WILLINGNESS TO PAY FOR THE CONTROL OF WATER HYACINTH

IN AN URBAN ENVIRONMENT OF SOUTH AFRICA

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ABSTRACT

Water hyacinth is recognised as one of the most problematic invasive aquatic plant species in Africa. For this reason considerable funds are spent each year on its control.

As a consequence of the amount of money being spent on problems such as the invasion of water hyacinth, and because of the recognition of the ongoing and accelerated efforts that are required in the future, recent research has focused on accurately quantifying the costs and benefits of control of invasive species to aid policy decisions. A comprehensive cost-benefit analysis would be able to identify if the funds are justified and are being spent effectively. This thesis provides an example of a cost-benefit analysis of funds spent on the control of water hyacinth in an urban environment in South Africa.

In order to develop a comprehensive assessment of the total economic value of the control of water hyacinth to an urban population, the Nahoon River in East London was selected as the study site to calculate the benefits of control. In addition to valuing the direct services provided by the resources that are traded in the market (in this case water provision), a contingent valuation study was undertaken in Abbottsford and Dorchester Heights (two suburbs in East London banking the Nahoon River). These were done in order to assess any non-use value a sample of 132 households of the population has for the control of water hyacinth, and any use values that are not traded in the market, for example recreational value.

When the benefits of control of water hyacinth were compared to the costs of one of the least cost effective methods of control (herbicidal control), the benefits outweighed the costs by a ratio of more than 4:1, and for the most cost effective method of control the ratio was almost 6:1. These results provide a justification for the funds that are devoted to the control of water hyacinth, providing an argument for the continued expenditure for its control, and for further research into more cost effective methods of control, such as biological control.

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CHAPTER ONE: INTRODUCTION

1.1 Invasive Alien Species

- **Background**

In recent years the problem of invading alien plant species has received much attention, largely because of the increased recognition of the occurrence and severity of the consequences of invading alien plant species (Perrings *et al.*, 2000: 3). This is not to say that the problem is recent in nature; the movement of organisms can be viewed as a human driven phenomenon over the past 200 to 500 years (Mack *et al.*, 2000: 691). In South Africa, for example, the first environmental problems associated with floral species that are not indigenous to South Africa were documented in the early 1900s (Macdonald, 2004: 21). Invasive species are defined by Mack *et al*. (2000: 689) as:

> "Biotic invaders are species that establish a new range in which they proliferate, spread and persist to the detriment of the environment. They are the most important ecological outcomes from the unprecedented alterations in the distribution of the earth's biota brought about largely through human transport and commerce. In a world without borders, few if any areas remain sheltered from these immigrations"

Although it is common for species to be transported to new habitats, the pace that this is occurring increases with improvements in the speed and range of transport on a global scale (Perrings *et al.*, 2000: 3; Mack *et al.*, 2000: 690). Increased transportation accounts for the increase in occurrence and frequency of invasive alien species. Mack *et al*. (2000: 690) argue that the rise in invasive species mirrors improvements in world transport.

The introduction of non-indigenous species to new sites due to human activity can be seen as both deliberate and accidental (Mack *et al.*, 2000: 690). Ancient trade in domesticated animals led to the start of the introduction of non-indigenous species and their parasites; for this reason biological invasions can be viewed as "post-Columbian events". Deliberate examples of the introduction of non-indigenous species include the introduction of crops, and the introduction of fish species for game fishing or aquarium plants for aesthetic value. Accidental introductions include rats being inadvertently transported on ships to remote islands, or invertebrate marine species that are transported on the hulls of ships and in ships' ballast and deposited at new sites (Mack *et al.*, 2000: 690).

Not all 'non-indigenous' species become invaders; on the contrary it has been found that the majority of migrating species either die in transit or become extinct by physical or biotic factors at the new site (Mack *et al.*, 2000: 690). A minority of non-indigenous species do however survive, and although re-occurrence of the arrival of the new species is not essential for it to become an invader, it does markedly increase the probability that it will do so. Bright (1999: 23) describes Mark Williamson's "tens rule" to illustrate the number of introduced exotic species that become invasive. The tens rule states that only 10 out of 100 of the introduced species into any area will establish breeding populations, and only 1 exotic species out of the ten which have established breeding populations will become invasive.

