in the Everglades Swamp. Merron and Bruton (1995) found clear distinctions between fish communities at sites with different flooding regimes in the Okavango Delta. Tejerina-Garro *et al.* (1998) report similar changes in fish communities in Amazonian basin floodplain lakes caused by changes in environmental variables, driven by seasonal water level changes. On the Eastern Shores, it is reasonable to expect that the seasonal changes in water level and the subsequent changes in both the physical environment and suitable habitat for fishes will be reflected in the fish assemblages present in the freshwater wetlands.

Table 9: Freshwater fish species occurring or thought to occur on the Eastern Shores of Lake St Lucia. Information compiled from a number of sources: Bruton, 1980; Coke, 1991, 1993; Froese & Pauly, 2003; unpublished EKZNW records; and other references where indicated.

Family	Scientific Name	Common name	Conservation Status/Endemic	Occurrence at St Lucia	Other References
			LR – locally rare nt – near threatened V – vulnerable E (SA) – South African Endemic E(KZN) – KwaZulu Natal endemic	C – current H – historical ● Within natural range, but not previously recorded on Eastern Shores	
Mormyridae	<i>Marcusenius macrolepidotus</i>	Bulldog	-	●	Skelton, 2001; Gosse, 1984
Anguillidae	<i>Anguilla mossambica</i>	African longfin eel	-	C	Castle, 1984; Skelton 2001
Cyprinidae	<i>Barbus bifrenatus</i>	Hyphen barb	-	H	Skelton, 2001
	<i>Barbus paludinosus</i>	Straightfin barb	-	C	Skelton, 2001
	<i>Barbus unitaeniatus</i>	Longbeard barb	-	C	Skelton, 2001
	<i>Barbus viviparus</i>	Bowstripe barb	-	C	Skelton, 2001
	<i>Brycinus lateralis</i>	Striped robber	LR	C	Skelton, 1987
Clariidae	<i>Clarias gariepinus</i>	Sharptooth catfish	-	C	Teugels, 1986; Skelton, 2001
	<i>Clarias theodora</i>	Snake catfish	LR	C	Teugels, 1986; Skelton, 1987
Poeciliidae	<i>Aplocheilichthys katangae</i>	Striped topminnow	-	C	Huber, 1996; Skelton, 2001
	<i>Aplocheilichthys myoposae</i>	Natal topminnow	E(KZN)	●	Huber, 1996; Skelton, 2001
Syngnathidae	<i>Microphis brachyurus</i> ¹	Opossum pipefish	-	●	Skelton, 2001
	<i>Microphis fluviatilis</i>	Freshwater pipefish	-	●	Skelton, 2001
Mugilidae	<i>Myxus capensis</i> ²	Freshwater mullet	V,E(SA)	●	Thomson, 1986; Skelton, 2001
Cichlidae	<i>Oreochromis mossambicus</i>	Mozambique tilapia	-	C	Trewavas, 1982; Skelton, 2001
	<i>Pseudocrenilabrus philander</i>	Southern mouthbrooder	-	C	Skelton, 2001
	<i>Tilapia rendalli</i>	Redbreast tilapia	-	●	Teugels & Thys van den Audenaerde, 1991; Skelton, 2001

Family	Scientific Name	Common name	Conservation Status/Endemic	Occurrence at St Lucia	Other References
			LR – locally rare nt – near threatened V – vulnerable E (SA) – South African Endemic E(KZN) – KwaZulu Natal endemic	C – current H – historical ● Within natural range, but not previously recorded on Eastern Shores	
	<i>Tilapia sparrmanii</i>	Banded tilapia	-	C	Teugels & Thys van den Audenaerde, 1991; Skelton, 2001
Eleotridae	<i>Eleotris fusca</i> ³	Dusky sleeper	-	C	Maugé, 1986; Skelton, 2001
	<i>Eleotris melanosoma</i>	Broadhead sleeper	LR/nt	●	Maugé, 1986 Skelton, 1987
Gobiidae	<i>Hypseleotris dayi</i>	Golden sleeper	LR/nt, E(KZN)	H	Bruton, 1996; IUCN, 2000
	<i>Awaous aeneofuscus</i>	Freshwater goby	-	C	Eccles, 1992; Skelton, 2001
	<i>Glossogobius callidus</i>	River goby	-	C	Maugé, 1986; Skelton, 2001
	<i>Redigobius dewaali</i>	Checked goby	LR/nt	C	IUCN, 2002
	<i>Stenogobius polyzona</i>	-	-	●	Watson, 1991
	<i>Mugilogobius inhacae</i>	Meander goby	-	●	Hoese, 1986
Anabantidae	<i>Ctenopoma multispine</i>	Manyspined climbing perch	-	C	Skelton, 2001
	<i>Microctenopoma intermedium</i>	Blackspot climbing perch	LR	H	Gosse, 1986 Skelton, 1987

1. Estuarine species

2. Marginal estuarine/freshwater species probably associated with Lake St Lucia rather than Eastern Shore wetlands.

3. Marginal estuarine species, but may penetrate freshwater streams connected to the lake.

METHODS

COLLECTION

Fish were collected from ten of the 16 routine sites on the Eastern Shores as well as an additional ten *ad hoc* sites during the course of sampling. Since not all sites yielded fish catches consistently and others dried completely during the sampling period only 49 samples were available for analysis. Fish were collected by electrofishing, using custom made aluminium electrodes mounted 2m apart on a Y-shaped pole. These were attached to a Honda generator on the bank providing 220V AC power. Electrofishing is an effective method for relatively shallow, vegetated habitats as it has the advantage of drawing cryptic species from cover (Perrow, Côté & Evans, 1996). Personal experience and that of others (M. Coke, pers. comm.) has also found this method to work well for most habitats on the Eastern Shores, although is not effective in deep, open water as fish can easily escape beyond the range of the field generated by the gear. Large, open water bodies were generally avoided due to the aforementioned limitations, as well as the threat posed by crocodiles (*Crocodylus niloticus*) that are abundant on the Eastern Shores. Each sample involved 15 minutes of active operation of electrofishing gear in vegetation, channels and smaller bodies of open water. There are various problems associated with timed sampling, relating primarily to maintaining a constant catch per unit effort across different habitats and by different operators (Elliot, 1983). This was eliminated as far as possible by ensuring that the 15 minute sampling period included only active searching time and not 'downtime' while emptying nets and moving through the habitat, but not actively electrofishing. All samples were taken by the same operator. Most specimens were identified and enumerated in the field and returned unharmed after sampling. Fish caught while dipnetting for invertebrates were also recorded, but these records were not used in the quantitative analyses. A limited number of specimens was retained as a reference collection, or if unidentifiable in the field, for further examination and identification. Specimens were preserved whole in a 10% formalin solution.

DATA ANALYSIS

Data matrices of species abundances per sample were analysed using the PRIMER 5 for Windows, version 5.2.9 (Clarke & Gorley, 2002) and CANOCO for Windows, version 4.51 (ter Braak & Šmilauer, 2003).

In PRIMER, Bray-Curtis similarity matrices were generated from the square root transformed (\sqrt{y}) abundance data. Bray-Curtis similarities are robust, semi-metric measures that are recognised as a good measure of ecological distance for species abundances (Legendre & Legendre, 1998). When used with appropriately transformed ecological data, all species will contribute something to the definition of similarity. By retaining some information on the prevalence of a species, commoner species will generally be given greater weight than the rare ones (Clarke & Warwick, 2001). The first matrix compared similarities between samples based on their species composition. A second similarity matrix was created from a secondary matrix where species in the original dataset were aggregated to family level, comparing species based on their occurrence within the dataset. Using the sample similarity matrix, samples were ordinated using non-metric Multidimensional Scaling (MDS) (Shepard, 1962; Kruskal, 1964) in PRIMER. Fish families were classified using the CLUSTER routine in PRIMER, to run a hierarchical cluster analysis using group average linking on the family similarity matrix.

To establish links between measured environmental variables and fish distributions, Legendre & Anderson's (1999) distance-based Redundancy Analysis (db-RDA), was used. The technique uses the method of redundancy analysis (RDA), but allows the analysis to be based on Bray-Curtis or other ecologically meaningful measures, through the use of principle coordinates analysis (PcoA). More extensive details of the technique and suitability of db-RDA as a technique for the analysis of the response of many species to several factors are given by Legendre & Anderson (2001) and McArdle & Anderson (2001). The main advantages of this technique are that it can be used with any non-Euclidian distance measure and interaction terms can be tested in a structured ANOVA model. The Euclidian distance measure is

generally not appropriate for ecological datasets (Clark, 1993; Legendre & Legendre, 1998) where abundance distributions may be aggregated or skewed, and rare species contribute many zeros to the data set. A matrix of fish abundances from sites on the Eastern Shores was matched to a matrix of environmental variables and habitat types recorded for each sample. A number of samples were missing values in the environmental dataset and these were removed from the analysis, resulting in an unfortunately small dataset of 19 samples that was analysed using the scheme depicted in Figure 18. The Bray-Curtis measure was used to generate a matrix of differences between $\sqrt{}$ transformed samples; the resulting matrix was input into a db-RDA along with the environmental dataset. Permutations for the Monte Carlo test of significance were run under the reduced model with samples arranged as time series in blocks defined by sample site.

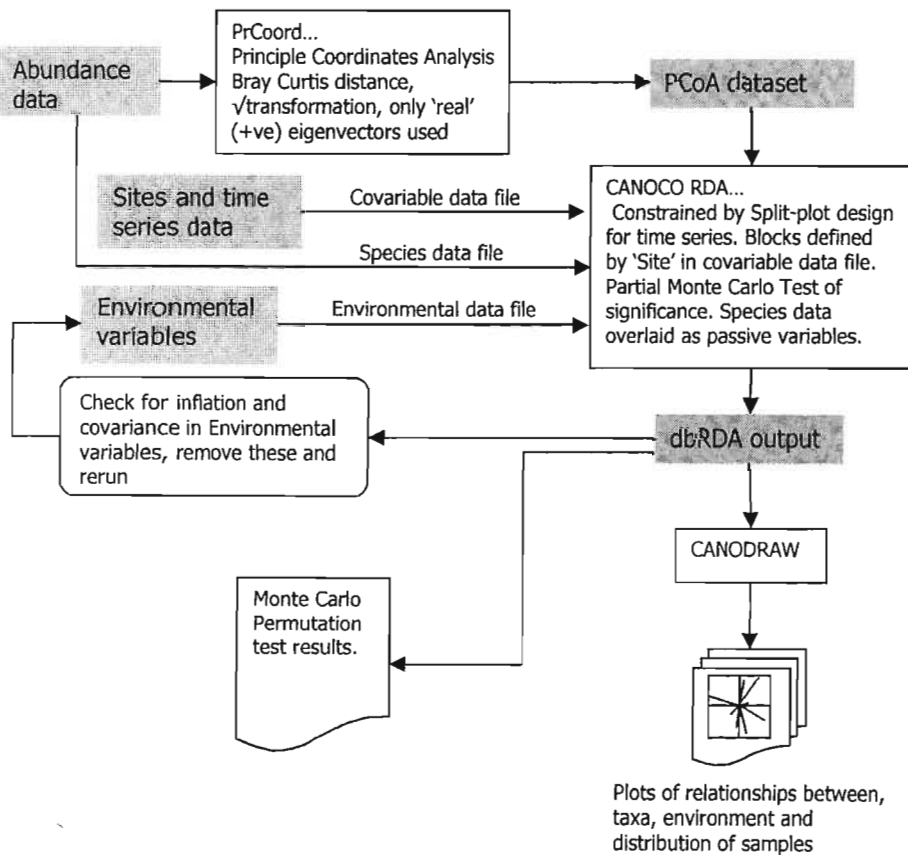


Figure 18: Analysis scheme for db-RDA of fish abundance data.

RESULTS

A total of 20 species out of the expected 28 freshwater species in (Table 9) were collected. Species expected for the region, but not collected were *Barbus unitaeniatus*, *Brycinus lateralis*, *Aplocheilichthys myoposae*, *Myxus capensis*, *Eleotris melanosoma*, *Awaous aeneofuscus*, *Glossogobius callidus*. One specimen of the genus *Microphus* was recorded, but the species is not certain. A complete list of all fish taxa collected is given in Appendix I.i. Of the families collected, Poeciliidae, Cichlidae, Cyprinidae and Clariidae most commonly encountered (in that order), accounting for over 85 percent of total occurrences and 10 of the species (Figure 19). The remaining ten species, in six families, occurred only infrequently or on single occasions.

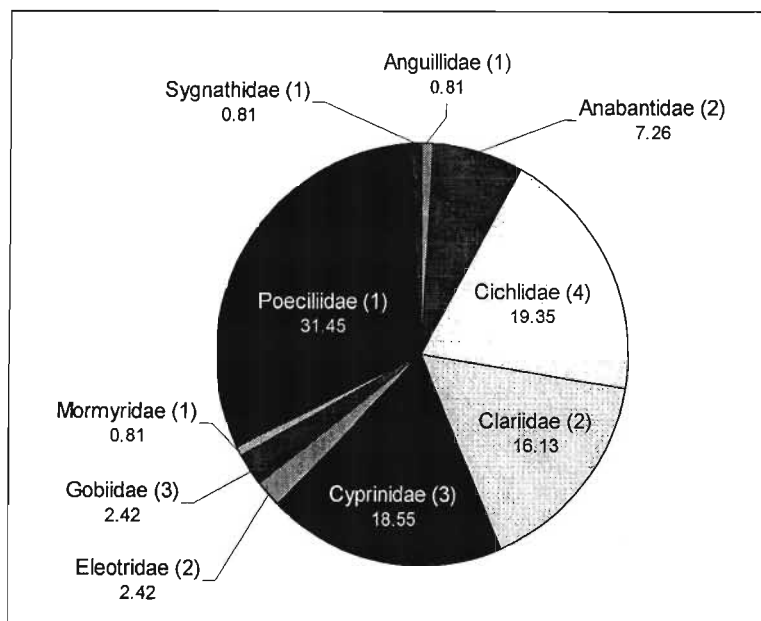


Figure 19: Relative contributions of fish families to overall percentage occurrence of fishes in samples. Numbers in parentheses indicate the number of species collected per family.

Fish were not evenly distributed in space and time. High abundances of certain groups of fishes appeared to exclude others in those samples, as is clear in the MDS plots for the four main fish families (Figure 20). The Cyprinidae and Cichlidae share similar distributions that overlap to some extent with that of the Poeciliidae. The Clariidae form a more distinct group away from the other families. The stress value for the two-dimensional MDS

analysis was 0.1 which corresponds to a good ordination that accurately represents the relationships between data points (Clarke & Warwick, 2001). Cluster analysis of the fish families shows a similar separation of families, which can be placed into four groups at approximately 30 percent similarity (Figure 21). Group A comprises the rarer species, including Mormyridae and Anabantidae that have isolated or scattered occurrences. Group B consists of 'pond species' that are more commonly occurring, and often associated with open or vegetated waters. Group C contains only one family the Clariidae, generally hardy species that are tolerant of a wide range of environmental conditions. The open waters of larger pans were also seemingly dominated by *C. gariepinus* although sampling constraints prevented accurately assessing their numbers. Concentrations of large numbers of *C. gariepinus* were observed on several occasions in shallow muddy pools as pans dried out. *C. gariepinus* was usually the last remaining species found in pans that were in the last stages of drying out, occasionally with a few individuals of tilapiines or barbs. Group D contains the Gobiidae and Eleotridae, two families generally considered as estuarine or marginally estuarine species that occur in habitats either connected to, or on the margins of Lake St Lucia itself. Both of these families occurred at a single site on several occasions and contain two Red Data listed species, *Hypseleotris dayi* and *Redigobius dewaali*.

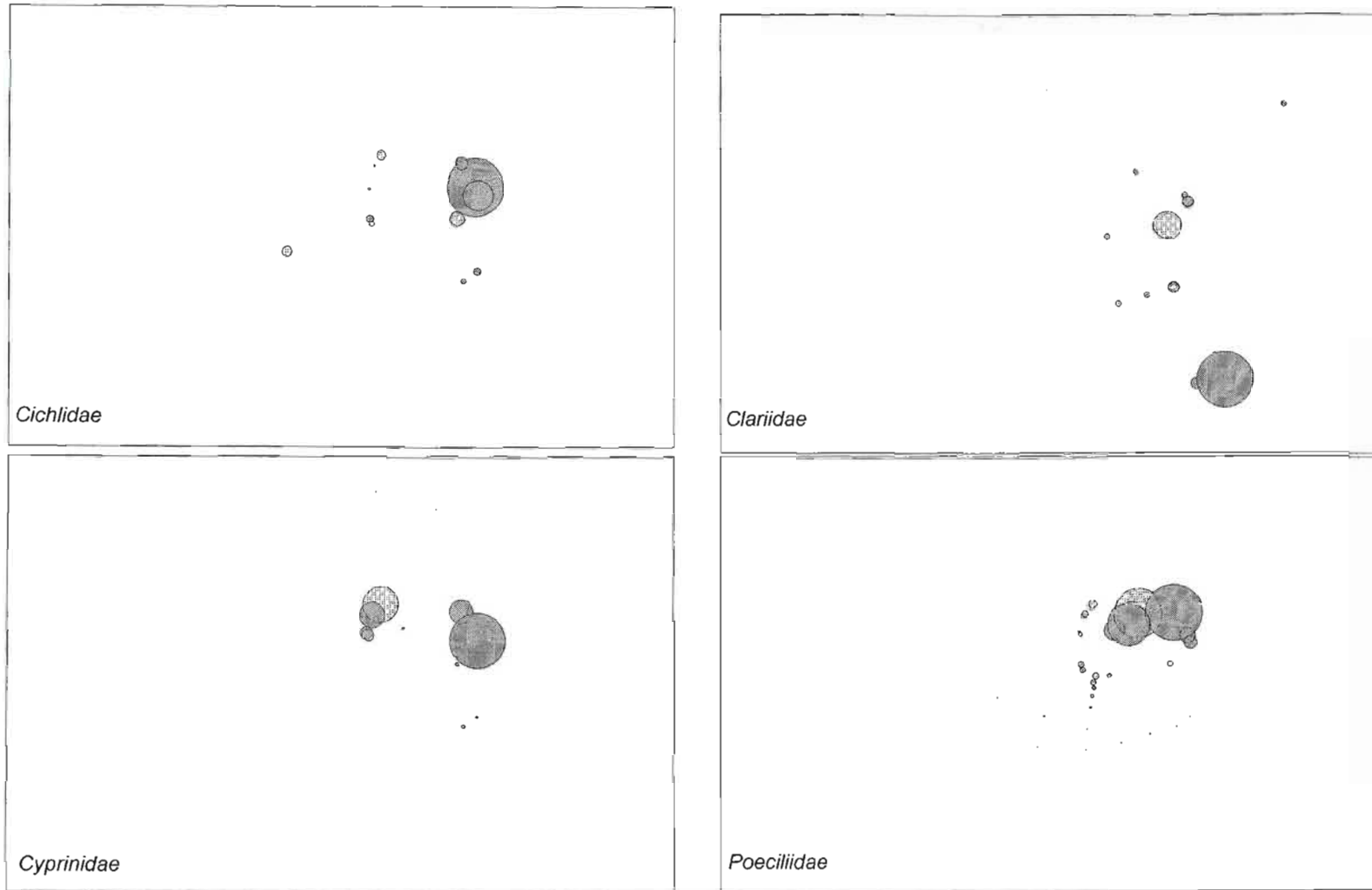


Figure 20: MDS plots from Bray Curtis similarities of $\sqrt{}$ transformed abundance data from the Eastern shores. The four main fish families, Cichlidae, Clariidae, Cyprinidae and Poeciliidae, are illustrated on separate plots with bubble sizes representing the relative importance of the family per sample (Stress for all plots = 0.1).

