Economic Consequences of Ecological Change: Restoration options for the Mfolozi Floodplain and implications for Lake St Lucia, South Africa

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Abstract

Lake St Lucia in northern KwaZulu-Natal, South Africa, experiences severe ecological stress during dry periods largely as a result of diminishing freshwater supplies and conditions of hypersalinity. Possible intervention involves diverting the Mfolozi River to the St Lucia Lake system. However, due to high sediment loading, water from the Mfolozi River requires considerable filtration before a link can be established. A suggested option considered in this study is to restore the existing sugarcane farmlands on the Mfolozi Floodplain (~ 20 800 ha) to previous wetland conditions to reinstate a sediment removal function amongst other benefits. Proposed restoration will have a direct impact on the industries currently supported by the iSimangaliso Wetland Park and the Mfolozi Floodplain (tourism, sugar, conservation). To understand a measure of such impacts, ecosystem services for both Lake St Lucia and the Mfolozi Floodplain were analysed (flood alleviation, water provision, water purification, sediment regulation, tourism, fisheries, vegetation for harvest, existence, cultural and research).

Annual economic values for each ecosystem service were determined by means of valuation methods that included benefit transfer and replacement cost. Results showed a current annual minimum value of the Mfolozi Floodplain and Lake St Lucia as greater than R 21 million and R 1.1 billion respectively. Partial restoration of the floodplain (~ 6000 ha) is expected to increase the sum of all ecosystem services values by approximately 26 % for the Mfolozi Floodplain and by 23 % for the St Lucia System. Full restoration (~ 20 800 ha) increases the total ecosystem services value by 88 % and 50 % for the Mfolozi Floodplain and St Lucia System respectively.

Results showed that economic values for existence, fisheries, tourism and water provision increase by the greatest percentage for the St Lucia System under both restoration scenarios. Partial and full restoration of the floodplain will result in the greatest increases in economic value for the services existence, tourism, fisheries and the harvesting of vegetation on the Mfolozi Floodplain.

Key words: Economic valuation, ecosystem services, floodplain, wetland, restoration

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Abbreviations

ARCMAP:	ArcMap 9.0 GIS Software, ESRI Suite
DWAF:	Department of Water Affairs and Forestry (Pre 2009 elections)
GGP:	Gross Geographic Product
IDP:	Integrated Development Plan
MEA:	Millennium Ecosystem Assessment
SACU:	South African Customs Union
SAfMA:	Southern African Millennium Ecosystem Assessment
UDM:	Umkhanyakude District Municipality
VEGMAP:	National Vegetation Map of Southern Africa Project (Mucina and Rutherford, 2006)

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1. Introduction

1.1 Lake St Lucia: International significance

Lake St Lucia, in northern KwaZulu-Natal, holds international recognition for its environmental uniqueness. South Africa's first World Heritage Site, the iSimangaliso (formerly known as The Greater St Lucia) Wetland Park boundaries encompass the largest estuarine system in Africa (Pillay and Perissinotto, 2009) and is recognised as a Ramsar Wetland Site.

Historically (6000BP – 1930's) the St Lucia estuary mouth was permanently open and formed the 'St Lucia Bay' (Taylor, 2006; Figure 1). In addition to precipitation and groundwater, freshwater input to the lake system was supplied by six rivers, of which the Mfolozi River contributed the greatest volume. The constant head of water at the St Lucia estuary maintained a permanently open mouth and ensured the northwards movement of suspended sediment along the coastline due to long shore drift (Lindsay *et al.*, 1996; Grenfell *et al.*, 2009). During dry periods, the mouth would close naturally and the system could rely on the water from the Mfolozi River to maintain freshwater contributions. However, freshwater supplies to Lake St Lucia have changed dramatically over the last few decades (Taylor, 2007). Major droughts, increasing agriculture and infrastructure have contributed to the altering and in some cases, decreasing of freshwater supplies to the lake.

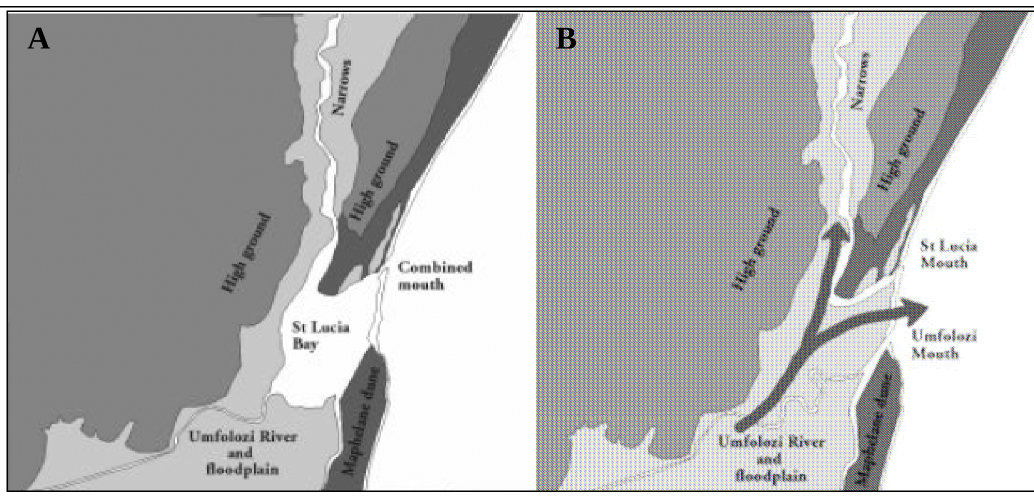

Figure 1: A: Combined St Lucia and Mfolozi mouths in the early 1900's. B: Present day situation with the Mfolozi mouth separated to the south. The arrow indicates the impact of a large flood confined to the previous St Lucia Bay area (Taylor, 2006).

1.2 Land use on the Mfolozi Floodplain

The Mfolozi Settlement, south west of Lake St Lucia was established by the South African government in the early 1900's specifically as a sugar-producing region (Lincoln, 1995). The construction of the local mill was funded by the state, which also frequently assisted farmers with flood relief, given the high-risk nature of farming conditions. The mill, still in operation today, was acquired from the state by the local sugarcane cooperative in 1923.

As sugar-farming grew more intensive, the Mfolozi River was heavily canalised and consequently flood-dissipating and filtering functions of the floodplain were largely lost (Taylor, 2006). The naturally high sediment loads of the Mfolozi River were worsened by increased erosion in the catchment, caused by growing populations and poor farming practices, which together presented a threat to the linked Lake St Lucia System (Bate and Taylor, 2007). High sediment loads are associated with conditions such as the reduction of light penetration, prevention of oxygen diffusion and impediment of vision of sight-reliant predators (Mainstone, 2008). During the 1950's, the accumulated sedimentation accelerated the closing of the combined mouths and isolated the estuaries from the ocean for longer periods of time (Taylor, 2006). Management at the time feared that sediment deposition threatened the survival of the entire lake system.

1.3 Management of the current situation

To prevent the possible collapse of the St Lucia System, a separate mouth was dredged for the Mfolozi River in 1952 (Taylor, 2006). This succeeded in reducing the unfavourably high sediment deposition rates, but also withdrew the largest volume of freshwater inflow from Lake St Lucia. Consequently, the head of water at the mouth had to be artificially maintained by means of dredging, as the previous self-scouring of the mouth was no longer possible (Taylor, 2006).

The lake system currently experiences severe ecological stress during dry periods as the water balance is dominated by high rates of evaporation from the lake, which is worsened by its shallow nature. These conditions lead to periods of extreme hypersalinities, at times reaching levels higher than 120 parts per thousand (‰), which is over three times higher than sea water (35 ‰; Taylor, 2008; Whitfield *et al.*, 2006). The drought impacted the epibenthic meofauna of the St Lucia System (Pillay and Perissinotto, 2009) and consequent hypersalinities triggered a decline in fish species diversity (Cyrus and Vivier, 2006; Taylor, 2006).

Following the Mfolozi River's diversion, Lake St Lucia has slowly been starved of freshwater inflow due to numerous pressures on the remaining five rivers. Currently, the most effective intervention involves diverting the Mfolozi River back to link with the St Lucia System, providing an additional 700 x 10^6 m^3 of freshwater annually (Whitfield *et al.*, 2006). However, to avoid the harmful effects associated with high sediment loads, the Mfolozi River water requires filtration before it can be linked to Lake St Lucia. A suggested management option would be to restore existing farmlands within the Mfolozi Floodplain to wetland condition, thereby reinstating a natural sediment removal function for the river water and providing 'cleaner' water to supply Lake St Lucia.

Although St Lucia is the most studied estuary in the country, the majority of this research was completed after the 1950's, after the Mfolozi River was diverted and the floodplain converted to agricultural lands (Whitfield and Taylor, 2009). There is thus a great demand for anticipating how both the Mfolozi Floodplain and Lake St Lucia would respond given the potential for wetland restoration of the floodplain and subsequent re-connection of the Mfolozi River to Lake St Lucia. The need for a comprehensive environmental economic assessment was recently acknowledged by Whitfield and Taylor (2009).

1.4 Aim and objectives

The aim of this study was to provide an economic valuation of the current ecosystem services provided by Lake St Lucia and the Mfolozi Floodplain and to determine the expected changes to these values brought about by possible restoration scenarios for the Mfolozi Floodplain that would allow the reintroduction of water from the Mfolozi River into Lake St Lucia.

The objectives for this study were to:

- Identify current ecosystem services present in the Lake St Lucia System and the Mfolozi Floodplain and assess monetary values of each.
- Using knowledge from specialists, determine the expected changes to ecosystem service values under the two potential restoration scenarios of the Mfolozi Floodplain, currently being considered by management (Ezemvelo KZN Wildlife/iSimangaliso Wetland Park Authority).
- Construct an empirical economic model as a framework into which data can be entered for computational purposes, thereby providing a decision-making tool for management.
- Using the model, calculate expected economic outcomes associated with restoration scenarios in the Mfolozi Floodplain and highlight potential implications for management.
- Apply methods integrating expert knowledge from ecological and economic disciplines, thereby contributing to current knowledge gaps and contributing to the field of resource economics.

Along with other relevant ethical considerations, the author acknowledges the obligation to communicate the findings of this research with the relevant stakeholders identified in this thesis.

This thesis contributes to the knowledge of the expected economic outcomes of possible land use change within the Mfolozi Floodplain, an issue that has been suspected for over a decade to be a ‘saviour’ of the St Lucia System. This resource economics study, addressing the practical freshwater issue of the Lake St Lucia System using an integrated ecological/economic approach, is a first of its kind.

2. Theoretical Framework

It is essential to address existing interactions between economic, social and ecological sectors in order to anticipate consequences of land use change such as the restoration initiative in this study. Given the range of ecological and economic measures involved in this study, an interdisciplinary approach was required, including the application of empirical modelling. This was accompanied by the accumulation of data sets for model input in order to address the outcomes of different land use options for the floodplain. Furthermore, due to the broad scope of impacts and the number of industries affected by this freshwater management issue (sugarcane, tourism, conservation and fisheries), several themes were raised. These were broadly: Wetland restoration, Empirical modelling and Ecological economics.

2.1 Wetland restoration

Due to a greater awareness of global climate change and environmental degradation, efforts to restore natural systems for their benefits to society are increasing. 'Ecological restoration' is the process of returning ecosystem structure and function to its former natural state and, in most cases, to that prior to anthropogenic interference (Grenfell *et al.*, 2007). With respect to wetlands, restoration has been regarded as the reinstating of natural ecological driving forces in order to 'recover former or desired ecosystem structure, function, biotic composition and/or ecosystem services' (Grenfell *et al.*, 2007). Both intricate and dynamic, wetlands are recognised as some of the world's most productive environments (Lamberth, 2003) providing services such as nutrient storage and cycling, catchment-level sediment retention, shoreline stabilisation and erosion control, flood abatement, water storage and purification, retention of pollutants, groundwater recharge and discharge and biodiversity maintenance (Daniels and Cumming, 2008, Moreno *et al.*, 2007, Smith *et al.*, 2007, Stern *et al*., 2007, Lambert, 2003, Turner *et al.*, 2000).

However, wetlands have been identified as the most threatened of all ecosystem types by the Millennium Ecosystem Assessment (Smith *et al.*, 2007). Faced with the reality of global climate change, implications for wetlands pertain largely to the hydrology of these systems (Erwin, 2009). Wetlands, currently covering 6 % of the world's surface, and about 7 % of South Africa's surface area, are expected to be affected mostly through changes in precipitation and temperature regimes. Many universities, NGO's, corporate partnerships and other institutions are heavily involved in wetland restoration projects. Examples of such initiatives include; the Severn and Avon Vales Wetlands Partnership (SAVWP) in the UK, the Massachusetts Wetland Restoration Program and Giacomini Wetland Restoration Project (US National Park Service, 2009) in the USA, and the South African Working for Wetlands Programme in South Africa. As wetland conservation is becoming more of a concern, new incentives are being developed to support this activity. Entrepreneurial Wetland Banking is one such initiative, involving the purchasing of wetland 'credits' in a manner that is similar to the carbon credit market (Robertson, 2009).

As with the desired sediment retention function from a restored Mfolozi wetland system in this study, it is often the benefits of a specific ecosystem function that will motivate a restoration initiative. For example, hypoxic conditions in the Gulf of Mexico require the reduction of nitrogen loads in the Mississippi-Ohio-Missouri basin (Mitsch and Day, 2006). Since wetlands provide this function, Mitsch and Day (2006) estimated that for the removal of 40 % of the total nitrogen discharge to the Gulf of Mexico, 2.2 million ha of wetlands would need to be created or restored within the catchment. Along with nitrogen reduction, other benefits were then expected for the public health sector through improved water quality, habitat restoration, flood control and increased protection of agriculture in the catchment (Mitsch and Day, 2006). Fennessy *et al.* (1994) reported the retention of 80 % of total suspended solids in constructed wetlands in Florida over a period of eight years and also mention the retention of 55 % of the annual sediment inflow during a drought year by a wetland bordering Lake Erie. Moreno *et al.* (2007) looked at wetland capability for improving water quality in degraded agricultural lands in Spain. It was found that wetland restoration resulted in 24-43 % total nitrogen removal from agricultural wastewater, leading to recommendations to re-establish specific areas of wetland within the total watershed for effective nitrogen removal (Moreno *et al.*, 2007).

Restored wetlands are reported to have the potential to re-establish previous ecosystem services (Cui *et al.*, 2009; Moreno *et al.*, 2007; Mitsch and Day, 2006; Coveney *et al.*, 2002). Improvements in physical and soil chemical conditions following the Yellow River Delta Restoration Programme in China triggered the re-colonisation of aquatic plant species, along with the improvement of nutrient retention and in re-colonisation by a range of formerly locally extinct species (Cui *et al.*, 2009). For this research, it is assumed that the proposed wetland restoration of the Mfolozi Floodplain will result in the re-establishment of natural wetland habitats and ecosystem services.

2.2 Empirical modelling

Ramifications of the restoration initiative proposed in this study extend over a number of industries and required analyses that span both ecological and economic boundaries. Empirical modelling is an effective analytical tool for addressing such interdisciplinary studies. By attempting to understand complex natural, social or economic systems, simulation modelling integrates 'theoretical and empirical analyses' resulting in the ability to forecast various outcomes (Riebsame *et al.*, 1994). It is therefore specifically beneficial for decision makers or managers of natural systems in providing a tool with a range of software available. Examples of appropriate modelling tools and software include Powersim, Extend, Simulink, Vensim and Stella (Costanza and Voinov, 2001).

The demand for integrated environmental management that addresses the choice between alternative land uses preceded the use of modelling in this study. An example similar to this study that involved consideration of the impact of land use change, is the Ecosystem Landscape Modelling System (ELMS) in Rocky Mountain West, which was used to determine future effects of land use change on economic growth and development (Prato, 2005). With the use of remote sensing to complement foundational data, Prato's (2005) study utilised Markovian transition probabilities to assess outcomes, specifically 'trade-offs between economic and ecological values of future growth and development'. Riebsame *et al.* (1994) linked existing simulation models and modified certain 'socio-cultural behaviours and ecosystem responses' for the simulation modelling of agricultural land use and land cover change.

Notwithstanding the capabilities of modern research, difficulty exists in bridging the gap between disciplines to include intrinsically different information such as ecological and economic data in the same model, and often results in 'compromising or simplifying' essential data (Turner *et al.*, 2000). This is evident in the challenge of defining relationships between chosen variables in a model. Eco-tourism is an example where environmental, social and economic systems meet, and has been modelled in a number of studies (Lacitignola *et al.*, 2007, Wunder, 2000, Chopra *et al.*, 2004). A dynamic model of tourism in The Commonwealth of Dominica is an example of a 'whole-systems' assessment approach to model construction, and provides a framework to which new data can be included for evaluating development alternatives (Figure 2; Patterson *et al.*, 2004). Social, economic and ecological variables were coupled to produce model inputs that would 'bridge the gap' between these disciplines. For example, a value for a sense of place (Figure 2) is the product of the interaction of a social system with an ecological system. Export agriculture is an example of where the environment interacts directly with the economy. Place-based tourism however, is shown as an interaction between all three sectors.

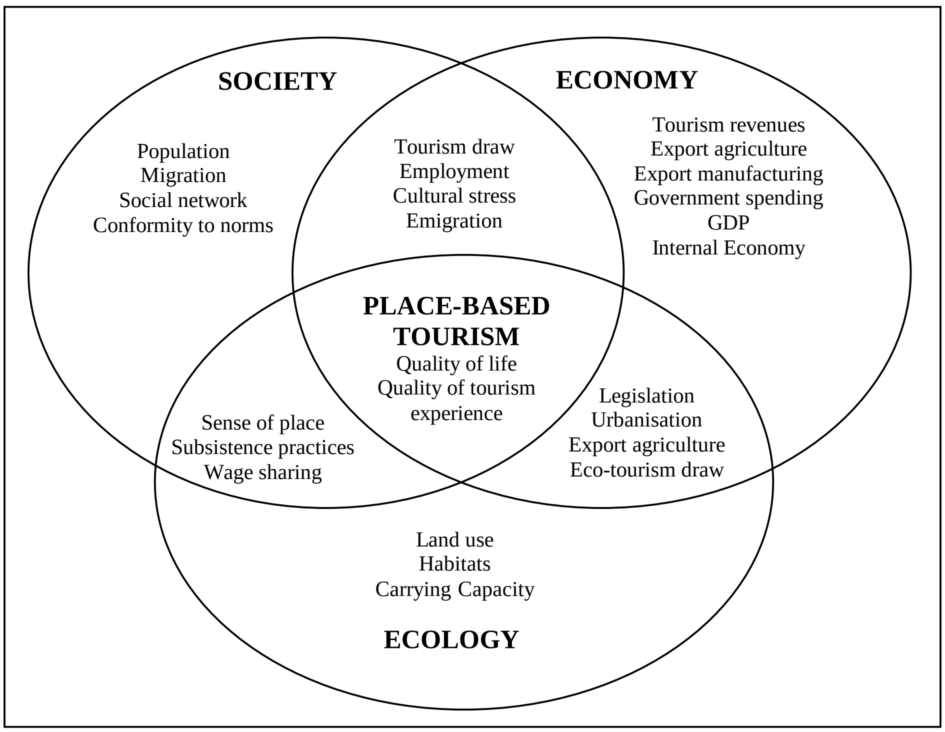

Figure 2: Diagram of economic, ecological and social factors of eco-tourism adapted from Patterson *et al.* (2004).

In the study of Patterson *et al.* (2004), quantitative measures representing the influences between variables were determined in order to illustrate relationships between existing data. For example, the model simulated a decrease in coral population as the tourist population increased (Patterson *et al.*, 2004). Model outputs allowed for conclusions regarding government spending, internal economy and planning, such as development alternatives.

Lynne *et al.* (1981) modelled ecological-economic data for coastal zone areas on the Gulf Coast of Florida in the United States to determine the relationship between natural marsh-estuarine habitats and the production of marketable marine life. Results of the study suggested that the 'availability' of marsh-estuarine systems influenced the 'marginal product of man induced fishing effort' (Lynne *et al.*, 1981). A similar study concerned mangrove-fishery linkages, investigating the effect mangrove area had on open access fisheries in Thailand (Barbier *et al.*, 2002). In this last study, bio-economic fishery models responded to changes that supported mangrove habitats, assuming that mangrove area would influence fish stocks and therefore impact on the fisheries. The research by Barbier *et al.* (2002) was valuable for fisheries management and highlighted the importance of a natural system supporting an economic activity, a situation similar to the contribution of Lake St Lucia to South African national fish stocks.

Due to the complexity of natural systems and their non-linear responses to anthropogenic influences, one should not expect rigid answers to targeted questions. However, as Costanza and Voinov (2001) explain, models should be seen as 'a synthesis of existing information and guides to direct future work'. A key component in model design is establishing what data are required for input values. In this study monetary values for ecosystem services were approximated to provide input values for the model. Although often debated and cautiously approached, there are a number of methods of 'environmental valuation', which form 'the basis of most resource-economics research' (Turpie, 2007). Bridging this gap between the disciplines of ecology and economics has given rise to the study of ecological economics.

2.3 Ecological economics

2.3.1 Valuation of ecosystem services

Biological diversity has been regarded as essential for human survival (Edwards and Abivardi, 1998) and is argued to be of infinite value to economies (Costanza *et al.*, 1998). However, despite the enormity of the task in defining this value, studies greatly benefited ecosystem management from local to national scales, mainly because the contribution of natural systems to human support has been recognised. Monetary valuation of ecosystem services provides 'traction in the decision making process' particularly with policy agents and scientists (Fisher *et al.*, 2008). For example, economic analyses coupled with scenario-based planning provided a method relevant to stakeholders in determining the consequences (the costs and benefits) of potential land use changes or development options (Turpie, 2007). Prior to the concept of environmental valuation or in cases where valuation has not occurred, environmental systems are deemed unimportant to policy and decision makers (Edwards and Abivardi, 1998), resulting in degradation and destruction. The benefits derived from natural resources have been identified and critically examined since the mid-1960's (De Groot *et al.*, 2002). Classifications of these ecosystem goods and services (from this point forward referred to as "ecosystem services") are highlighted in the literature (MEA, 2003; De Groot *et al.*, 2002), as are numerous studies calculating the economic values of these services (Chen *et al.*, 2009; Tong *et al.*, 2007; Hein *et al.*, 2006; Kroeger, 2005; Turpie *et al.*, 1999; Edwards and Abivardi, 1998; Costanza *et al.*, 1998; Hanemann, 1994). As this research has expanded, it has led to the establishment of online databases such as Environmental Valuation Reference Inventory, Envalue, and the Ecosystem Services Database (McComb *et al.*, 2006). Information can be drawn from primary studies acting as a quick reference alternative to performing full-scale valuation studies, and in some databases such information may be accessed at no cost (McComb *et al.*, 2006).