The reason that some non-indigenous species are so successful as invaders in new habitats, is that their natural control mechanisms in general do not occur in the adventive range (Perrings *et al.*, 2000: 3; Bright, 1999: 24). Indigenous species are then unable to compete with the invading species, and in some cases become extinct, further enhancing the success of the new species. But are these problems worth so much attention if only 1% ('tens rule') of introduced species become invasive? Bright (1999: 24) refers to the 99% of species that do not invade as "duds", and the 1% that do, as "detonations"; and observes that with the speed that the "global economy is showering exotics over the earth's surface…, the bombardment is continual and so are the detonations".

Biological invasions are therefore said to be one of the biggest causes of biodiversity loss, and hence loss to system value (Perrings *et al.*, 2000: 3; Lonsdale, 1999: 1522). The problem of biodiversity loss lies in the fact that certain species are fundamental to certain ecosystem functions, and loss of these species may cause a loss to system functioning. These functions represent economic value, for example functions such as water purification, nutrient cycling, soil erosion prevention and flood mitigation represent economic value. Recently, attempts have been made to value such ecosystem services. Hence the environmental and economic impact of biodiversity loss (invasive species) depends on the connection between the species that are lost and the functioning of the system (Perrings *et al.*, 2000: 4).

- **Aquatic Species in Africa**

The five most prolific invasive aquatic weeds in Africa are: water hyacinth, red water fern, parrot's feather, water lettuce and salvinia (Cilliers *et al.*, 2003: 161), and in 2006 a new aquatic weed called hydrilla was recorded (Hill, 2006). The invasion of aquatic resources represents one of the most important threats to the socioeconomic development of Africa and is a major threat to the water resource as a whole (Cilliers *et al.*, 2003: 161; Gorgens and Wilgen, 2004: 27). Water hyacinth, which is native to South America, and has been present in Africa since the late 1800s (Cilliers *et al.*, 2003: 161), is the most problematic of the aquatic invaders in Africa. Due to the absence of natural enemies, and because of generally nutrient-enriched waters in Africa, these species have become extremely successful as invaders. To date there has been a considerable amount spent on the control of water hyacinth, roughly R11 million annually, largely by the Working for Water programme (Hughes, 2006). Spending has been on both chemical and mechanical control, and more recently on biological control (van Wyk and van Wilgen, 2002).

In South Africa there is a history of research on the impact of invading aquatic species dating back to the 1930s; quantitative predictions on water loss, however, came to the fore only in the 1970s (Macdonald, 2004: 22; Gorgens and Wilgen, 2004: 27). Macdonald (2004: 22) outlines the main conclusions from this research: removing aquatic alien plants and weeds increases available water; the amount of extra water is directly proportional to the extent of clearing; and the greatest impacts are experienced when the invaded environment has a higher quantity of biomass to support than the original indigenous habitat. It is therefore clear that aquatic invasions represent a loss in system functioning, not to mention the direct economic losses from reduced water supply. These costs would represent a benefit to clearing the invasive species, which should be considered in the decision making process of invasive species clearing programmes. These benefits, such as optimum system functioning, are difficult to quantify, and although a number of non-market valuation techniques do exist, sound economic valuation techniques are yet to be developed that adequately place monetary values on the structures that allow for the provision of environmental goods and services.

1.2 Goals of the Research

This thesis discusses the costs, relative cost effectiveness, and efficiency of the various methods available for the control of water hyacinth, and attempts to quantify the benefits of control in monetary terms to an urban community, with the inclusion of both use and non-use environmental values. This cost-benefit analysis is used to assess whether or not the benefits of control in an urban context outweigh the various costs of the methods available for control, and provide a cost/benefit ratio for the large amount of investment into this problem nationally.

1.3 Method to be Followed

The analysis will be conducted using a cost-benefit approach. The benefits of control will include both market goods (e.g. increased water flows) and non-market environmental goods and services, the value of the latter being elicited using contingent valuation surveys at the Nahoon River in East London, South Africa, where water hyacinth has been identified as a problem (Hill, 2006). In this way the economic costs to the population will be identified (other potential economic costs of invasive species are however identified and discussed in the body of the thesis).

To assess the cost effectiveness of control and the benefits thereof the research will be conducted at two different levels of water hyacinth invasion on the river. There is data available regarding the relative costs of the various control options for water hyacinth (e.g. van Wyk and van Wilgen, 2002; Jones, 2006). The research will therefore be drawing on both primary and secondary sources.