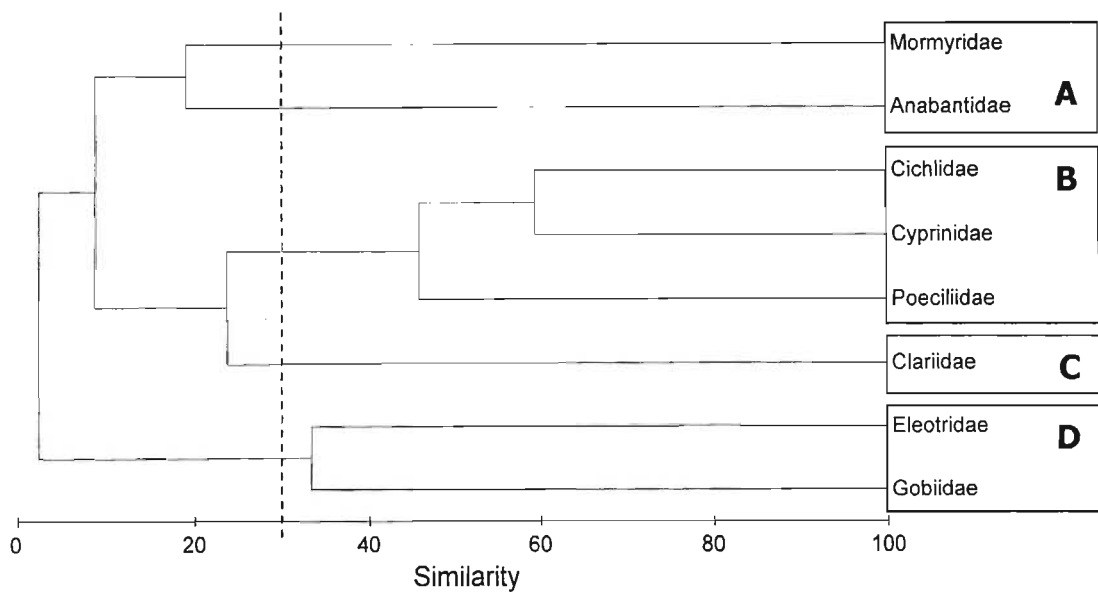


Figure 21: Results of a hierarchical cluster analysis, using group average linking on Bray-Curtis similarities between $\sqrt{\text{transformed abundance data}}$. Letters in bold represent groups discussed in text. A – Rare species; B – Pond and Channel Species; C – Hardy species; D – Marginal Estuarine species.

Axes plotted in the db-RDA were non significant, but this is to be expected, given the small sample size. The biplot of species (plotted as nominal variables) and environmental variables (Figure 22) suggests that species from the families included in groups B and C of the cluster analysis (Figure 21) are aligned more or less along gradients of temperature and conductivity along the second ordination axis, with some separation of species along the primary ordination axis, that does not appear to bear any strong correlations to a particular environmental variable. Certain species, namely *C. theodora*, *A. katangae*, *T. rendalli* and *B. viviparus*, are almost orthogonal to the primary axis and these taxa seem to be more strongly affected by a combination of other environmental variables. However, given the small sample size and lack of significance, these relationships are probably best regarded as putative rather than definite. It is also likely that fish distributions are affected by direct and indirect biotic interspecific interactions that are not included in this analysis.

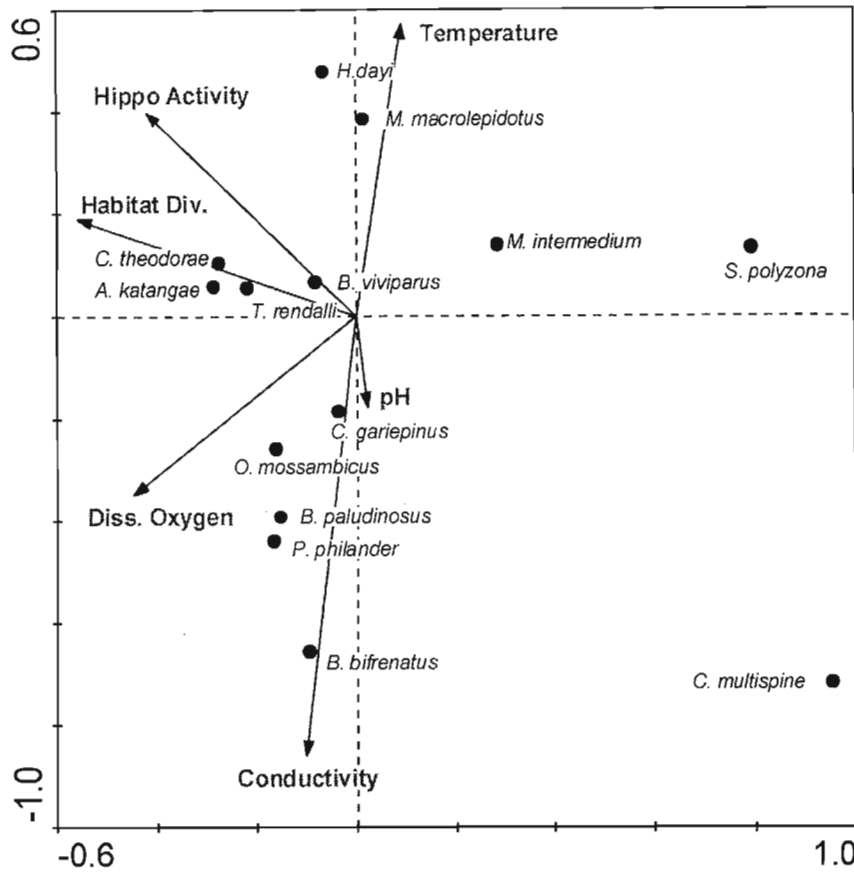


Figure 22: Plot of first two axes of a db-RDA showing relationships between fish-plotted as points and measured environmental variables-plotted as arrows. Summary statistics are given in Table 10.

Table 10: Summary statistics for db-RDA based on Bray Curtis distances of $\sqrt{}$ transformed fish abundance data from sites on the Eastern Shores.

a) Summary Statistics for RDA of principle coordinate axes						
Axes		1	2	3	4	Total variance
	Eigenvalues:	0.120	0.091	0.056	0.043	1.000
	Species-environment correlations:	0.855	0.942	0.785	0.714	
	Cumulative percentage variance					
	of species data:	13.7	24.1	30.5	35.4	
	of species-environment relation:	35.1	61.6	78.0	90.7	
	Sum of all eigenvalues:					0.875
	Sum of all canonical eigenvalues:					0.342
b) Summary of Monte Carlo test						
Test of significance of first canonical axis:	eigenvalue=	0.120				
	F-ratio=	1.588				
	P-value=	0.1560 (NS)				
Test of significance of all canonical axes:	Trace =	0.342				
	F-ratio=	1.069				
	P-value=	0.2720 (NS)				

c) Summary statistics for supplementary (species) data					
Axes	1	2	3	4	Total variance
Species-environment correlations:	0.964	0.998	0.964	0.984	
Cumulative percentage variance					
of species data:	13.7	24.1	30.5	35.4	
of species-environment relation:	18.2	30.4	40.4	50.3	
Sum of all eigenvalues:					0.875
Sum of all canonical eigenvalues:					0.838

RED DATA SPECIES

Four species of fish listed by IUCN (2000) or Skelton (1987) as rare or threatened species were encountered during the survey. Of these species *Microctenopoma intermedium* and *Clarias theodora* appear to be fairly widespread, being encountered at seven and four sites respectively. *Redigobius dewaali* and *Hypseleotris dayi* occurred at the same single location, although were recorded on more than one occasion. This is the first record of *H. dayi* at St Lucia since the first specimens were collected in July 1948 by A.D. Harrison (Smith, 1950). Kyle (1989) reports that the species is not uncommon in the Kosi system, and it is not unlikely that it occurs at other similar locations at St Lucia. It is interesting to note that *R. dewaali* and *H. dayi* occurred at the same site (Site 9), on the lake shoreline. This site is remarkable because it is an apparently permanent seepage of fresh water on the edge of the saline Lake St Lucia, with hippopotamus trails forming a network of shallow, freshwater streams flowing into the lake from pools on the margins of swamp forest (Figure 17). Similar freshwater habitats exist along the length of the eastern shoreline of Lake St Lucia (Taylor⁵, pers comm.). These shoreline habitats form an interface between the saline lake and the freshwater Eastern Shores wetlands and could form important refuge sites for freshwater species during dry periods, or periods of high salinity in the lake.

DISCUSSION

The Eastern Shores wetlands form an important habitat for freshwater fishes. The spatial and temporal heterogeneity of wetland habitats create an area with a diverse and dynamic fish community that is not only important to the functioning

⁵ R. Taylor, EKZNW, St Lucia.

of these wetlands as ecological entities within themselves, but also as a source of freshwater colonists for Lake St Lucia during periods of low salinity.

The four dominant freshwater fish families (Poeciliidae, Cichlidae, Cyprinidae, Clariidae) on the Eastern Shores seemingly rely on different strategies to survive the seasonal perturbations of drying out. The Poeciliidae, represented here by a single genus, *Aplocheilichthys*, are serial spawners, breeding over an extended period whenever food is available (Skelton, 2001). Such a life history will allow rapid population growth and expansion into suitable habitats following inundation. Consequently, they were the most ubiquitous and abundant fish on the Eastern Shores, in spite of the fact that their eggs are not desiccation resistant. The Cichlids, Cyprinids and Clariids are slightly more conservative in their reproductive strategies, generally spawning seasonally, but include hardier species, able to survive harsher environmental conditions. The triumvirate of *Tilapia-Barbus-Clarias* is the ultimate successional stage in fish assemblages when vegetation invades freshwater systems (Lévêque, 1997). They are usually the last species to survive before drying up. During drydown, species and individual numbers decline, but if the system does not dry up completely these 'last three' are the only ones to survive adverse conditions. This has been observed many times. In Lake Ngami (Jackson, 1989 in Lévêque, 1997), *Barbus paludinosus*, *Clarias gariepinus* and *Oreochromis andersonii* were the last species recorded before drying up. In Lake Mweru Wa'Ntipa (Jackson, 1989 in Lévêque, 1997) the fish community consisted of 12 species at high water but during the drying phase only *C. gariepinus* and *Oreochromis macrochir* were recorded. *C. gariepinus* has an accessory breathing organ and is well adapted to overcrowded and deoxygenated conditions. On the Eastern Shores, *C. gariepinus* is likely to be the top fish predator in the freshwater wetlands and is described as Skelton (2001) as a '...dominant ecological presence where it occurs...'. Species in the other two genera must be flexible in their life history styles and be able to succeed in unstable, crowded environments, from which other more specialised species have disappeared (Lévêque, 1997).

The more specialized species have to rely on refugia within this dynamic environment in order to survive seasonal and longer term perturbations. Lancaster & Belyea (1997, in Magoulick & Kobza, 2003) provide a general definition of refugia as 'places (or times) where the negative effects of disturbance are lower than in the surrounding area (or time)'. Refugia may operate across a range of spatial and temporal scales and incorporate protection from a variety of biotic and abiotic factors. By default, refugia for obligate aquatic organisms will require water. Once water is present, four physico-chemical variables will arguably be most influential for fish survivorship: oxygen, temperature, pH and mineral content (conductivity) (Magoulick & Kobza, 2003). Within refugia, biotic interactions such as increased competition, overcrowding and increased predation both from fish and other predators such as piscivorous birds will also play a role in survivorship of fish in aquatic refugia. The effect of these modified biotic interactions will play a role in which species survive as founders for the subsequent structuring of fish communities that arise from post-inundation recolonisation and population expansion (*sensu* Magoulick & Kobza, 2003).

The sample period happened to fall during a season that experienced unseasonal rainfall (see Figure 8) and particularly low water. Many wetlands on the Eastern Shores dried up and did not refill during this period. For those that did refill, or did not dry up completely, water levels on the Eastern Shores remained low enough that many wetlands remained cut off from each other, precluding the opportunity for fish to migrate between the remaining water bodies. Under these conditions, the role of refugia and sites with persistent water will be even more important for providing a source of potential colonists to restore fish communities in suitable habitats once they are reconnected.

Disturbance, such as hydrological fluctuation, plays an important role in structuring biotic communities. In saturated assemblages, where strong biotic interactions take place among the species within a local habitat, a species cannot be added unless it replaces and eliminates another species (Ricklefs, 1987). Seasonal disturbances such as wetting and drying, as well as those that occur

more unpredictably, such as drought are important factors in wetland ecology. Through the removal of organisms disturbance creates a situation where assemblages are not saturated, maintaining populations at sub maximal densities. This reduces the exclusion of species that are competitively inferior, resulting in greater biodiversity (Connell, 1978). In the absence of seasonal drying, piscivorous predators can achieve high abundances, contributing to reduced fish species diversity (Kushlan, 1976).

Due to their complexity and dynamism, wetland fish communities are difficult to study and model (Bruton & Jackson, 1985). The fish communities on the Eastern Shores appear to be no different, responding to the complex interaction between biotic and abiotic factors, coupled with the effects of regular as well as irregular disturbance. The result is a diverse and dynamic fish community that with further investigation has the potential to provide insights into the ecological functioning of non-riverine wetlands.

AQUATIC MACROINVERTEBRATES

If one could conclude as to the nature of the Creator from a study of his creation it would appear that God has a special fondness for stars and beetles. J.B.S. Haldane

The aquatic invertebrates of the Eastern Shores are largely unstudied and unknown. No extensive surveys of macroinvertebrates have been undertaken in the Eastern Shores wetlands although some reports on selected taxa exist in the 'grey literature' (e.g. Reavell, 1990). No comprehensive or extensive checklists of aquatic invertebrates exist for the area. Even for groups such as the dragonflies that are well known in Southern Africa, at least in the adult stage (Pinhey, 1984, 1985) knowledge of the aquatic nymphal stages is not extensive and even completely absent for some genera. The sheer abundance and diversity of aquatic invertebrates makes any attempt to catalogue them a significant undertaking requiring a large investment of time, effort and expertise. Aquatic invertebrates also exist in a place where few people ever see them, especially those that inhabit largely inaccessible wetlands. For these reasons the aquatic invertebrates in the Eastern Shores freshwater wetlands appear to have been largely overlooked or ignored, at least in published literature.

Four groups comprise the majority of wetland dependant species: the insects, molluscs, crustaceans and annelid worms. Insects, the most diverse of these groups occur in most wetlands and throughout all major habitat zones (Gibbs, 1995). In some biotopes, insects may comprise over 95% of the total individuals or species of macroinvertebrates present. Thirteen orders of insects contain aquatic or semiaquatic stages (Ward, 1992), including exclusively aquatic orders as well as those containing semiaquatic and terrestrial representatives (Table 11).

Wetlands, especially those that dry seasonally or periodically represent an ecotonal environment between aquatic and terrestrial habitats. As such, the invertebrate assemblages of wetlands will contain representatives of aquatic, semiaquatic and terrestrial groups. In dry periods, terrestrial groups can represent an important component of invertebrate fauna in wetlands that experience a

completely dry phase (Collinson *et al.*, 1995). Aquatic invertebrates in the Eastern Shores wetlands are not uniformly distributed in space and time, and this heterogeneity represents the response of insect communities to an ever changing suite of biotic and abiotic factors in the environment that they inhabit.

Table 11: Aquatic associations and habitats of insect orders with aquatic or semiaquatic representatives. (Ward 1992)

Order	Aquatic Association ^b	Habitats of Life Stages ^a			
		Eggs	Larvae	Pupae	Imagos
Collembola	2	A,T	A,S	-	S
Ephemeroptera	1	A	A	-	T
Odonata	1	A,T	A	-	T
Hemiptera	2	A,T	A,S,T	-	A,S,T
Orthoptera	3	T	S	-	S
Plecoptera	1	A	A	-	T
Coleoptera	2	A,T	A,T	T	A,S,T
Diptera	2	A,T	A	A,T	T
Hymenoptera	2	P	P	P	A,T
Lepidoptera	2	A	A	A	T
Megaloptera	1	T	A	T	T
Neuroptera	2	T	A	T	T
Trichoptera	1	A,T	A	A	T

^aHabitats refer to those of only the aquatic or semiaquatic species of orders that also contain terrestrial species. There may be rare exceptions not indicated.

^bKey: 1= all species aquatic; 2= primarily terrestrial, some truly aquatic; 3= primarily terrestrial, some aquatic species, no truly aquatic species. A= aquatic; T= terrestrial; S= semiaquatic; P= parasitic on an underwater host.