A number of environmental economic studies address the total economic value (TEV) of a system. This value can be determined from the summation of a system's use values and non-use values (Figure 3). Use values include direct use values such as harvesting of resources, indirect or ecological function values such as flood control, and option value such as future drugs. Non-use values include existence values, that place importance based purely on the presence of a system, and bequest value, which considers future significance (Edwards and Abivardi, 1997).

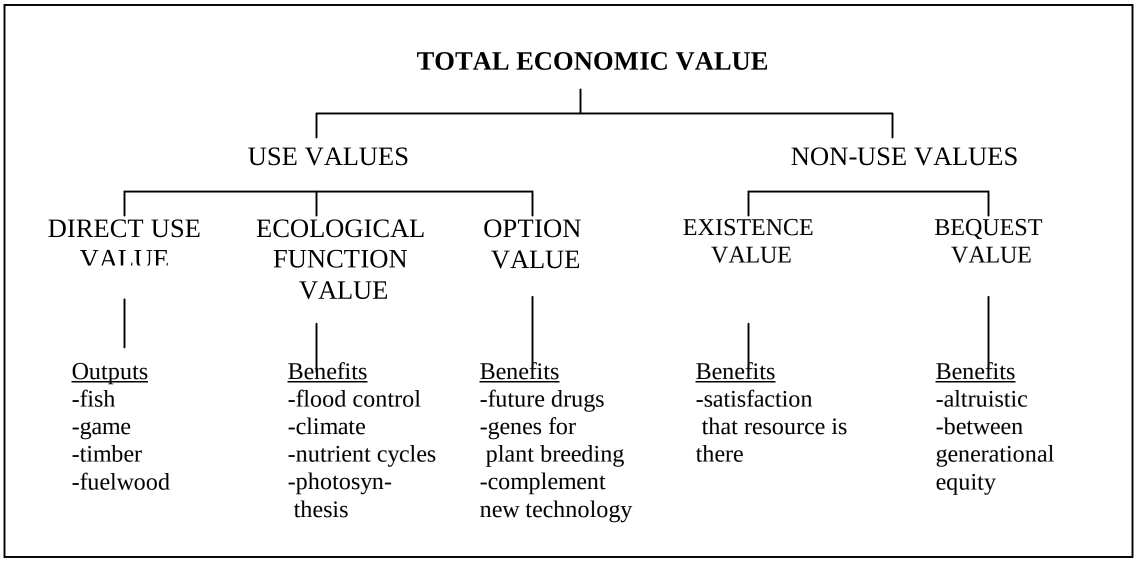

Figure 3: Classification of total economic value (Edwards and Abivardi, 1997; Turpie and Lannas, 2007).

2.3.2 Valuation methods

A number of valuation methods have arisen in this area of research. Contingent valuation, group valuation, indirect market valuation and direct market valuation are broad categories of these methods (De Groot *et al.*, 2002). Contingent valuation involves asking informants to provide a monetary value for their willingness to pay (WTP) for a certain resource or for its improvement (Hanemann, 1994, Shultz *et al.*, 1998). In a similar approach, questionnaires or surveys record people's willingness to accept (WTA) compensation for the loss of a particular resource (De Groot *et al.*, 2002; Edwards and Abivardi, 1998). Group valuation creates opportunities for open public debate regarding values of ecosystems (De Groot *et al.*, 2002). Indirect market valuation includes Benefits Transfer, where values assigned to an ecosystem have been calculated from another comparable study site (van Bueren and Bennett, 2004) and Replacement Costs, where the costs of alternative provision of the specific service are considered (Turpie et al, 1999). Methods such as Travel Cost, Factor Income and Hedonic Pricing are other examples of indirect market valuation. Direct market valuation involves traded natural 'goods' that have an existing market value. Alternatively, a number of models have been designed for valuation purposes, particularly for non-market goods (Kaiser and Roumasset, 2002). However, many studies, such as Beaumont *et al.* (2008), utilise more than one valuation method for a particular site.

Natural resource valuation is influenced by a number of factors. The integrity of ecosystem functioning, its complexity, the diversity and rarity of a particular site, will all influence ecological valuation (De Groot *et al.*, 2002). Other important influences include spatial and temporal scales of ecosystem services, their landscape setting (Mitsch and Gosselink, 2000), as well as the presence or absence of stakeholders, namely those who 'can affect or be affected by the ecosystem's services' (Hein *et al.*, 2006). Social influences of valuation include a society's perceptions and values (De Groot *et al.*, 2002), cultural specific biases (Shultz *et al.*, 1998), and the levels of education of those responding. Turpie (2003) examined how interest, experience, knowledge, income and perceived level of threat all influence local willingness to pay. Although these influences cannot be avoided, researchers need to be aware of their existence. Calculated monetary outcomes for ecosystem functions might differ depending on the methods chosen for valuation. Economic values will also differ with the demands on a country's natural resources or services, and thus may be directly related to the 'level of socio-economic development achieved by society' (Azqueta and Sotelsek, 2007). Greater levels of poverty can increase the demand for natural resources as is the case in many countries in Africa, where wetlands in particular provide a vital supply of natural resources to rural settlements (Schuyt, 2005).

Due to inconsistencies, the field of Ecological Economics has received much resistance, with some viewing the valuation of natural resources as subjective or a 'guessing game' (Carson *et al.*, 2001). Many argue that the environment has 'intrinsic value, which cannot be valued in conventional economic terms' (MEA, 2003). At times, even peoples' willingness to pay for a certain service simply 'cannot be directly observed or measured' (MEA 2003). However, there is no standard to which valuation methods can be compared to ensure accurate measurement (Carson *et al.*, 2001). This is largely due to the high variability inherent in valuation techniques, as well as to site-specific ecosystem attributes that do not allow for a standardised method of environmental valuation. Complex ecosystems are often categorised or broken down by their products or functions to determine isolated monetary values. This rigid option however, has its disadvantages. Certain ecosystem functions may 'overlap', resulting in double counting of economic values (De Groot *et al.*, 2002; Hein *et al.*, 2006). For example river water can be valued for its provision to a farmer for irrigation but could also be valued as a supporting function for kayaking, boating or other tourist activities.

As ‘total economic values’ are determined within the framework of ecosystem management or policy development, society is beginning to think about environmental resources in economic terms. The advantages of this thinking may prove vital in certain situations. For example, placing a price tag on a certain ecosystem function will provide a method of anticipating a potential change from an infrequent natural disaster. Management plans along with relevant budgets can thus better deal with such ecosystem “surprises” (MEA, 2003).

2.3.3 Linking ecosystem services and human welfare

Economics has been quoted as the study of how humanity provides for itself (Fisher *et al.*, 2008). Given humanity’s demand for natural resources, Fisher *et al.* (2008) link ecosystem services to human welfare with a supply and demand relationship as proposed by Pearce (2007; Figure 4).

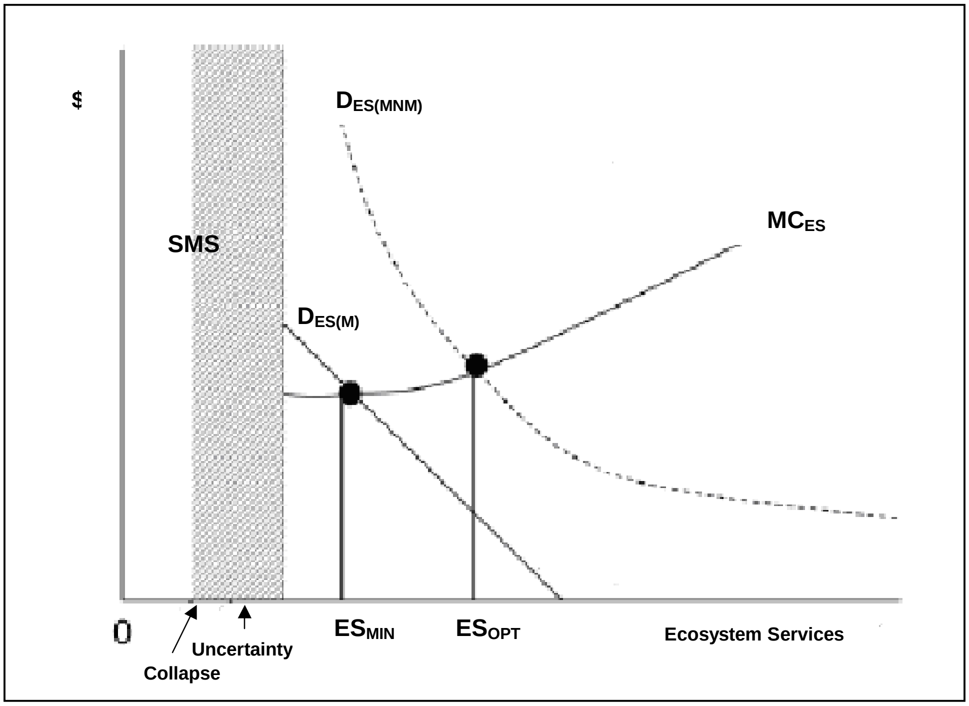

Figure 4: Stylised costs and benefits of ecosystem service (ES) provision as in Fisher *et al.* (2008). $D_{ES\ (MNM)}$: Demand for all ES benefits (market and non-market goods). $D_{ES(M)}$: Demand for ES benefits from market goods only. MC_{ES}: Supply curve or the marginal cost of managing ES or acquiring additional units of ES benefits. ES_{MIN}: The point where only marketed ES are provided/demanded and ES_{OPT}: the optimal level of ES provision. SMS: Safe minimum standard or quantity of ES below which the system may collapse.

The demand curve ($D_{ES(M)}$) represents the demand for marketed services from an ecosystem, or products such as fuelwood or fish. $D_{ES(MNM)}$ is the demand for both marketed and non-marketed services including goods such as scientific knowledge or watershed protection (Pearce, 2007). As every potential non-marketed good is unknown, $D_{ES(MNM)}$ represents an ideal scenario that includes all of these unknown services. MC_{ES} illustrates the marginal cost curve or supply curve for ecosystem services. The interaction of supply and demand curves denotes the economic cost of the supply or, in this case, the cost incurred to gain an additional unit of the ecosystem service. ES_{MIN} indicates the cost associated for marketed services whilst ES_{OPT} relates to the potential trading of all ecosystem services - both marketed and non-marketed. This relationship describes an optimal diversity services level where marginal costs meet the demand for all ecosystem service benefits. It was recognised, however, that a degraded ecosystem might collapse. A Safe Minimum Standard (SMS) of services that an ecosystem may offer was thus introduced to account for uncertainty regarding initial quantities of ecosystem services. Pearce (2007) mentions limitations of this model and acknowledges its simplicity. However, it provides a helpful economic basis to approaching ecosystem services trading and valuation.

2.3.4 Wetland valuation

Research in resource valuation is becoming more frequent in the management of natural systems (Beaumont *et al.*, 2008; Kroeger, 2005; Lamberth and Turpie, 2003; Turner *et al.*, 2000), and may often complement assessments such as Environmental Impact Assessments, or the justification for conservation areas (Turpie and Lannas, 2007). Wetlands in particular, have received much attention regarding restoration and conservation, and, as both the Mfolozi Floodplain and iSimangaliso Wetland Park comprise wetland ecosystems, valuation of similar systems was investigated in the literature. On a global scale, an average monetary value of the world's wetlands was estimated at $ 14785/ha/yr (Costanza *et al.*, 1998). In a South African study, wetlands were reported to be worth property values ranging from $ 47 200 - $ 80 900/ha, tourism values of between $ 159 - $ 40 440/ha/yr, resource harvesting values of $1.4 - $ 378/ha/yr and ecosystem service values, such as flood attenuation and water quality enhancement, of between $ 28.35 - $ 5 423/ha/yr (Turpie and Lannas, 2007).

On a smaller scale (1000 ha), the Hennepin and Hopper Lakes Restoration Project (USA), calculated the economic impacts affecting the regional economy (total output, household incomes and employment) of agricultural land reversion to wetland, along with their costs (i.e. loss of agriculture; Prato and Hey, 2006). Tong *et al.* (2007) compared current and future economic values of the Sanyang wetland in China to complement restoration plans for the system. Wetland service valuation allowed for the recommendation of priority ecosystem services for restoration in order to improve current economic value of the system (5087 Yuan/ha/yr) to its potential value (55 332 Yuan/ha/yr which translate to approximately 740 to 8000 US$/ha/yr respectively).

Values for ecosystem services from a natural, a human-interfered and a constructed wetland were compared by Chen *et al.* (2009). Contingent valuation-related methods were employed for their analyses (e.g. hedonic pricing, voided, replacement and travel costs, production approach, and market pricing). Net ecosystem service values were given as 'the difference between ecosystem services value and ecological engineering or maintenance costs' (Chen *et al.*, 2009). Analyses of six categories of ecosystem services (waste treatment, food and material production, water supply, gas regulation, disturbance and water regulations, and habitat and refugia) for the three wetland types resulted in total ecosystem service values of 206 740 US$/ha/yr for the 'constructed' Beijing Wetland, 15 643 US$/ha/yr for a typical 'natural' wetland and 702 $/ha/yr for the human-interfered Sanyang wetland system. Wetland valuation in the Chen *et al.* study (2009) presented a comparative economic analysis appropriate for future 'wetland engineering and management'.

Gren (1995) compared the costs and benefits of wetland restoration initiatives in the Stockholm Archipelago, and in Gotland Island in Sweden. Restoration costs were determined from opportunity costs or the 'benefits forgone in the best alternative use of the land', in addition to operational costs. Current and future benefits were calculated using a number of inputs. One such input was through data from a previous study for public willingness to pay for better water quality and improved ecosystem services. Nitrogen and saltwater filtering, water, nutrient and food supply services were valued by means of replacement costs (Gren, 1995). Results showed that benefits from both restoration initiatives outweighed any artificial alternative, particularly with regards to nitrogen abatement (Gren, 1995).

2.4 Relevance of research

Given current global measures, the MEA (2003) states that 'a country could cut its forests and deplete its fisheries and this would show only as a positive gain to GDP despite the loss of the capital asset'. By applying various resource valuation techniques, this research attempts to determine the economic value of particular ecosystem services that constitute a part of South Africa's natural capital. The suggested large-scale restoration of this study demands an interdisciplinary tool, such as empirical modelling, in order to anticipate how ecosystem service values will change into the future. By targeting the ecosystem services fundamental to successful ecological functioning, this research will form part of an environmental/economic understanding of both the Mfolozi Floodplain and the St Lucia Lake system, bringing to light their significance in a language more familiar to key decision makers, as well as contributing to the growing field of resource economics.

3. Study Area

3.1 Socio-economic characteristics and climate

Lake St Lucia and the Mfolozi Floodplain are located approximately 275 km north of the city of Durban, both falling within the boundaries of the Umkhanyakude District Municipality (DC27) in the northern KwaZulu-Natal Province (Figure 5). A minor portion (<500ha) of the demarcated Mfolozi Floodplain, which lies in the southern most region of the study area, extends into the neighbouring Uthungulu district.

In 2006, an estimated 625 358 people resided in the Umkhanyakude district, making up about 6 % of the province's population (Department of Local Government and Traditional Affairs, 2006) with an estimated population growth rate of about 10 % from 2001 to 2006 (Umkhanyakude, 2004). The district consists primarily of poor, low-income households, 25.6 % of which have no formal income at all (Sharpe Southern, 2003). About 80 % of these households bring in less than R1 500 per month, with more than 50 % earning approximately R 500 monthly (Sharpe Southern, 2003). Only about 46 % of the population that are able and willing to work are employed in the district, the majority of which work for the social services (27.6 %) and agricultural sectors (20.4 %; Sharpe Southern, 2003). Agriculture, hunting, forestry, fishing and mining have been identified as the primary contributors to the Umkhanyakude District GDP (Department of Local Government and Traditional Affairs, 2006). The Gross Geographic Product for Umkhanyakude was estimated to be R 1.2 billion in 2000 (Sharpe Southern, 2003).

The climate in Northern KwaZulu-Natal is typically sub-tropical with an average annual rainfall of approximately 1000-1200 mm, the majority of which falls during the hot, humid summer months of January to March, with temperatures reaching an average daily maximum of 29˚C (SAWS, 2003; Bate and Taylor 2008). Winters are cool and dry, with an average daily minimum of 12˚C (SAWS, 2003) experienced in the coldest months of June and July. Dry spells often lead to extended periods of drought typically occurring about once every ten years (Taylor, 2006a, Bate and Taylor, 2008).

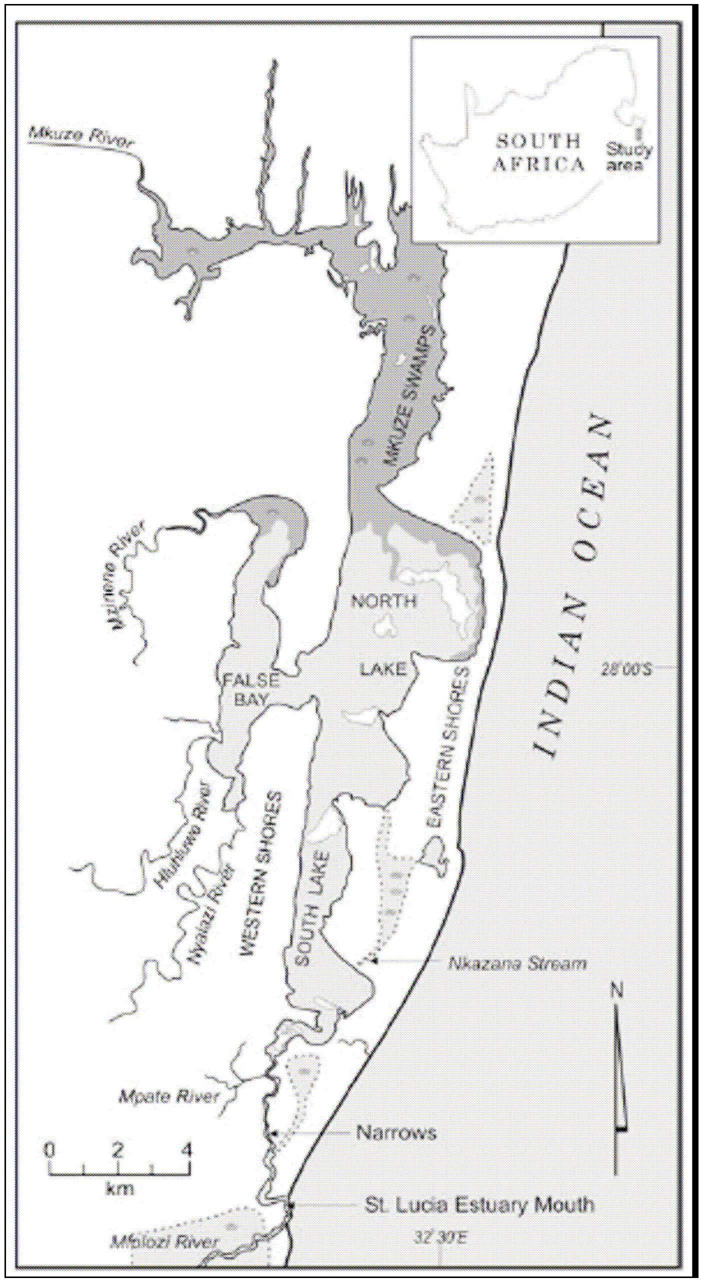

Figure 5: Map of the study areas taken from Whitfield *et al.* (2006): the St Lucia Lake system with the Mfolozi River and Floodplain to the south.

3.2 Lake St Lucia

Lake St Lucia falls within the 239 566 ha of the iSimangaliso Wetland Park, previously known as the Greater St Lucia Wetland Park (UNEP, 2002). The lake is situated between 27°52'S to 28°24'S and 32°21'E to 32°34'E (Wright *et al.*, 1990). Sections of this conservation area have been protected since 1895 (Whitfield *et al.*, 2006). The St Lucia wetland system was recognised as a Ramsar site in 1986 (Ramsar, 2008) owing to its international uniqueness. The abundance and diversity of habitats such as wetlands, coastal dune forests, beaches, lakes, grasslands and savanna led to the Park becoming the country's first World Heritage Site in 1999 (UNESCO, 1999). The St Lucia estuary is the largest estuarine system in Africa (Cyrus and Vivier, 2006), with a volume of about 320 $x10^6$ m^3 and a surface area of 350 km^2 (Bate and Taylor, 2008), making up approximately one half of the total surface area of all South African estuaries combined (Lamberth and Turpie, 2003). Freshwater inflow, currently supplied by five rivers (Figure 5), contributes an average of about 362 x 10^6m^3 to the system annually with groundwater seepage delivering approximately 23 x 10^6m^3 annually (Whitfield *et al.*, 2006). Evaporation is given at 420 x 10^6m^3 annually indicating a shortage of freshwater inflow during drought years (Whitfield *et al.*, 2006). The lake is relatively shallow with a mean depth of 0.9 m (Bate and Taylor, 2008), which exacerbates the effects of evaporation causing the lake to experience dramatic shifts in water level, temperature and salinity (Whitfield *et al.*, 2006).

3.2.1 Tourism

Tourism has been recognised as 'one of the fastest-growing economic sectors in the world', which is true of Southern Africa (SAfMA, 2004). An estimated value of US$ 3.6 billion was given in 2000 for nature-based tourism in Southern Africa (MEA, 2003). An impact study of tourism on the economy of KwaZulu-Natal was done over the summer holiday period from 15 December 2004 to 15 January 2005 (Tourism KwaZulu-Natal, 2005), which estimated from 90 000 international tourists that visited the province, the expected direct spending was approximately R 0.5 billion with a total economic impact of R 0.7 billion (Tourism KwaZulu-Natal, 2005). It remains challenging, however, to measure overall impacts of tourism, as it is not a 'clearly defined industry' in the System of National Accounts. Agriculture, mining and forestry are examples of clearly defined industries (Stats SA, 2005). Rather tourism can be viewed as 'an amalgamation of industries such as transportation, accommodation, food and beverage services, recreation and entertainment, and travel agencies' (Stats SA, 2005). Statistics such as the number of arrivals to a particular country or overnight stays are valuable indicators of tourism measure as is the UN recommended tourism satellite account (TSA), which explores the supply and demand of tourism goods and services within integrated economic systems (Stats SA, 2005).