1.4 Outline

Following this introductory chapter, the context of the problem of invasive aquatic species is set in Chapter Two. Chapter Three discusses the economic value of environmental goods and services, which incorporates an explanation of the value of biodiversity. The valuation of biodiversity is an important aspect in the consideration of the economic costs associated with invasive species (the invasion of water hyacinth in this case), to which they are considered a major threat. Chapter Four is a literature review which discusses the method used to conduct the primary research, namely the contingent valuation method. Chapter Five outlines the method of study used to conduct the cost-benefit analysis at the Nahoon River. Chapter Six presents the results of the research. In this chapter the costs of the invasion of water hyacinth are identified by the respondents to the contingent valuation exercise. The results are discussed and recommendations are made in Chapter Seven.

CHAPTER TWO: THE CONTEXT OF ENVIRONMENTAL COSTS

2.1 Water Hyacinth

- **The Control of Water Hyacinth**

The spread of water hyacinth in South Africa can be largely attributed to gardeners, aquarium owners and boating enthusiasts. Hill (2003: 20) outlines the main environmental consequences of invasive aquatic species, namely reduced drinking water quality, the increase of water borne diseases, increased siltation of rivers and dams, increased water loss through evapotranspiration, reduced water surface area for recreation, reduced biodiversity, clogging of irrigation pumps, drowning of livestock and reduced water flow. Aquatic invasive species are able to reproduce at rapid rates in the absence of natural control mechanisms and the high incidence of nutrient-enriched water bodies. Water hyacinth is however the most damaging due to its ability to invade large water bodies with the potential to have negative impacts on a far greater spectrum of infrastructure, such as rail, bridges and hydroelectric power facilities (Hill, 2003: 22).

In most cases, the first control option for water hyacinth is manual or mechanical control, usually by means of pitchforks, rakes, and at larger scales, mechanical harvesters (Cilliers *et al.*, 2003: 162; Hill, 2003: 22). There has been notable success in the mechanical control of water hyacinth, but due to drawbacks such as the high level of labour intensity, the cost of the method, and the limits to the size of infestation in which it is successful; it is not an ideal option for control (Hill, 2003: 22). In some cases, barriers or fences have been erected to limit the spread of the weed, although successes through this form of control have been limited (Cilliers *et al.*, 2003: 162).

Herbicidal control is made more efficient when used in conjunction with barriers that restrict the spread of water hyacinth, as more dense stands can be controlled thereby saving time and energy, hence making the process more cost effective (Cilliers *et al.*, 2003: 162; Hill, 2003: 22). It is essential that herbicidal control is reinforced by continual follow-up programmes due to the persistence and strength of the reproductive process of the weed. Such programmes have failed in the past due to a lack of commitment to these operations (Hill, 2003: 22).

Due to the problems associated with mechanical and chemical control of water hyacinth, these options are not seen to be sustainable over the long-term (Hill, 2003: 22). Biological control is the most recent management option in South Africa, first used in South Africa during the 1970s (Hill, 2003: 22). Biological control, which can be described as the introduction of an invasive species' natural enemy (from an indigenous site) where the invasive species has established itself in an exotic location, is seen to be the most feasible long-term option (Hill, 2006).

Although at some sites water hyacinth has been effectively controlled through biological control, successes are varied, largely due to climatic variations, the speed at which the weed reproduces and interference from other control strategies (Hill, 2003: 23). More research is required to identify other biological control species that would be successful over a greater range of temperatures, and management plans need to be carefully developed so that biological control can be successfully integrated into other control strategies (Hill, 2006).

- **The Cost of the Control of Water Hyacinth**

Van Wyk and van Wilgen (2002) compared the costs of water hyacinth control between three alternatives, namely herbicidal, biological and integrated control. Since herbicides used for the control of water hyacinth were readily available, the full market price was used for comparative purposes. There is no market for biological control agents that kill weeds as yet. The study therefore used an estimation of the minimum price for research and development of biological control agents as the cost of control as a means for comparison.

To calculate the cost of herbicidal control, van Wyk and van Wilgen (2002) used a case study of water hyacinth on the large Hartebeespoort Dam, on the Crocodile River near Pretoria in South Africa. Water hyacinth was a very successful invasive weed on the dam. Clearing involved an intensive initial spray that reduced the weed to 8% of its original surface area, which accounted for the majority of the expenditure on control. Following this, less intensive sprays managed to control the water hyacinth to only 2% of the dam's surface area (58% improvement), which represented incremental or maintenance costs subsequent to the initial cost of clearing.