METHODS

COLLECTION

Invertebrates were collected at all routine sample sites as well as *ad hoc* sites on the Eastern Shores during the course of sampling. Each site was sampled on eight occasions during the study period, although sites that dried completely during this time were obviously unavailable for the full sampling frequency. On each occasion, invertebrates were collected using a standard, square-mouthed pond net, with a 30cm gape and 0.5mm mesh size. Target taxa were Coleoptera and Heteroptera, although other taxa collected were also recorded. The sampling strategy is based upon the semi quantitative method by Savage (1989), using a fixed distance for each sample. Sampling over a fixed distance is more desirable than dip netting for a fixed time as the distance covered in a fixed time will vary depending on habitat and operator (Elliott, 1983). Each sample comprised three sweeps along a two-meter distance at separate locations within the dominant biotope at the site. Material from these three sweeps was pooled to form the final sample for that

site. Larger debris and vegetation matter was removed from the samples in the field and samples were fixed in the field with 70% ethanol, or 10% formalin if the sample contained fish as well as invertebrates. Invertebrates were later manually removed from any remaining organic debris under a binocular microscope and preserved in 70% ethanol. Invertebrates were identified at least to family level and in some cases genus and species. Where this was not practical, a morphospecies approach was taken to distinguish unknown taxa. The morphospecies approach is based on separation of the taxa based on readily discernable morphological characters rather than identifying species per se. The assumption underpinning this approach is that the use of morphological characters allows the distinction of taxa to some degree without the investment of time and specialised expertise required for species identifications (Derraik *et al.*, 2002)

DATA ANALYSIS

The scheme of analysis used for invertebrates was similar to that outlined for fishes in the previous chapter (Figure 18). Data matrices of species abundances per sample were analysed using the PRIMER 5 for Windows, version 5.2.9 (Clarke & Gorley, 2002) and CANOCO for Windows, version 4.51 (ter Braak & Šmilauer, 2003).

Bray-Curtis similarity matrices were generated from log transformed ($\log(y+1)$) abundance data. As with the fish analyses, similarities between samples were used to generate MDS plots in PRIMER. In the initial MDS analysis, two samples (ES051A and ES119A) were outliers that compressed the distribution of the other sites into a tight cluster on the plot. These sites were removed and the analysis was rerun.

For the db-RDA, invertebrate abundances were matched to environmental data. Sites missing pH values were removed from the data set and subsequent analyses. Dissolved oxygen was removed as a variable from the environmental data set as it also contained missing values. Leps and Šmilauer (2003) recommend that when dealing with missing values in data sets 'case-wise' removal of entire samples is best suited when these samples are concentrated in a few samples, as was the case with pH. Since many aquatic invertebrates are air breathing,

dissolved oxygen may not be as critical as it would in the case of fish. Removal of a variable rather than samples maintains the size of the dataset. Imputation of missing variables, by regression of existing values could be used, but this leads to erroneous assumptions about the number of degrees of freedom when the supplemented data are used in a statistical test. The db-RDA was run in the same fashion as for fish except that abundance data were log transformed prior to PcoA. Permutations for the Monte Carlo test of significance were run under the reduced model with samples arranged as time series in blocks defined by sample site.

An index of habitat preference was calculated in order to assess the affinity of invertebrate taxa for various habitat types. The habitat preference for invertebrate taxa was calculated as the number of occurrences each taxon in a specific habitat taken as a percentage of the total occurrences of that taxon across all habitats. The four habitat classes used (open wetland, swamp forest, streams and *Cyperus* swamp) were generated *a posteriori* from the groupings in the RDA of habitat types and physico-chemical variables (Figure 11) described in chapter 3.

RESULTS

Invertebrates were unevenly distributed in time and space in the Eastern Shores wetlands. No distinct groupings were immediately discernible in the MDS plots, but when the plots are overlaid with abundances of different invertebrate orders, some separation of samples in terms of the dominance of these orders becomes apparent (Figure 24). Stress for these ordinations was 0.19 which is still a potentially useful 2-D representation, although comparison with alternative techniques is desirable for stress values between 0.15 and 0.2 (Clarke & Warwick, 2001). A hierarchical cluster analysis of the Bray-Curtis similarities between orders of aquatic invertebrates (Figure 25) shows similar separation of orders. The separation of orders in the dendrogram occurs at two levels. The first (indicated by solid boxes) separates taxa with aerial and highly mobile adult stages from those with poorer dispersal abilities. Within the larger group, separation of the taxa illustrated on the MDS plots (enclosed in dashed box) can be discerned, although these separations occur at fairly high levels of similarity (50% to 70%).

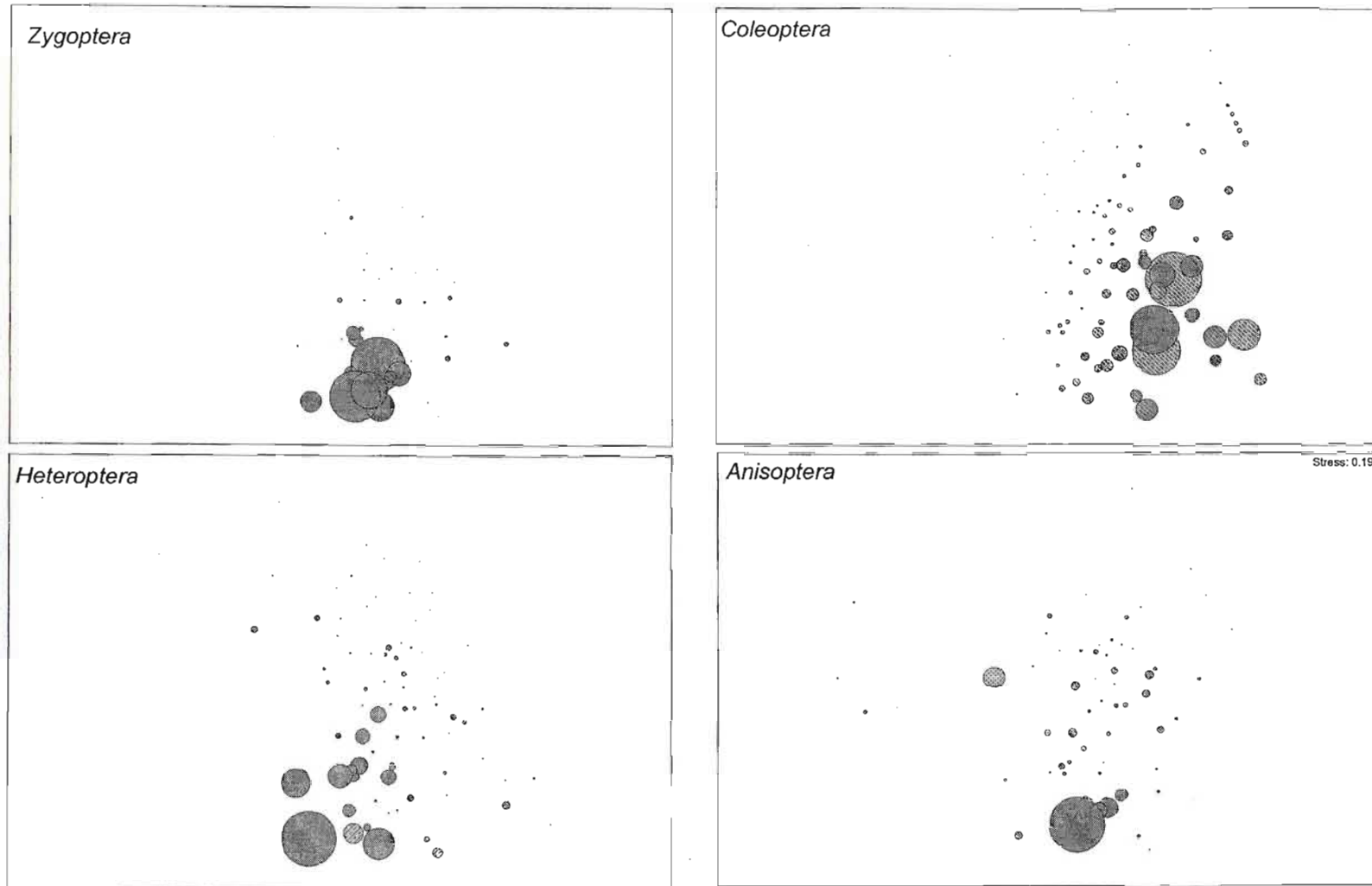


Figure 24: MDS plots from Bray Curtis similarities of $\sqrt{}$ transformed invertebrate abundance data from the Eastern Shores. Zygoptera, Coleoptera, Heteroptera and Anisoptera are illustrated on separate plots with bubble sizes representing the relative importance of the order per sample. Stress value = 0.19 for all plots.

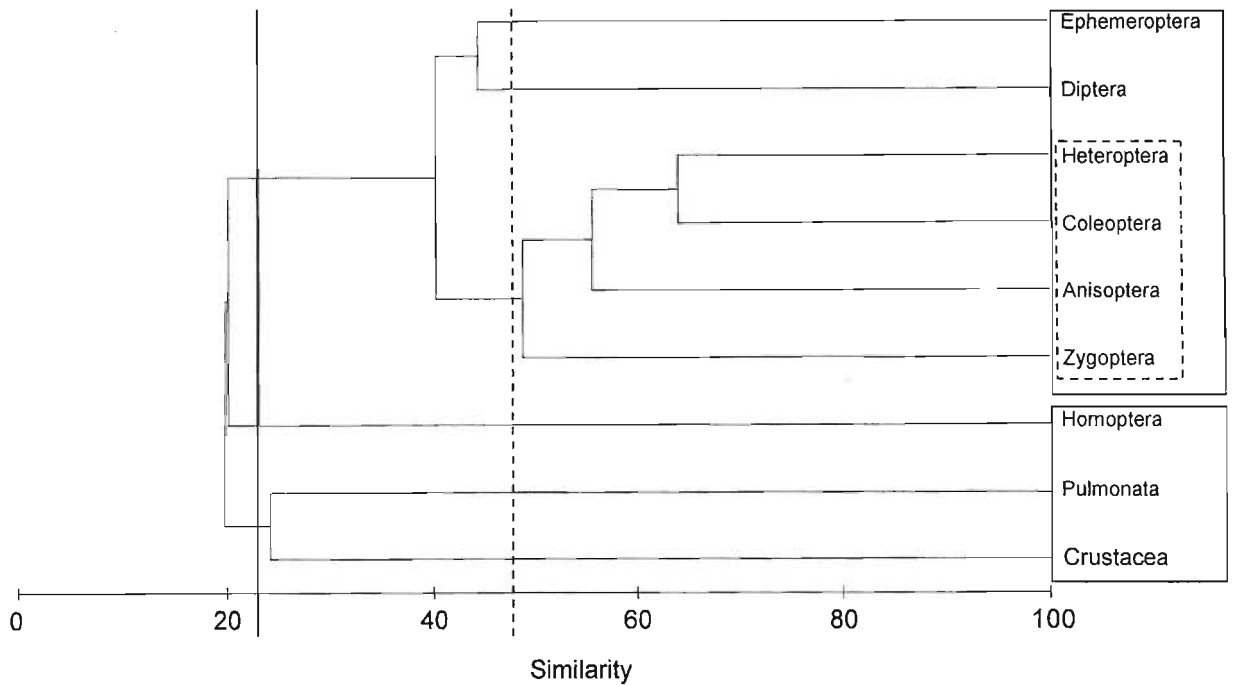


Figure 25: Hierarchical cluster analysis from Bray-Curtis similarities of \sqrt{x} transformed invertebrate abundance data aggregated at order level. (Terrestrial groups excluded).

Temporal variation within sites did not show any clear patterns in terms of the direction and magnitude of change within the invertebrate communities. Vector plots based on scores from the 2D MDS ordination of invertebrate abundance data (Figure 26) show that changes in invertebrate assemblages within sites are highly variable in terms of both the direction and magnitude of change between samples. No consistent patterns in these temporal changes could be discerned, other than a general progression from left to right on many of the plots in Figure 26. This may imply a general shift in fauna from those associated with high water to those associated with drier and lower water levels. Sites 8, 13, 14 and 15 dried completely during the sample period.

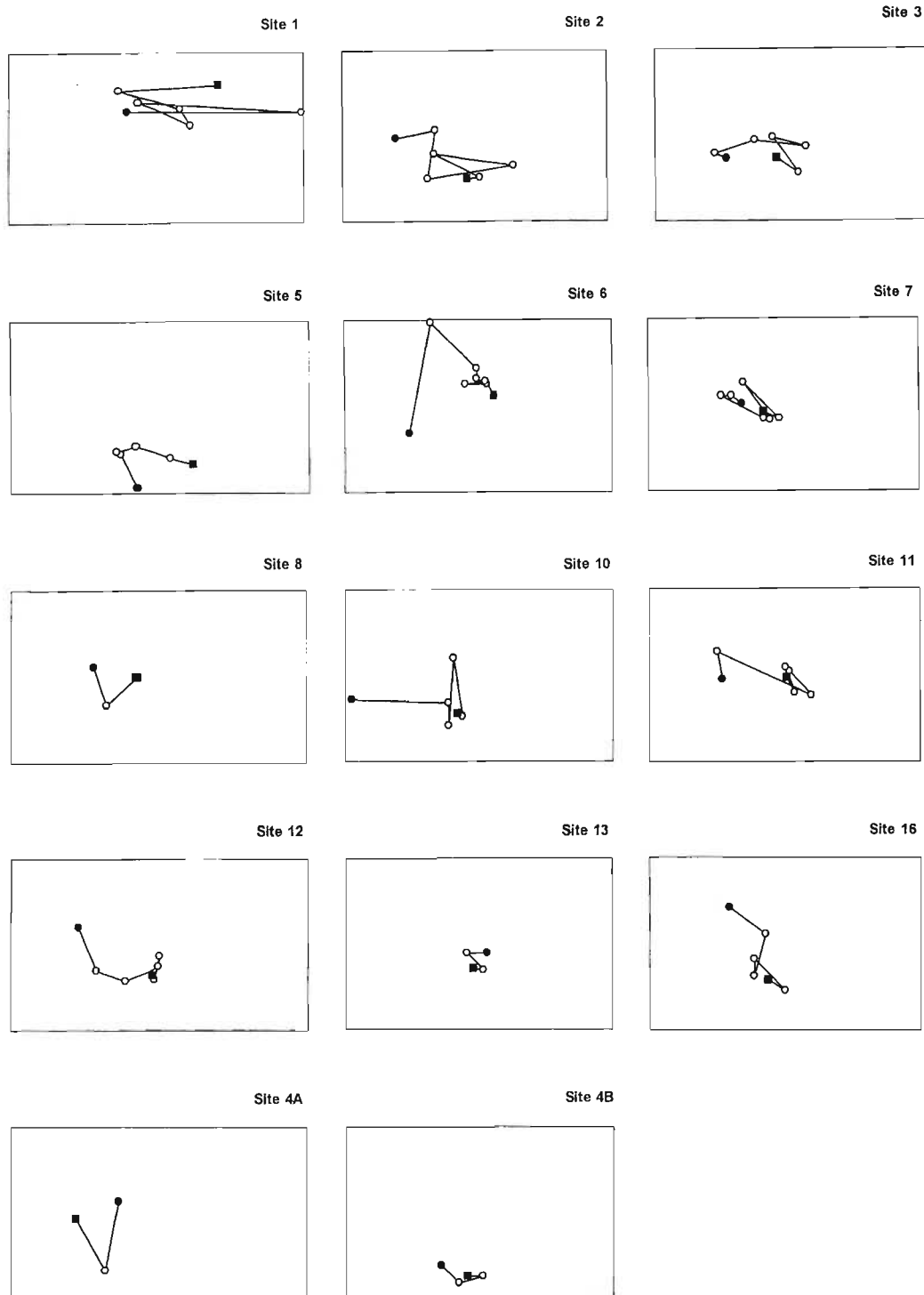


Figure 26: Vector plots showing the relative degree and direction of change in invertebrate assemblages from selected sites on the Eastern Shores. Start points in each sequence are represented by a closed circle and end points by a square. Plots are based on scores from 2 dimensional MDS analysis of Bray Curtis similarities between $\sqrt{}$ -transformed invertebrate abundance data. Stress value for all plots is 0.19.

Examination of the db-RDA plot (Figure 27) reflects a complex relationship between the distributions of aquatic invertebrates and their environment. No single factor or set of factors can be singled out as being most important in determining the distribution of invertebrates on the Eastern Shores. Although the Monte Carlo test of significance deemed the first canonical axis to be non significant, all of the canonical axes combined were significant at the 2% level ($F=1.817$, $P=0.02$). This suggests that the combined effects of environmental variables, rather than specific environmental variables acting independently have a significant effect on the distribution of aquatic macroinvertebrates. The distribution of invertebrate families in the ordination reflects the lack of dominance of any particular environmental trend, although some associations between invertebrates and their habitat and environment can be discerned. The families ordinating towards the top of the plot, associated with the *Cyperus* root mat habitat (CYPE) tend to comprise semiaquatic and terrestrial taxa, utilising what is essentially a terrestrial habitat floating above an aquatic one. Group ii on the plot is comprised of the Belastomatidae, Naucoridae, Dystiscidae and Culicidae. With the exception of the Culicidae, the species in these families are generally large predators that in the absence of fish will take the place of top predators in aquatic food webs. The position of this group indicates that they are associated with deeper water and channel habitats and those where fish are absent. Groups iii and v comprises three terrestrial families, the Cicadellidae, Cerambycidae and Tettigotonidae, four aquatic families, Nepidae, Pleidae, Aeshnidae and the semiaquatic Mesovelidae and Baetidae. The two groups are likely to be associated with emergent vegetation types such as the *Eliocharus* species and floating grass species, for example *Leersia hexandra*. The last group of invertebrates, group iv, are all families with mobile flying adult stages.