The provincial conservation authority, Ezemvelo KZN Wildlife, which operates in and around the study area, considers tourism as a 'key driver of job creation and economic growth' (EKZNW, 2004). This is clearly evident in the town of St Lucia in northern KwaZulu-Natal, with the majority of enterprises in the area centred around tourism activities or their support. The St Lucia coastline, the estuary and the lake host a number of these activities, including birding, fishing, hiking, boating and kayaking. It is therefore not surprising that the iSimangaliso Wetland Park has previously been recognised as one of the top five eco-tourism destinations in the country (Mann, 1993). Income from Ezemvelo Wildlife accommodation facilities, that depend in some way on the ecology of Lake St Lucia, brought in R 3.5 million in 1991, with a further R 854 000 from consumptive resources (fish, bait), entrance fees, trails and tours (Porter and Haynes, 1993). More recently, however, the number of tourism enterprises in the town of St Lucia has increased. Efficient ecological functioning of the Lake St Lucia supports this thriving tourism industry and should conditions deteriorate, it is expected that the number of visitors to the area would decline.

3.2.2 Cultural significance

Along with providing employment through tourism, the natural environment in Northern KwaZulu-Natal has great cultural significance to local people. A 'vital source of inspiration for science, culture and art' and providing 'opportunities for education and research' (De Groot *et al.*, 2002), are not attributes society may easily assess in economic terms. The literature states that some natural resources are harvested in Northern KwaZulu-Natal purely for the production of goods for cultural purposes (Traynor, 2008). Incema (*Juncus kraussii*), for example, is significant specifically for the making of bridal mats by the local Zulu community, and there is no suitable substitute (Traynor, 2008). Further, Impey (2002) discusses the significance of the culture/nature interface to the Zulu communities in Northern KwaZulu-Natal. Natural resources were noted to play a vital role in cultural rituals including cleansing, medicating, marriage ceremonies, the making of musical instruments, ancestral worship and others (Impey, 2002). This reliance of culture on available resources is captured in the words of a student; ‘without these rituals, we cannot call ourselves Zulu’ (Impey, 2002).

3.2.3 Fisheries

3.2.3.1 National fisheries

The South African Fishing industry was calculated in 2003 to generate approximately R 2,63 billion of wholesale revenue annually, contributing about 1 % to the country’s GDP (Food and Agriculture Organisation, 2008). Estimates in 2000 gave a value of R 168 billion for the direct benefits from all coastal goods and services in South Africa and R 134 billion for indirect benefits (DEAT, 2008). The Pelagic Purse-Seine fishery is the largest fishery in the country, having harvested about 538 000 tonnes in 2002 (DEAT, 2008). This fishery targets mostly sardine (*Sardinops sagax*) and anchovy (*Engraulis encrasicolus*), but also includes redeye herring (*Etrumeus whiteheadi*) and horse mackerel (*Trachurus species*). Demersal trawling is the second largest fishery, harvest having brought in 163 000 tonnes in 2003, with deep-sea hake (*Merluccius capensis* and *Merluccius paradoxus*) having contributed the highest value catch (DEAT, 2008). The total commercial catch from linefish, the third largest fishery, was about 24 104 tonnes in 2000 (DEAT, 2008). The South African fishery shifts from mostly commercial operations on the West Coast to subsistence towards the northeast into KwaZulu-Natal (Lamberth and Turpie, 2003). With regard to estuaries, it was found that the estuarine contribution to inshore marine fisheries in South Africa was R 490 million each year with the KwaZulu-Natal estuarine contribution valued at R 4114/ha (Lamberth and Turpie, 2003).

3.2.3.2 Local fisheries

Fishing is an important contributor to the local economy of St Lucia, with the Primary Economic Sector into which fisheries falls contributing 73.3 % to the GDP of the Umkhanyakude Municipality in 2003 (Department of Local Government and Traditional Affairs, 2006). Recreational fishing is very popular in the country with St Lucia alone boasting linefishing estimates of 30 000 boat angler outings and 18 000 shore angler outings per year (Lamberth and Turpie, 2003). There are 37 gillnet permit holders in St Lucia with a further 270 people suspected to be operating illegally (Lamberth and Turpie, 2003). Although also illegal, seine netting is present in KwaZulu-Natal along with many other traditional methods of fishing. About 80 of the 160 species that are present in South African estuaries are exploited in national fisheries, giving the country's estuary-dependant fisheries a value of R 1.3 billion in 2002 (Lamberth and Turpie, 2003). The total estuarine species catch was estimated at 653.5 tons for KwaZulu-Natal (Lamberth and Turpie, 2003). The highest catch for KZN is the dusky kob (*Argyrosomus japonicus*) with 227.5 tons, flathead mullet (*Mugil cephalus*) with 72.1 tons and spotted grunter (*Pomadasys commersonni*) with 71.9 tons. The estuarine species catch (Table 1) included records of recreational shore-angling and spearfishing, commercial boat-based linefishing and commercial gillnet and beach-seine netting. Combined data from Lamberth and Turpie (2003) and Whitfield *et al.* (2006) in Table 1 show that nine out of the ten fish species with the highest catch in the province are present in the Lake St Lucia System.

Table 1: The 10 highest recorded estuarine species catch in KwaZulu-Natal, all species of which are present in Lake St Lucia. Categories of utilisation of estuaries are also included, denoting every species' dependence on estuarine habitats.

Species (M): Marine fish species (F): Freshwater fish species	Common name	Recorded total catch (tons) in KZN (Lamberth & Turpie 2003)	Category of utilisation of South African estuaries (Lamberth & Turpie 2003)	Approximate salinity ranges ($^{o}/_{oo}$) of species recorded in Lake St Lucia (Whitfield *et al.*, 2006)
Argyrosomus japonicus (M)	Dusky kob	227.51	Iia	0 – 90
Mugil cephalus (M)	Flathead mullet	72.14	Iia	0 – 90
Pomadasys commersonni(M)	Spotted grunter	71.88	Iia	0 – 90
Gerres methueni/rappi (M)	Evenfin pursemouth	50.52	IIb	0 – 40
Oreochromic mossambicus (F)	Moçambique tilapia	44.11	IV	0 – 100+
Liza macrolepis (M)	Largescale mullet	35.20	Iia	0 – 75
Liza dumerilii(M)	Groovy mullet	35.07	IIb	0 – 90
Claruis gariepinus (F)	Sharptooth catfish	28.34	IV	0 – 10
Acanthropagrus berda (M)	Perch/riverbream	19.33	Iia	Not recorded in St L.
Leiognathus equula (M)	Slimy	14.25	IIb	0 – 80

Description of relevant categories of fish that utilize South African Estuaries (Lamberth & Turpie 2003):
Category II: Euryhaline marine species that usually breed at sea, with juveniles showing varying degrees of dependence on estuaries

IIa: Juveniles dependant on estuaries as nursery areas

IIb: Juveniles occur mainly in estuaries, but are also found at sea

Category IV: Freshwater species, whose penetration into estuaries is determined primarily by salinity tolerance. This category includes some species that may breed in both freshwater and estuarine systems.

Table 1 shows that the majority of these species rely on a linked estuarine/ocean environment for successful breeding and recruitment. Salinity ranges tolerated by these species indicate that most of the targeted species cannot tolerate the hypersaline conditions that were reached during the last drought

(Whitfield *et al.*, 2006). Salinities in False Bay have risen up to 150 $^{o}/_{oo}$ in 2003 (Whitfield *et al.*, 2006) and 80-100 $^{o}/_{oo}$ in November of 2004 (Cyrus and Vivier, 2006). Given that St Lucia's surface area (35 000 ha) is half of all the estuaries in South Africa (roughly 70 000 ha), Whitfield *et al.* (2006) argue that losing Lake St Lucia as a nursery area, specifically for estuary-associated marine fish, would result in 'significant short-term declines in the future abundance of these taxa on both a local and regional scale' (p 14), regional referring to the national scale. Lamberth and Turpie (2003) noted the consequent impacts of stressed estuarine environments, particularly as nursery grounds, which may result in a decline of essential fish supplies to the country's in-shore marine harvesting (Lamberth and Turpie, 2003), and thus the income that is generated. This was confirmed by Mann and Pradervand (2007), who showed a significant ($p < 0.05$) decline in stumpnose, *Rhabdosargus sarba*, in the St Lucia Marine Reserve, north of St Lucia mouth, during the 2001- 2005 drought. Mann and Pradervand (2007) attribute the CPUE decline solely to the close of the St Lucia Estuarine System, which prevented access to the estuary as a nursery area and therefore inhibited further recruitment of the species.

3.2.4 Current condition

Lake St Lucia historically received its freshwater input from six sources (the Hluhluwe, Mkhuze, Nyalazi, Mzinene, Mpate and the Mfolozi Rivers), but following the Mfolozi River's diversion in 1952, its contribution was thus removed. The remaining water sources are fast diminishing due to catchment developments, which are contributing to desiccation and endangering the system in the long term (Taylor, 2007). Following a persistent drought since 2002, the St Lucia mouth has remained closed, opening only briefly in January 2004 following a flood event, and from March to August 2007 due to the rare combination of a spring high tide, extreme wave heights following Cyclone Gamede, as well as strong onshore winds (Pillay and Perissinotto, 2009; R. Taylor pers. comm.). Water levels in the lake steadily dropped during this drought, triggering hypersaline conditions that have resulted in the deaths of many plants and animals (Pillay and Perissinotto, 2009; Cyrus and Vivier, 2006). In the winter of 2006, the lake waters were confined to a few small pools (Figure 6), exposing 90 % of the lake floor (Whitfield and Taylor, 2009).

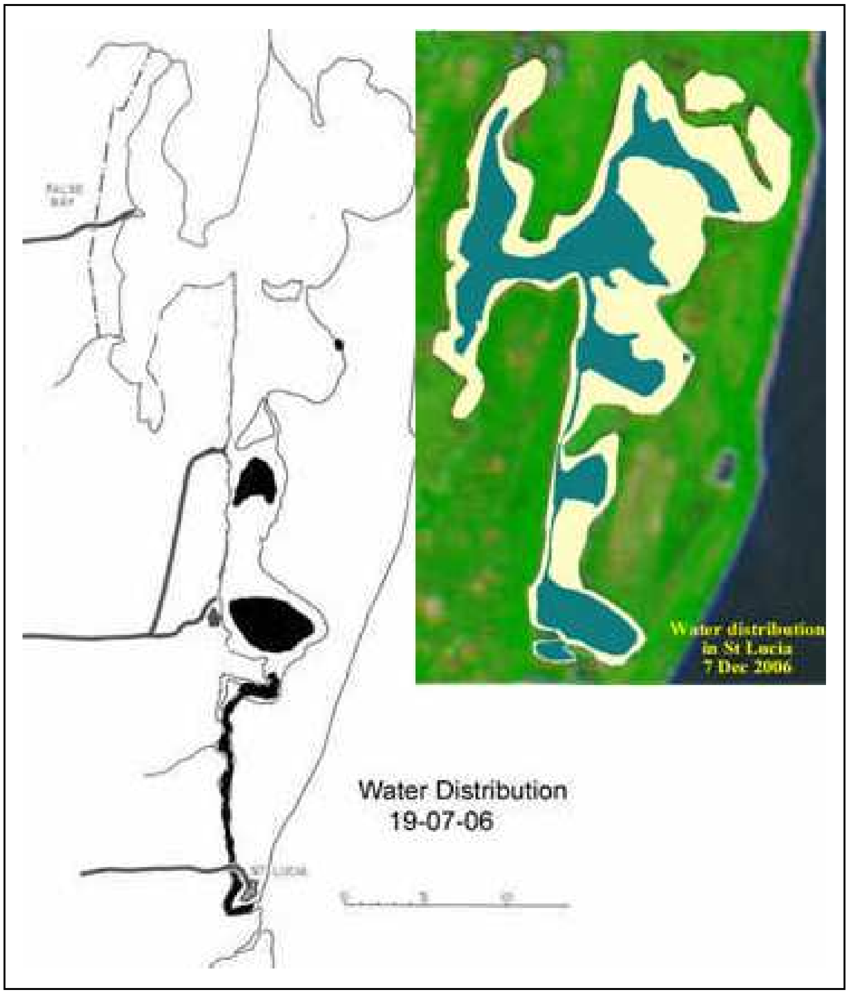

Figure 6: Maps from Taylor (2007) of the water coverage of Lake St Lucia in July and December of 2006 compiled by Johan Gerber and Greg Nänni respectively.

Conditions during these dry periods resulted in dramatic changes in the biota, the most obvious being the mass mortality of fish. Although fairly typical in subtropical estuarine systems, the fish mortality during this drought is suspected to have been triggered by low oxygen levels brought about by the lake's low water levels and high temperatures, along with high salinities (Cyrus and Vivier, 2006), reaching up to 200 $^{o}/_{oo}$ in the northern parts of the lake (Pillay and Perissinotto, 2009; Cyrus and Vivier, 2006). By 2007 water levels had recovered to 70 % of the lake cover (Taylor, 2007) although some irregularities still persisted such as the presence of submerged water plants in the Narrows, which are naturally absent from this area (Taylor, 2007). As the water levels continued to rise, salt marsh areas were flooded attracting waders and ducks back to these areas and also providing new warm habitats for small fish (Taylor, 2007). Fish populations, particularly those that rely on an open mouth for spawning, remained stressed while the mouth remained closed. Crocodile populations were also under pressure due to low lake levels, forcing nesting to the southern areas of the lake and the Narrows (Taylor, 2007). It is therefore evident that without the input of Mfolozi River water to the lake, the St Lucia System becomes severely stressed and unable to recover fully between drought periods - to the point that it may not survive in the long-term (Taylor, 2008; Whitfield and Taylor, 2009). It is the immediate hope of key decision makers to make use of Mfolozi River waters in order to alleviate such dramatic ecological fluctuations experienced by the lake, whilst protecting the system from the harmful sediment it carries.

3.3 Mfolozi Floodplain

The Mfolozi Floodplain, one of South Africa's largest (Grenfell *et al.*, 2009), is situated to the south of Lake St Lucia (Figure 1). The Mfolozi River mouth, since its diversion from the St Lucia System, lies south of the St Lucia estuary at 28^{o}24'S; 32^{o}25'E (DEAT, 2001). Subsequent to the diversion, a 'link canal' was constructed in the late 1970's/early 1980's at great cost between the Mfolozi River and the Narrows of Lake St Lucia (Figure 7), to allow for the provision of supplementary water to Lake St Lucia should the need arise. However, following good rainfall seasons and favourable freshwater inflows to Lake St Lucia that allowed for frequent mouth opening, the canal was no longer necessary and ongoing costly maintenance was discontinued (W. Ellery, pers. comm.).

The majority of the floodplain is currently farmed intensively for sugarcane, with the estuary and coastal reaches of the floodplain incorporated into the iSimangaliso Wetland Park (Figure 7). Although these areas fall within a protected area, small-scale subsistence farmers cultivate these areas (Grenfell *et al.*, 2009). The Mfolozi Estuary, about 180 ha in size, ranges in salinity from about 35 $^o/_{oo}$ at the mouth to about 2 $^o/_{oo}$ in the upper reaches (Vivier and Cyrus, 2009).

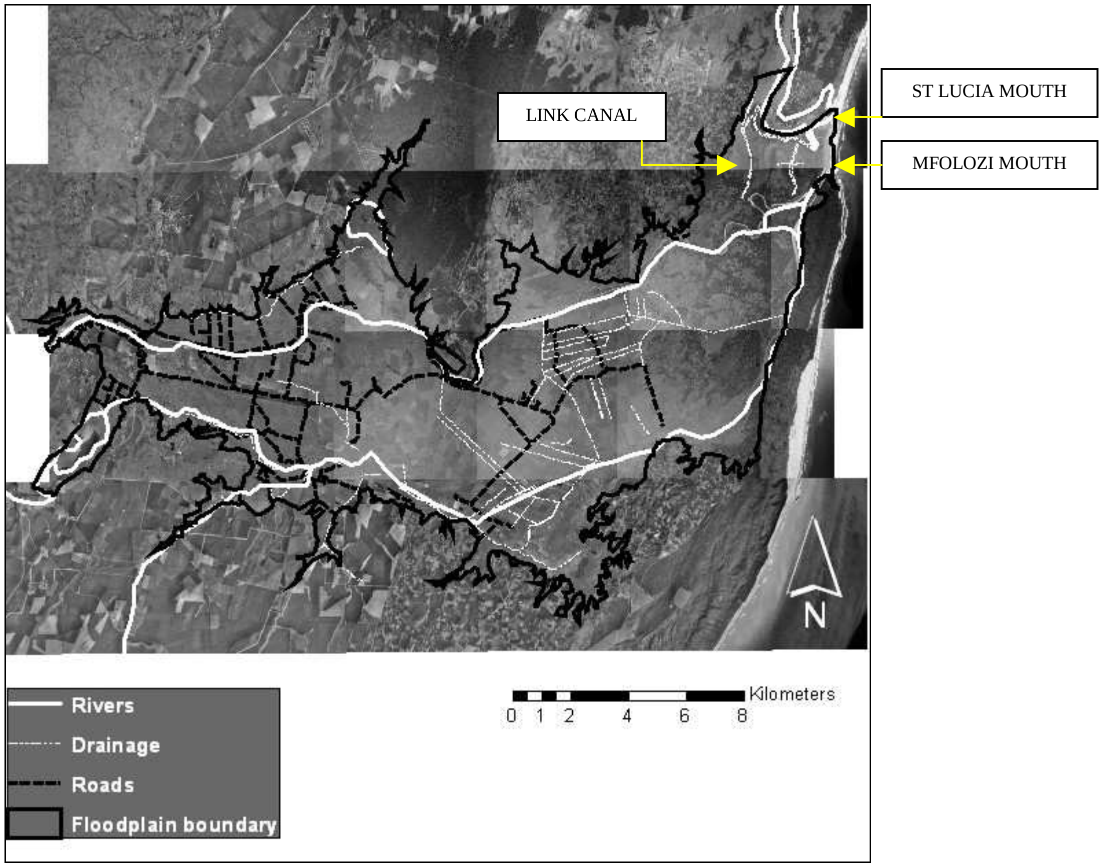

Figure 7: GIS delineation of the Mfolozi Floodplain with major infrastructure (Collings, 2007). The link canal remains noticeable from the Mfolozi River to Honeymoon Bend at the base of The Narrows in the St Lucia System.

The Mfolozi Floodplain is characterised by infrequent flooding events, the largest of which, in recent history, was triggered by Cyclone Domoina in 1984 where discharges far surpassed the capacity of the river channel to accommodate them, with discharges three times the 100-year return flood, resulting in extensive flooding and forcing the river southward to join the Mzunduzi River channel (Grenfell, 2009). The Mfolozi River has been in flood 18 times since Cyclone Domoina (L. McGrath pers. comm.). The floodplain is dominated by clastic sediments of very fine to medium silt (Figure 8; Grenfell *et al.*, 2009).

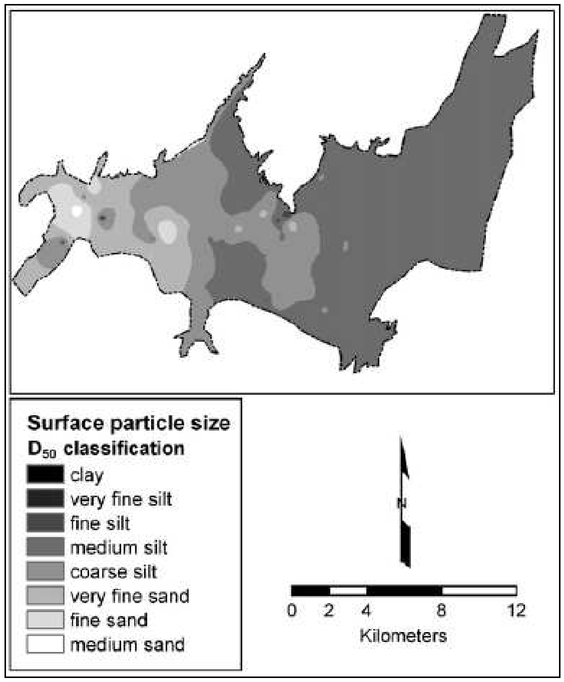

Figure 8: The surface of the floodplain's interpolated median particle size according to the Wentworth-Udden scale classification from Grenfell *et al.* (2009).

As sugarcane farming expanded on the floodplain, so too did infrastructure and canalisation in order to straighten river channels and lead them more directly to the mouth in order to prevent floodwaters from damaging crops (Figure 7; Grenfell, 2009). The Mfolozi River naturally carries high sediment loads, which have been worsened by growing populations in the catchment and associated negligent farming practices (Bate and Taylor, 2007). This has resulted in an estimated mean annual sediment load for the Mfolozi River of 0.68 x 10^6 tonnes year^{-1} (Whitfield and Taylor, 2009). However, there is much variability in the sediment loading, both seasonally and annually (Grenfell and Ellery, 2009), which is noticed during low flows, particularly in winter, when sediment loading is reduced (Whitfield and Taylor, 2009). Compared to other rivers however, sediment loading is relatively low in the Mfolozi River, with the Zambezi River transporting 20 x 10^6 tonnes year^{-1} (Grenfell and Ellery, 2009) and the Tana River, Kenya at 6.8 x 10^6 tonnes yr^{-1} (Kitheka *et al.*, 2005). Nevertheless, the Mfolozi River's sediment loading is far greater than that of the neighbouring St Lucia System (Figure 9).

Figure 9: Image from Lindsay *et al.* (1995) of the visible difference in Suspended Particulate Matter (SPM) when the Mfolozi and St Lucia estuaries were combined during an ebb tide in January 1995.

However, turbidity provides an advantage to fish species recruitment due to increased food availability that has been shown by larger quantities of benthos (mean annual dry biomass) recorded in more turbid areas of the St Lucia System than in those with clear water (Vivier and Cyrus, 2009). Reduced light penetration is also advantageous to fish species, which, by decreasing the visibility in the water, protects young fry from the view of predators (Vivier and Cyrus, 2009). As the Mfolozi Estuary is the only estuary in a 70 km stretch along the coast apart from the Lake St Lucia System, it is very important for alternative nursery grounds when St Lucia mouth is closed. In a study on the fish community of the Mfolozi system which used gill and seine nets, Vivier and Cyrus (2009) found that when the St Lucia mouth was closed, there were 17 more fish species present in the Mfolozi Estuary than when the St Lucia mouth was open.

3.3.1 The sugar industry

The sugar industry contributes significantly to South Africa's economy. During the 2006/2007 season 2.26 million tons of sugar was produced from a registered 45 300 cane growers (SASA, 2008). Exports reach Asia, the Middle East and a number of African counties, but most of South Africa's sugar is marketed in the South African Customs Union (SACU). Based on SACU sales, the country's sugar industry generates an estimated annual average direct income of R 6 billion (SASA, 2008). The industry provides around 77 000 jobs, with indirect employment of approximately 350 000 (SASA, 2008). One million people are said to depend on the sugar industry for a living (SASA, 2008).