The cost of biological control was calculated using a case study at the New Year's Dam in the Eastern Cape (van Wyk and van Wilgen, 2002: 144). In 1990 the Dam was 80% covered by water hyacinth; the initial biocontrol programme using weevils initiated in that year reduced the levels to 20% of the dam's surface area over the following five years. There was however resurgence in the levels of the weed in 1996 – up to 80% of the dam's surface area, but this entailed essentially no cost because the weevils were able to cope with the increased load over the following year (Hill, 2006).

A good example of integration between herbicidal and biological control of water hyacinth is the Nseleni River and Lake Nsezi near Richard's Bay in Kwazulu-Natal for which the costs of an integrated control strategy were estimated (van Wyk and van Wilgen, 2002: 145). Initially both herbicidal and biological control operations were initiated independently; following this an integrated management plan was developed. Over the entire period the costs of herbicidal control far outweighed the costs of biocontrol, although it is not known in what proportion they were effective in clearing the weed. For this reason the cost of control for the system was calculated by combining the various costs.

The study concluded that herbicidal control was about five times less cost effective (US$208.6/ha) than biological control (US$43.5/ha) or integrated control strategies (US$39/ha). Mechanical clearing is widely accepted to be both labour and time intensive and hence cost ineffective. Van Wyk and van Wilgen (2002) confirmed what is widely accepted; namely that biological control offers a cost saving alternative and should be actively explored as an aquatic weed control mechanism (Cilliers *et al.*, 2003; Hill, 2003). The potentially high initial costs of research and development into biological control should, however, be borne in mind when calculating the relative costs of control.

2.2 The Economics of Environmental Goods and Services

To determine the value or benefit of clearing alien invasive species it is necessary to take into account the loss of environmental goods and services that would have been incurred if the invasion were to continue. For that, estimates are needed of the levels and rates of invasion and methods that accurately place economic values on environmental goods and services.

In order to conceptualise the idea that environmental goods and services have financial value, it is necessary to consider these goods and services to be associated with what the environment produces for current and future human consumption. Ecosystem functions are the structures that provide those goods and services at given quality levels. With functions such as water purification, for example, the value associated with any given quantity of water will also depend on the quality of that water.

Turner *et al.* (2003: 495) defined two classes of environmental value, namely anthropocentric value and non-anthropocentric value, which are combined to give an estimate of Total Economic Value. Total Economic Value of biodiversity provides a good framework when assessing the impact of invasive alien species; this however is not completely accepted by ecologists due to the weak links of the concept of goods and services with biodiversity (Turpie, 2004: 88).

The Total Economic Value (TEV) includes use values, which incorporate options value (anthropocentric) and non-use values, which incorporate existence value and bequest value (anthropocentric and non-anthropocentric) (Turner *et al.*, 2003: 495).

Use values are further divided into two classes; namely direct use values and indirect use values (Pearce and Moran, 1994: 12). Direct use values incorporate all actual uses (goods), while indirect use values refer to the ecosystem's functions (services), such as water filtration through a catchment (Pearce and Moran, 1994: 12).

Non-use values can be described as the value of environmental goods and services not attained through current or future consumption, such as existence value. Existence value is the value we place on the mere existence of a specific aspect of the environment, even though tangible benefits may never be experienced.

According to Humphries *et al.* (1995: 101), environmental conservation is a system of optimising "future insurance and investment against environmental change". It can therefore be suggested that the option value component may be a useful measure of the importance of biodiversity. It should however be noted that option value may be to some extent incorporated in use and non-use value, the potential for double counting therefore exists. Although these values have tangible economic benefits, they may only be realised when technologies facilitating their productive use have been developed. Furthermore there is no way of knowing which species will generate the greatest cash inflows from future utilisation (Humphries *et al.*, 1995: 102).

Non-use values are described as all other possible forms of income not arising from current or future production and consumption (use values) (Turner *et al.*, 2003: 494). There is consensus among resource economists that the difficulty in environmental valuation does not lie in the acquisition of the values that the environment generates on a local scale from current production and consumption, but rather in the calculation of the often subjective non-use values, and indirect use values (Turner *et al.*, 2003: 497; Kassar and Lasserre, 2004: 859; Curtis, 2004: 167).

Difficulties often arise in placing monetary values on the benefits that humans acquire from the mere existence of the environment in its natural state (existence value), because not all people value the environment identically and it is often difficult to translate this concept of value into economic terms. Attempting to predict the future economic benefits from the environment and the assumption that humans have the capacity to assign such a price to the environment also presents difficulties in environmental valuation (Turner *et al.*, 2003: 495).