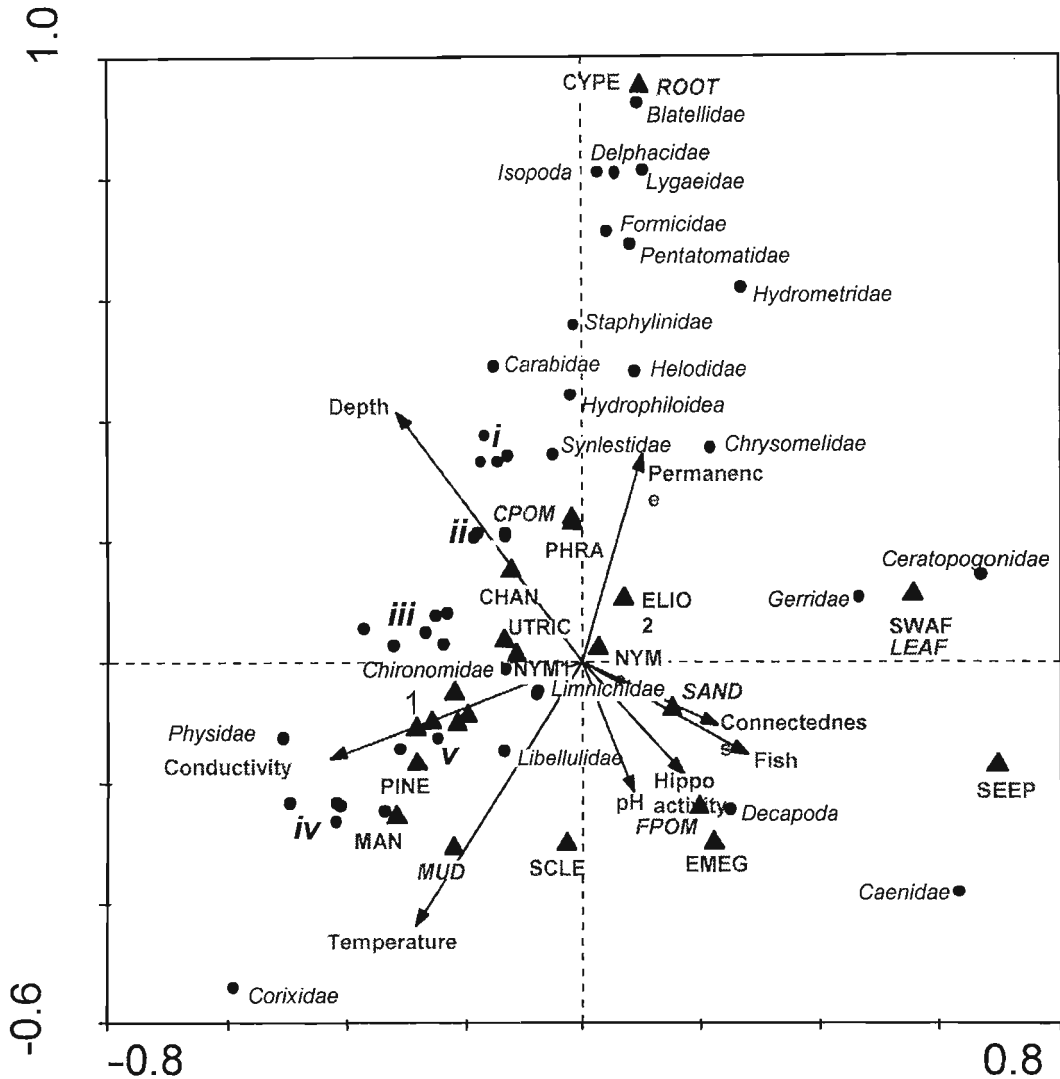


Figure 27: Plot of first two axes of a db-RDA showing relationships between invertebrate families^a, plotted as points and measured environmental variables^b, plotted as arrows. Summary statistics are given in Table 12. Key: ^a Clusters of invertebrates: i – Tabanidae, Curculionidae, Buprestidae; ii – Belastomatidae, Naucoridae, Dytiscidae, Culicidae; iii – Nepidae, Cicadellidae, Cerambycidae, Pleidae, Baetidae, Tettigogonidae; iv – Lestidae, Cleridae, Coenagrionidae, Notonectidae, Gyrinidae Planorbidae; v – Aeshnidae, Mesovelidae. ^b Clusters of environmental variables: 1 – FLOG, MUD, PEAT, ELIO1 NYM2. Other environmental variables are labeled individually.

Table 12: Summary statistics for db-RDA based on Bray Curtis distances of $\sqrt{\text{transformed invertebrate abundance data}}$ (aggregated at family level) from sites on the Eastern Shores.

a) Summary statistics for RDA of principle coordinates analysis					
Axes	1	2	3	4	Total variance
Eigenvalues:	0.110	0.086	0.054	0.050	1.000
Species-environment correlations:	0.895	0.860	0.885	0.817	
Cumulative percentage variance					
of species data:	11.5	20.6	26.3	31.5	
of species-environment relation:	21.1	37.6	48.0	57.6	
Sum of all eigenvalues:				0.950	
Sum of all canonical eigenvalues:				0.520	

b) Summary of Monte Carlo test	
Test of significance of first canonical axis:	eigenvalue= 0.110 F-ratio= 5.871 P-value= 0.9920 (NS)
Test of significance of all canonical axes:	Trace= 0.520 F-ratio= 1.817 P-value= 0.0200*

*Significant (P<0.05)

c) Summary statistics for supplementary (species) data					
Axes	1	2	3	4	Total variance
Species-environment correlations:	0.887	0.879	0.919	0.852	
Cumulative percentage variance					
of species data:	11.5	20.6	26.3	31.5	
of species-environment relation:	15.7	28.7	37.3	45.1	
Sum of all eigenvalues:				0.950	
Sum of all canonical eigenvalues:				0.687	

The grouping of samples in the db-RDA ordination (Figure 28) appears very similar to that in the analysis of habitat and environment (Figure 11), indicating a clear link between invertebrates and their habitat and environment. Four main groupings of samples are apparent: open vegetated wetlands, swamp forest, stream sites and *Cyperus* swamp. The distinction between the stream sites and other open wetlands is greater than in the ordination of environmental variables without species data. Although the sites differ in their composition (Figure 29), the Coleoptera tend to be the dominant order at each site. This is not surprising given the fact that the Coleoptera are the largest known order of living organisms (Endrödy-Younga, 1985). For most sites, the Coleoptera were most dominant order, followed by the Heteroptera, Odonata and thereafter a variable combination of other orders. Collectively, the open wetlands and *Cyperus* swamp contain the greatest diversity of invertebrates, but it should be considered that many more

samples were taken in open wetlands than the other habitat types, so collecting effort was not equally distributed across the four habitat classes shown.

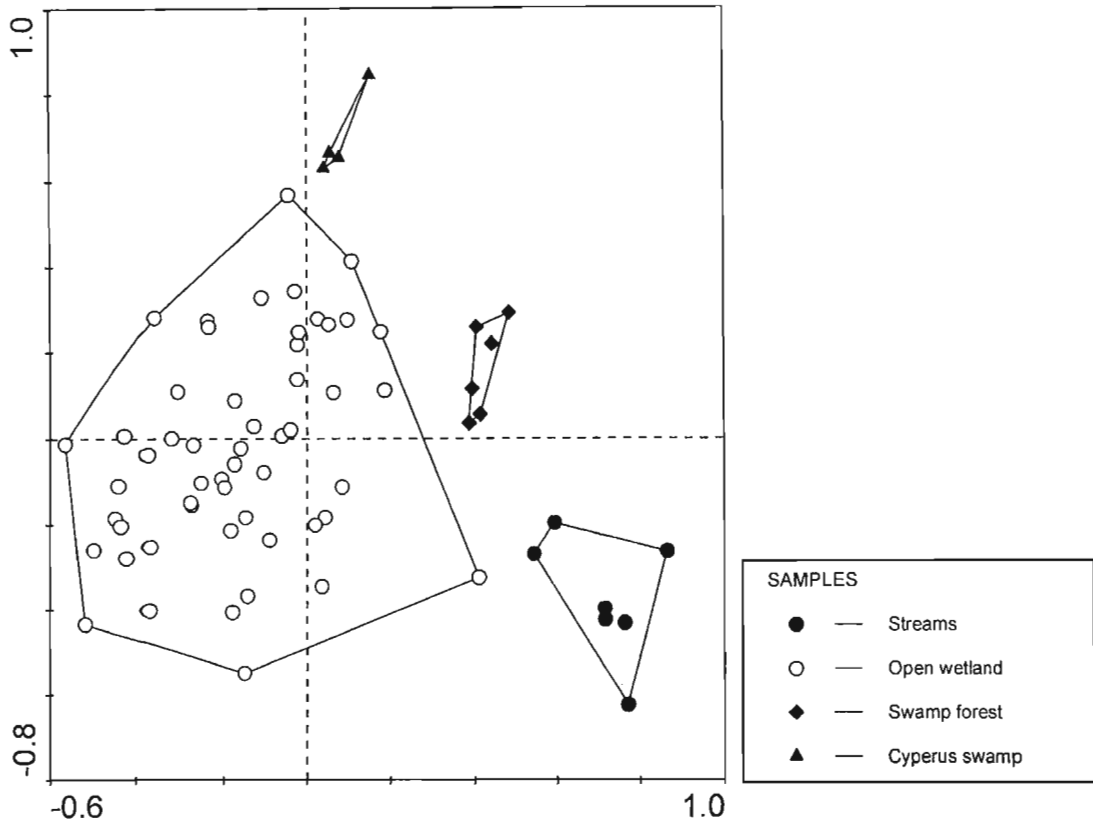


Figure 28: Scatterplot showing relative distributions of samples on the first two axes of db-RDA based on Bray Curtis distances of $\sqrt{\text{transformed}}$ invertebrate abundance data (aggregated at family level) from sites on the Eastern Shores. Envelopes enclose samples taken from each of the four habitat types indicated in the legend. Summary statistics are given in Table 12.

For the open wetlands, 52% of the taxa recorded were found only in these habitats and did not occur in the swamp forest, streams or *Cyperus* swamp. Of the remaining three habitat types, taxa in the swamp forest appeared to be most specific with more than 40% of the taxa occurring there found only in swamp forest habitat. (Figure 30) In the *Cyperus* swamp, more than 25% of the taxa were only found in this habitat, probably due to a large number of terrestrial invertebrates that were able to live in the floating root mat. Taxa in the stream habitats were the least specific, and may have included vagrants from other nearby wetlands. Complete species lists for each habitat are given in the

Appendices II.i-II.iv. Taxa that occur only within a single habitat are indicated in bold type on these lists.

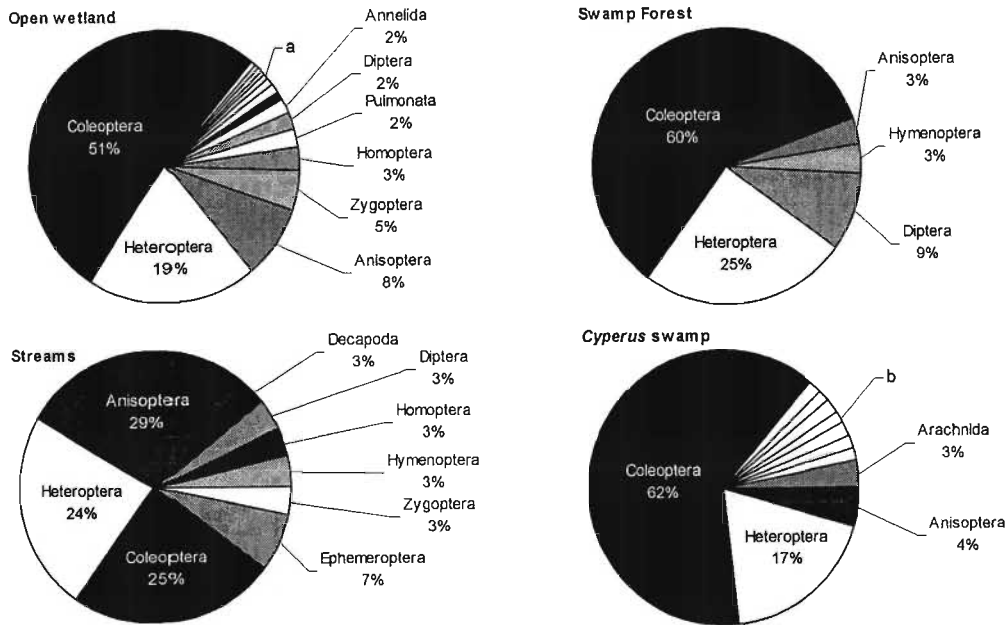


Figure 29: Relative composition of invertebrate assemblages by family for the four groupings of samples in Figure 28. Key: a = Isopoda, Hymenoptera, Lepidoptera, Nematoda & Orthoptera, Arachnida, Decapoda, Ephemeroptera (All occurring at 1%) b = Isopoda, Diptera, Homoptera, Hymenoptera, Lepidoptera, Pulmonata, Zygoptera. (All occurring at 2%).

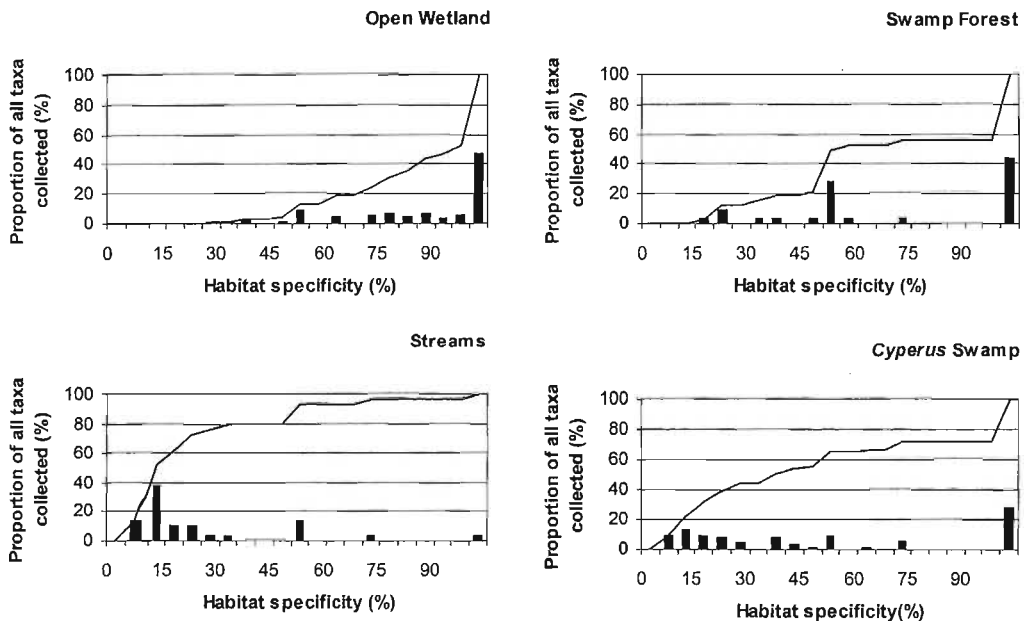


Figure 30: Frequency histograms of habitat specificity for the four groupings of samples shown in Figure 28. Habitat specificity is the number of occurrences of a taxon in a particular habitat as a percentage of the total occurrences of that taxon in the entire dataset. Bars represent the proportions of taxa occurring in 5% classes of habitat specificity, lines represent cumulative frequency of taxa collected.

DISCUSSION

Determining that there are patterns in these assemblages is relatively easy. Unravelling the combination of factors that give rise to these patterns is not. There are many factors affecting the distribution of macroinvertebrates in wetlands. These include water quality (Batzer & Wissinger, 1996); habitat preferences in the form of macrophytes or substratum types (Minshall, 1984; Olson *et al.*, 1995; Hoffman *et al.*, 1996); the presence of fish (Wong *et al.*, 1998) and the effects of seasonal flooding and drying regimes (Neckles *et al.*, 1990; Balla & Davis, 1995). The overarching factor that drives all of these dynamics and subsequently the distribution of macroinvertebrates that result from the interplay of these factors is the hydrological regime of these wetlands. However, it is often difficult to establish correlations between observed biological changes, and the fluctuations in the environmental variables thought to drive those changes. Verschuren *et al.*, (2000) discuss some of the problems hampering efforts to separate the effects of particular environmental factors on invertebrate populations in shallow fluctuating lakes. Some of the issues raised are also relevant in the context of the Eastern Shores – a shallow, fluctuating wetland. Field studies of this nature are often complicated by large temporal and spatial variation in species abundances, the short time frame of studies compared to the time scale of the processes at work and the fact that all the environmental factors involved change simultaneously or with different lag intervals. This combination of factors may obscure clear links between the observed effects and causal factors. The element of stochasticity adds another layer of complexity to an already multifarious system. Macroinvertebrate communities in smaller lentic water bodies have been considered as relatively random combinations of species and hence, unpredictably structured (Friday, 1987; Jeffries, 1989). This may be particularly true for taxa with good dispersal capabilities such as Odonata, Coleoptera and Heteroptera, considering the close proximity of most of the wetlands on the Eastern Shores. This stochastic effect would create a certain amount of noise in the dataset that may obscure relationships between distribution patterns and measured environmental variables.

Nonetheless, the importance of hydrological regime in shaping communities of aquatic macroinvertebrates has been recognized in other systems that experience periodic wetting and drying, for example dryland rivers in Australia (Balla & Davis, 1995; Sheldon *et al.*, 2002); temporary ponds in Britain (Collinson *et al.*, 1995), Italy (Bazzanti *et al.*, 1996) and The Netherlands (Verdonschot, 1992). In spite of the differences between these systems and the Eastern Shores, it is possible to draw parallels between them. As on the Eastern Shores, the ecological functioning of these other systems tends to be dominated by a pulsing hydroperiod and alternate wetting and drying events. On a seasonal level, these events may be quite predictable, but may become less predictable in the event of stochastic events such as drought. Another factor recognized by many of these authors is the conservation value of a variable hydrological regime in maintaining diversity in these macroinvertebrate communities. Seasonal disturbances in the form of drying events as well as those brought about by drought (Brock *et al.*, 2003) are important ecological components of wetlands. The removal of organisms through regular disturbances like drying events can maintain populations at sub-maximal densities (Connell, 1978) reducing the exclusion of competitively inferior species and resulting in an overall increase in diversity. Sheldon *et al.* (2002) found that in Cooper Creek, a dryland Australian river, variable hydrological regime promoted macroinvertebrate diversity but conceded that the influence of hydrology and connectivity in such systems is complex. Although the wetlands on the Eastern Shores are fed by groundwater rather than rivers, it is likely that invertebrate diversity is driven by the similarly complex effects of hydrological regime. Rivers will provide direct surface inter-connectivity to their wetlands which groundwater generally cannot unless wetlands expand sufficiently to form these linkages. This could enhance the 'lottery' nature of the biotic assemblages as dispersing organisms need to find relatively isolated patches of suitable aquatic habitat in a dry-land matrix.