During the early 1900's, the Mfolozi Settlement was established by the South African Government specifically for the production of sugarcane (Lincoln, 1995). The government subsidised the construction of the local mill, the establishment of commercial farms as well as frequent assistance with flood relief. Owing to frequent flooding of the Mfolozi River during its history, and consequently the deposition of nutrient-rich sediments (Lindsay *et al.*, 1996), conditions are arguably among the most productive in the country for sugarcane farming. Currently approximately 8000 ha of the floodplain are covered by sugarcane (Collings, 2007). However, flooding has also been responsible for the destruction of many sugarcane crops in the past, prompting heavy investment into drainage systems and canals, which prevent the river water from the dissipating and filtering functions of the floodplain (Taylor, 2006). The local Mfolozi Mill, employing over 250 people, produces about 150 000 tons of raw sugar per year, which is roughly 6% of the country's total production (SASA, 2007). During the 2006/2007 season the mill crushed approximately 1 113 986 tons of cane (SASA, 2008). The majority of the sugarcane supply to the Mfolozi Mill (70 %) is sourced from the Mfolozi Floodplain (G. Shange, pers. comm.). The ownership of the mill changed hands in 2005 from Illovo Sugar Ltd to the BEE Company Umvoti Transport Ltd (SASA, 2007). After failing to meet certain sales agreement considerations, the mill was bought out by the local Umfolozi Co-operative Sugar Planters (UCOSP) in early 2009 (L. McGrath, pers. comm.).

Regardless of the fate of the mill, sections of large-scale sugar farms in the floodplain have already been targeted for poverty relief initiatives. The Department of Land Affairs is in the process of buying out low-lying areas of certain farms in order to establish previously disadvantaged farmers (Taylor, 2008). Not only will this disrupt any future prospect for restoration and the potential linkage of the Mfolozi River to the St Lucia System, but the allocated land will not prove very productive (for sugarcane) since these areas are flooded more frequently given their location. Without extensive drainage or flood alleviation efforts, small-scale farming in these areas would in all likelihood fail and would probably have to be abandoned in a few years (Taylor, 2008).

3.3.2 Mouth management

The Mfolozi River has migrated northwards, at times at a rate of 1.9 m per day and without intervention is expected to erode into the St Lucia estuary (Taylor, 2007). Although this rate of migration is not constant, Ezemvelo KZN Wildlife needs to intervene regularly in order to prevent the Mfolozi River from re-connecting with the St Lucia System causing premature breaching of the St

Lucia mouth and from delivering undesirably high sediment loads into the lake. Figure 10 shows the bulldozing of a new mouth to ensure the Mfolozi Mouth remains south of St Lucia.

Figure 10: A bulldozer constructing a ‘weak link’ to prevent the northwards migration of the Mfolozi River. (Terminology of Whitfield and Taylor, 2009; Photo: S. Collings, November 2008).

4. Methods

Ecosystem services for the Mfolozi Floodplain and the Lake St Lucia System were identified and monetary value for each ecosystem service was assessed. Changes to these monetary values were determined under two restoration scenarios for the Mfolozi Floodplain in order to establish the economic consequences associated with the proposed restoration of the floodplain.

4.1 Classification of ecosystem services

The Millennium Ecosystem Assessment (2003) and De Groot *et al.* (2002) were considered in identifying ecosystem services present in both the Mfolozi Floodplain and the Lake St Lucia System. Representation of services from each service category from the Millennium Ecosystem Assessment (Regulating, Support, Provisioning and Cultural) was included in the study (Table 2). Services were included on the basis of their significance to possible floodplain restoration and the availability of data necessary for valuation.

Table 2: Ecosystem services analysed in this study.

Millennium Ecosystem Assessment Category	Service valued for the Mfolozi Floodplain and the Lake St Lucia System	Service Description
Regulating	Flood Alleviation	Mitigating impacts of flood events or storms; water regulation such as drainage
	Water Provision	Water supply to users within the site
	Water Purification	Pollution control and detoxification; specifically reducing Nitrogen & Phosphorous levels
	Sediment Retention	Sediment retaining capabilities; prevention of damage from erosion & siltation
Supporting	Tourism	Enterprises based on tourism or recreation supported by natural habitat
Provisioning	Vegetation Harvesting	Direct Use Values; Harvesting raw materials for fuel use, building, manufacturing, food etc.
	Fisheries	Habitats as nursery grounds/refugia for national stocks, supply to recreational & commercial fishing
Cultural	Existence	Aesthetic; enjoyment of scenery, sense of place
	Cultural & Education	Spiritual, artistic, historic & Research, education

4.2 Economic valuation of ecosystem services

Valuation of ecosystem services employed a number of methods most suited to the scope and time allowance of this study as well as the availability of data. Where calculations included a US Dollar value, conversions were made to South African Rands using the Rand/Dollar exchange rate of approximately 1USD: R10, as on 12 December 2008. Due to the availability and nature of data, certain values for ecosystem services for the 'St Lucia System' were determined for the area within the iSimangaliso Wetland Park boundary, others were determined for the St Lucia Lake, and one was calculated for the town of St Lucia. Methods for valuing ecosystem services included replacement cost method, market value, benefit transfer and the assigning of a proxy value (Table 3).

The assumption was made for this study that restoring the Mfolozi Floodplain would reinstate efficient ecological functioning and return natural ecosystem services to their natural capacity. It is acknowledged that most of the services present in the Mfolozi Floodplain would operate with the highest efficiency if the river were in flood and under natural wetland conditions.

Table 3: Valuation methods employed for each ecosystem service in each study site. Note services valued for different components of the St Lucia System.

Ecosystem Services	Mfolozi Floodplain	St Lucia System	St Lucia component valued
Flood alleviation	Replacement cost	Benefit transfer	Lake
Water Provision	Market value	Replacement cost	Lake
Water Purification	Benefit transfer	Benefit transfer	Lake
Sediment Retention	Replacement cost	Management costs	Park
Tourism	Tourism proxy	Tourism proxy	Town
Vegetation Harvesting	Benefit transfer	Market value	Park
Fisheries	Benefit transfer	Benefit transfer	Lake
Existence	Benefit transfer	Benefit transfer	Park
Cultural & Education	Benefit transfer	Benefit transfer	Park

4.2.1 Flood alleviation

Mfolozi Floodplain

The replacement cost method was used to determine flood alleviation, using the annual costs of maintaining current drainage systems within the floodplain boundary as well as other annual expenses specifically for flood prevention. The total value for these costs, provided by the Umfolozi Co-operative Sugar Planters Association (UCOSP), gave the current 'flood alleviation' value for the Mfolozi Floodplain. The assumption was made that current drainage infrastructure does not need to be replaced every year. There have been 18 flood peak events since cyclone Domoina in 1984. Should drainage fail, re-planting sugarcane following a flood event is estimated to cost R 7500/ha (L. McGrath, pers. comm.). Re-planting costs, however, were not included in the calculated flood alleviation value as these costs are not associated with flood prevention. In order to test a more comparable result with that of the St Lucia System, a benefit transfer method was also performed for flood alleviation. This was unsuccessful due to the lack of data applicable to the Mfolozi Floodplain given from the Costanza *et al.* study (1998), as was considered for the St Lucia System.

St Lucia System

As Lake St Lucia falls within a conservation area, there is no artificial flood alleviation or flood prevention infrastructure to use to calculate the economic value using the replacement cost method, as was the case for the Mfolozi Floodplain. A benefit transfer method was used, using a disturbance regulation function value for estuaries within coastal ecosystems given by Costanza *et al.* (1998). This per ha value was presented by Costanze *et al.* (1998) from a study which synthesised data from over a hundred international studies giving the economic values of seventeen ecosystem services categories. This number was applied to the surface area of Lake St Lucia. The assumption was made that the St Lucia System operates with similar functioning to the systems that were used in a study that synthesised over 100 wetland valuation studies by Costanza *et al.* (1998).

4.2.2 Water provision

Mfolozi Floodplain

Current payments for water abstraction by users within the floodplain were assessed, providing a current market value for water supply. It was reasoned that the water provided by the Mfolozi River is worth what is currently paid to access it. Groundwater provision to the Mfolozi Floodplain was assumed to be negligible in relation to water provided by the Mfolozi River (S. Grenfell, pers. comm.). Groundwater was thus subsequently excluded from calculations. There are however a few users accessing water for domestic use by means of private boreholes, which were also excluded from calculations. It is estimated that about 4 750 ha is irrigated in the floodplain annually (L. McGrath, pers. comm.). Registered user data were accessed from DWAF, which provided specific Water Resource Management charges (WRM) for different use sectors within the floodplain region (irrigation, commercial, aquaculture etc.; Table 9). Records of registered users within the Usutu to Mhlatuze water management area (WMA) were isolated and further sorted for users abstracting from the Mfolozi River only. All water use sectors were included in calculations. It should be noted that the Water Management Charge is not a payment for the water, but rather payment for the management of the catchment along with the regulation of water use. Due to variation of water abstraction charges for registered user groups, all records of registered water use from DWAF were considered. GPS co-ordinates were provided with registered user information indicating the location of water abstraction. Through this process it was clear that some water abstracted outside the marked floodplain boundary is used on the floodplain. Thus, points of abstraction were investigated using Arc 9 software to confirm proximity to the marked floodplain. Orthophotos of the floodplain and relevant floodplain boundary shapefiles were obtained from Collings (2007). Abstraction sites located either within the marked floodplain or in close proximity (roughly 5 km) were included in calculations. Monetary values from the total Water Resource Management charges were added to irrigation costs in the floodplain thus summing the current payments made for water in the area and therefore establishing a total monetary value for the water provisioning function of the Mfolozi River.

St Lucia System

The replacement cost method was used to estimate the water provisioning value for Lake St Lucia. Estimation followed the logic that if water supply ceases completely, the costs associated with supplying the current volume of water to the lake artificially would provide an indication of its economic value. Water abstraction costs from a dam (50c/m^3), such as Klipfontein Dam on the northern reaches of the Mfolozi River (J. Perkins, pers. comm.), was used to calculate the cost of providing a substitute for the current 320 x 10^6 m^3 in the lake (Bate and Taylor, 2007) of water currently in the lake. It was acknowledged that the water resource charge used in this calculation is the cost associated with abstracting from a water storage system. This potential replacement scenario considers water flowing to a storage system, or in this case the lake. Dam abstraction payment not only includes payment for the water provision service by the dam, but also the dam infrastructure, its maintenance and management. Given the demand, however, of replacing such a large volume of water, it was reasoned that this scenario could realistically only consider a dam as an appropriate abstraction point to satisfy replacement volumes.

4.2.3 Water purification

The literature refers to the reduction of contaminant concentrations by wetland systems in many studies (Siracusa and Rosa, 2006; Moreno *et al.*, 2007; Stern *et al.*, 2007; Turner *et al.*, 2000; Woltemade, 2000). It was also acknowledged that a wetland system's ability to remove nutrients and heavy metals from an environment is dependent on the biological processes that are present (Tong *et al.*, 2007) as one would associate with a restored natural ecosystem. Studies such as Coveney *et al.* (2002) have shown results of nutrient removal by wetland filtration. Nitrogen (68 %) and phosphorous (43 %) reduction have been analysed in restored wetlands receiving agricultural drainage water (Woltemade, 2000). Although the removal of nutrients may differ among wetlands and different flows (Jordan, 2003), the ability of wetlands to 'transform nutrients' will increase as the water retention time increases (Jordan *et al.*, 2003; Woltemade, 2000). This was also considered when estimating ecological changes following a potential restoration initiative in the Mfolozi Floodplain. The water purification function for this study considered the reduction of nutrients from a river system and did not include the removal of sediment. To avoid double counting sediment removal was considered under the 'sediment retention' function.

Mfolozi Floodplain

Due to the current infrastructure on the Mfolozi Floodplain and its design for rapid drainage of water, biological processes natural to a floodplain wetland system, such as dilution, assimilation and chemical transformation (Montreuil and Merot, 2006; De Groot *et al.*, 2002) are no longer present as is the case in a natural state. Also, given that the Mfolozi River is heavily channelled and controlled (UCOSP, 2008), water retention time, is currently minimal. These processes were assumed to be present, even though in a reduced capacity.

An economic value for water treatment by 'rivers and lakes' from Costanza *et al.* (1998) was used for this valuation. The Costanza *et al.* (1998) US$ per ha value was used for a benefit transfer calculation for water purification function. The surface area for the Mfolozi and Msundusi Rivers, both falling within the Mfolozi Floodplain boundary, were determined using Arc9 Software. The length and width of each river was calculated from the relevant shapefiles provided by Collings (2007). River width was estimated using orthophotos in Arc9 and measuring across 20 points of each river at a scale of 1:12 000. River surface area in the floodplain was then applied to the Costanza *et al.* (1998) values.

St Lucia System

Due to the diversity of habitats included in the iSimangaliso Wetland Park, information pertaining to water purification or reduction in nutrients would involve research beyond the scope of this study. Local data specific to each ecosystem within the park were not available or have not been measured. Thus, the benefit transfer value for 'rivers and lakes' for waste treatment value from Costanza *et al.* (1998) was applied to the surface area of Lake St Lucia.

4.2.4 Sediment retention

Wetland systems offer an effective mechanism to retain sediment (Fennessy *et al.*, 1994). Coveney *et al.* (2002) demonstrated the removal of 90 % particulate matter by means of pilot treatment wetlands for Lake Apopka in Florida, USA. The replacement cost method has been used in a number of studies to measure the value of sediment retention. Costs associated with artificial sediment removal indicate the value of the service provided by an ecosystem in its natural state. Detailed sediment budgets for the Fraser River in Canada, for example, provided management recommendations following which necessary funds could be allocated for dredging or other such initiatives (FREMP, 2005).

Mfolozi Floodplain

As the Mfolozi River water is channelled through the floodplain, it does not travel through any vegetation, or at a velocity conducive to sediment filtration. However, to measure whether a change in sediment concentration in the Mfolozi River is occurring currently, water samples were taken from the river and analysed in 2 x 250 ml water samples, which were taken from the Mfolozi River on the 22 November 2008 at Mtubatuba (S 28 45646 E 032 20108) and at Monzi (S 28 46754 E032 29554) about 13 km down river from Mtubatuba. This was repeated on 26 November 2008 at a second access point in Mtubatuba (S 28 45202 E 032 18238) and the same point at Monzi. The samples were left to stand for a few weeks to ensure the settling of suspended solids. The samples were weighed, the supernatant liquid decanted and the remaining solution evaporated in an oven at 90˚C. The sediment remaining after evaporation was then weighed. The experiment assumed any natural dissolved solids within the sample were negligible. The difference in sediment concentrations between sites provided an indicative measure of filtration occurring in the River system currently.

The replacement cost method was used to value filtration occurring in the floodplain as was done by Turpie *et al.* (1999), where the cost of installing sediment traps was calculated. Determining the costs of artificially filtering the river water to the same extent that it is currently occurring provides a monetary value of this service. In this case, a cost effective means of artificially filtering the Mfolozi River water is the use of a concrete sediment trap such as one used by the local Mtubatuba water works before treatment of the Mfolozi River water for municipal use. Engineering firm PD Naidoo & Associates (PDNA) was approached to quote the construction of a concrete sediment trap with the same dimensions as that of the Mtubatuba Water Works sediment trap (10 m x 5 m and 3 m depth, T. Mabika, pers. comm.).

St Lucia System

Due to the concern regarding the build up of sediment at the St Lucia mouth following the absence of freshwater inflows that provide the necessary scouring, Ezemvelo KZN Wildlife maintains a dredging operation. The annual costs associated with dredging were used to provide a value of the management of sedimentation that is occurring currently.

4.2.5 Tourism

Tourism is a major contributor to the South African economy (SA Tourism, 2006). In 2006 over 8 million foreign tourists arrived in South Africa (SA Tourism, 2006). Information relating to tourism is often limited to arrival and departure counts or overnight-stay statistics (Stats SA, 2005). National tourism statistics were consulted such as average foreign tourist spending, average length of stay, number of visitors to certain areas, as well as national corporate income tax sector information. However, none provided a local and therefore accurate representation of tourism. Statistics South Africa provided data for monthly individual incomes for municipal wards that were used for calculations.

Mfolozi Floodplain

Data from Statistics South Africa provided the population numbers within various income categories for the town of Mtubatuba. The Umkhanyakude District profile (2006) provided the percentage contribution to the GDP for primary, secondary and tertiary sectors. The primary sector, including agriculture, hunting, forestry, fishing and mining, best represented tourism activities in the area. The proportion of GDP that was contributed by the primary sector (15 %) was applied to the total annual income of Mtubatuba. As this sector breakdown is ‘shared’ with agriculture, hunting etc, 10 % of the primary sector annual income was used to quantify the contribution of tourism activity to the local GDP. This value (10%) was chosen as there are few tourism activities currently operating within the floodplain and activities that are categorized within the primary sector do not attract equal contributions to the economy.

St Lucia System

The town of St Lucia is largely supported by tourism. It was assumed for this calculation that if tourism were not present, the town’s economy would collapse. Thus, the sum of individual incomes for St Lucia from Statistics South Africa was used to assess the value of tourism. Categories of income were averaged and multiplied by the recorded numbers of the population in each category. Values were then totalled to provide a total annual value for tourism in the town of St Lucia. When computing a ‘per ha’ value for St Lucia Tourism, it was reasoned that most of the tourism enterprises accounted for in the annual value operate within the Eastern Shores of iSimangaliso Wetland Park and the town itself. The area of the town of St Lucia was measured using ArcMap, which was added to the area of Eastern Shores.

4.2.6 Vegetation harvesting

Wetland plant resources are harvested by local people in KZN for a number of functions including supplementary food items and materials for craftwork (Traynor, 2008).

St Lucia System

Ezemvelo KZN Wildlife provided records of the harvesting of vegetation currently occurring within the iSimangaliso Wetland Park boundaries. Estimates of species harvested, quantities removed, frequency of harvesting and respective sales values were provided. Value estimates were totalled, giving an economic value for the iSimangaliso Wetland Park's vegetation provision function.

Mfolozi Floodplain

No data were available for the current harvesting occurring within the Mfolozi Floodplain. However, the use of natural resources is known to be significant in the Umkhanyakude District, particularly within the 'extensive wetland and floodplain areas' (Sharpe and Southern, 2003). From the total value estimates given for harvesting within the iSimangaliso Wetland Park area, a Rands per ha value was calculated. This was applied to the area of the Mfolozi Floodplain excluding the area under sugarcane. This gave a value estimate for the current harvesting occurring in the floodplain under the assumption that the same products that are harvested within the iSimangaliso Wetland Park are available in the floodplain and that the local community with access to the floodplain seek the same variety of products.

4.2.7 Fisheries

Methods from case studies in the literature were used to calculate St Lucia's value or contribution to national fisheries. The McDowell Group (2000) estimated the value of commercial fisheries by determining economic losses associated with potentially closing commercial fishing, in Glacier Bay, a World Heritage Site in Alaska. However, the St Lucia System differs in that the only fishing activities occurring within the Wetland Park itself are for recreational or research purposes. The value of the St Lucia and Mfolozi systems' indirect support of the recreational and commercial fishing industry was acknowledged, as estuaries are vital for providing nursery grounds for juvenile estuary dependant fish (Whitfield *et al.*, 2006). Therefore, Lake St Lucia and the Mfolozi River are particularly valuable for replenishing the fish stocks of the eastern seaboard (Lamberth and Turpie, 2003).

St Lucia System

An existing estuarine Rand per ha value from Lamberth and Turpie (2003) was applied to the area of Lake St Lucia. In their study Lamberth and Turpie (2003) consulted catch data from over half of South Africa's functioning estuaries in order to investigate the relationships between estuary size, type and biogeographical region and fish catch size. As St Lucia is classified as an 'estuarine lake' (Gordon *et al.*, 2008) and referred to as an 'estuarine system' (Cyrus and Vivier, 2006), the surface area of Lake St Lucia was used in the calculation. It is acknowledged however that the St Lucia Estuary, along with the Bot and Klein Estuaries were excluded from analyses in Lamberth and Turpie (2003), as they are 'large estuaries in which catches are disproportionately low' (p4). Calculations proceeded using Lamberth and Turpie's (2003) per ha data given the lack of a site-specific value.

Mfolozi Floodplain

The surface area of the Mfolozi Estuary, given from Vivier and Cyrus (2009.), was applied to Lamberth and Turpie's (2003) per ha value for 'estuarine contribution to fisheries' to determine an economic value of the Mfolozi Estuary's value in terms of supporting South Africa fisheries.

4.2.8 Existence value

Results ($/ha values) from Turpie *et al.*'s (2003) study investigating the existence value for South African Biodiversity were applied to both the Mfolozi Floodplain and the St Lucia System. Monetary values ($/ha) of willingness to pay (WTP) for biodiversity conservation for each biome in South Africa were applied to the area of biomes present within the Mfolozi Floodplain and the iSimangaliso Wetland Park and translated into 2008 Rand equivalents.

ArcMap was used to calculate the approximate area of each natural vegetation type and relevant biome within the study sites. Shapefiles were accessed from The National Vegetation Map of South Africa Project (Mucina and Rutherford, 2006), herein referred to as VEGMAP, providing polygon data for vegetation cover in the study area.

St Lucia System

The iSimangaliso Wetland Park boundary shapefile was provided by VEGMAP and used along with vegetation polygons to determine the area of each vegetation type located within the park boundary. The WTP values from Turpie *et al.*'s study (2003) were applied to each vegetation area and totalled, providing an existence value for the iSimangaliso Wetland Park. Certain vegetation types given by VEGMAP did not match those of Turpie *et al.* (2003) and therefore no specific monetary value could be applied directly. In these cases the lowest per ha monetary value (Savanna Biome) was applied to these vegetation types in order to provide a conservative estimate of value per ha.

Mfolozi Floodplain

The floodplain boundary shapefile was taken from Collings (2007) and the area of natural vegetation type calculated using ArcMap. Vegetation type area was applied to the WTP value from Turpie *et al.* (2003). Vegetation that did not match the VEGMAP classifications was considered 'Maputuland Coastal Belt' and assigned the lowest per ha existence value (Savanna Biome), from Turpie *et al.* (2003).

4.2.9 Cultural and educational value

Although the available resources in a natural environment are particularly significant in terms of cultural services (Impey, 2002), the vegetation harvested for cultural means in the study sites were included with the resources harvested for subsistence in the 'Vegetation Harvest' value in this study in order to avoid double counting (Hein *et al.*, 2006; De Groot *et al.*, 2002).

It is acknowledged that an effective method for valuing cultural, artistic or spiritual significance is to conduct intensive contingent valuation (De Groot *et al*, 2002) as in the cultural study by Impey (2002). However, due to the scope and time frame of this study, valuation was limited to a benefit transfer method for cultural significance.