According to Kassar and Lasserre (2004: 858), the non-use values include ecosystem stability and survival. The multi-dimensional and interconnected nature of the environment makes it inherently difficult to collect enough information to describe this concept in monetary terms. There is also limited scientific knowledge on the component parts of the ecosystem that ensure its survival and therefore describe its value (Turner *et al.*, 2003: 498).

Although it is not possible to assign a comprehensive value for any given level of biodiversity, the concept of Total Economic Value goes a long way not only towards valuing the aspects of an ecosystem that provide direct use value, but also to include an estimate of the value of the functioning of the ecosystem. Although there are a number of methods available that attempt to value non-use environmental goods and services, a valuation of ecosystem functioning is an altogether more complicated exercise that would facilitate a more comprehensive estimate of the value of biodiversity.

2.3 Ecological Systems Valuation

Recently attempts have been made to describe the value of ecosystem functioning, or systems value (Farber *et al.*, 2002; Limburg *et al.*, 2002; Howarth and Farber, 2002). The challenge is to place an accurate set of values on ecosystem goods and services, comprising of both use and non-use values. The biggest obstacle in this process is the valuation of indirect use values, assuming non-use and non-market use values can be elicited through revealed or stated preference methods, and realistic markets exist for final environmental goods used for human consumption. Market prices however seldom represent the true value for environmental goods because of the existence of externalities.

Furthermore, not all environmental resources are valued in the market as is the case of water. The total exchange value for any level of water supply, assuming the price of water is purely market derived, can be calculated by Quantity (Litres) × Price (Rand) – while the area below the demand curve 'DD' on figure 2.1 gives the total use value of the resource. However, due to the inefficiencies of most markets for environmental goods and services, i.e. the existence of externalities, this is not always possible and market prices have to be estimated indirectly (Farber *et al.*, 2002: 379). Using various techniques it is possible to derive an individual's Willingness to Pay (WTP) for, or Willingness to Accept (WTA) compensation for marginal changes in the supply of environmental goods and services that are not valued in the market. This allows for the calculation of the value of marginal changes in the supply of environmental resources (Farber *et al.*, 2002: 379).

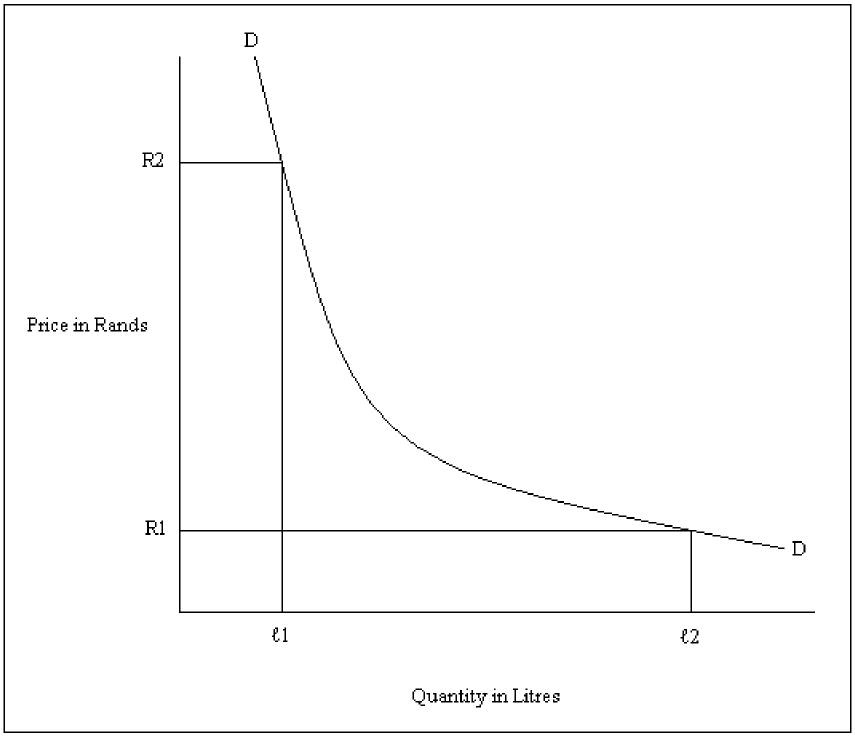

Fig. 2.1: The exchange value of water

Source: Farber *et al*., 2002: 379

Although the above example provides a useful means to explain the determination of exchange value of an environmental good or service, in this case water, it does not provide an estimation of the value of the environmental function as a whole.