CONCLUSIONS AND IMPLICATIONS FOR BIODIVERSITY CONSERVATION ON THE EASTERN SHORES

The inherent variability in dynamic systems like the Eastern Shores wetlands makes them difficult to study. The complications associated with conducting field studies in dynamic systems (Verschuren *et al.*, 2000) can obscure links between causal factors and their observed effects, making it extremely difficult to extract any clear relationships between observed changes in the aquatic macrofauna and the observed changes in their environment. One may be able to observe events over a 'normal' seasonal cycle but these events may be altered by unpredictable external influences such as unseasonal rains or drought that may either truncate or reset any expected successional sequences. Natural disturbances such as drying out and drought play a major role in the structuring of aquatic communities (Magoulick & Kobza, 2003). One such effect of frequent disturbance is that communities will not be saturated, and populations will be maintained at sub maximal densities, reducing the pressure on competitively inferior species and allowing greater species diversity to exist. Connell's (1978) intermediate disturbance model proposes that unstable habitats will be dominated by colonizer species with good dispersal ability that will be replaced gradually by competitively superior, but more sedentary species as stability increases. Differences in the stability of sites can therefore be expected to play a role in determining faunal distributions as well as the constraints imposed by the structural and physicochemical characteristics of certain habitat types. On the Eastern Shores, the vegetated wetlands generally exhibited lower stability (Table 8) in terms of the constancy of physico-chemical conditions in the water than other wetland types, namely swamp forest, seepage streams and the *Cyperus* swamp. A recurring pattern in both the db-RDA of faunal assemblages and RDA of habitat types was that samples from vegetated wetlands forms a large, temporally variable group, while samples from the other three habitat types form distinctly separate grouping on the plot. This suggests that stability of environmental habitats plays a part in determining faunal assemblages, but is not divorced from the effects of environmental factors. Death (1995) found that for benthic communities in

streams in New Zealand, stability was a pervading influence on community structure, but the characteristic fauna of the site still seemed to be a result of the site's intrinsic character and possibly biotic interactions rather than strictly a result of stability. Nonetheless, the concept of stability could be an important consideration in further understanding the functioning of the Eastern Shores wetlands, especially in relation to the more patchily distributed habitats such as swamp forest.

The concept of certain habitats or sites maintaining stable internal conditions while other habitats undergo changes in the character of their biotic and abiotic environment has implications for the ideas of metapopulations and refugia for aquatic organisms on the Eastern Shores. In a disturbance driven system, the relative stability or constancy of conditions within a site may become an important factor in determining aquatic faunal assemblages. Are these more stable habitats acting as refugia, or sources of colonists for the other more variable habitat patches, or do they support their own unique suite of habitat specific fauna? The limited data available for fish and the fact that fish were not recorded from either the *Cyperus* swamp or swamp forest habitats do not really allow any conclusions to be drawn about the role of such stable habitats in maintaining fish populations on the Eastern Shores. It is interesting to note however, that both of the seepage stream habitats supported small fish populations all year round, and the species occurring in one of these habitats included the Red Data listed species *Redigobius dewaali* and *Hypseleotris dayi*. It is not unreasonable to expect that similar habitats exist at other locations on the Eastern Shores. Such sites may be important for the conservation of rarer fish species. The fact that fish are obligate aquatic organisms means that they lack the dispersal ability of many facultatively aquatic or semi-aquatic organisms. In this case the stability of conditions within refugia becomes important, as fish surviving in these refugia will not be able to migrate from these sites until a physical reconnection occurs. Their survival within these patches will depend upon conditions within refugia remaining within tolerable limits. However, the importance of refugia is relative depending upon spatial and temporal scale, species adaptations and disturbance regime (Magoulick

& Kobza, 2003). A site that forms a refuge for certain species may not be at all suitable for others. This highlights the importance of heterogeneity within the system. Given the variety of responses and tolerances of aquatic organisms to disturbances such as drying out and drought, the diversity of wetland habitats needs to be maintained to allow populations to survive and recover from such disturbances.

In terms of the macroinvertebrates, it is possible to consider the habitat specificity or fidelity of various taxa encountered. The open vegetated wetlands did exhibit the highest proportion of habitat specific taxa but this may be an artefact of greater sampling effort by virtue of the fact that far more sites and taxa occur in this habitat than any of the others. In the swamp forest 43% of the 32 taxa occurring in this habitat do not occur elsewhere. Although, the swamp forest does seem to remain stable, it is unlikely to provide a good source of colonists for other, dissimilar habitats. Taxa from the stream sites were the least specific of those recorded and 93% of taxa were recorded at other sites at least half of the times that they were encountered. The low specificity of the taxa encountered in the stream habitat is somewhat surprising, as this habitat is relatively distinct from most other aquatic habitats on the Eastern Shores in that it possesses running water. The only organism encountered exclusively in this habitat was the crab *Potomonautes sidneyi*. This habitat was also poorest in terms of species richness, with a total of only 29 species occurring there. These facts indicate that although these sites apparently exhibit greater stability than those in the open wetlands, they are unlikely to play any major role as refugia for aquatic invertebrates, apart from those that occur exclusively in these habitats.

Habitats on the Eastern Shores varied, both in terms of their physical characteristics and associated assemblages of aquatic macrofauna. The aquatic faunal assemblages are also temporally dynamic, and changes in the composition of these assemblages can be observed within certain habitat types over time as well as between different habitat types. Whether or not aquatic fauna actually exist as metapopulations is difficult to assess, even though the concept does hold

a certain amount of intrinsic appeal. While it is true that organisms inhabit patches of wetland habitats within a dryland matrix, the discreteness of these patches decreases when dealing with organisms that possess good dispersal abilities, such as many of the aquatic Coleoptera and Heteroptera. Macroinvertebrate communities in smaller lentic water bodies have been considered as relatively random combinations of species and hence, unpredictably structured (Friday, 1987; Jeffries, 1989). If the Eastern Shores wetlands are considered as a collection of small lentic water bodies, then chance may be a major factor in determining which colonists are able to find and establish populations in suitable habitat. This type of lottery effect could play a role in determining initial faunal compositions of aquatic habitats, although this will not necessarily preclude the effects of other factors such as the intrinsic physical characteristics, biotic interactions or stability of a site. In the case of obligate aquatic organisms such as the fishes, a physical connection between sites will still be required for large scale dispersal and colonisation to occur. In times of particularly low water, as was experienced during this study, this physical reconnection will not occur between sites, and subsequently fish will not be able to disperse from their existing locations until water levels rise again. This implies that suitable aquatic refugia are even more important in times of drought in order to impart sufficient resilience to the system to enable it to recover from more severe perturbations. The question still remains as to where these refugia exist, especially as not all sites where water remains during dry periods will necessarily provide a suitable refuge for all aquatic organisms. They may exist as small source 'islands', scattered over the extent of the Eastern Shores or possibly as large 'mainland' sources in the form of larger waterbodies such as Lake Bhangazi South, that maintains a connection to the Eastern Shores via the Mfabeni depression. Whether or not either of these two scenarios holds true is a moot point while the wetlands remain dry and disconnected. In spite of the dramatic impacts of drought, fish, invertebrate and plant communities and assemblages seem to recover quickly from these events. Although our understanding of drought as an ecological process is still largely incomplete, drought should not be considered as a catastrophic event, but rather

an extreme and important event in the long term ecological functioning of aquatic systems (Humphries & Baldwin, 2003).

The suite of ecological processes at work in the wetlands needs to be considered in plans for management and conservation. In an area like the GSWLP, that may potentially be the focal point of much development and increased utilization, given its international status, it is important to ensure that this development does not affect the dynamics operating within the wetlands on the Eastern Shores. Road construction and increased human presence are two major ways in which humans transform landscapes (Findlay & Bourdages, 2000). It is important for any development of this nature to take place in a responsible and informed manner. This does not imply only the implementation of correct procedures such as Environmental Impact Assessments (EIA's) prior to the development, but should also include follow-up monitoring of the state of the Eastern Shores wetlands. Findlay and Bourdages (2000) found that the impacts of road construction are cumulative, and may take years, even decades to manifest themselves. In this type of situation, it is clear that a once-off EIA will not be sufficient and further long-term monitoring is essential. South Africa is a contracting party to the Ramsar Convention, and the GSLWP is a site listed as a wetland of international importance (Ramsar Convention Bureau, 2003). The Ramsar Convention advocates the idea of a holistic approach to wetland conservation and management. Encompassed within the concept holistic management of wetlands is the importance of maintaining the 'ecological character' of the wetland. Resolution VII.10 of the convention defines ecological character as "the sum of the individual biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions, and attributes". In order to maintain the ecological character of the Eastern Shores wetlands it is important to maintain both the inherent variability of the system, as well as a heterogeneous mix of habitats that vary both in their intrinsic character and hydrological regime. Given the protected area status of the GSLWP and its listing as a World Heritage site it is likely that the Eastern Shores

wetlands will remain well protected in the future, with a variety of wetland types being maintained within the boundaries of the park.

An important aspect of effective conservation is a thorough knowledge of species that occur within the area being conserved. Populations of species of conservation importance that are known or thought to occur in GSLWP include 48 species listed as internationally threatened, 161 that are threatened in South Africa, and 147 species that are listed in various categories of risk by CITES list. Studies on the larger and more charismatic species like the black rhino and sea turtles are ongoing, the current status and viability of populations of the majority of the species on the list, particularly the lower vertebrates (fish and amphibians) and invertebrates is largely unknown.⁶ There is a need to update this information, and extend studies to include these less charismatic taxa. Smaller wetland fauna are often neglected or overlooked, by the public as well as conservation practitioners, as illustrated by a passage quoted by Bruton (1995)

"The common perception of all small non-game fishes as 'minnows' and their existence in environments where few persons ever see them makes it difficult to muster public support for their conservation. In conflicts over development of increasingly valuable water resources, the fishes have few advocates." (Andrew L. Sheldon, 1988 quoted in Bruton, 1995)

Although Sheldon refers specifically to fishes, the idea is equally, or perhaps even more relevant to other wetland taxa such as the aquatic macroinvertebrates. Public awareness and participation in conservation issues can greatly assist in the protection of areas and species considered to be of importance to conservation. This was well illustrated by the decision not to mine the coastal dunes at St Lucia following an extensive EIA of the proposed mining and public participation in the final recommendation to the South African government not to mine the dunes (Kruger *et al.*, 1997). To fulfill the requirements of the World Heritage Convention and maintain the biological integrity of the GSLWP a more complete knowledge of

⁶ Wildlands Trust. 2002. Unpublished project proposal for Rare and Threatened Species Project for the GSLWP.

both the functioning of the Eastern Shores wetlands as well as the taxa present in the system is required. In order to achieve this goal, it is vital that sustained research and monitoring are incorporated into management plans for the area.

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APPENDICES

Appendix I

Appendix I. i: All fish collected in freshwater habitats on the Eastern Shores.

Taxonomic information compiled from Skelton (2001) and Froese & Pauly (2003)..... 86

Appendix II

Lists of macroinvertebrate taxa collected in Eastern Shores wetlands. Each taxon is designated as a morphospecies based upon external morphological features.

Taxonomic details are given as far as is known for each taxon, but usually at least to family level.

Appendix II. i: List of all Coleoptera collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Brinck(1955); Hansen (1999); Nilsson (2001); Pederzani (1994); Scholtz & Holm (1985) and Turner (in litt.)..... 87

Appendix II. ii: List of all Heteroptera collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Schuh & Slater (1995) and Villet & Reavell (1997)... 90

Appendix II. iii: All Odonata collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled from Pinhey, (1984, 1985)..... 91

Appendix II. iv: All other Arthropoda collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Dippenaar-Schoeman (2002); Hart, Stewart & Bickerton (2001) and Scholtz & Holm (1985)..... 92

Appendix II. v: All non-Arthropoda collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Appleton (2002) and Oosthuizen & Siddall (2002). 93

Appendix III

Lists of macroinvertebrate taxa occurring in each of the following four habitat types, swamp forest, stream habitats, *Cyperus* swamp and open vegetated wetland. Species that are unique to a particular habitat are indicated in bold type.

Appendix III. i: Invertebrate taxa collected in swamp forest habitat on the Eastern Shores between May 2002 and April 2003.	95
Appendix III. ii: Invertebrates collected in seepage stream habitat on the Eastern Shores between May 2002 and April 2003.	96
Appendix III. iii: Invertebrates collected in <i>Cyperus</i> swamp habitat on the Eastern Shores between May 2002 and April 2003.	97
Appendix III.iv: Invertebrates collected in open wetland habitat on the Eastern Shores between May 2002 and April 2003.....	99

Note: These appendices are not intended as systematic lists, merely preliminary checklists of taxa occurring in the samples taken during this study and in some specific habitats. As such, full taxonomic details for some taxa may be incomplete.

APPENDIX I

**Appendix I. i: All fish collected in freshwater habitats on the Eastern Shores.
Taxonomic information compiled from Skelton (2001) and Froese & Pauly (2003).**

Family	Scientific Name	Common name	Conservation Status/Endemic
			LR – locally rare nt – near threatened V - vulnerable E (SA) – South African Endemic E(KZN) – KwaZulu Natal endemic
Mormyridae	<i>Marcusenius macrolepidotus</i>	Bulldog	-
Anguillidae	<i>Anguilla</i> sp. Schrank, 1798	Freshwater eel	-
Cyprinidae	<i>Barbus bifrenatus</i> Fowler, 1935	Hyphen barb	-
	<i>Barbus paludinosus</i> Peters 1852	Straightfin barb	-
	<i>Barbus viviparus</i> Weber, 1897	Bowstripe barb	-
Clariidae	<i>Clarias gariepinus</i> (Burchell, 1822)	Sharptooth catfish	-
	<i>Clarias theodora</i> Weber, 1897	Snake catfish	LR
Poeciliidae	<i>Aplocheilichthys katangae</i> (Boulenger, 1912)	Striped topminnow	-
	<i>Aplocheilichthys myoposae</i> (Boulenger, 1908)	Natal topminnow	E(KZN)
Syngnathidae	<i>Microphis</i> sp. Kaup, 1853	Pipefish	-
Cichlidae	<i>Oreochromis mossambicus</i> Günther, 1889	Mozambique tilapia	-
	<i>Pseudocrenilabrus philander</i> (Weber, 1897)	Southern mouthbrooder	-
	<i>Tilapia rendalli</i> (Boulenger, 1896)	Redbreast tilapia	-
Eleotridae	<i>Tilapia sparmanii</i> A. Smith, 1840	Banded tilapia	-
	<i>Eleotris fusca</i> (Schneider, 1801)	Dusky sleeper	-
	<i>Eleotris melanosoma</i> Bleeker, 1852	Broadhead sleeper	LR/nt
Gobiidae	<i>Hypseleotris dayi</i> Smith, 1950	Golden sleeper	LR/nt, E(KZN)
	<i>Awaous aeneofuscus</i> (Peters, 1852)	Freshwater goby	-
	<i>Redigobius dewaali</i> (Weber, 1897)	Checked goby	LR/nt
Anabantidae	<i>Stenogobius polyzona</i> Bleeker, 1867)	-	-
	<i>Mugilogobius inhacae</i> (Smith, 1959)	Meander goby	-
	<i>Ctenopoma multispine</i> Peters, 1844	Manyspined climbing perch	-
	<i>Microctenopoma intermedium</i> (Pellegrin, 1920)	Blackspot climbing perch	LR

.....
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APPENDIX II

Appendix II. i: List of all Coleoptera collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Brinck(1955); Hansen (1999); Nilsson (2001); Pederzani (1994); Scholtz & Holm (1985) and Turner (in prep.).

Pseudonym	Family	Subfamily	Genus	species
Anobiid I	Anobiidae	-	-	-
Small Black Buprestid	Buprestidae	Agrilinae	-	-
Brown Carabid	Carabidae	-	-	-
Carabid Beetle II	Carabidae	-	-	-
Carabid III (Minute Brown Carabid)	Carabidae	-	-	-
Bronze Metallic Cerambycid	Cerambycidae	-	-	-
Green Metallic Cerambycid	Cerambycidae	-	-	-
Black & Yellow Chrysomelid	Chrysomelidae	-	-	-
Yellow Chrysomelid	Chrysomelidae	-	-	-
Curculionid III	Curculionidae	-	-	-
Curculionid I	Curculionidae	Bagouinae	-	-
Curculionid II	Curculionidae	Bagouinae	-	-
Dytiscid larva IV	Dytiscidae	-	-	-
Dytiscid Larva VI	Dytiscidae	-	-	-
Dytiscid Larva VII	Dytiscidae	-	-	-
Pinstripe Dytiscid	Dytiscidae	Colymbetinae	<i>Copelatus</i> Erichson 1832	<i>sylvaticus</i>
Long Goldstripe Dytiscid	Dytiscidae	Colymbetinae	<i>Rhantus</i> Dejean 1833	<i>sp.</i>
Side stripe Dytiscid	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>guignoti</i>
Cybister Larva	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>larva sp I.</i>
Cybister Larva II (Giant)	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>larva sp II.</i>
Yellow cheek Dytiscid	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>marginicollis</i>
Giant Dytiscid	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>sp.</i>
Plain Dytiscid	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>vulneratus</i>
Gold Stripe Dytiscid	Dytiscidae	Dytiscinae	<i>Aethionectes</i> Sharp 1882	<i>sp.</i>
Yellow Collar Dytiscid	Dytiscidae	Dytiscinae	<i>Hydaticus</i> Leach 1817	<i>congestus</i>
Plain Brown Hyphidrid	Dytiscidae	Hydroporinae	-	-
Tan Dytiscid	Dytiscidae	Hydroporinae	-	-
Dytiscid Larva II	Dytiscidae	Hydroporinae	-	-
Tiny Mottled Dytiscid	Dytiscidae	Hydroporinae	<i>Bidessus</i> Sharp 1882	(?) <i>octoguttatus</i>
Black Hairyback	Dytiscidae	Hydroporinae	<i>Derovatellus</i> Sharp 1882	<i>sp.</i>
Long Brown Dytiscid	Dytiscidae	Hydroporinae	<i>Derovatellus</i> Sharp 1882	<i>sp. II</i>
Small Yellowhead Dytiscid	Dytiscidae	Hydroporinae	<i>Herophydrus</i> Sharp 1882	<i>sp.</i>
Rotund Brown Dytiscid	Dytiscidae	Hydroporinae	<i>Herophydrus</i> Sharp 1882	<i>sp. II</i>
Fat Brown Dytiscid	Dytiscidae	Hydroporinae	<i>Herophydrus</i> Sharp 1882	<i>sp. III</i>
Tiny Dark Brown Dytiscid	Dytiscidae	Hydroporinae	<i>Hydovatus</i> Motschulsky 1855	<i>sp.</i>
Tiny Brown Dytiscid II	Dytiscidae	Hydroporinae	<i>Hydovatus</i> Motschulsky 1855	<i>sp. II</i>
Small Mottled Dytiscid	Dytiscidae	Hydroporinae	<i>Hyphydrus</i> Illiger 1802	<i>maculatus</i>
Fat Goldhead Dytiscid	Dytiscidae	Hydroporinae	<i>Hyphydrus</i> Illiger 1802	<i>grandis</i>
Brown 4 Spot Dytiscid	Dytiscidae	Hydroporinae	<i>Hyphydrus</i> Illiger 1802	<i>cycloides</i>
Dytiscid Larva III	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	<i>larva sp.</i>
Tiny Yellowcheek Dytiscid	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	<i>sp.</i>
Tiny yellowcollar Dytiscid	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	<i>sp. II</i>