St Lucia System

The area for each vegetation type was calculated in ArcMap as for 'Existence Value'. Cultural values ($/ha) for specific biomes from Costanza *et al.* (1998) were applied to each of the calculated vegetation areas within the iSimangaliso Wetland Park boundary.

Educational value was measured by the annual income generated from visitors to the Crocodile Centre on Eastern Shores of the iSimangaliso Wetland Park. The record of gate entry income of visitors to Mission Rocks (mostly school groups) was added to this figure. Subsequently, the associated costs of research projects currently registered with the iSimangaliso Wetland Park Authority were also included in the calculation. A third of the registered projects were treated as being funded as higher degree research bursaries, with the remainder having reduced budgets for follow up or limited annual expenses.

Mfolozi Floodplain

The vegetation areas as for existence value, from ArcMap were used for each vegetation type in the floodplain. The cultural values ($/ha) from Costanza *et al.* (1998) were applied to each area.

A value for education or research was included as the current annual expenditure involved in sugarcane research. The South African Sugar Association was consulted for overall annual research expenditure. Data for the 2007/2008 sugar season were used to determine the total area in South Africa under sugarcane and subsequently to calculate an annual 'research expense per ha' value for the Mfolozi Floodplain. The area under sugarcane on the floodplain (Collings, 2007) was applied to the research expenses value per ha, giving a value associated with the sugarcane in the floodplain. Existence and educational values for the Mfolozi Floodplain were then added.

4.3 Outline of restoration scenarios

Each scenario presented by this study does not consider outcomes over a specific period of time, nor do they concentrate on the time required for restoration. Rather, the restored ecological state following restoration as per the scale suggested by each scenario was considered.

4.3.1 Current land use: no restoration

The first scenario considers the current environmental conditions of the Mfolozi River and St Lucia System should the situation remain as it is currently, with no restoration of the Mfolozi Floodplain. Therefore, no link between the Mfolozi River and Lake St Lucia would be established under this scenario.

4.3.2 Partial restoration

Partial restoration considered re-establishing wetlands in low-lying areas of the floodplain along the Mfolozi River channel as delineated by Collings (2007). Low-lying areas have the highest risk of flooding and therefore are considered to be the most suitable for wetland restoration. This concept was first raised in the 1980's by van Heerden (Figure 11). This area of about 6 000 ha includes approximately 1 800 ha of sugarcane (Collings, 2007). The restored wetland system is assumed to reinstate effective sediment removal for the Mfolozi River water to a level that would allow only a temporary link with the St Lucia System as the area of floodplain available for sediment filtration is not expected to provide sufficient filtration to allow for the Mfolozi River to flow into the St Lucia System permanently.

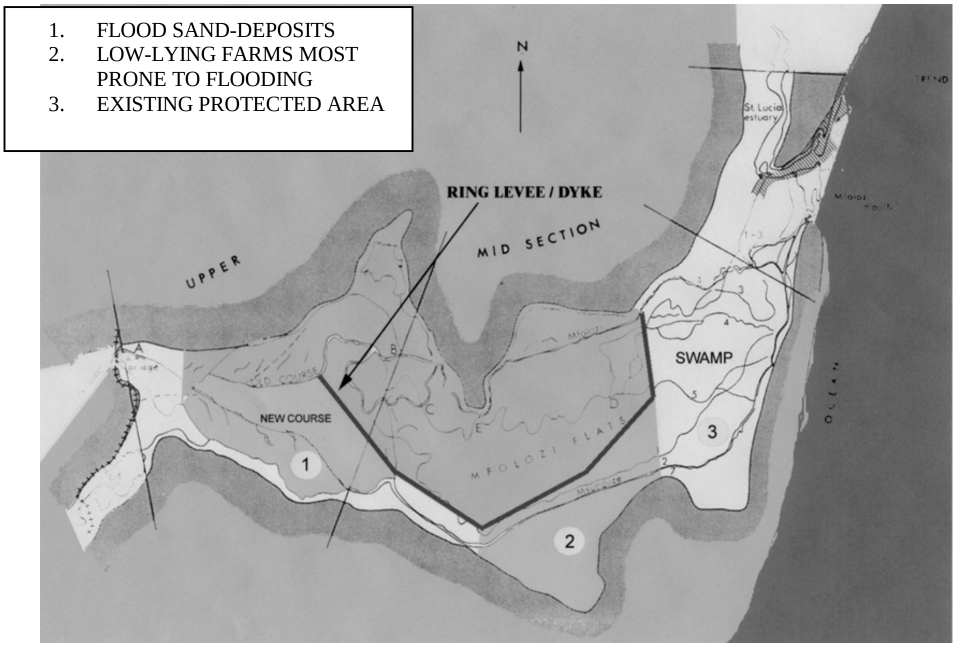

Figure 11: Image taken from a presentation to Ezemvelo KZN Wildlife entitled: 'The Umfolozi Floodplain as a sediment trap' illustrating the van Heerden concept.

With an increase in freshwater supply to Lake St Lucia, although temporary in this scenario, environmental conditions are expected to improve. Salinity levels would stabilise and the St Lucia mouth would breach more frequently. However, although this scenario allows for the Mfolozi River to provide supplementary waters to Lake St Lucia, this may only occur during high flows during summer. However, this scenario may not provide adequate alleviation of the stress experienced by the St Lucia System during dry periods.

Restoration of the allocated land in the floodplain in this scenario would reinstate a natural wetland habitat, thereby improving the biodiversity and ecosystem service provision of the area. This 'new' natural habitat is expected to attract new tourism initiatives.

4.3.3 Full restoration

This scenario considers the potential restoration of all land in the demarcated floodplain area of approximately 20 000 ha, of which 8 000 ha is currently covered by sugarcane (Collings, 2007). Under this scenario it was assumed that all privately owned land would be purchased and included into the iSimangaliso Wetland Park or form a separate conservation area.

This scenario assumes that restoring the floodplain would reinstate filtration of the Mfolozi River water sufficiently to allow for a permanent link with Lake St Lucia. It is assumed in this scenario that the volume of freshwater input to the lake system during high flow months would be sufficient in order to maintain efficient ecological functioning into dry periods. It is thus expected that the St Lucia System would no longer experience dramatic fluctuations in salinity along with other ecological stresses during drought periods. The increased freshwater supply would alleviate pressures on the local biota as well as support tourism activities. The St Lucia mouth would again be expected to breach more frequently than currently following the increase in water volume as a consequence of Mfolozi River water entering the St Lucia System.

Land use in of the Mfolozi Floodplain would shift from intensive sugarcane to natural habitat. This scenario involves the removal of all drainage and infrastructure to accommodate wetland restoration. The restored natural habitat, along with an expected increase in biodiversity, would attract nature based tourism enterprises as well as vegetation harvesting.

4.4 Changes to economic values

Communication was made via email with 19 specialists selected on the basis of their experience in the field of environmental economics or their ecological knowledge of the Lake St Lucia System or the Mfolozi Floodplain. Emails provided necessary background information regarding the study. Specialists were required to complete a table, indicating their estimates of change (percentage increase or decrease) to given economic values of ecosystem services that would be expected under each restoration scenario (Appendix A). Specialists were asked to provide a rating from 1-3 for their confidence regarding their answers for each ecosystem service. It was recognized that certain respondents have more experience or knowledge of a particular ecosystem service than others. A score of one indicated weak confidence in the given answers, two represented moderate confidence and three indicated strong confidence. ‘Confidence’ points were used to weight each specialist’s estimates of change to ecosystem service values in MS Excel. To maintain anonymity, respondents were assigned a letter for identification throughout analyses.

The weighted averages of percentage changes to ecosystem services from specialist responses were applied to the initial monetary values for each service for both the partial and full restoration scenarios, in order to assess the economic value of different restoration scenarios.

5. Results

Ecosystem service valuation produced summaries of a number of data sets that were required for calculations. Summation of economic values for ecosystem services gave an approximation of the total economic value for both the Mfolozi Floodplain and the Lake St Lucia system in their current condition. Results show that the majority of ecosystem services, under both restoration scenarios for both the Mfolozi Floodplain and the Lake St Lucia system, are expected to increase in economic value.

5.1 Data assimilation

5.1.1 Water provision

Valuation for the water provision service function made use of data from DWAF records, including water management charges for a number of sectors in the Mfolozi River municipal region and registered volumes of water abstraction (Table 4). Under current farming practices, irrigation was responsible for the largest volume registered for extraction and therefore incurred the highest charge.

Table 4: Registered user information for the Mfolozi River for each sector summarised from DWAF raw data.

Sector	Number of registered users	Total Volume (m^3/annum)	WRM: Water Resource Management Charge (ZAR)
Irrigation	79	34 531 175	200 281
Aquaculture	1	288 000	-
Commercial (urban-industry)	49	6 407 194	20 503
Industry (non-urban)	1	2 007 500	13 651
Livestock	1	54 000	313
Schedule 1	15	21 470	-
10-100% industrial waste	1	100 000	-
TOTAL	**147**	**43 409 339**	**234 748**

5.1.2 Vegetation harvesting

Preliminary estimates of the current annual vegetation use within the iSimangaliso Wetland Park were provided by Ezemvelo KZN Wildlife (Table 5). Harvesting estimates were given for resources currently utilised for both subsistence and small-scale commercial farming. Incema (*Juncus kraussii*) is targeted by the greatest number of users, followed by other reeds and firewood. In terms of estimated market values, firewood, sedges and Incema (*Juncus kraussii*) are estimated at the highest annual values.

Table 5: Summary of the current annual resource harvesting within the iSimangaliso Wetland Park (Ezemvelo KZN Wildlife). (E Shore: Eastern Shores, W Shore: Western Shores, CFR: Coastal Forest Reserve)

Resource	Locality	No. of Users	Total Bundles	Estimated value (ZAR)
Total Firewood		**500**	**50 000**	**750 000**
Incema (*Juncus kraussii*)	Kosi	150	7 008	280 320
	St. Lucia E. Shore	120	4 000	160 000
	St. Lucia Mouth	250	2 000	80 000
	St. Lucia W. Shore	25	1 000	40 000
	Ozabeni	50	1 000	40 000
	Sibaya	30	500	20 000
Total Incema		**625**	**15 508**	**620 320**
Reeds	Kosi	150	5 475	164 250
	Ozabeni	80	5 000	150 000
	Mkhuze	200	4 500	135 000
	Mngoboseleni	35	1 000	30 000
	St. Lucia W. Shore	50	500	15 000
	Sibaya	40	500	15 000
	St. Lucia Mouth	60	200	6 000
Total Reeds		**615**	**17 175**	**515 250**
Sedges	Ozabeni	150	20 000	700 000
	Mkhuze	60	800	28 000
	CFR	50	1 000	35 000
Total Sedges		**260**	**21 800**	**763 000**
Thatch	Mkhuze	40	1 000	20 000
	CFR	20	200	4000
Total Thatch		**60**	**1 200**	**24 000**
Raffia palms	CFR	50	500	25 000
Binding materials	CFR	20	100	2 000
Forbs (muthi)	CFR	20	200	8 000
Lala Palms	Ozabeni	200	25 000	875 000
TOTALS		**3 410**	**131 483**	**3 582 570**

5.1.3 Existence value

The existence value for both the Mfolozi Floodplain and St Lucia System was calculated by valuing the area of each natural vegetation type present in both sites (Table 6). Data from Turpie (2003) resulted in the highest per ha value for the forest biome at US$ 22.27 per ha with marine, grassland and savanna vegetation with per ha values under US$1. Owing to an area of over 180 000 ha in the iSimangaliso Wetland Park and over 11 000 ha on the Mfolozi Floodplain, the Maputaland coastal belt, freshwater wetlands and saltpans generated the highest existence values.

Table 6: WTP values per biome along with classification and vegetation area cover in the iSimangaliso Wetland Park and Mfolozi Floodplain.

Biome (Turpie et al. 2003)	**WTP value (US$/ha/yr) (Turpie, 2003)**	**Applied VEGMAP Vegetation classification**	**Area within Park or Floodplain Boundary (Ha)**	**Calculated WTP values (US$/yr)**
St Lucia System				
Forest	22.27	Northern Coastal Forest	34 004	
		Swamp Forest	2 205	
		Mangrove Forest	1 816	
		Lowveld Riverine Forest	1 008	
		Sand Forest	1835	
		Total Forest	40 868	910 133
Grassland	0.02	Maputaland Wooded Grassland	31 990	
		Total Grassland	31 990	640
Marine	0.64	Subtropical Seashore Vegetation	264	
		Subtropical Dune Thicket	141	
		Subtropical Coastal Lagoons	3 692	
		Total Coastal	4 097	2 622
Savanna	0.01	Western Maputaland Sandy Bushveld	1 493	
		Western Maputaland Clay Bushveld	1 805	
		Makatini Clay Thicket	8 770	
		Total Bushveld (Savanna)	12 068	121
Other (Savanna)	0.01	Maputaland Coastal Belt	164 374	
		Subtropical Freshwater wetlands	24 742	
		Inland saline vegetation Salt pans	311	
		Total Other	189 426	1 894
TOTALS				US$ 915 410
Existence value TOTAL				**ZAR 9 069 231**
Mfolozi Floodplain				
Forest	22.27	Mangrove Forest	1 814	
		Total Forest	1 814	40 402
Other	0.01	Maputaland Coastal Belt	11 041	
		Total Other	11 041	110
TOTALS				US$ 40 512
Existence value TOTAL				**ZAR 401 364**

5.1.4 Cultural and educational

Calculations of the cultural and education service values produced values of over R 320 million for the iSimangaliso Wetland Park and over R 6 million for the Mfolozi Floodplain. The vegetation classified under 'wetlands and pans' contributed the greatest monetary value for the iSimangaliso Wetland Park. The 'coastal vegetation' type on the floodplain contributed the greatest cultural value.

Table 7: Per ha values for cultural importance from Costanza *et al.* (1998) as applied to vegetation areas for the iSimangaliso Wetland Park and Mfolozi Floodplain.

Applied VEGMAP Vegetation Classification	**Cultural value $/ha/yr (Costanza *et al.*, 1998)**	**Area in study site (Ha)**	**Calculated Cultural Value (US$)**
iSimangaliso Wetland Park			
Forest	2	40 868	81 736
Grassland	-	31 990	-
Coastal (including Maputuland Coastal Belt)	62	164 779	10 216 270
Bushveld	-	12 068	-
Wetlands & Pans	881	25 053	22 071 332
TOTAL			US$ 32 369 338
		Total Cultural Value (ZAR)	**320 692 743**
Mfolozi Floodplain			
Vegetation Classification given by Costanza *et al.* (1998)			
Estuaries	29	360	10 446
Wetlands	881	-	-
Swamp/flood plains	1 761	-	-
Cropland	0	8030	-
Forest	2	1814	3 628
Coastal vegetation (remaining area of floodplain)	62	10 682	662 261
TOTAL			US$ 676 335
		Total Cultural Value (ZAR)	**6 700 657**

Note values may not add up due to rounding

5.2 Ecosystem service values

Economic valuation of ecosystem services required the use of data from a number of sources. The calculations of each ecosystem service value along with corresponding data references were summarised (Table 8).

Table 8: Summary of ecosystem services valuation and data sources for each calculation.

Ecosystem Goods & Services	**Reference / Data Source & Calculation**			
	Mfolozi Floodplain		**St Lucia System**	
Flood alleviation	UCOSP: Annual drainage maintenance + other precautionary costs	R3 500 000 + R1 500 000	Estuaries disturbance regulation value (Costanza *et al.*, 1998) Lake St Lucia surface area (Taylor *et al*, 2006)	\$567/ha x 35 000 ha (x 9.9073)
Water provision	UCOSP Irrigation Cost estimates DWAF registered users & tariffs	R4 370 000 +R234 748 See Table 4	Dam abstraction cost (Perkins pers. comm.) Lake St Lucia volume (Bate & Taylor, 2007)	R0.5 x 320 000 000 m^3
Water purification	'Rivers & Lakes' waste treatment value (Costanza *et al.*, 1998) Estimated surface area of rivers within Floodplain (Arc9 GIS software)	\$665/ha/yr x 22 ha (x 9.9073)	'Rivers & Lakes' waste treatment value (Costanza *et al.*, 1998) Lake St Lucia surface area (Taylor *et al.*, 2006)	\$665/ha/yr x 35 000 ha (x 9.9073)
Sediment retention	Filtration confirmed from lab tests Cost of concrete sediment trap to water works specs (PDNA: D. Collings, pers. comm.)	R 500 000	Dredging costs per annum for mouth management (Ezemvelo KZN Wildlife, 2008)	R 2 000 000
Tourism	Primary sector activities are 15 % of district GDP (Umkhanyakude District: Profile, 2006); Tourism assumed to contribute 10 % to primary sector; Total annual individual income for Mtubatuba (Statistics South Africa, 2009)	0.015 x R 110 623 200	Total annual individual income for St Lucia, Individual monthly income (Statistics South Africa, 2009)	R 35 824 800
Vegetation harvesting	Records of harvesting in iSimangaliso Wetland Park (Ezemvelo KZN Wildlife, 2008) per area of Park (UNESCO, 1999). Area of Mfolozi Floodplain (Collings, 2007). Less the area under sugarcane (Collings, 2007)	(R 3 582 570/ 234 566 ha) x (20 886ha – 8 030 ha)	Records of harvesting in iSimangaliso Wetland Park (Ezemvelo KZN Wildlife, 2008)	R 4 755 140

Ecosystem Goods & Services	Reference / Data Source & Calculation			
	Mfolozi Floodplain		St Lucia System	
Fisheries	R/ha value for KZN estuaries (Lamberth and Turpie, 2003). Surface area of Mfolozi Estuary (Vivier and Cyrus, 2009)	R 4 114 /ha/yr x 180 ha	R/ha value for KZN estuaries (Lamberth and Turpie, 2003). Surface area of Lake St Lucia (Bate & Taylor, 2008)	R 4 114 /ha/yr x 35 000 ha
Existence	R/ha/yr WTP Existence values for SA Biomes (Turpie, 2003). Area of vegetation types in Mfolozi Floodplain (ArcMap) as from VEGMAP (Mucina & Rutherford, 2006)	See Table 6	R/ha/yr WTP Existence values for SA Biomes (Turpie, 2003). Area of vegetation within iSimangaliso Park boundary (ArcMap) as from VEGMAP (Mucina & Rutherford, 2006)	See Table 6
Cultural & education	\$/ha Cultural Values (Costanza *et al.*, 1998) Area of vegetation types in Mfolozi Floodplain (ArcMap) as from VEGMAP (Mucina & Rutherford, 2006) Research expense in SA per area of sugarcane (SASA, 2009). Area of sugarcane in floodplain	See Table 7 R 6 700 657 + (R 157 / ha x 8 030 ha)	Area of vegetation types within iSimangaliso Park boundary (ArcMap) as from VEGMAP (Mucina & Rutherford, 2006) Cultural Value for biomes (Costanza *et al.*, 1998) Income from Crocodile Centre visits & Mission Rocks (Ezemvelo KZN Wildlife, 2008) Estimated costs of current research projects within Park	See Table 7 R 320 692 743 + R 1 259 500 + R 2 720 000

Note: Totals may not add up due to rounding.

Resultant annual economic values showed that cultural and educational services were the greatest for both the St Lucia System (R 325 mil/yr) and the Mfolozi Floodplain (R 8 mil/yr), following which, regulating services were the highest (Table 9). These included water purification (R 231 mil/yr), flood alleviation (R 197 mil/yr) and water provision (R 160 mil/yr) for the St Lucia System and flood alleviation (R 5 mil/yr) and water provision (R 4.6 mil/yr) services for the Mfolozi Floodplain. Fisheries and tourism, important industries in the district were valued at 13 and 3 % of the total economic value for the St Lucia System respectively. The current fisheries value for the Mfolozi Floodplain was calculated as 3 % of the total economic value of the floodplain and a tourism value about 8 % of the total. In comparison to other ecosystem services, under the current land use, the Mfolozi Floodplain offers a relatively low economic value for its sediment retention and water purification function.

Regulating ecosystem services flood alleviation, water provision and water purification, among the highest valued services for the St Lucia System, were calculated for the St Lucia Lake. This is important to note, as the lake currently experiences major stress during drought periods. Should environmental conditions deteriorate into the future, ecosystem services may be adversely affected, thereby impacting on associated economic values.

Table 9: Economic values of ecosystem services for the Mfolozi Floodplain and St Lucia System. Millennium Ecosystem Assessment classification of ecosystem (Reg: Regulating, Sup: Supporting, Prov: Provisioning, Cult: Cultural).

MEA	Ecosystem Goods & Services	Current Annual Economic Value (ZAR)		
		Mfolozi Floodplain	St Lucia System	
Reg.	Flood Alleviation	5 000 000	196 610 400	Lake
	Water Provision	4 604 700	160 000 000	Lake
	Water Purification	144 900	230 592 400	Lake
	Sediment Retention	500 000	2 000 000	Park
Sup.	Tourism	1 659 300	35 824 800	St Lucia town
Prov.	Vegetation Harvesting	196 400	3 582 600	Park
	Fisheries	740 500	143 990 000	Lake
Cult.	Existence	401 400	9 069 200	Park
	Cultural & Education	7 959 800	324 672 200	Park
	Total Annual Value	**21 948 400**	**1 106 341 600**	

Note: Totals may not add up due to rounding.

5.3 Scenario outcomes

5.3.1 Specialist responses

The emailed questionnaires that targeted 19 specialists resulted in the response from eight, giving a response rate of 42.1 %. Specialists who provided feedback have a range of experience in a number of fields (Table 10).

Table 10: Specialists who contributed to the study.

Name	Area of Expertise	Organisation
Janine Adams	Estuarine ecology, Estuarine management and Environmental flow requirements	Water Research Commission, Nelson Mandela Metropolitan University, Port Elizabeth
Maura Andrew	Social Scientist	Coastal and Environmental Services, Grahamstown
Fred Ellery	Wetland ecology and	Rhodes University,

Name	Area of Expertise	Organisation
	rehabilitation	Grahamstown
Suzanne Grenfell	Geomorphology and Mfolozi Sediments	University of Exeter, UK
Christo Marais	Biodiversity protection, Water management & Resource economics, Payment for ecosystem services	Working for Water, DWA
Ricky Taylor	Regional ecologist	Ezemvelo KZN Wildlife, St Lucia
Damien Walters	Wetland ecology and rehabilitation	WESSA Mondi Wetlands Program, KwaZulu-Natal
Alan Whitfield	Ichthyology, Biological oceanography, Marine ecology, Estuarine ecology	South African Institute of Aquatic Biodiversity, Grahamstown

Additional comments were given by respondents, which provided reasoning for their estimations of change to ecosystem service values under each restoration scenario (Table 11). A common concern was that restoration of the Mfolozi Floodplain would reduce the number of users in the floodplain who benefit from ecosystem services and therefore decrease the amount of value attributed to those services. An increased provision of water to the St Lucia System, following restoration and a link with the Mfolozi River, was also mentioned to increase the flood risk to the town of St Lucia. Specialists also stated however, that once the Mfolozi Floodplain is returned to a natural wetland state, generally ecosystem services would improve on the floodplain and positively influence those provided by the St Lucia System. Restored sediment retention on the Mfolozi Floodplain was highlighted as a very important consequence of restoration as was the increase in biological productivity (Table 11).

Table 11: Summary of additional comments given by respondents with their estimates of changes to economic values of ecosystem services.

	MFOLOZI FLOODPLAIN	ST LUCIA SYSTEM
Flood alleviation	• Flood attenuation is as low as can be expected for a floodplain of this size under current use. This is expected to increase appreciably. • Flood risk to remaining floodplain farms will increase due to flood back up when the swamp is re-established. When all farms are rehabilitated, flood risk will be limited to rural dwellers on upstream margins of the swamp. • As the floodplain is at the sea, the opportunity of flood alleviation is actually 0. Any increase in flood attenuation is not truly beneficial as there are no downstream assets. Thus, although flood attenuation would increase, there'd not be a monetary value associated with that increase.	• Additional water from Mfolozi to St Lucia will increase flood risk to St Lucia Village. • There is a lack of opportunity for this service. However, it would decrease if permanently joined (the water level would be constantly higher). And would likely be unchanged with partial restoration. • Currently the lake is not linked to the Mfolozi – except during floods, when connectivity is increased. Therefore, during floods the Lake does function well and restoration will not do a huge amount with respect to flood alleviation.
Water provision	• Water will be held in the landscape for much longer. • As there would be fewer sugar cane farms after restoration, the measurable monetary value of water provision would decrease. However, some would be used for the ecological reserve. • The loss of farms due to rehabilitation of swamp will reduce water provision to current users.	• If the lake and Mfolozi River is reconnected with partial or complete restoration, the lake will be permanently full and have an open mouth. • If water provision in the system is providing freshwater for abstraction, restoration will not influence this. • The amount of Mfolozi River water entering St Lucia will exceed all the other rivers combined under the full restoration scenario.
Water purification	• It is unclear whether there is opportunity for the purified water to be used but perhaps "downstream" ecosystems are the beneficiaries. • Rehabilitation of the swamp will have major positive benefits for the Mfolozi Estuary. • Water purification would only occur when the river flooded its floodplain, a relatively rare occurrence (maybe once or twice a year). The rest of the time, the rehabilitated floodplain would offer no water purification benefit. Removing levees may improve the situation. However, the slope of the floodplain means that 'purified' water does not flow back into the river, and this therefore does not actually benefit Lake St. Lucia. • Water purification is as low as can be expected for a floodplain of this size under current use, and this will be increased appreciably.	• Re-establishing the link (Mfolozi & St Lucia) should improve the quality of the water in the system, as it will be flushed more regularly. • Is there opportunity for this service i.e. a need for water purification (as with a pollution source and a beneficiary)? • The lake currently (and with restoration) plays little or no role in water purification. It's the wetlands of the Mfolozi and Mkhuze (and others on the coastal plain that link with St Lucia) that do the work in this respect.

	MFOLOZI FLOODPLAIN	ST LUCIA SYSTEM
Sediment retention	• More soil would be retained on site if the drains were blocked. The proportional contribution of sediment eroded from the floodplain, compared to that from the Mfolozi catchment is however, negligible. • Generally there is a linear relationship between vegetation cover and soil movement. This however doesn't take into account plough, which might increase soil movement even more. I prefer more conservative estimates therefore cultivated land (limited tillage) was used as the norm. • Floodplains are good at retaining sediments during flood events, but not at low flows. The floodplain in its current form is still a good sediment trap during flood events. The only difference is during medium flow stages, when the rehabilitated floodplain will perform better, and in a system where flow is either low or high, the difference is not as great as might be expected.	• Soil retention by the Mfolozi Swamp is very important to prevent infilling of St Lucia. • The restoration of the Mfolozi – St Lucia link won't have a significant effect on soil retention. Improved riparian zone vegetation will trap soil movement.
Tourism	• The limiting factor for tourism in the area is the availability of land for potential tourism infrastructure. • A healthy Mfolozi Floodplain will attract tourism development to the area. There'll be an increased opportunity for bird watching, trails and canoeing. • Tourists will increase to see the "rehabilitation" and a "rehabilitated" system. • Returning the floodplain to natural vegetation offers huge tourism potential. It would add significantly to the wetlands reserve.	• An ecosystem full of water will promote St Lucia eco-tourism. • The Lake will be restored and the Estuary fully functional. This is a major attraction – that is sadly compromised when there is no water in the lake. Fishermen will return in droves!
Vegetation harvesting	• Swamp rehabilitation will open up new harvesting opportunities. • The extensive restoration of the floodplain will definitely increase the productive potential of the natural resources on the land. However, I did not take into account the loss in productive potential of removing the sugarcane. • Having indigenous vegetation available on this scale following rehabilitation will increase its use.	• The increased productivity of emergent vegetation will allow additional harvesting. • There would be much greater opportunities – but the demand would be limited. • The biological productivity of floodplains and fringing marshes will be reinstated and the natural resources provisioning will greatly increase.

	MFOLOZI FLOODPLAIN	ST LUCIA SYSTEM
Fisheries	• The frequent interference (breaching/moving of the mouth) would result in a decrease in fish productivity in the Mfolozi River estuary with a partial restoration. However, if linked (and left to natural dynamic), and with the floodplain restored (providing nutrients etc for fish) there is a likelihood of fishing productivity increasing for the 2nd scenario (full restoration). • Rehabilitation of swamp and re-linkage with St Lucia will improve estuarine and coastal fisheries considerably. • One would also expect increase in fresh water ponds in the floodplain.	• Restoration of St Lucia will have a major positive impact on fisheries. • The functioning of the St Lucia Estuary will be reinstated, with huge benefits for fisheries (both in the Lake and marine).
Existence	• There is undoubtedly a value in having extra regions of natural floodplain in such a dynamic region. • Restoring the function of the floodplain system is nearly priceless in terms of its biodiversity benefits. Rehabilitation will raise awareness about this issue. • Restoration would re-establish an important swamp biome.	• The restoration of the lake is important to the overall park biome integrity. • Its existence value would increase the more the natural dynamic is reinstated. • Again, restoring the function of the system is nearly priceless in terms of its biodiversity benefits.
Cultural & education	• Restoration of the Mfolozi swamp is vital to restore full cultural and educational value of river. • With the advent of global climate change both of these factors are going to become more and more important. • It will present many opportunities!	• Restoration of the lake is vital to restore full cultural and educational value of park. • Great opportunities exist in the park for education whether the floodplain is rehabilitated or not, but opportunities will increase with rehabilitation.

5.3.2 Changes to ecosystem service values under restoration scenarios

In order to provide a measure of the change to overall economic value of each study site under each scenario, the sum of economic values for every ecosystem service was considered. It is important to note however, that these figures do not represent a total economic value (TEV) as referred to in the literature (Turpie and Lannas, 2007, Edwards and Abivardi, 1997). A number of variables required for calculating such a TEV were not included in the analyses in this study (e.g. option value). Further, valuation of ecosystem services were calculated using different sizes areas for the St Lucia System (Table 3), such as the area of the lake or the area of the Park, and therefore cannot provide a total economic value for a specific area. Thus, the sum of the ecosystem service values presented does not provide a TEV for each system but rather can only be considered indicative of the overall economic value.

With the exception of the water provisioning service, every ecosystem service on the Mfolozi Floodplain experienced a greater percentage increase than the St Lucia System under both restoration scenarios (Figure 13).

5.3.2.1 Partial Restoration

Mfolozi Floodplain

Under a partial restoration scenario, the sum of all ecosystem service values increased by approximately 26 % from the current land use value (Figure 13). The results showed existence value, tourism, fisheries and vegetation harvesting, all increased by over 80 % (Figure 13). It was expected that the potential increased natural habitat would provide new opportunities for tourism as well as the harvesting of natural vegetation (Table 11).

Restoration of wetland habitats in the lower lying areas of the floodplain would reduce the risk of flooding due to the available habitat in which flood waters would be dissipated. Wetland vegetation in these restored areas would increase the filtering of sediments as well as purify the water travelling through the system. Annual economic values for these regulating services, flood alleviation, water purification and sediment retention, would increase under this scenario by between 25 – 40 % (Figure 13). It is believed that the additional natural habitat would also provide greater opportunities for cultural and educational practices, expected to increase by about 26 %. The value of water provision to the Mfolozi Floodplain, however, was expected to decline by approximately 14 %, due to the reduction in water users under partial restoration, particularly for irrigation purposes.

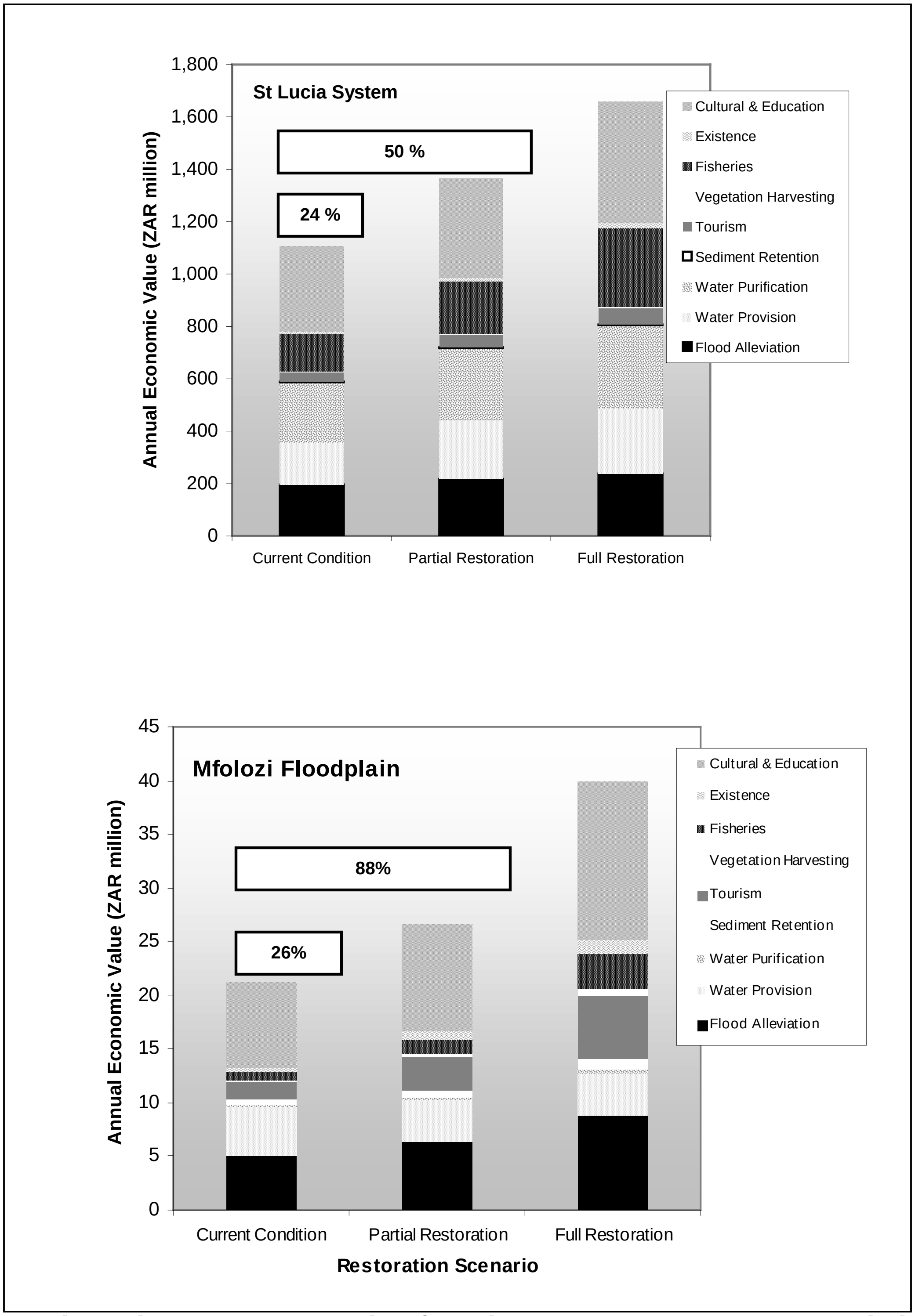

Figure 12: The total annual ecosystem service values for each restoration option. Percentages (calculated from the difference between the Annual Economic Value for the restoration scenario and the Economic Value of the current condition) indicate the expected change under each scenario from current total economic value.

St Lucia System

The total ecosystem service value was expected to increase by about 24 % from the current situation (Figure 12). The existence value of the St Lucia System would experience the greatest percentage increase of 61 % following partial restoration of the floodplain. Additional water supply from the Mfolozi River in this scenario, although temporary in this scenario, would increase the water provision service value by 40 % (Figure 13). Returning freshwater volumes to the St Lucia Estuary, along with regular flushing of the system due to the mouth opening more frequently, would re-establish vital nursery grounds for estuary dependant marine fish. This would impact positively on the countries fisheries, as the case would be for the Mfolozi Estuary under this scenario. The results showed approximately 40 % increase in the value for fisheries under this scenario. Concern was raised however, that the increased freshwater inflow might also increase the flood risk to the town of St Lucia (Table 11). The annual value of tourism was also expected to increase by approximately 34 %. Results showed economic values for flood alleviation, water purification, sediment retention, vegetation harvesting and cultural and education would increase by less than 20 % under this scenario.

5.3.2.2 Full Restoration

Mfolozi Floodplain

Restoring the entire floodplain area is expected to increase the sum of current ecosystem service values by approximately 88 % (Figure 12). Fisheries would increase by 330 %, which is more than double the expected increase following a partial restoration of the floodplain. Opportunities for tourism would also improve substantially, increasing the value of tourism by about 260 %. Further, the additional habitat restored under this scenario would increase the supply of natural resources available for harvesting, growing in economic value by 230 %. The change from sugarcane to natural wetland habitat would see the existence value of the floodplain increase by approximately 250 %. Flood alleviation, water purification, sediment retention and cultural and education services would increase more than 75 % under this scenario. Following the decrease in downstream users in the floodplain, water provision is expected to decrease by about 10 %.

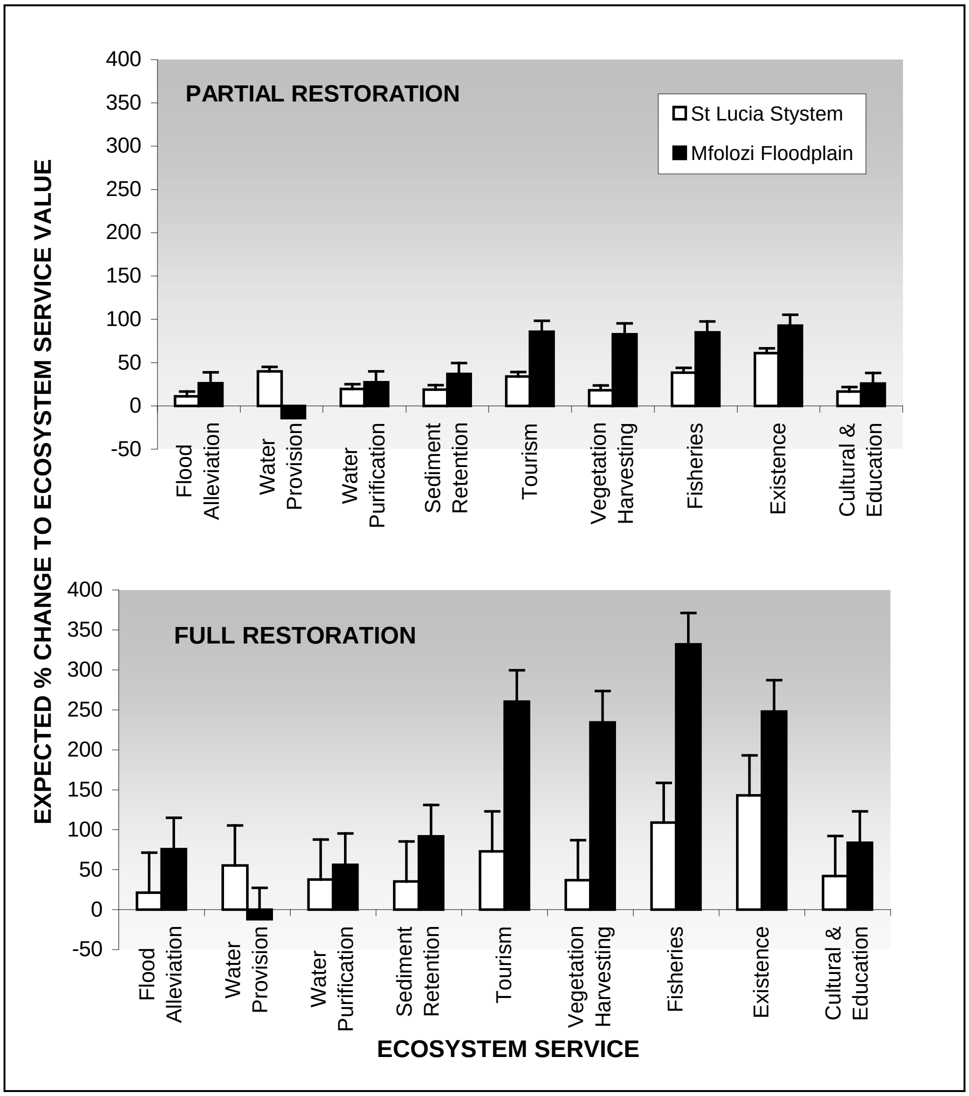

Figure 13: Expected percentage changes to ecosystem services in each study site under a partial (above) and full (below) restoration scenario.

St Lucia System

Total added ecosystem service values for the St Lucia System would increase by 50 % if the Mfolozi Floodplain were fully restored (Figure 12). The existence value would experience the greatest percentage change of over 140 % under this scenario (Table 12), which may be expected given the conservation area of its size as well as the expected increase in overall health of the system. The permanent link with the Mfolozi River under this scenario would provide the freshwater inflow required to alleviate the severe ecological stress currently experience by the lake system. Salinity and water temperatures are expected to stabilise and the St Lucia mouth would open more frequently, re-establishing nursery grounds for estuary dependant marine fish as experienced under a partial restoration scenario. Greater hydrological and chemical stability is also expected to influence tourism activities positively. Results show fisheries and tourism values increasing by 109 % and 73 % respectively. An increase in the value of cultural and education service (40 %) is also expected. Given greater volumes of water that would be entering the system from a link with the Mfolozi River, the value of water provision was expected to increase by 55 %. However, increasing the available water supply to the St Lucia System was also mentioned to potentially increase flood risk to the St Lucia Village (Table 11). Despite this concern, the flood attenuation value was estimated to increase by about 20 % in this scenario. Increasing water levels in the lake and the possible submergence of shoreline vegetation is not expected to offer much greater opportunities for the harvesting of vegetation. However, these conditions may still provide increased purification of the water along with the retention of sediments. Water purification, sediment retention and the harvesting of vegetation values are expected to increase between 30-40 %.

Table 12: Ecosystem services listed from highest to lowest expected percentage change to economic values under each restoration scenario.

Rank	MFOLOZI FLOODPLAIN		Rank	ST LUCIA	
	Partial Restoration	**Full Restoration**		**Partial Restoration**	**Full Restoration**
1	Existence	Fisheries	1	Existence	Existence
2	Tourism	Tourism	2	Water Provision	Fisheries
3	Fisheries	Existence	3	Fisheries	Tourism
4	Vegetation Harvesting	Vegetation Harvesting	4	Tourism	Water Provision
5	Sediment Retention	Sediment Retention	5	Water Purification	Cultural & Education
6	Water Purification	Cultural & Education	6	Sediment Retention	Water Purification
7	Flood Alleviation	Flood Alleviation	7	Vegetation Harvesting	Vegetation Harvesting
8	Cultural & Education	Water Purification	8	Cultural & Education	Sediment Retention
9	Water Provision	Water Provision	9	Flood Alleviation	Flood Alleviation

6. Discussion

6.1 Ecosystem service valuation

Under the current land use, the sum of all ecosystem service values for the St Lucia System was calculated at over R 1.1 billion and R 22 million for the Mfolozi Floodplain (Table 9). This equates to approximately 90.8 % and 2.0 % of the Umkhanyakude District gross geographic product (GGP) for 2000 (Sharpe Southern, 2003) for the St Lucia System and Mfolozi Floodplain respectively. The highest calculated ecosystem service values for both the St Lucia System and Mfolozi Floodplain was the cultural and educational service, which falls under the 'Cultural' services of the MEA classification (Table 2). Following the cultural services, regulating services resulted in the greatest annual economic values (Table 9), which included water purification, water provision and flood alleviation. Regulation functions are often overlooked due to their indirect benefits to society (De Groot *et al.*, 2002), although they are significant in influencing a number of processes such as the frequency and magnitudes of natural 'catastrophes', which in turn affect provisioning, supporting and cultural services (MEA, 2003). Appreciation for such influential services is illustrated in the results that show regulating services among the highest economic values for both the St Lucia System and Mfolozi Floodplain. Given the lack of site-specific data available for certain valuation calculations and consequently the use of the benefit transfer valuation method (Tables 3 and 8), it is acknowledged that site-specific variables would have provided a more accurate representation of economic values. Certain 'context dependent' limitations apply when one imputes data from a reference site to an alternative study site, such as a difference in scale or in population characteristics (van Bueren and Bennett, 2004).

Given the lack of site-specific data, it was expected that calculations would produce conservative results in comparison to other studies. This was confirmed by the results from a recent valuation study for another KwaZulu-Natal estuary. Results, which could not be disclosed due to confidentiality agreements (Anon., pers. comm.), imply that given the size of the St Lucia System and the number of people who benefit from its existence and ecosystem goods and services, its annual value for fisheries in particular should be almost 10 times the estimated value given in this study of the St Lucia System.

The economic values for ecosystem services given for the Mfolozi Floodplain and the St Lucia System are noticed to be different from the values given in other studies (Table 13). Such differences may result from a number of factors including: varying valuation methods for different studies, a difference in the number and socio-economic characteristics of downstream beneficiaries of ecosystem services and variability in ecosystem properties and characteristics from one site to another. Apart from the Okavango Delta, the water purification values for the Mfolozi Floodplain and St Lucia System are shown to be much lower than all the other compared valuation studies. This is also true for the value of harvesting vegetation as all other compared studies resulted in a per hectare value lower than the value calculated for the St Lucia System and Mfolozi Floodplain.