Pseudonym	Family	Subfamily	Genus	species
Two tone Dytiscid	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. III
Small Goldstripe Dytiscid	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. IV
Tiny Goldstripe Dytiscid	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. V
Brown & Tan Noterid	Dytiscidae	Noterinae	-	-
Noterid Larva I	Dytiscidae	Noterinae	-	-
Eyespot Noterid	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	<i>notula</i>
Tiny Yellowhead Noterid	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp.
Tiny Brown Noterid	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp. II
Yellow shoulder Noterid	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp. III
Yellow Stripe Noterid	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp. IV
Black Noterid	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	(?) <i>funnebris</i>
Dytiscid Larva V	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	<i>larva</i> sp. I
Bicolour Noterid	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	sp. II
Large Brown Noterid	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	sp. III
Tiny Brown Dytiscid	Dytiscidae	Noterinae	<i>Hydrocoptus</i> Motschulsky 1853	sp.
Tiny Yellow & Tan Dytiscid	Dytiscidae	Noterinae	<i>Hydrocoptus</i> Motschulsky 1853	sp. II
Yellow Noterid	Dytiscidae	Noterinae	<i>Methles</i> Sharp 1882	sp.
Tan Noterid	Dytiscidae	Noterinae	<i>Synchortus</i> Sharp 1882	sp.
Yellow & Tan Noterid	Dytiscidae	Noterinae	<i>Synchortus</i> Sharp 1882	sp. II
Hairyback Limnichid II	Eucinetidae	-	-	-
Spiny Chrysomelid	Eumolpinae	-	-	-
Gyrinid III	Gyrinidae	-	-	-
Gyrinid Larva	Gyrinidae	-	-	-
Gyrinid Larva	Gyrinidae	-	-	-
Gyrinid I	Gyrinidae	Enhydrinae	<i>Dinuetus</i> McLeay 1825	<i>subspinosus</i> Klug 1834
Gyrinid II	Gyrinidae	Gyrininae	<i>Gyrinus</i> Linnaeus 1767	<i>natalensis</i>
Helolidae Larva	Helolidae	-	-	-
Sequinned Hydrophilid	Hydrochidae	-	<i>Hydrochus</i>	sp.
Sequinned Hydrophilid II	Hydrochidae	-	<i>Hydrochus</i> Leach 1817	sp. II
Perforated Hydrochid	Hydrochidae	-	<i>Hydrochus</i> Leach 1817	sp. III
Sequinned Hydrophilid	Hydrochidae	-	<i>Hydrochus</i> Leach 1817	sp. IV
Brown Hydrophilid II	Hydrophiloidea	-	-	-
Hydrophilid Larva I	Hydrophiloidea	-	-	-
Hydrophilid Larva II	Hydrophiloidea	-	-	-
Minute Humpback Hydrophilid	Hydrophiloidea	-	-	-
Tiny Tan Hydrophilid III	Hydrophiloidea	-	-	-
Minute Brown Hydrophilid	Hydrophiloidea	-	-	-
Shortleg Hairyback	Limnichidae	-	-	-
"Legless" Limnichid (Hairyback)	Limnichidae	Limnichidae	-	sp2
Redeye Macrovelid	Macrovelidae	-	-	-
Scarabeid I	Scarabeidae	-	-	-
Scarabeid II	Scarabeidae	Psammobiinae	<i>Rhyssemus</i> (?)	sp
Scirtid Larva	Scirtidae	-	-	-
Ant Mimicking Beetle	Scydmaenidae	-	-	-
Ant mimicking beetle II	Scydmaenidae	-	-	-
Brown Humpback Hydrophilid II (small)	Spercheidae	Berosinae	<i>Amphiops</i> Erichson 1843	sp. III
Black Humpback Hydrophilid 2	Spercheidae	Hydreophilinae	<i>Amphiops</i> Erichson 1843	sp.

Pseudonym	Family	Subfamily	Genus	species
Hydrophilid Larva III	Spercheidae	Hydrophilinae	<i>Helochares</i>	<i>larva sp. I</i>
Black Humpback Hydrophilid III	Spercheidae	Hydrophilinae	<i>Allocotocerus</i> Kraatz 1883	<i>sp.</i>
Brown Humpback Hydrophilid	Spercheidae	Hydrophilinae	<i>Amphiops</i> Erichson 1843	<i>senegalensis</i>
Tiny Olivehead Hydrophilid	Spercheidae	Hydrophilinae	<i>Anacaena</i> Thomson 1859	<i>sp.</i>
Tan Hydrophilid	Spercheidae	Hydrophilinae	<i>Berosus</i> Leach 1817	<i>sp.</i>
Tan Hydrophilid II (Dark, Striped)	Spercheidae	Hydrophilinae	<i>Berosus</i> Leach 1817	<i>sp. II</i>
Mottled Hydrophilid	Spercheidae	Hydrophilinae	<i>Berosus</i> Leach 1817	<i>sp. III</i>
Tiny Tan Hydrophilid	Spercheidae	Hydrophilinae	<i>Enochrus</i> Thomson 1859	<i>sp.</i>
Tiny Tan Hydrophilid II	Spercheidae	Hydrophilinae	<i>Enochrus</i> Thomson 1859	<i>sp. II</i>
Tiny Brown Hydrophilid II	Spercheidae	Hydrophilinae	<i>Enochrus</i> Thomson 1859	<i>sp. III</i>
Tiny Brown Hydrophilid	Spercheidae	Hydrophilinae	<i>Enochrus</i> Thomson 1859	<i>sp. IV</i>
Brown Pinstripe Hydrophilid	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	<i>sp. V</i>
Black Hinged Beetle	Spercheidae	Hydrophilinae	<i>Hydrochara</i> Berthold 1827	<i>sp.</i>
Brown Hooded Hydrophilid	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	<i>sp. II</i>
Small Black Hydrophilid	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	<i>sp. III</i>
Black Humpback Hydrophilid	Spercheidae	Hydrophilinae	<i>Régimbartia</i> Zaitsev 1908	<i>sp.</i>
Sternolophus I (Bicolour)	Spercheidae	Hydrophilinae	<i>Sternolophus</i> Solier 1834	<i>angolensis</i>
Sternolophus II (Shortspine)	Spercheidae	Hydrophilinae	<i>Sternolophus</i> Solier 1834	<i>sp. II</i>
Black Hydrophilid II	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	<i>sp.</i>
Brown Edged Hydrophilid	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	<i>sp. II</i>
Hydrophilid	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	<i>sp. III</i>
Hydrophilid II	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	<i>sp. IV</i>
Pinstriped Hydrophilid	Sphaeridiinae	Hydrophilinae	<i>Dactylosternum</i> Wollaston	<i>sp.</i>
Staphylinid III	Staphylinidae	-	-	-
Staphylinid IV (Large, Black)	Staphylinidae	-	-	-
Staphylinid V (Large Brown)	Staphylinidae	-	-	-
Staphylinid II	Staphylinidae	Aleocharinae	-	-
Staphylinid I	Staphylinidae	Steninae	-	-

Appendix II. ii: List of all Heteroptera collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Schuh & Slater (1995) and Villet & Reavell (1997).

Pseudonym	Family	Subfamily	Genus	species
Appasus sp	Belostomatidae	Lethocerinae	<i>Diplonychus</i>	<i>nepoides</i> Fabricius
Belostomatid Nymph	Belostomatidae	Lethocerinae	-	-
Giant Belostomatid	Belostomatidae	Lethocerinae	<i>Hydrocyrius</i>	<i>columbiae</i> Spinola 1852
Small Flat Belostomatid	Belostomatidae	Lethocerinae	<i>Diplonychus</i>	<i>grassei</i> Poisson 1937
Big Corixid	Corixidae	Corixinae	<i>Agraptocorixa</i> Kirkaldy	<i>sp.</i>
Corixid Nymph	Corixidae	Corixinae	-	-
Corixid Nymph II	Corixidae	Corixinae	<i>Agraptocorixa</i>	<i>swierstrai</i> Hutchinson
Micronecta scutallaris	Corixidae	Corixinae	<i>Micronecta</i>	<i>scutellaris</i> Stål 1858
Redeye Corixid	Corixidae	Corixinae	<i>Trichocorixa</i>	<i>verticalis*</i> (Fieber)
Sigara wahlbergi	Corixidae	Corixinae	<i>Sigara</i>	<i>wahlbergi</i> Lundblad 1928
Tiny Corixid	Corixidae	Corixinae	<i>Trichocorixa</i>	<i>verticalis*</i> (Fieber)
Gerrid 1	Gerridae	Gerrinae	<i>Tenagogonus</i>	<i>albovittatus</i> Stål 1853
Gerrid III	Gerridae	Gerrinae	-	-
Gerrid IV (Black Gerrid)	Gerridae	Gerrinae	-	-
Gerrid Nymph	Gerridae	Gerrinae	-	-
Limnogonus sp.	Gerridae	Gerrinae	<i>Limnogonus</i>	<i>capensis</i> Gersaeker 1873
Small Gerrid	Gerridae	Gerrinae	<i>Limnogonus</i>	<i>capensis</i> (nymph)
Hebrid I	Hebridae	-	<i>Hebrus</i> Poisson	<i>sp.</i>
Hydrometridian I	Hydrometridae	Hydrometrinae	<i>Hydrometra</i> Latreille	<i>sp.</i>
Lygaeid I (Previously Macrovelid I)	Lygaeidae	-	-	-
Lygaeid II	Lygaeidae	-	-	-
Mesovelia vittigeria	Mesovelidae	-	<i>Mesovelia</i>	<i>vittigeria</i> Horvarth 1859
Greenhead Naucorid	Naucoridae	Ambrysinae	<i>Macrocoris</i>	<i>flavicollis</i> Signoret 1861
"Cockroach" Naucorid	Naucoridae	Laccocorinae	<i>Centipocoris</i> Poisson	<i>sp.</i>
Pale Cheek Naucorid	Naucoridae	Limnocorinae	<i>Laccocoris</i> Stål 1865	<i>sp.</i>
Whitehead Naucorid	Naucoridae	Limnocorinae	<i>Laccocoris</i> Stål 1865	<i>sp.</i>
Plain Brown Naucorid	Naucoridae	Naucorinae	<i>Neomacrocoris</i>	<i>poissoni</i>
Redeye Naucorid	Naucoridae	Naucorinae	<i>Macrocoris</i>	<i>flavicollis</i> Signoret 1861
Laccotrephes sp (Nymph)	Nepidae	Nepinae	<i>Laccotrephes</i> Stål	<i>sp II</i>
Oval Nepid	Nepidae	Nepinae	<i>Laccotrephes</i>	<i>fabricii</i> Stål 1861
Slender Nepid	Nepidae	Ranatrinae	<i>Ranatra</i>	<i>grandicollis</i>
Small Ranatrid	Nepidae	Ranatrinae	<i>Ranatra</i> Signoret 1860	<i>sp. II</i>
Greenback Notonectid	Notonectidae	Anisopinae	<i>Enithares</i>	<i>transvaalensis</i> Poisson 1956
Anisops sp IV (Wide eye Anisops)	Notonectidae	Notonectinae	<i>Anisops</i> Spinola	<i>sp. IV</i>
Beaked Notonectid	Notonectidae	Notonectinae	<i>Anisops</i>	<i>sardea</i> Kirkaldy 1904
Harlequin Enithares	Notonectidae	Notonectinae	<i>Enithares</i> Stål 1855	<i>sp. V</i>
Redeye Notonectid	Notonectidae	Notonectinae	<i>Anisops</i>	<i>apicalis</i>
Silverback Notonectid	Notonectidae	Notonectinae	<i>Anisops</i>	<i>pellucens</i> Gerstaecker 1873
Greenback Bug	Pentatomatidae	Pentatomatinae	-	-
Pentomatid II	Pentatomatidae	Pentatomatinae	-	-
Large Brown Pentatomatid	Pentatomatidae	Podopinae	-	-
Pygmy Backswimmer	Pleidae	-	<i>Plea</i> Leach	<i>sp.</i>

* Allen Species

Appendix II. iii: All Odonata collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled from Pinhey, (1984, 1985)

Pseudonym	Order/Suborder	Family	Subfamily	Genus	species
Anax II	Anisoptera	Aeshnidae	-	<i>Anax</i>	?(<i>imperator</i>)
Anax imperator	Anisoptera	Aeshnidae	-	<i>Anax</i>	<i>imperator</i> Rambur 1842
Dark Anax	Anisoptera	Aeshnidae	-	<i>Anax</i> Leach 1815	<i>sp. II</i>
Light Anax	Anisoptera	Aeshnidae	-	<i>Anax</i> Leach 1815	<i>sp. IV</i>
Striped Anax	Anisoptera	Aeshnidae	-	<i>Anax</i> Leach 1815	<i>sp. III</i>
Hemicordulia sp1	Anisoptera	Corduliidae	-	<i>Hemicordulia</i> Selys 1882	<i>sp.</i>
Bradinopyga sp.	Anisoptera	Libellulidae	-	<i>Bradinopyga</i> Kirby 1893	<i>sp.</i>
Chalcostephia sp	Anisoptera	Libellulidae	-	<i>Chalcostephia</i> Kirby 1889	<i>sp.</i>
Diplacodes sp1	Anisoptera	Libellulidae	-	<i>Diplacodes</i> Kirby 1889	<i>sp.</i>
Hairy Libellulid (Orthetrum sp.)	Anisoptera	Libellulidae	-	<i>Orthetrum</i> Newman 1833	<i>sp.</i>
Indeterminate Libellulid	Anisoptera	Libellulidae	-	-	-
Indeterminate Libellulidae	Anisoptera	Libellulidae	-	-	-
Pantala sp1	Anisoptera	Libellulidae	-	<i>Pantala</i> Hagen 1861	<i>sp.</i>
Rhyothemis sp1	Anisoptera	Libellulidae	-	<i>Rhyothemis</i> Hagen 1867	<i>sp.</i>
Rhyothemis sp2	Anisoptera	Libellulidae	-	<i>Rhyothemis</i> Hagen 1867	<i>sp.</i>
Tetrathemis sp1	Anisoptera	Libellulidae	-	<i>Tetrathemis</i> Brauer 1868	<i>sp.</i>
Tholymis sp1	Anisoptera	Libellulidae	-	<i>Tholymis</i> Hagen 1867	<i>sp.</i>
Tholymis sp2	Anisoptera	Libellulidae	-	<i>Tholymis</i> Hagen 1867	<i>sp.</i>
Tramea sp1	Anisoptera	Libellulidae	-	<i>Tramea</i> Hagen	<i>sp.</i>
Acisoma sp.	Anisoptera	Libellulidae	-	<i>Acisoma</i> Rambur 1842	<i>sp.</i>
Notiothemis sp.	Anisoptera	Libellulidae	-	<i>Notiothemis</i> Ris 1919	<i>sp.</i>
Pseudagrion sp.	Zygoptera	Coenagrionidae	-	<i>Pseudagrion</i> Selys 1876	<i>sp.</i>
Ischnura sp.	Zygoptera	Coenagrionidae	-	<i>Ischnura</i> Charpentier 1840	<i>sp.</i>
Ceriagrion sp.	Zygoptera	Coenagrionidae	-	<i>Ceriagrion</i> Selys 1876	<i>sp.</i>
Agriocnemis	Zygoptera	Coenagrionidae	-	<i>Agriocnemis</i> Selys 1869	<i>sp.</i>
Enallagma	Zygoptera	Coenagrionidae	-	<i>Enallagma</i> Charpentier 1840	<i>sp.</i>
Enallagma sans zigzag	Zygoptera	Coenagrionidae	-	<i>Enallagma</i> Charpentier 1840	<i>sp. II</i>
Indeterminate Coenagrionidae	Zygoptera	Coenagrionidae	-	-	-
Lestes	Zygoptera	Lestidae	-	<i>Lestes</i> Leach 1815	<i>sp.</i>
Synlestidae	Zygoptera	Synlestidae	-	-	-

Appendix II. iv: All other Arthropoda collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Dippenaar-Schoeman (2002); Hart, Stewart & Bickerton (2001) and Scholtz & Holm (1985)

Pseudonym	Order/Suborder	Family	Subfamily	Genus	species
Hydracarines (water mites)	Hydrachnellae	-	-	-	-
Various Spiders	Araneae	-	-	-	-
Long Jawed Spider	Araneae	Tetragnathidae	-	<i>Tetragnatha</i>	sp.
Blatodea I	Blattoidea	Blatellidae	-	-	-
<i>Caridina nilotica</i>	Crustacea	Decapoda	Atyidae	<i>Caridina</i>	<i>nilotica</i> H. Milne Edwards 1837
<i>Caridina typus</i>	Crustacea	Decapoda	Atyidae	<i>Caridina</i>	<i>typus</i> Roux 1833
<i>Potomonautes sidneyi</i>	Crustacea	Decapoda	Potomonautidae	<i>Potomonautes</i>	<i>sidneyi</i> Rathbun 1904
Isopod I	Crustacea	Isopoda	-	<i>Talorchestia(?)</i>	sp
Ceratopogonid Larva	Diptera	Ceratopogonidae	-	-	-
Chironomid Larva	Diptera	Chironomidae	-	-	-
Culicid Larva	Diptera	Culicidae	-	-	-
Culicid Larva and Pupa	Diptera	Culicidae	-	-	-
Tabanid Larva	Diptera	Tabanidae	-	-	-
Baetid Larva	Ephemeroptera	Baetidae	-	-	-
Caenid Larva	Ephemeroptera	Caenidae	-	-	-
Aphids	Homoptera	Aphidae	Drepanosiphonae	-	-
Black & White Cicadellid	Homoptera	Cicadellidae	-	-	-
Cicadellid 1	Homoptera	Cicadellidae	-	-	-
Cicadellid 2	Homoptera	Cicadellidae	-	-	-
Delphacid I	Homoptera	Delphacidae	-	-	-
Delphacid II	Homoptera	Delphacidae	-	-	-
Ants	Hymenoptera	Formicidae	-	-	-
Lepidoptera I	Lepidoptera	-	-	-	-
Tettogoniid I (Bush Cricket)	Orthoptera	Tettigoniidae	-	-	-

Appendix II. v: All non-Arthropoda collected in freshwater habitats on the Eastern Shores between May 2002 and April 2003. Taxonomic information compiled in part from Appleton (2002) and Oosthuizen & Siddall (2002).