Table 13: Comparative summary of ecosystem services values from other case studies. Values are presented as US$$\text{ha}^{-1}\text{yr}^{-1}$. Chinese Yuan to US$ were converted 1US$: 6.83186 CNY (online http://www.xe.com/ on 26/08/09). Letters A-F indicate references: A: Turpie & Lannas, 2007; B: Mmopelwa & Blignaut, 2006; C: Tong et al., 2007; D: Tianhong et al., 2008; E: Schyt, 2005 (Nakivubo urban wetland, Uganda & Lake Chilwa wetland, Malawi; F: Costanza *et al.*, 1998. St Lucia Area given as P: Park area, L: Lake area and T: Town & Eastern Shores. WTP: Willingness to pay valuation method.

<table>
<tr><th></th><th>St Lucia System</th><th>Mfolozi Flood-plain</th><th>Cape Town Metropolitan Wetlands (A)</th><th>Okavango Delta, Botswana (A & B)</th><th>Sanyang Wetland China (C)</th><th>Shenzing Wetland (D)</th><th colspan="2">Uganda & Malawi (E)</th><th>The World's Wetlands (F)</th></tr>
<tr><td>Area (ha)</td><td>P: 234 566
L: 35 000
T: 13 088</td><td>20 886</td><td>Area not given</td><td>M: 491 400</td><td>1141</td><td>6427.5</td><td colspan="2">Uganda: 529
Malawi: 240 000</td><td>330 x10^6</td></tr>
<tr><td>Flood Alleviation</td><td>567.00</td><td>24.16</td><td></td><td></td><td>Disturbance Regulation
334.76</td><td></td><td colspan="2"></td><td>Disturbance Regulation
4539</td></tr>
<tr><td>Water Provision</td><td>L: 461.42</td><td>22.25</td><td rowspan="2">Storage & Purification
2 100 – 2 325</td><td></td><td>250.04</td><td>2 196.37</td><td colspan="2"></td><td>3800</td></tr>
<tr><td>Water Purification</td><td>L: 665.00</td><td>0.70</td><td>(A)
0.32</td><td></td><td>Waste Treatment
2 575.76</td><td colspan="2">Uganda
1 323-2 457</td><td>Waste Treatment
4 177</td></tr>
<tr><td>Sediment Retention</td><td>L: 0.86</td><td>2.42</td><td></td><td></td><td></td><td>Soil formation & Retention
242.31</td><td colspan="2"></td><td></td></tr>
<tr><td>Tourism</td><td>T: 276.29</td><td>8.02</td><td>220 – 500</td><td>(B) Direct non-consumpt. use value
28.51</td><td></td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>Vegetation Harvesting</td><td>P: 1.54</td><td>0.95</td><td></td><td>(A) Agric & Nat resource use
2.33</td><td>Material Production
1 082.59</td><td>Raw Materials
9.92</td><td colspan="2">Uganda
18.9</td><td>Raw Materials
106</td></tr>
<tr><td>Fisheries</td><td>L: 15.25</td><td>7.16</td><td></td><td></td><td></td><td></td><td>Uganda
5.6</td><td>Malawi
77.92</td><td>Habitat Refugia
304</td></tr>
<tr><td>Existence</td><td>P: 3.90</td><td>1.94</td><td rowspan="2">Recreation Value (WTP)
220 – 500</td><td>WTP (B)
4.70</td><td></td><td rowspan="2">Cultural & Recreation
786.45</td><td></td><td></td><td>Recreation
574</td></tr>
<tr><td>Cultural & Education</td><td>P: 139.71</td><td>38.47</td><td>(T)
2.56</td><td></td><td></td><td></td><td>Cultural
881</td></tr>
</table>

6.2 Scenario outcomes

6.2.1 Specialist responses

Specialists who contributed to this study differed in their disciplines and professional experience. Also, as replies from specialists were received via email, they were unaware of answers given by other specialists. Thus, variation among responses was expected. Variation was confirmed by performing principal components analyses (PCA) using Statistica 8.0 (Statsoft, Inc.) on the weighted responses for each restoration scenario for each respondent. PCA ordination plots (Figure 14) indicated the greatest variation in responses occurred for the Mfolozi Floodplain under a full restoration scenario. This is noticed by the greatest distance between the respondents illustrated by the PCA plot. The degree of variation as well as the factor responsible for variation is indicated by the distance the letters (representative of the specialist responses) are spaced from one another on the plot area. Four respondents (allocated the letters A, B, C and E) were responsible for much of the variation. Corresponding eigenvalues and factor coordinates for each analysis are presented in Appendix B (Tables 14-20). Plots also showed that one respondent (C) was most responsible for the variation under each scenario. Given that every specialist was required to rank their confidence per ecosystem service for their given answers which was then used to weight every answer accordingly, it was decided that data from this respondent should not be removed from analyses.

Due to differing interpretation of the valuation methods in this study, the responses from one specialist were adjusted. In this case, the respondent estimated changes to economic values in terms of the replacement costs avoided by an increasing ecosystem service supply. This conflicted with the reasoning of this study that assumed an increase in the supply or quality of an ecosystem service would increase its economic value.

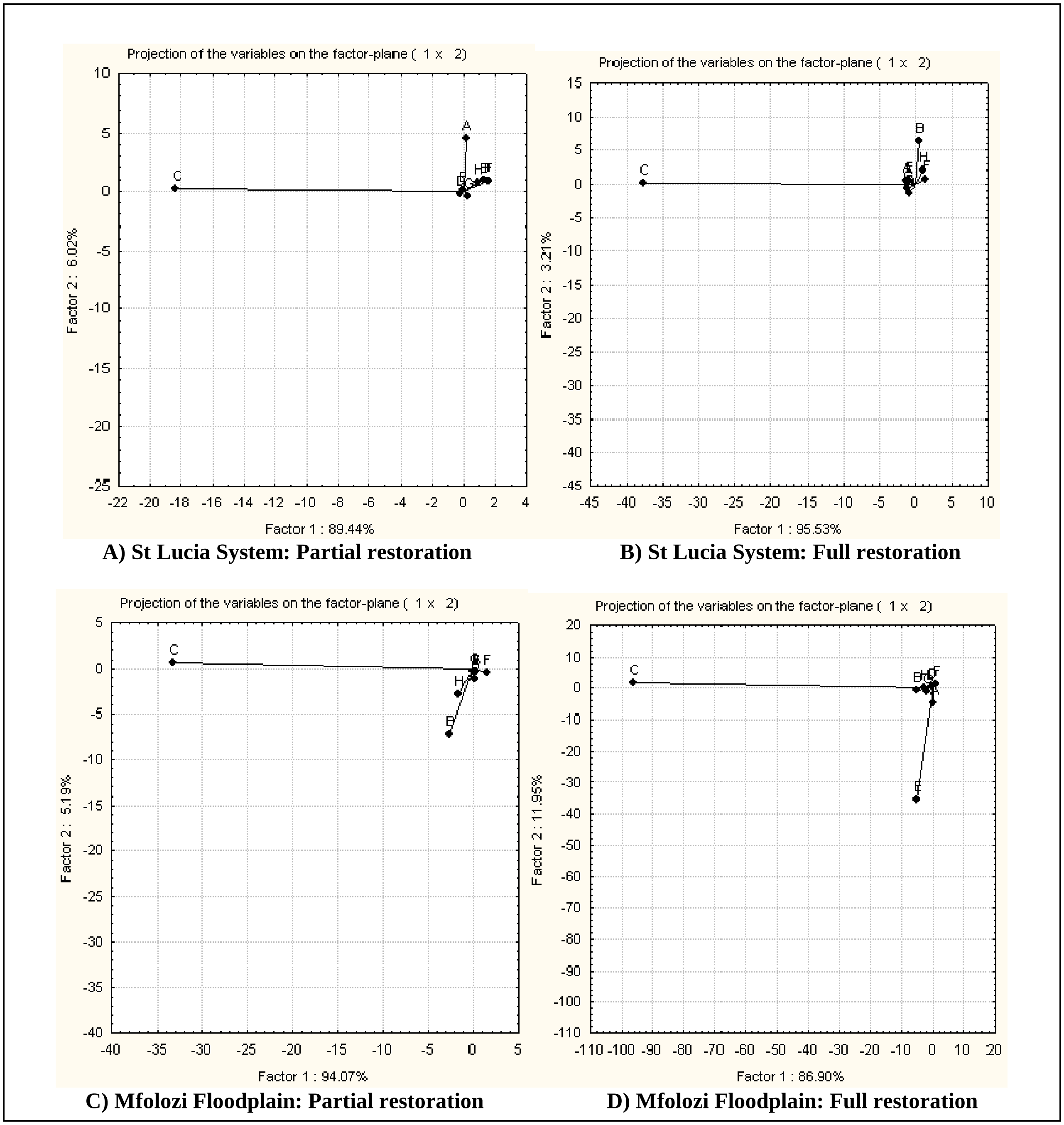

Figure 14: PCA ordinations of specialist responses (A-H) for each site under either a partial or full restoration of the Mfolozi Floodplain. All plots illustrate the Factor 1 or Principal Component (PC) 1 against Factor 2 (PC 2) with corresponding % explained variance.

Given that the local conservation authority recognizes the freshwater requirements of the St Lucia System as an urgent concern (R. Taylor, pers. comm.), there was not sufficient time to research potential long-term restoration outcomes (i.e. 50-100 years) by gathering intensive data for any of the ecological, economic or social sectors. Participation from specialists from different disciplines via email contact allowed for response at any time and from any geographical location. However, had a participatory workshop been convened to elicit specialist input, particularly in an environment where the atmosphere was conducive to open discussion and achieving consensus between experts, results may have been different. Face-to-face debates facilitate the sharing of knowledge and experience that would have been beneficial in estimating the changes of ecosystem service values under each restoration scenario (M. Mander, pers. comm.). Specialist answers may also have been challenged by others in which case a workshop environment would create the opportunity for given answers to be revised.

6.2.2 Economic values under each scenario

The results show a greater increase for all ecosystem service values under a full restoration scenario for both study sites, than under a partial restoration scenario.

Economic values for the ‘existence’ value, a non-use value (Figure 3), would undergo the greatest increase for both the Mfolozi Floodplain and St Lucia System under a partial restoration scenario, and under a full restoration scenario for the St Lucia System (Table 12; Figure 13). It is possible that these relatively high estimates of change are a result of respondents over-compensating due to the difficulties involved in valuing this service. Although valuation methods employed data that considered the general public’s willingness to pay for the environment, estimating changes to these figures may still have involved a level of subjectivity. Alternatively however, as argued in the literature (MEA, 2003; Carson *et al.*, 2001), the value of the existence of natural ecosystems may not be accurately assessed in economic terms. Therefore, over-estimates may be a means by which relevant stakeholders appreciate that the significance of natural systems far exceeds a monetary value.

6.2.2.1 No Restoration

The St Lucia System is highly stressed and will deteriorate if there is no deliberate intervention to provide freshwater to it (A. Whitfield, pers. comm.). This degradation increases the longer a drought persists (Whitfield and Taylor, 2009). Such degradation would directly impact the capacity of the St Lucia System to provide the ecosystem services valued in this research. Following such circumstances, industries currently reliant on the provision of ecosystem services would be negatively affected, such as tour operators, the fishing industry and conservation initiatives.

Without restoration of the Mfolozi Floodplain, alternative means of filtering the sediment from the Mfolozi River will be required in order to provide the supplementary water to the St Lucia System. Ezemvelo KZN Wildlife experimented with such alternatives recently (2008), by diverting the Mfolozi River into the St Lucia Estuary during winter low-flows when sediment levels were relatively low (Whitfield and Taylor, 2009). This allowed for approximately 15 million m^3 of Mfolozi River water to enter the Narrows and a small section of South Lake during May to December of 2008 (Whitfield and Taylor, 2009). This exercise succeeded in creating a simulation of the system in its natural, linked state and suggested that low flows carry enough freshwater into the St Lucia system to alleviate hypersalinities (Whitfield and Taylor, 2009).

6.2.2.2 Partial Restoration

The results showed that under a partial restoration scenario, the majority of the monetary values for ecosystem services would increase. Partial restoration and re-establishment of the Mfolozi estuarine system would offer a habitat on the floodplain more favourable to indigenous plant and animal species (Table 11). Fish populations would also improve following the re-establishment of habitat associated with restoration. Fisheries are included in the Primary Economic Sector, which contributed 73.3 % to the local Umkhanyakude District Municipality GDP in 2003 (Department of Local Government and Traditional Affairs, 2006). As the results show an expected increase in value of over 85 % for the Mfolozi Floodplain's fisheries would occur under this scenario (Figure 13), the local economy would be considerably impacted.

Following the restoration of natural wetland habitat, the production of natural wetland products is expected to increase. The increase in economic value of vegetation harvesting by about 83 %, would also impact positively on the local community, supporting local livelihoods and influencing cultural practices positively (Impey, 2002). The economic value of the sediment filtration service on the floodplain increases by 37 % under this scenario, confirming that a semi-permanent link of the

Mfolozi River to the St Lucia System may prove beneficial. The costs of such a link and the subsequent management of the St Lucia mouth would need to be considered.

With a portion of the floodplain restored, the remaining sugarcane farms would receive annual revenue of approximately R 32 million (Collings, 2007). However, as 70 % of the supply of sugarcane to the local Umfolozi Mill is sourced from the floodplain (Collings, 2007), reducing input to the mill would probably result in its closure. Should this occur, the cane would need to be transported to Felixton Mill over 60 km south of the Mfolozi Floodplain (L. McGrath, pers. comm.). Further, the lower lying farmlands on the floodplain targeted for restoration in this scenario (Figure 11) include areas that have recently (2008/9) been handed over by local government to local, historically disadvantaged farmers as part of a poverty relief initiative.

The increase in freshwater inflow to the St Lucia System expected under this scenario, would increase the water provisioning function value by about 40 %, which would stabilise the fluctuating conditions currently experienced by the system such as hypersalinity and high water temperatures.

6.2.2.3 Full Restoration

Complete restoration of the Mfolozi Floodplain would replace all the sugarcane currently present on the floodplain with natural wetland habitat. Apart from the existence value (a non-use value; Figure 3), results show the greatest increase in economic value for both the Mfolozi Floodplain and St Lucia System for the direct use-value of provisioning (fisheries) and supporting (tourism) services.

The annual economic value of sediment retention in the Mfolozi Floodplain, increasing by 92 % under a full restoration scenario, suggests the link of the Mfolozi River with the St Lucia System would provide great benefits if established on a permanent basis. However, sediment retention and water purification services would only be provided when the Mfolozi River was in flood and the water inundated the floodplain (Table 11). Large flows that would initiate such flow and be subject to the desired filtration only occur once or twice a year (UCOSP, 2009). Further, restoration planning would need to consider the morphology of the floodplain to ensure purified, sediment-free water would flow into the St Lucia System.

Removing the entire sugarcane crop from the floodplain would forfeit current annual revenues of over R 135 million (Collings, 2007). By removing farmland for restoration, the number of water users on the floodplain would be reduced considerably such that water provision under a full restoration scenario would be expected to decrease by 12 %.

Under the full restoration scenario, the economic value for fisheries for the Mfolozi Floodplain will experience the highest increase of all other ecosystem services, with an expected rise of over 330 % (Table 12; Figure 13). The St Lucia system's contribution to fisheries was also expected to increase by 109 % under this scenario. A link with the Mfolozi River would provide the volume of water required to reinstate natural mouth dynamics that would restore a more permanent connection between the St Lucia Estuary and the ocean. As St Lucia is the largest estuarine system in Africa (Cyrus and Vivier, 2006) with a surface area greater than the total area of all other South African estuaries combined (Whitfield *et al.*, 2006), restoring the link of this nursery area with the ocean is expected to impact dramatically on the country's estuary-dependant fisheries valued at R 1.3 billion (Lamberth and Turpie, 2003).

Tourism, with an expected increase of 73 % for the town of St Lucia, would also influence the local economy positively. Together with agriculture, tourism is mentioned as a main economic sector in the district (Umkhanyakude District IDP, 2008/9). Greater opportunities for tourism would increase employment in the district and support the local community. Tourism activities, such as craft sales, accommodation, guided walks and other outdoor holiday recreation, would increase following the restoration of the floodplain wetland habitat. Tourism will experience a greater increase in economic value than most other ecosystem services on the Mfolozi Floodplain under a full restoration scenario (Table 12).

6.3 Management implications and suggested options

Restoration of the Mfolozi Floodplain will involve a number of management considerations. The process of land procurement for the purposes of restoration would need to address many current land users, including sugarcane farmers, farm employees and illegal subsistence farmers, and consider potential legal issues such as land claims or resettlement. Long-term management strategies would also need to consider the affects of future global climate change on the St Lucia System, which is expected to raise sea level by about 0.5 m as well as cause a rainfall increase of 5–10 % in this region (Whitfield and Taylor, 2009).

6.3.1 Mfolozi as a site for biodiversity offsets

Large expansions of the Richards Bay Harbour in northern KwaZulu-Natal are expected to destroy much of the estuarine habitat in the Harbour. Due to unavoidable damage to these habitats, discussions among consultants and planners raised the possibility of seeking offset areas for the proposed development to compensate for the estuarine habitat loss. The suggestion was made that Transnet purchase the farms within the Mfolozi Floodplain with the intention of restoring the floodplain wetlands, thereby restoring 'functionality of the St Lucia System' (R. Taylor, pers. comm.). Other large organisations or developments may also wish to 'offset' biodiversity losses by contributing to land procurement of the Mfolozi farms.

6.3.2 Financial incentives and political factors

An example can be taken from the Kavlinge River Programme in Sweden, which involved creating wetlands for the purpose of reducing nutrient loads to the sea (Turner *et al.*, 2003). An agreement between local municipalities and landowners promoted the construction of buffer zones and irrigation ponds. Landowners benefited financially, being offered rental payments for their land in affected areas of certain wetlands.

Financial benefits also included payment of the opportunity costs forgone by the farmland following restoration. This was calculated as 'the market value of the land subject to conversion' (Turner *et al.*, 2003). Financing of the project was shared by the municipality (60 % of the total costs), an EU grant (about 20 %) and local donations (about 20 %). In terms of applying a similar approach to the Mfolozi Floodplain, the local Sugar Planters Cooperative (UCOSP) explains that farmers would consider the sale or lease of their farms if offered similar financial incentives that matched the current income from sugarcane farming (L. McGrath, pers. comm.).

However, from a government perspective, ecosystem services have not been mentioned as a priority in terms of their conservation or restoration. New projects targeted by the local municipality in the IDP review report include providing ‘additional grazing and cultivation land for the Dukuduku resettlement project, a fruit drying project, the development of a sports and recreational centre, a multipurpose centre and erecting a bronze sculpture of Inkosi Mtubatuba (Mtubatuba IDP, 2004). In fact, the only project that mentions natural resources in the IDP report is the upgrading of the current water treatment works adjacent to the Mfolozi River to ‘ensure adequate water supply for the Mtubatuba low-income and Dukuduku housing projects, and GSLWP (iSimangaliso Wetland Park) developments’ (Mtubatuba IDP, 2004). It should be noted that restoration initiatives highlighted in this research that may secure the long-term ecological stability of the St Lucia System may be in direct conflict with future land use practices within the floodplain intended by local government.

However, the Umkhanyakude District Municipality IDP reports that management is ‘concerned with the utilization and protection of its natural resources’ and stresses that the District aims to integrate environmental issues with poverty reduction strategies (UDM IDP, 2008). Such plans include land rehabilitation, wetland restoration and soil conservation (UDM IDP, 2008). The report reiterates its confidence in an effective integrated management approach stating:

> “Environmental, economic and social goals can be compatible, and are interrelated in such a way that one goal cannot be effectively pursued at the expense of another”
> (UDM IDP, 2008)

Unfortunately this is not the case when considering the current practices in the District. One such example is the current illegal clearing of the Mfolozi Floodplain swamp forests within the borders of the iSimangaliso Wetland Park. This demonstrates the direct conflict of conservation with local livelihoods and does not reflect the noble ambitions stated in the District Municipality IDP. On the other hand however, current illegal clearing illustrates the demand for harvesting natural resources or other activities on the floodplain, which would be alleviated following the reintroduction of wetland vegetation from either restoration scenario.

According to national legislation alluded to by Bate and Taylor (2007), the responsibility of preventing further ecological deterioration of the St Lucia System falls upon the national Department of Water Affairs. According to the National Water Act (36) of 1998, the government is required to 'protect' the country's water resources.

The Umkhanyakude District IDP recognizes the presence of the iSimangaliso Wetland Park World Heritage Site, as 'a scenic pristine environment' that is key to tourism and development opportunities (UDM, 2008/9). The District's environmental management needs, however, are listed with 'Economic Growth' as the first point, and the 'Protection of the natural environment' as the second point (UDM, 2008/9). This study has shown the economic benefits that are expected to follow initiatives that will protect the natural environment. Thus, should 'protection of the natural environment' be afforded very high priority for the local and district municipality, it may be possible for economic growth to follow as a direct consequence.

6.4 Overall research contribution and future research recommendations

6.4.1 Ecological economics context

This research considered ecosystem services offered by the Mfolozi Floodplain and the St Lucia System in terms of their supply to stakeholders as opposed to the demand (Figure 4). Results can therefore be considered as baseline research from which further economic analyses can progress. Quantifying the demand for ecosystem services in these study sites, as illustrated by the demand curve ($D_{ES(M)}$) from top left to bottom right of Figure 15, would allow for more comprehensive economic understanding through market research, including price analyses, optimal levels of supply or safe minimum standards for ecosystem service exploitation (Figure 4). Figure 15 illustrates how the results of this Mfolozi Floodplain and St Lucia System study, which has focussed on supply, indicated by the supply curve (MC_{ES}) from left to right of Figure 15, to potential broader economic analyses.

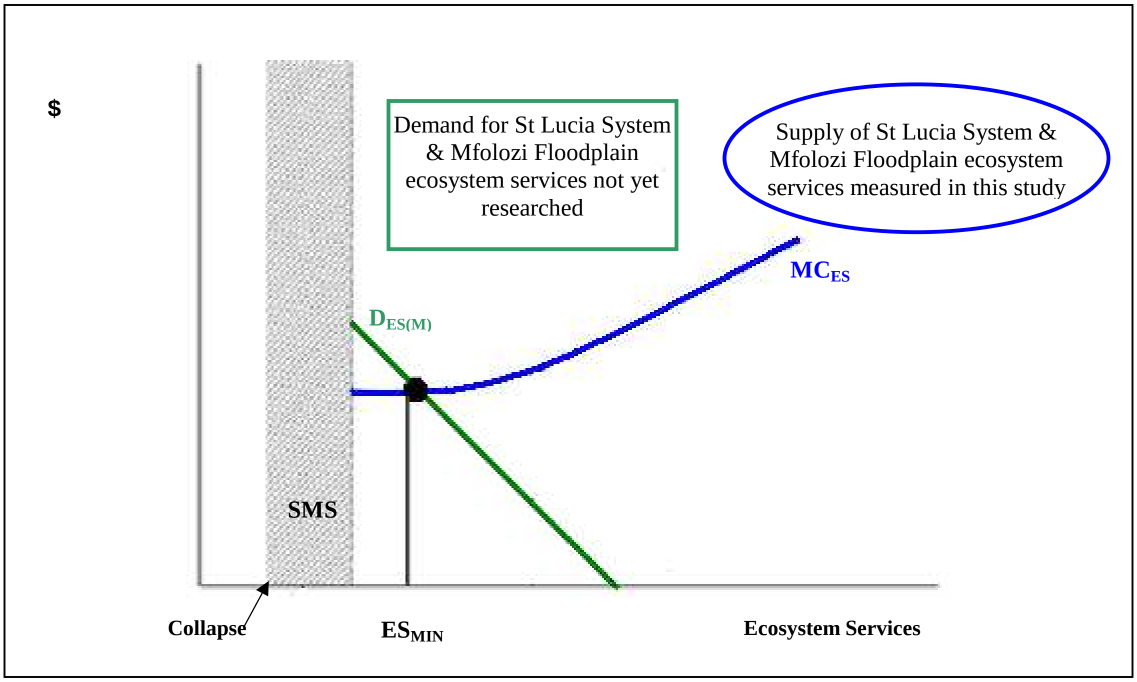

Figure 15: Relevance of St Lucia System and Mfolozi Floodplain ecosystem service valuation to resource economics. Adapted stylised costs and benefits of ecosystem services (ES) provision as in Fisher *et al.* (2008). MC_{ES} depicts the supply of ES or the marginal cost of acquiring additional ES. $D_{ES(M)}$: the demand for market ES. ES_{MIN}: the point where marketed ES are provided/demanded. SMS: safe minimum standard or quantity of ES below which the system may collapse.

Ecosystem service demand is related to the local socio-economic climate in the areas in and surrounding the Mfolozi Floodplain and the St Lucia System. Further study into potential restoration of the floodplain should include a detailed social impact assessment that would identify the expected impacts on the local communities.

6.4.2 Future research recommendations

Ecosystems are complex and dynamic (MEA, 2003) and experience fluctuating conditions of many kinds and on many scales. External changes may include seasonal and long-term climatic conditions (temperatures, rainfall), day and night cycles (light availability), tidal exchange (salinity fluctuations) as well as anthropogenic disturbances. Any of these mentioned changes would influence the quantity or quality of services provided by the ecosystem. Should the delivery or production of ecosystem services change, the economic values would be affected. Unlike a manufactured product, the production of ecosystem services cannot be controlled in as stringent a manner. Future large-scale ecosystem valuation by management would therefore need to consider natural and anthropogenic variability and consequent effects on targeted ecosystem services.

This study assumed that restoration in the floodplain would provide adequate sediment filtration of the Mfolozi River water, thereby allowing a link with the St Lucia System. It is important to note, however, that restoring the floodplain to a natural wetland condition will entail the removal of artificial drainage and canalisation. Following this, river water would disperse across the floodplain, decreasing in velocity. The local authorities or the relevant managers involved in restoration of the floodplain would need to take cognisance of the movement of water following any restoration initiatives.

Given the size of Lake St Lucia and its role in providing a nursery area for estuary dependent marine species, the system is very important to the country's fisheries. However, there are few studies addressing the relationship between the Lake St Lucia System specifically and the South African fisheries stocks (Vivier and Cyrus, 2009; Cyrus and Vivier, 2006; Lamberth and Turpie, 2003; Mann, 1993). It would thus prove beneficial for the ongoing monitoring and conservation of the St Lucia System if such relationships were understood for individual fish species and throughout different climatic seasons. A suggested approach is that of Lynne *et al.* (1981) who researched the link between the ecology of a marsh system and an exploited crab population, thereby investigating the influence of ecological factors on an economic activity.

It is likely that a large-scale Global Environment Facility (GEF) project run by the World Bank and the iSimangaliso Wetland Park Authority will commence within the next few years addressing various options for freshwater input into Lake St Lucia, including studies concentrating on the hydrology, ecology, sedimentology and resource economics of the Mfolozi Floodplain (P. Aguila, pers. comm.; Whitfield and Taylor, 2009). Such studies might consider incorporating some of the socio-economic (6.4.1) and ecological features (6.4.2) described above.

6.4.3 Research contribution

Considering the ecosystem service valuation and land use planning addressed in this research, similarities with other ecological economics studies are noticed. This report has highlighted key ecosystem services within the study sites and communicated their benefits to society in economic terms. In doing so, relevant authorities may become aware of the need to conserve such services. This objective is noticed in other research such as the study by Martı´nez-Harms and Gajardo (2008), which involved the valuation of ecosystem processes in Western Patagonia in order to justify nature conservation. This is also noticed in a study by Beaumont *et al.*, (2008) which aimed to promote the conservation of marine biodiversity in the UK by means of ecosystem service valuation.

Given that no previous valuation of ecosystem services of the St Lucia System and Mfolozi Floodplain has been performed, this research provides an initial inventory of the economic values associated with these services at these sites. This was also achieved by Kroeger (2005), who provided a baseline valuation of ecosystem services for four counties in Florida, USA.

Furthermore, this study, by addressing social, economic and ecological factors regarding the future of the St Lucia System and restoration options for the Mfolozi Floodplain, has contributed to the field of interdisciplinary research. Original methods include the quantifying of specialist wisdom as applied to restoration scenarios and the assimilation of such wisdom without the provision of a workshop environment. This research quantifies the key impacts associated with a major freshwater issue using a broad approach, whilst including sufficient detail, thereby providing an effective decision-making tool.

7. Conclusion

The St Lucia System, which forms part of South Africa's first World Heritage Site and is recognised as a Ramsar Site, comprises the largest estuarine system in Africa. It is subject to periodic mouth closure partly due to historical artificial separation of the Mfolozi River from the mouth of Lake St Lucia, during which periods of evaporation dominate the water balance and the lake becomes hypersaline, with salinities in excess of 120 $^{o}/_{oo}$. In order to avoid this and prevent further degradation of Lake St Lucia, a supplementary freshwater supply, ideally from the Mfolozi River, is required.

Economic valuation of ecosystem services provided by the Mfolozi Floodplain and the St Lucia System in their current condition, suggest total annual economic values of over R 21 million and R 1.1 billion respectively. Valuation has shown that the ecosystem service values increase for eight out of nine ecosystem services for both the Mfolozi Floodplain and St Lucia System, following the partial or full restoration of the Mfolozi Floodplain. Either of the two restoration initiatives explored in this study would however, require the replacement of commercial sugarcane crops with natural wetland habitat. Such initiatives would thus forfeit the annual revenue currently generated from sugarcane farming (of approximately R135 million, Collings 2007).

Although originally conceived some 40 years ago and partially implemented before being terminated, supplementary freshwater from the Mfolozi River, which is discharged into the St Lucia System, is still considered a promising option. This study has shown the expected economic outcomes associated with increased delivery of ecosystem services under potential wetland restoration scenarios of the Mfolozi Floodplain, which could be derived from such a plan. Recommendations include linking the Mfolozi River with the St Lucia System during low flows in order to supplement freshwater supply but avoid the adverse effects associated with high sediment loads from the Mfolozi River during periods of abundant water supply. However, to avoid any negative socio- or politico-economic repercussions, it is advisable that further research is undertaken before any permanent land use change or river diversion is undertaken.

This interdisciplinary research has addressed efforts to conserve the ecological health of one of South Africa's most pristine regions whilst recognising the direct conflict with other industrial and current political agendas. The field of environmental economics has provided a tool by which the contribution of natural, functioning ecosystems to the economy can be communicated. Limitations experienced in this study included assimilating the responses from specialists from a variety of disciplines without a workshop environment along with limited site specific data. This study has emphasised that the country's industries should be conscious of the need to preserve the long-term health of our natural capital upon which we are deeply reliant for our well-being.

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Appendix A:
Emailed question table to specialists

ESTIMATING CHANGES TO ECOSYSTEM SERVICES VALUES

I understand that you have either been involved in research regarding my study sites or have experience in the field of environmental resource valuation or restoration. I am currently putting together variables for a management model for my Masters research. If you have a few minutes I would really appreciate your help.

As I'm sure you are aware, Lake St Lucia in northern KZN, currently experiences severe ecological stress during dry periods. This has raised concern regarding the long-term sustainability of the country's first World Heritage Site. Possible intervention that my research addresses involves diverting the Mfolozi River to the St Lucia Lake system (providing an additional 700 x $10^6 m^3 yr^{-1}$). The Mfolozi River, which was historically linked to Lake St Lucia, was diverted in the early 1950's, as it was feared that its high sediment loads would eventually fill the lake. To avoid detrimental effects associated with high sediment loads, the river water thus requires considerable filtration before a link can be re-established. One suggestion is to restore farmlands within the Mfolozi Floodplain to its previous wetland condition in order to provide the required sediment removal function for the Mfolozi River water. In order to determine consequent economic impacts of the potential floodplain restoration, current ecosystem services have been valued for both the Lake St Lucia system and the Mfolozi Floodplain. Based on your input (along with other specialists), calculations will be made to determine the response of these economic values to proposed restoration scenarios.

Please find a table below (Page 3) with the listed ecosystem services and their assigned values. Note these figures are not accurate results from this research and have been randomly assigned in order to guide your responses. Could you kindly fill in your estimate of the change (% increase or decrease) to the given monetary values for each described scenario. Thank you again for your time.

<u>Scenario Description</u>:

1_CURRENT LAND USE

St Lucia System:
- Major tourist attraction
- Possible collapse of system in the future with no additional freshwater
- Vital support for national fisheries (both recreational and commercial)
- Harvesting of resources currently permitted for local communities
- Popular area for extensive scientific research as well as visiting school groups

Mfolozi Floodplain:
- Approximately 8000 ha of sugarcane within the floodplain
- Annual sugarcane harvest
- Floodplain heavily canalised (minimal sediment trapping capability)
- Few tourism initiatives
- Minimal harvesting of resources by local communities
- One environmental education establishment in the floodplain
- Research on sugarcane

2_PARTIAL RESTORATION

St Lucia System:
- Mfolozi River linked to Lake St Lucia only when critical (controlled link by relevant management)
- Mouth may breach more frequently
- Increase in freshwater = system less stressed during drought periods
- Environmental conditions improve = industries reliant on the environment improve

Mfolozi Floodplain:
- Lower lying sugar farms restored to wetland (farm acquisition will not be covered by this research)

Wetland improves sediment-trapping function
Approximately 1800 ha of sugarcane remain in floodplain
Possible increase in tourism enterprises due to greater area of wetland habitat & resources
Possible increase in harvesting of resources by local communities

3_100% RESTORATION

St Lucia System: Mfolozi River linked to Lake St Lucia permanently
System no longer experiences extreme conditions during drought periods
Ecosystem services improve
Supported industries (fisheries, tourism, conservation) benefit and are protected into the future

Mfolozi Floodplain: All farm area within floodplain restored to wetland (20 000 ha)
Wetland ecosystem services restored
No sugarcane remaining in designated floodplain area
Increase in nature based tourism enterprises
'New' natural habitat available for harvest as well as research

ECOSYSTEM SERVICES	Scenario 1: Current land use Value (ZAR/yr)	Method/Data used for valuation	Scenario 2: Partial Restoration	Scenario 3: 100% Restoration	Comments:
			% Change (increase or decrease) to Scenario 1 values		
ST LUCIA (* Values calculated for full area of iSimangaliso Wetland Park & not only St Lucia Lake)					
Flood alleviation	110,000,000	Benefit transfer (Lake R/ha value)			
Water provision	60,000,000	Replacement cost			
Water purification	90,000,000	Benefit transfer			
Sediment retention	5,000,000	Replacement cost			
Tourism	15,000,000	Income estimates for population of St Lucia town			
*Natural vegetation harvesting	5,000,000	Value estimates for recorded annual harvest			
Fisheries	50,000,000	Benefit transfer (Estuary R/ha)			
*Existence	7,000,000	Benefit transfer (R/ha for different biomes present)			
*Cultural & education	90,000,000	Benefit transfer (R/ha for each ecosystem types)			
MFOLOZI					
Flood alleviation	3,500,000	Replacement cost			
Water provision	5,000,000	Water supply costs for current users			
Water purification	150,000	Benefit transfer			
Sediment retention	100,000	Replacement cost			
Tourism	50,000	Benefit transfer			
Natural vegetation harvesting	400,000	Benefit transfer			
Fisheries	1,500,000	Benefit transfer (Estuary R/ha)			
Existence	500,000	Benefit transfer (R/ha for different biomes present)			
Cultural & education	2,000,000	Current research expenditure & Benefit transfer (R/ha for each ecosystem types)			

Appendix B:
Results from statistical analyses

PCA analyses

St Lucia under Partial Restoration Scenario

Table 14: Eigenvalues of covariance matrix, and related statistics (St Lucia under partial restoration scenario)

	Eigenvalue	% Total	Cumulative Eigenvalue	Cumulative %
1	9905.841	74.96726	9905.84	74.9673
2	1598.960	12.10091	11504.80	87.0682
3	1002.005	7.58316	12506.81	94.6513
4	581.624	4.40172	13088.43	99.0530
5	92.226	0.69797	13180.66	99.7510
6	30.375	0.22988	13211.03	99.9809
7	2.041	0.01544	13213.07	99.9963
8	0.484	0.00366	13213.56	100.0000

Table 15: Factor coordinates of the variables, based on correlations (St Lucia under partial restoration scenario)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
A	6.7233	20.39081	-20.0743	12.5492	-1.62562	0.95020	0.089082
B	-7.5147	-7.58469	-19.6107	-16.7414	-2.57940	0.77852	0.000108
C	96.5110	4.95368	0.5689	-4.6189	0.69604	-0.21568	0.033501
D	5.0140	-3.24441	4.3239	2.1319	-7.00858	-2.41768	0.698618
E	0.4448	1.16320	-0.6530	0.1038	-1.29037	-0.71237	-0.401336
F	-19.8403	32.93282	8.6813	-10.7537	-0.34243	-0.32586	0.077929
G	-2.8986	-1.87402	0.8886	-1.1124	2.71596	2.26169	1.135897
H	-7.9000	1.07098	-10.9016	-1.0482	4.91595	-4.15282	0.293301

St Lucia under Full Restoration Scenario

Table 16: Eigenvalues of covariance matrix, and related statistics (St Lucia under full restoration scenario)

	Eigenvalue	% Total	Cumulative Eigenvalue	Cumulative %
1	40574.09	87.38634	40574.09	87.3863
2	2896.84	6.23906	43470.92	93.6254
3	1666.14	3.58845	45137.06	97.2138
4	927.09	1.99672	46064.16	99.2106
5	195.29	0.42061	46259.45	99.6312
6	134.10	0.28881	46393.54	99.9200
7	36.72	0.07908	46430.26	99.9991
8	0.43	0.00093	46430.69	100.0000

Table 17: Factor coordinates of the variables, based on correlations (St Lucia under full restoration scenario)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
A	-13.840	8.2599	-7.9055	10.66936	6.18822	2.13872	3.92553
B	-3.952	36.6291	16.0273	14.64994	-4.29875	1.18798	-1.13941
C	-199.254	3.4362	-1.3442	-3.42796	-0.07290	-0.43231	-0.26582
D	-18.210	-25.5173	2.7566	21.99307	3.28179	-3.48168	-1.82573
E	-4.950	4.0345	-3.0463	6.44586	-0.17354	2.70825	2.01150
F	13.804	22.0144	-32.7617	2.44444	1.10613	-3.08639	-1.87190
G	-0.772	-0.5134	-1.0126	-1.23184	6.09538	8.68689	-2.99710
H	10.841	17.9668	15.9289	-7.35855	9.45176	-4.84559	-0.26764

Mfolozi Floodplain under Partial Restoration Scenario

Table 18: Eigenvalues of covariance matrix, and related statistics (Mfolozi Floodplain under partial restoration scenario)

	Eigenvalue	% Total	Cumulative Eigenvalue	Cumulative %
1	28368.06	86.47106	28368.06	86.4711
2	3607.39	10.99599	31975.44	97.4670
3	363.15	1.10695	32338.59	98.5740
4	253.63	0.77311	32592.22	99.3471
5	128.55	0.39186	32720.78	99.7390
6	74.25	0.22634	32795.03	99.9653
7	11.17	0.03405	32806.20	99.9993
8	0.21	0.00066	32806.42	100.0000

Table 19: Factor coordinates of the variables, based on correlations (Mfolozi Floodplain under partial restoration scenario)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
A	1.421	-1.6346	9.73572	1.5013	7.62569	-3.62264	-0.77196
B	-25.564	-53.5287	-6.89984	0.2110	1.04216	-1.36001	-0.05380
C	-165.906	10.1420	0.01307	-0.2708	0.19644	-0.13391	-0.00286
D	-1.870	-8.8389	1.58262	-7.4727	5.74063	5.28085	0.15846
E	1.245	-4.1218	-0.12218	1.8675	-0.75608	-2.76050	-1.24624
F	1.152	-2.6562	3.70865	-13.3959	-3.41772	-3.42503	-0.01505
G	0.686	-2.0924	1.93549	1.4183	1.45702	-2.45812	2.99832
H	-13.449	-23.0215	14.16817	3.2349	-4.68487	2.44576	0.07015

Mfolozi Floodplain under Full Restoration Scenario

Table 20: Eigenvalues of covariance matrix, and related statistics (Mfolozi Floodplain under full restoration scenario)

	Eigenvalue	% Total	Cumulative Eigenvalue	Cumulative %
1	247482.6	72.28762	247482.6	72.2876
2	86863.1	25.37200	334345.7	97.6596
3	5407.1	1.57938	339752.8	99.2390
4	1417.5	0.41403	341170.3	99.6530
5	852.2	0.24893	342022.5	99.9020
6	279.3	0.08159	342301.9	99.9836
7	56.3	0.01645	342358.2	100.0000
8	0.0	0.00000	342358.2	100.0000

Table 21: Factor coordinates of the variables, based on correlations (Mfolozi Floodplain under full restoration scenario)

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
A	-3.906	-40.741	-1.0750	0.4934	26.64088	-1.40500	2.49702
B	-33.024	-14.777	-54.4520	-0.7239	-6.15123	-8.80332	2.14249
C	-495.612	7.646	5.9468	0.1094	-0.12545	0.24125	0.04229
D	-7.966	5.656	-14.1599	-35.7522	2.30942	3.35384	-0.86202
E	-11.218	-291.151	2.6856	-0.7418	-3.10290	0.36841	-0.59806
F	-6.974	10.536	-1.0919	-0.3455	7.65757	-9.87779	-4.80587
G	-6.028	-3.619	-10.1442	4.2068	2.23370	2.30572	-4.43366
H	-21.710	1.248	-45.7580	10.9597	5.10313	9.24862	-1.27349

<u>Appendix C:</u>
Summary of expected changes to ecosystem service values

Table 22: Average expected percentage changes and standard deviations (Std Dev) from the eight responses used in analyses.

Ecosystem Service	St Lucia				Mfolozi			
	Partial Restoration		Full Restoration		Partial Restoration		Full Restoration	
	WA % change	Std Dev	WA % change	Std Dev	WA % change	Std Dev	WA % change	Std Dev
Flood alleviation	11.05	1.56	21.32	4.82	26.32	3.89	75.53	9.99
Water provision	39.77	4.52	55.40	5.81	-14.23	5.50	-11.89	7.62
Water purification	19.68	3.14	37.78	5.73	27.43	2.70	56.08	4.66
Sediment retention	18.74	3.97	35.12	6.00	36.86	3.75	91.63	11.27
Tourism	33.76	5.65	72.94	11.42	85.59	24.24	260.59	45.67
Vegetation harvesting	18.18	1.74	36.97	4.65	82.73	18.08	234.24	61.86
Fisheries	38.53	5.68	108.82	17.01	85.00	24.32	332.06	97.51
Existence	61.00	19.71	143.13	38.57	92.81	25.70	248.13	51.29
Cultural & education	16.56	1.19	42.19	3.47	25.63	2.02	83.75	8.84

Table 23: Calculated annual economic values for ecosystem services for each site. The Weighted Averages (WA) of the % changes from specialist responses are included along with the outcome of ecosystem service values under each restoration scenario.

Study site & Ecosystem Service	Current Land Use Annual value (ZAR)	Partial Restoration Scenario		Full Restoration Scenario	
		WA % change	Resultant value (ZAR)	WA % change	Resultant value (ZAR)
ST LUCIA SYSTEM					
Flood Alleviation	196,610,369	11.05	218,340,988	21.32	238,519,421
Water Provision	160,000,000	39.77	223,634,286	55.40	248,640,000
Water Purification	230,592,408	19.68	275,963,022	37.78	317,718,944
Sediment Retention	2,000,000	18.74	2,374,884	35.12	2,702,326
Tourism	35,824,800	33.76	47,920,938	72.94	61,955,831
Vegetation Harvesting	3,582,570	18.18	4,233,946	36.97	4,907,035
Fisheries	143,990,000	38.53	199,468,500	108.82	300,685,000
Existence	9,069,231	61.00	14,601,462	143.13	22,049,567
Cultural & Education	324,672,243	16.56	378,446,084	42.19	461,643,346
TOTAL	**1,106,341,620**	**1,364,984,109**		**1,658,821,470**	
MFOLOZI FLOODPLAIN					
Flood Alleviation	5,000,000	26.32	6,315,789	75.53	8,776,316
Water Provision	4,604,748	-14.23	3,949,558	-11.89	4,057,441
Water Purification	144,944	27.43	184,705	56.08	226,230
Sediment Retention	500,000	36.86	684,302	91.63	958,140
Tourism	1,659,348	85.59	3,079,555	260.59	5,983,414
Vegetation Harvesting	196,352	82.73	358,789	234.24	656,292
Fisheries	740,520	85.00	1,369,962	332.06	3,199,482
Existence	401,364	92.81	773,881	248.13	1,397,250
Cultural & Education	7,959,810	25.63	9,999,511	83.75	14,626,151
TOTAL	**21,948,409**	**26,716,053**		**39,880,714**	