Pseudonym	Order/Suborder	Family	Subfamily	Genus	species
Annelid Worms	Annelida	Oligochaeta	-	-	-
Hirudinae I (Large, Striped)	Hirudinea	Hirudinidae	-	<i>Aliolimnatus</i>	<i>sp.</i>
Hirudinae II (Small)	Hirudinea	Hirudinidae	-	-	-
Aquatic Snail I *	Pulmonata	Physidae	-	<i>Aplexa</i>	<i>marmorata</i> (Guilding, 1828)
Aquatic Snail IV	Pulmonata	-	-	-	-
Aquatic Snail II	Pulmonata	Physidae	-	<i>Aplexa</i>	<i>marmorata</i> (Guilding, 1828)
Aquatic Snail V	Pulmonata	Planorbidae	-	-	-
<i>Bulinus forskali</i>	Pulmonata	Planorbidae	-	<i>Bulinus</i>	<i>forskali</i> (Ehrenberg 1831)
<i>Bulinus tropicus</i>	Pulmonata	Planorbidae	-	<i>Bulinus</i>	<i>tropicus</i> (Krauss, 1848)
<i>Oxyloma patentissima</i>	Pulmonata	Succineidae	-	<i>Oxyloma</i>	<i>patentissima</i> (Pfeiffer, 1853)

* Allen Species

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References - Appendix II

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APPENDIX III

Appendix III. i: Invertebrate taxa collected in swamp forest habitat on the Eastern Shores between May 2002 and April 2003.

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ.	Rank Abun.	Preference (%)
Black Humpback Hydrophilid II	Coleoptera	Spercheidae	Hydrophilinae	<i>Amphiops</i> Erichson 1843	sp.	1	5	100
Hairy Libellulid	Anisoptera	Libellulidae	-	<i>Orthetrum</i> Newman 1833	sp.	1	6	50
Scirtid Larva	Coleoptera	Scirtidae	-	-	-	1	8	55
Yellow Collar Dytiscid	Coleoptera	Dytiscidae	Dytiscinae	<i>Hydaticus</i> Leach 1817	sp.	4	1	100
Gerrid III	Heteroptera	Gerridae	Gerrinae	-	-	4	4	100
Gerrid I	Heteroptera	Gerridae	Gerrinae	<i>Tenagogonus</i> <i>Aethionectes</i> Sharp 1882	<i>Stål</i> 1853	4	6	67
Gold Stripe Dytiscid	Coleoptera	Dytiscidae	Hydaticinae	-	sp.	4	10	50
Chironomid Larva	Diptera	Chironomidae	-	-	-	8	3	43
Tiny Yellowcheek Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp.	8	13	100
Pinstripe Dytiscid	Coleoptera	Dytiscidae	Colymbetinae	<i>Copelatus</i> Erichson 1832	<i>syvaticus</i>	10	9	100
Sternolophus III (Bicolour)	Coleoptera	Spercheidae	Hydrophilinae	<i>Sternolophus</i> Solier 1834	<i>angolensis</i>	10	10	100
Black Hinged Beetle	Coleoptera	Spercheidae	Hydrophilinae	<i>Hydrochara</i> Berthold 1827	sp.	10	12	50
Small Ranatrid	Heteroptera	Nepidae	Ranatrinae	<i>Ranatra</i> Signoret 1860	sp. II	10	13	100
Culicid Larva and Pupa	Diptera	Culicidae	-	-	-	10	16	29
Tan Hydrophilid II	Coleoptera	Spercheidae	Hydrophilinae	<i>Berosus</i> Leach 1817	sp.	10	16	50
Sternolophus II (Shortspine)	Coleoptera	Spercheidae	Hydrophilinae	<i>Sternolophus</i> Solier 1834	sp. II	16	2	100
Brown Pinstripe Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	sp. V	16	13	100
Anisops sp IV (Wide eye Anisops)	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i> Hutchinson	sp. IV	16	16	17
Gerrid Nymph	Heteroptera	Gerridae	Gerrinae	-	-	16	16	100
Plain Brown Naucorid	Heteroptera	Naucoridae	Naucorinae	<i>Neomacrocoris</i> <i>Anisops</i> Hutchinson	<i>poissoni</i>	16	16	33
Redeye Notonectid	Heteroptera	Notonectidae	Notonectinae	<i>apicalis</i>		16	16	17
Small Yellowhead Dytiscid	Coleoptera	Dytiscidae	Hyhydrinae	<i>Herophydrus</i> Sharp 1882	sp.	16	16	50
Ants	Hymenoptera	Formicidae	-	-	-	16	23	50
Black Noterid 1	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	(?) <i>funnebris</i>	16	23	14
Brown Hooded Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	sp. II	16	23	17
Ceratopogonid Larva	Diptera	Ceratopogonidae	-	-	-	16	23	100
Gold Stripe Dytiscid	Coleoptera	Dytiscidae	Dytiscinae	<i>Aethionectes</i> Sharp 1882	sp.	16	23	50
Hydrometridian I	Heteroptera	Hydrometridae	-	<i>Hydrometra</i> Stål 1855	sp.	16	23	100
Hydrophilid Larva I	Coleoptera	Hydrophiloidea	-	-	-	16	23	100
Hydrophilid Larva II	Coleoptera	Hydrophiloidea	-	-	-	16	23	50
Noterid Larva I	Coleoptera	Dytiscidae	Noterinae	-	-	16	23	50
Tiny Brown Dytiscid	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocoptus</i> Motschulsky 1853	sp.	16	23	100

Appendix III. ii: Invertebrates collected in seepage stream habitat on the Eastern Shores between May 2002 and April 2003.

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ.	Rank Abun.	Preference
Potomonautes sidneyi	Crustacea	Decapoda	Potomonauidae	Potomonautes	sidneyi Rathbun 1904	1	4	100
Hairy Libellulid	Anisoptera	Libellulidae	-	Orthetrum	Newman 1833	2	6	10
Limnogonus sp.	Heteroptera	Gerridae	Gerrinae	Limnogonus	capensis Gersaeker 1873	3	7	67
Gerrid 1	Heteroptera	Gerridae	Gerrinae	Tenagogonus	albovittatus Stål 1853	3	9	29
Redeye Notonectid	Heteroptera	Notonectidae	Notonectinae	Anisops	apicalis Hutchinson	3	10	6
Aphids	Homoptera	Aphidae	Drepanosiphonae	-	-	6	1	50
Striped Anax	Anisoptera	Aeshnidae	-	Anax Leach 1815	sp. III	6	2	6
Mesovelia vittigeria	Heteroptera	Mesovelidae	-	Mesovelia	vittigeria Horwarth 1859	6	3	6
Indeterminate Coenagrionidae	Zygoptera	Coenagrionidae	-	-	-	6	4	7
Light Anax	Anisoptera	Aeshnidae	-	Anax Leach 1815	sp. IV	6	8	8
Anax imperator	Anisoptera	Aeshnidae	-	Anax	imperator Rambur 1842	6	10	6
Brown Humpback Hydrophilid	Coleoptera	Spercheidae	Berosinae	Amphiops	sp. III Erichson 1843	6	10	4
Culcid Larva and Pupa	Diptera	Culicidae	-	-	-	6	10	6
Dark Anax	Anisoptera	Aeshnidae	-	Anax Leach 1815	sp. II	6	10	6
Indeterminate Libellulidae	Anisoptera	Libellulidae	-	-	-	6	15	17
Tiny Tan Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	Enochrus	Thomson 1859	6	15	6
Acisoma sp.	Anisoptera	Libellulidae	-	Acisoma Rambur	sp. 1842	6	17	17
Ants	Hymenoptera	Formicidae	-	-	-	6	17	13
Baetid Larva	Ephemeroptera	Baetidae	-	-	-	6	17	3
Beaked Notonectid	Heteroptera	Notonectidae	Notonectinae	Anisops	sardea Kirkaldy 1904	6	17	5
Black Hinged Beetle	Coleoptera	Spercheidae	Hydrophilinae	Hydrochara	Berthold 1827	6	17	14
Brown Hooded Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	Helochares	Mulsant 1844	6	17	6
Caenid Larva	Ephemeroptera	Caenidae	-	-	-	6	17	50
Greenhead Naucorid	Heteroptera	Naucoridae	Ambrysinae	Macrocoris	flavicollis Signoret 1861	6	17	3
Rhyothemis sp1	Anisoptera	Libellulidae	-	Rhyothemis	Hagen 1867	6	17	17
Small Black Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	Helochares	-	6	17	14
Small Gerrid (nymph)	Heteroptera	Gerridae	Gerrinae	Limnogonus	capensis Gersaeker 1873	6	17	50
Tiny Brown Hydrophilid II	Coleoptera	Spercheidae	Hydrophilinae	Enochrus	Thomson 1859	6	17	50
Tiny Tan Hydrophilid II	Coleoptera	Spercheidae	Hydrophilinae	Enochrus	Thomson 1859	6	17	25

Appendix III. iii: Invertebrates collected in *Cyperus* swamp habitat on the Eastern Shores between May 2002 and April 2003.

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ.	Rank Abun	Preference
Delphacid I	Homoptera	Delphacidae	-	-	-	1	1	57
Hydrophilid 1	Coleoptera	Sphaeriinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	<i>sp. III</i>	1	9	44
Various Spiders	Arachnidae	-	-	-	-	3	2	18
Ants	Hymenoptera	Formicidae	-	-	-	3	3	38
Isopod I	Crustacea	Isopoda	-	<i>Talorchestia</i>	<i>sp.</i>	3	3	33
Scirtid Larva	Coleoptera	Scirtidae	-	-	-	3	12	18
Lygaeid I	Heteroptera	Lygaeidae	-	-	-	3	16	100
Brown Hooded Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	<i>sp. II</i>	3	21	19
Greenback Bug	Heteroptera	Pentatomatidae	Pentatomatinae	-	-	9	5	67
Tiny Brown Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	<i>sp. II</i>	9	5	6
Yellow & Tan Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocoptus</i> Motschulsky 1853	<i>sp. II</i>	9	7	40
Brown Hydrophilid II	Coleoptera	Hydrophiloidea	-	-	-	9	8	100
Blattoidea	Blattoidea	Blatellidae	-	-	-	9	9	100
Yellow Chrysomelid	Coleoptera	Chrysomelidae	-	-	-	9	11	100
Lepidopteran	Lepidoptera	-	-	-	-	9	13	50
Curculionid 1	Coleoptera	Curculionidae	Bagouinae	-	-	9	15	50
Brown Humpback Hydrophilid	Coleoptera	Spercheidae	Berosinae	<i>Amphiops</i> Erichson 1843	<i>sp. III</i>	9	16	7
Large Brown Pentatomatid	Heteroptera	Pentatomatidae	Podopinae	-	-	9	16	67
Fat Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Herophydrus</i> Sharp 1882	<i>sp. III</i>	9	24	10
Pinstriped Hydrophilid	Coleoptera	Sphaeriinae	Hydrophilinae	<i>Dactylosternum</i> Wollaston	<i>sp.</i>	9	24	100
Staphylinid I	Coleoptera	Staphylinidae	Steninae	-	-	9	24	67
Tiny Yellowcheek Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	<i>sp.</i>	9	24	33
Black Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	<i>(?)funebris</i>	9	30	9
Hydrometridian I	Heteroptera	Hydrometridae	-	<i>Hydrometra</i> Stål 1855	<i>sp.</i>	9	30	67
Silverback Notonectid	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i>	<i>pellucens</i> Gerstaecker 1873	9	30	4
Staphylinid II	Coleoptera	Staphylinidae	Aleocharinae	-	-	9	30	100
Tiny Tan Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Enochrus</i> Thomson 1859	<i>sp.</i>	9	30	13
Small Black Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	<i>sp. III</i>	28	14	14
"Cockroach" Naucorid	Heteroptera	Naucoridae	Laccocorinae	<i>Centipocoris</i> Poisson	<i>sp. nov.</i>	28	16	25
Culicid Larva and Pupa	Diptera	Culicidae	-	-	-	28	16	6
Brown Carabid	Coleoptera	Carabidae	-	-	-	28	21	50
Synlestidae	Zygotera	Synlestidae	-	-	-	28	21	11
Minute Brown Hydrophilid	Coleoptera	Hydrophiloidea	-	-	-	28	24	50
Small Mottled Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hyphydrus</i> Illiger 1802	<i>maculatus</i>	28	24	6

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ.	Rank Abun	Preference
Anax II	Anisoptera	Aeshnidae	-	<i>Anax</i>	<i>imperator</i> Rambur 1842	28	30	20
Appasus sp	Heteroptera	Belostomatidae	Lethocerinae	<i>Diplonychus</i>	<i>nepoides</i> Fabricius	28	30	5
Aquatic Snail V	Pulmonata	Planorbidae	-	-	-	28	30	17
Brown Edged Hydrophilid	Coleoptera	Sphaeriinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	<i>sp. II</i>	28	30	25
Carabid III	Coleoptera	Carabidae	-	-	-	28	30	100
Hairy Libellulid	Anisoptera	Libellulidae	-	<i>Orthetrum</i> Newman 1833	<i>sp.</i>	28	30	3
Lygaeid II	Heteroptera	Lygaeidae	-	-	-	28	30	100
Minute Humpback Hydrophilid	Coleoptera	Hydrophiloidea	-	-	-	28	30	33
Scarabeid I	Coleoptera	Scarabeidae	-	-	-	28	30	100
Shortleg Hairyback	Coleoptera	Limnichidae	-	-	-	28	30	100
Small Yellowhead Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Herophydrus</i> Sharp 1882	<i>sp.</i>	28	30	10
Staphylinid V (Large Brown)	Coleoptera	Staphylinidae	-	-	-	28	30	100
Tiny Mottled Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Bidessus</i> Sharp 1882	(?) <i>octoguttatus</i>	28	30	11
Yellow Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Methles</i> Sharp 1882	<i>sp.</i>	28	30	50
Ant Mimicking Beetle	Coleoptera	Scydmaenidae	-	-	-	28	49	100
Beaked Notonectid	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i>	<i>sardea</i> Kirkaldy 1904	28	49	5
Black & Yellow Chrysolimid	Coleoptera	Chrysomelidae	-	-	-	28	49	100
Black Hairyback	Coleoptera	Dytiscidae	Hydroporinae	<i>Derovatellus</i> Sharp 1882	<i>sp.</i>	28	49	100
Carabid Beetle II	Coleoptera	Carabidae	-	-	-	28	49	33
Giant Dytiscid	Coleoptera	Dytiscidae	Cybirinae	<i>Cybister</i> Curtis 1827	<i>sp.</i>	28	49	4
Greenhead Naucorid	Heteroptera	Naucoridae	Ambrysinae	<i>Macrocoris</i>	<i>flavicollis</i> Signoret 1861	28	49	3
Hebrid I	Heteroptera	Hebridae	-	<i>Hebrus</i> Poisson	<i>sp.</i>	28	49	100
Hydracarinae	Hydrachnellae	-	-	-	-	28	49	8
Redeye Naucorid	Heteroptera	Naucoridae	Naucorinae	<i>Macrocoris</i>	<i>flavicollis</i> Signoret 1861	28	49	6
Rotund Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Herophydrus</i> Sharp 1882	<i>sp. II</i>	28	49	13
Small Black Buprestid	Coleoptera	Buprestidae	Agrilinae	-	-	28	49	33
Staphylinid III	Coleoptera	Staphylinidae	-	-	-	28	49	100
Staphylinid IV (Large, Black)	Coleoptera	Staphylinidae	-	-	-	28	49	100
Tan Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	-	-	28	49	100
Tetralthemis	Anisoptera	Libellulidae	-	<i>Tetralthemis</i> Brauer 1868	<i>sp.</i>	28	49	25
Tiny Brown Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Enochrus</i> Thomson 1859	<i>sp.</i>	28	49	11
Tiny Dark Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hydovatus</i> Motschulsky 1855	<i>sp.</i>	28	49	50

Appendix III.iv: Invertebrates collected in open wetland habitat on the Eastern Shores between May 2002 and April 2003.

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ	Rank Abu.	Preference
Anax imperator	Anisoptera	Aeshnidae	-	Anax	<i>imperator</i> Rambur 1842	24	43	82
Dark Anax	Anisoptera	Aeshnidae	-	Anax Leach 1815	sp. II	30	48	75
Light Anax	Anisoptera	Aeshnidae	-	Anax Leach 1815	sp. IV	30	47	92
Striped Anax	Anisoptera	Aeshnidae	-	Anax Leach 1815	sp. III	20	32	88
Acisoma sp.	Anisoptera	Libellulidae	-	Acisoma	sp.	61	51	83
Bradinyopyga sp.	Anisoptera	Libellulidae	-	Rambur 1842 <i>Bradinyopyga</i> Kirby 1893	sp.	52	75	100
Chalcostephia sp.	Anisoptera	Libellulidae	-	<i>Chalcostephia</i> Kirby 1889	sp.	111	112	100
Diplacodes sp.	Anisoptera	Libellulidae	-	<i>Diplacodes</i> Kirby 1889	sp.	91	55	75
Hairy Libellulid (Orthetrum sp.)	Anisoptera	Libellulidae	-	<i>Orthetrum</i> Newman 1883	sp.	8	24	77
Indeterminate Libellulid	Anisoptera	Libellulidae	-	-	-	61	35	83
Notiothemis sp.	Anisoptera	Libellulidae	-	<i>Notiothemis</i> Ris 1919	sp.	137	102	100
Pantala sp.	Anisoptera	Libellulidae	-	<i>Pantala</i> Hagen 1867	sp.	38	39	91
Rhyothemis sp.	Anisoptera	Libellulidae	-	<i>Rhyothemis</i> Hagen 1867	sp.	91	112	50
Tetrathemis sp.	Anisoptera	Libellulidae	-	<i>Tetrathemis</i> Brauer 1868	sp.	91	102	75
Tamea sp.	Anisoptera	Libellulidae	-	<i>Tamea</i> Hagen	sp.	41	17	100
Annelid Worms	Annelida	Oligochaeta	-	-	-	111	85	100
Hirudininae I (Large, Striped)	Hirudinea	Hirudinidae	-	<i>Allolimnatus</i>	sp.	91	112	75
Hirudininae II (Small)	Annelida	Hirudinidae	-	-	-	61	65	83
Hydracarinae	Hydrachnellae	-	-	-	-	33	30	91
Various Spiders	Araneae	-	-	-	-	28	60	76
Anobiid	Coleoptera	Anobiidae	-	-	-	137	152	100
Small Black Buprestid	Coleoptera	Buprestidae	Agrilinae	-	-	111	125	66
Brown Carabid	Coleoptera	Carabidae	-	-	-	137	152	50
Carabid Beetle II	Coleoptera	Carabidae	-	-	-	111	137	66
Bronze Metallic Cerambycid	Coleoptera	Cerambycidae	-	-	-	137	152	100
Green Metallic Cerambycid	Coleoptera	Cerambycidae	-	-	-	52	75	100
Spiny Chrysomelid	Coleoptera	Chrysomelidae	Eupolminae	-	-	61	75	83
Curculionid I	Coleoptera	Curculionidae	Bagouinae	-	-	111	112	50
Curculionid II	Coleoptera	Curculionidae	Bagouinae	-	-	111	137	66
Curculionid III	Coleoptera	Curculionidae	-	-	-	24	33	100
Bicolour Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	sp. II	91	125	100
Black Noterid 1	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	(?) <i>funnebris</i>	15	9	73
Brown & Tan Noterid	Coleoptera	Dytiscidae	Noterinae	-	-	137	125	100

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ	Rank Abu.	Preference
Brown 4 Spot Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hyphydrus</i> Illiger 1802	<i>cycloides</i>	137	152	100
Cybister Larva	Coleoptera	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	-	33	40	84
Dytiscid Larva II	Coleoptera	Dytiscidae	Hydroporinae	-	-	91	85	60
Dytiscid Larva III	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	-	111	97	100
Dytiscid larva IV	Coleoptera	Dytiscidae	-	-	-	79	75	100
Dytiscid Larva V	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	larva sp. I	111	85	100
Dytiscid Larva VI	Coleoptera	Dytiscidae	-	-	-	137	152	100
Dytiscid Larva VII (Tasseled Dytiscid Larva)	Coleoptera	Dytiscidae	-	-	-	137	152	100
Eyespot Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	<i>notula</i>	33	33	91
Fat Brown Dytiscid	Coleoptera	Dytiscidae	Hyphydrinae	<i>Hyphydrus</i> Illiger 1802	<i>caffer</i>	17	28	80
Giant Dytiscid	Coleoptera	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	sp.	17	40	59
Gold Stripe Dytiscid	Coleoptera	Dytiscidae	Hydaticinae	<i>Hydaticus</i> Leach 1817	sp.	43	65	72
Large Brown Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Hydrocanthus</i> Say 1825	sp. VII	91	85	100
Long Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Derovatellus</i> Sharp 1882	sp.	91	85	100
Noterid Larva I	Coleoptera	Dytiscidae	Noterinae	-	-	61	85	100
Pinstripe Dytiscid	Coleoptera	Dytiscidae	Colymbetinae	<i>Copelatus</i> Erichson 1832	<i>sylvaticus</i>	111	71	66
Plain Brown Hyphidrid	Coleoptera	Dytiscidae	Hydroporinae	-	-	137	137	100
Plain Dytiscid	Coleoptera	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>vulneratus</i>	43	63	80
Rotund Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hyphydrus</i> Illiger 1802	sp.	47	65	87
Side stripe Dytiscid	Coleoptera	Dytiscidae	Cybistrinae	<i>Cybister</i> Curtis 1827	<i>guignoti</i>	137	152	100
Small Goldstripe Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. IV	91	112	100
Small Mottled Dytiscid	Coleoptera	Dytiscidae	Hyphydrinae	<i>Hyphydrus</i> Illiger 1802	<i>maculatus</i>	38	18	58
Small Yellowhead Dytiscid	Coleoptera	Dytiscidae	Hyphydrinae	<i>Hyphydrus</i> Illiger 1802	sp. I	52	36	60
Tan Noterid	Coleoptera	Dytiscidae	Noterinae	-	-	137	152	100
Tiny Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hydrocoptus</i> Motschulsky 1855	sp.	79	112	100
Tiny Brown Dytiscid II	Coleoptera	Dytiscidae	Hydroporinae	<i>Hydovatus</i> Motschulsky 1855	sp. II	111	137	100
Tiny Brown Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp. II	1	15	88
Tiny Dark Brown Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hydovatus</i> Motschulsky 1855	sp.	137	152	50
Tiny Goldstripe Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. V	137	152	100
Tiny Mottled Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Bidessus</i> Sharp 1882	(?) <i>octoguttatus</i>	79	75	44.
Tiny Yellow & Tan Dytiscid	Coleoptera	Dytiscidae	Hydroporinae	<i>Hydrocoptus</i> Motschulsky 1855	sp. VIII	137	152	100

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ	Rank Abu.	Preference
Tiny Yellowcheek Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp.	79	102	66
Tiny yellowcollar Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. II	111	137	100
Two tone Dytiscid	Coleoptera	Dytiscidae	Laccophilinae	<i>Laccophilus</i> Leach 1815	sp. III	137	152	100
Yellow & Tan Noterid	Coleoptera	Dytiscidae	Laccophilinae	<i>Hydrocoptus</i> Motschulsky 1855	sp. II	91	112	60
Yellow cheek Dytiscid	Coleoptera	Dytiscidae	Cybirinae	<i>Cybister</i> Curtis 1827	<i>marginicollis</i>	12	27	66
Yellow Collar Dytiscid	Coleoptera	Dytiscidae	Dytiscinae	<i>Hydaticus</i> Leach 1817	sp.	61	24	55
Yellow Noterid	Coleoptera	Dytiscidae	Noterinae	-	-	137	152	50
Yellow shoulder Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp III	137	152	100
Yellow Stripe Noterid	Coleoptera	Dytiscidae	Noterinae	<i>Canthydrus</i> Sharp 1882	sp IV	137	152	100
Gyrinid I	Coleoptera	Gyrinidae	-	<i>Dinuetus</i>	<i>subspinosus</i> Klug 1834	137	152	100
Gyrinid II	Coleoptera	Gyrinidae	-	<i>Gyrinis</i> Linnaeus 1767	<i>natalensis</i>	47	48	100
Gyrinid III	Coleoptera	Gyrinidae	-	-	-	137	152	100
Gyrinid Larva	Coleoptera	Gyrinidae	-	-	-	91	112	100
Scirtid Larva	Coleoptera	Scirtidae	-	-	-	24	37	82
Black Hinged Beetle	Coleoptera	Spercheidae	Hydrophilinae	<i>Hydrochara</i> Berthold 1827	sp.	61	82	71
Black Humpback Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	-	-	61	55	100
Black Humpback Hydrophilid 2	Coleoptera	Spercheidae	Hydrophilinae	<i>Amphiops</i> Erichson 1843	sp.	41	45	90
Black Humpback Hydrophilid III	Coleoptera	Sphaeridiinae	Hydrophilinae	<i>Allocotocerus</i> Kraatz 1883	sp.	111	97	100
Black Hydrophilid II	Coleoptera	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	sp.	137	152	100
Brown Edged Hydrophilid	Coleoptera	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	sp II	111	137	50
Brown Hooded Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	sp. II	33	40	68
Brown Humpback Hydrophilid	Coleoptera	Spercheidae	Berosinae	<i>Amphiops</i> Erichson 1843	sp. III	9	19	82
Brown Humpback Hydrophilid II (small)	Coleoptera	Spercheidae	Berosinae	<i>Amphiops</i> Erichson 1843	sp. III	137	102	100
Brown Pinstripe Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i> Mulsant 1844	sp. V	137	125	100
Hydrophilid 1	Coleoptera	Sphaeridiinae	Hydrophilinae	<i>Coelostoma</i> Brullé 1835	-	111	125	22
Hydrophilid Larva I	Coleoptera	Hydrophiloidea	-	-	-	61	75	100
Hydrophilid Larva II	Coleoptera	Hydrophiloidea	-	-	-	91	102	100
Hydrophilid Larva III	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i>	larva sp. I	137	152	100
Minute Brown Hydrophilid	Coleoptera	Hydrophiloidea	-	-	-	137	112	50
Minute Humpback Hydrophilid	Coleoptera	Hydrophiloidea	-	-	-	111	112	67

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ	Rank Abu.	Preference
Mottled Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Berosus</i>	sp. III	137	152	100
Perforated Hydrochid	Coleoptera	Hydrochidae	-	<i>Hydrochus</i>	sp. III	137	112	100
Sequinned Hydrophilid II	Coleoptera	Hydrochidea	-	<i>Hydrochus</i>	sp. II	137	97	100
Sequinned Hydrophilid	Coleoptera	Hydrochidae	-	<i>Hydrochus</i>	sp. I	61	71	100
Small Black Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Helochares</i>	sp. III	137	152	14
Tan Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Berosus</i>	sp.	61	85	50
Tan Hydrophilid II (Dark, Striped)	Coleoptera	Spercheidae	Hydrophilinae	<i>Berosus</i>	sp. II	52	85	85
Tiny Brown Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Enochrus</i>	sp. IV	47	63	77
Tiny Brown Hydrophilid II	Coleoptera	Spercheidae	Hydrophilinae	<i>Enochrus</i>	sp. III	137	152	50
Tiny Olivehead Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Anacaena</i>	sp.	61	85	83
Tiny Tan Hydrophilid	Coleoptera	Spercheidae	Hydrophilinae	<i>Enochrus</i>	sp.	30	59	75
Tiny Tan Hydrophilid II	Coleoptera	Spercheidae	Hydrophilinae	<i>Enochrus</i>	sp. II	91	102	75
Tiny Tan Hydrophilid III "Legless"	Coleoptera	Hydrophiloidea	-	-	-	137	152	100
Limnichid (Hairyback)	Coleoptera	Limnichidae	Limnichidae	-	sp. II	52	82	100
Hairyback Limnichid II	Coleoptera	Eucinetidae	-	-	-	137	137	100
Redeye Macrovelid	Coleoptera	Macrovelidae	-	-	-	137	152	100
Scarabeid II	Coleoptera	Scarabeidae	Psammobiinae	<i>Rhyssemus</i>	sp.	137	152	100
Ant mimicking beetle II	Coleoptera	Scydmaenidae	-	-	-	137	152	100
Caridina nilotica	Decapoda	Atyidae	Caridinidae	<i>Caridina</i>	<i>nilotica</i>	79	45	100
Caridina typus	Decapoda	Atyidae	Caridinidae	<i>Caridina</i>	<i>typus</i>	137	137	50
Isopod I	Isopoda	-	-	<i>Talorchestia</i>	sp.	52	53	66
Ceratopogonid Larva	Diptera	Ceratopogonidae	-	-	-	111	137	100
Chironomid Larva	Diptera	Chironomidae	-	-	-	3	1	100
Culicid Larva and Pupa	Diptera	Culicidae	-	-	-	20	21	88
Tabanid Larva	Diptera	Tabanidae	-	-	-	24	31	100
Baetid Larva	Ephemeroptera	Baetidae	-	-	-	3	3	90
Caenid Larva	Ephemeroptera	Caenidae	-	-	-	137	152	50
Appasus sp	Heteroptera	Belostomatidae	Lethocerinae	<i>Diplonychus</i>	<i>nepoides</i> Fabricious	12	14	90
Belostomatid Nymph (Long, striped)	Heteroptera	Belostomatidae	Lethocerinae	-	-	137	137	100
Giant Belostomatid	Heteroptera	Belostomatidae	Lethocerinae	<i>Hydrocyrius</i>	<i>columbiae</i> Spinola 1852	47	82	58
Small Flat Belostomatid	Heteroptera	Belostomatidae	Lethocerinae	<i>Diplonychus</i>	<i>grassei</i> Poisson 1937	111	137	66
Big Corixid	Heteroptera	Corixidae	Corixinae	<i>Agraptocorixa</i>	sp.	52	71	100

Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ	Rank Abu.	Preference
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Corixid Nymph	Heteroptera	Corixidae	Corixinae	-	-	137	152	100
Corixid Nymph II	Heteroptera	Corixidae	Corixinae	<i>Agraplocorixa</i>	<i>swierstrai</i>	79	97	80
Micronecta scutellaris	Heteroptera	Corixidae	Corixinae	<i>Micronecta</i>	<i>scutellaris</i>	14	2	95
Redeye Corixid	Heteroptera	Corixidae	Corixinae	<i>Trichocorixa</i>	<i>verticalis</i> (Fieber)	137	152	50
Sigara wahlbergi	Heteroptera	Corixidae	Corixinae	<i>Sigara</i>	<i>wahlbergi</i>	38	11	83
Tiny Corixid	Heteroptera	Corixidae	Corixinae	<i>Trichocorixa</i>	<i>verticalis</i> Fieber	111	137	100
Gerrid I	Heteroptera	Gerridae	Gerrinae	<i>Tenagogonus</i>	<i>albovittatus</i>	61	55	71
Gerrid III	Heteroptera	Gerridae	Gerrinae	-	-	61	48	100
Gerrid IV (Black Gerrid)	Heteroptera	Gerridae	Gerrinae	-	-	61	102	100
Gerrid Nymph	Heteroptera	Gerridae	Gerrinae	-	-	61	85	100
Limnogonus sp.	Heteroptera	Gerridae	Gerrinae	<i>Limnogonus</i>	<i>capensis</i>	137	125	33
Small Gerrid	Heteroptera	Gerridae	Gerrinae	<i>Limnogonus</i>	<i>capensis</i> (nymph)	137	152	50
Hydrometridian I	Heteroptera	Hydrometridae	-	<i>Hydrometra</i>	sp.	137	152	33
Mesovelia vittigeria	Heteroptera	Mesoveliidae	-	<i>Mesovelia</i>	<i>vittigeria</i>	15	26	94
"Cockroach" Naucorid	Heteroptera	Naucoridae	Laccocorinae	<i>Centipocoris</i>	sp.	91	125	75
Greenhead Naucorid	Heteroptera	Naucoridae	Ambrysiniae	<i>Macrocoris</i>	<i>flavicollis</i>	9	21	71
Pale Cheek Naucorid	Heteroptera	Naucoridae	Limnocorinae	<i>Laccocoris</i>	sp.	79	71	100
Plain Brown Naucorid	Heteroptera	Naucoridae	Naucorinae	<i>Neomacrocoris</i>	<i>poissoni</i>	91	112	100
Redeye Naucorid	Heteroptera	Naucoridae	Naucorinae	<i>Macrocoris</i>	Signoret 1861	20	43	83
Whitehead Naucorid	Heteroptera	Naucoridae	Limnocorinae	<i>Laccocoris</i>	sp.	79	85	100
Slender Nepid	Heteroptera	Nepidae	Ranatrinae	<i>Ranatra</i>	<i>grandicollis</i>	79	102	1
Small Ranatrid	Heteroptera	Nepidae	Ranatrinae	<i>Ranatra</i>	sp.	47	75	100
Anisops sp IV (Wide eye Anisops)	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i>	sp. IV	1	6	90
Beaked Notonectid	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i>	<i>sardea</i>	17	23	80
Greenback Notonectid	Heteroptera	Notonectidae	Anisopinae	<i>Enithares</i>	<i>transvaalensis</i>	52	68	85
Harlequin Enithares	Heteroptera	Notonectidae	Notonectinae	<i>Enithares</i>	sp.	91	125	100
Redeye Notonectid	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i>	<i>apicalis</i>	7	8	78
Silverback Notonectid	Heteroptera	Notonectidae	Notonectinae	<i>Anisops</i>	<i>pellucens</i>	3	5	60
Greenback Bug	Heteroptera	Pentatomatidae	Pentatomatinae	-	-	137	152	33
Large Brown Pentatomatid	Heteroptera	Pentatomatidae	Podopinae	-	-	137	137	33
Pentomatid II	Heteroptera	Pentatomatidae	Pentatomatinae	-	-	137	152	50
Pygmy Backswimmer	Heteroptera	Pleidae	-	<i>Plea</i> Leach	sp.	3	12	93
Aphids	Homoptera	Aphidae	Drepanosiphonae	-	-	137	152	50
Cicadellid 1	Homoptera	Cicadellidae	-	-	-	111	53	100

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Pseudonym	Group	Family	Subfamily	Genus	species	Rank Occ	Rank Abu.	Preference
Cicadellid 2	Homoptera	Cicadellidae	-	-	-	91	102	100
Delphacid I	Homoptera	Delphacidae	-	-	-	91	102	42
Delphacid II	Homoptera	Delphacidae	-	-	-	137	152	100
Ants	Hymenoptera	Formicidae	-	-	-	79	58	50
Lepidoptera I	Lepidoptera	-	-	-	-	111	137	50
Nematode worms	Nematoda	Nematoda	-	-	-	137	125	100
Tettigoniid I (Bush Cricket)	Orthoptera	Tettigoniidae	-	-	-	79	68	100
Aquatic Snail IV	Pulmonata	-	-	-	-	111	51	100
Aquatic Snail I	Pulmonata	Physidae	-	<i>Aplexa</i>	<i>marmorata</i> (Guilding 1828)	61	68	55
Aquatic Snail V	Pulmonata	Planorbidae	-	-	-	61	10	83
<i>Oxyloma patentissima</i>	Pulmonata	Succineidae	-	<i>Oxyloma</i>	<i>patentissima</i> (Pfeiffer, 1853)	111	125	100
<i>Agriocnemis</i>	Zygoptera	Coenagrionidae	-	<i>Agriocnemis</i> Selys 1869	sp.	91	62	100
<i>Ceriagrion</i> sp.	Zygoptera	Coenagrionidae	-	<i>Ceriagrion</i> Selys 1869	sp.	111	125	100
<i>Enallagma</i>	Zygoptera	Coenagrionidae	-	<i>Enallagma</i> Charpentier 1840		43	20	80
<i>Enallagma sans zigzag</i>	Zygoptera	Coenagrionidae	-	<i>Enallagma</i> Charpentier 1840	sp. II	20	13	100
Indeterminate Coenagrionidae	Zygoptera	Coenagrionidae	-	-	-	28	4	92
<i>Ischnura</i> sp.	Zygoptera	Coenagrionidae	-	<i>Ischnura</i> Charpentier 1840	sp.	33	16	84
<i>Pseudogrion</i> sp.	Zygoptera	Coenagrionidae	-	<i>Pseudogrion</i> Selys 1876	sp.	91	125	100
<i>Lestes</i>	Zygoptera	Lestidae	-	<i>Lestes</i> Leach 1815	sp.	11	7	95
Synlestidae	Zygoptera	Synlestidae	-	-	-	52	60	66