Kaiser and Roumasset (2002: 2) offer a simple method for valuing an indirect ecosystem service where the quality level of that service determines the future value of a renewable resource. Their method is based on a study of a watershed in Hawaii in which the value of ground water recharge was estimated using shadow prices with the outside limit price being that of salt water desalination. They estimate a stream of optimal prices and the present value of the water resource given the current population, the current population growth and the quality level of the indirect environmental service. The optimal stream of prices would be set at levels so that the demand for water is kept within the given supply. Estimations of the total present value of the resource can be made by the sum of the stream of optimal prices. They then show that marginal values can be given to the quality of indirect service by estimating the amount of change in present value that results from a given change in quality of that service. With reduced quality levels, the optimal price stream will reach the outside limit price sooner, giving a reduced present value of the water resource. This reduction in present value gives the marginal value of groundwater recharge quality, the indirect ecosystem service being valued.

The limitation of this method is that there has to be some market value for the renewable resource, which is often imperfect. Shadow prices therefore have to be estimated with the maximum price being the cost of a substitute.

According to both Kaiser and Roumasset (2002: 1) and Turner *et al*. (2003: 508), one of the most important limitations with current techniques that value the environment, is their inability to measure the value of indirect ecosystem services. The process of measuring these indirect benefits is complicated by the lack of markets to value such goods, and the limited understanding of the environmental systems of which they form a part.

Future valuation studies need to incorporate a range of ecosystem functions, as these values have a high level of significance to policy makers who are faced with the trade-off between conservation and development (Turner *et al*., 2003: 508). Similarly conservation projects cannot be justified on economic grounds if these functions are not fully understood or valued correctly (Turner *et al*., 2003: 508).

Apart from the limitations that are evident in environmental valuation techniques, another major shortcoming of much of the environmental valuation literature is the inconsistency in the approaches of each study, mitigating their value as a means of comparison (Groot *et al.*, 2002: 394). These inconsistencies manifest themselves in the understanding of value, concepts of ecosystem 'functioning and functions' and the way in which environmental valuation techniques are used (Groot *et al.*, 2002: 394).

For these reasons Groot *et al*. (2002) made a first attempt at a standard model or generic framework that could be used for systems valuation. Ecosystem functions were described as the ability of natural systems to provide humans with the goods and services they desire, both 'directly and indirectly'. All ecosystem functions are broken down into four groups, namely: regulation functions, habitat functions, production functions and information functions. Each function is dependent on the ecological complexities of the system of which they form part. Groot *et al.* (2002) further divide the functions into 23 more specific functions and briefly describe the possible goods and services that may be acquired from each. It is suggested that the list of functions is suitably comprehensive to form a basic framework for the valuation of most ecosystem goods and services.

It is interesting to note that Groot *et al.* (2002: 397) make the assumption that all the functions that are sought to be valued are sustainable and are being exploited at sustainable levels. This is an important distinction when the concept of ecological thresholds is incorporated, because when resources are used at unsustainable levels ecological thresholds are more likely to be reached where there is a negative divergence from the marginal pricing regime.

Once the problem of ecological complexity is dealt with by the development of a framework for the understanding of the environmental functions that derive value to humans, focus needs to be placed on the techniques available to value those functions. Groot *et al.* (2002) identify the tools for environmental valuation under the following categories: direct market valuation, indirect market valuation, contingent valuation and group discussion. Each of the valuation tools is then matched to the 23 environmental functions (environmental functions included as Appendix 1) that are said to generate value through the creation of environmental goods and services.

Groot *et al.* (2002) provide a good first attempt at a generic typology for the valuation of ecosystem functionality. Future research should however focus on the development of such a framework, so that data can be more accurately compared and contrasted (Groot *et al.*, 2002: 407), with the possible incorporation of the theory of marginal values, so that changes in environmental quality can be better understood and quantified.

It is necessary that ecosystem functioning is valued at sustainable levels, because the marginal pricing regime diverges from what is expected when ecological thresholds are reached, or in other words when a system moves from one ‘stable state’ to another (Limburg *et al.*, 2002: 416; Scheffer and Carpenter, 2003: 648). It is not possible to predict accurately these thresholds or levels, because it is not yet fully understood when an ecological system will shift from one stable state to another; valuation under these circumstances represents further challenges (Limburg *et al.*, 2002: 416). It seems logical to assume that an ecological system will shift when there is a significant shock to that system; however, research tends to indicate that this is not the case (Scheffer and Carpenter, 2003: 648). Even small changes in the forces acting and interacting in ecosystems (for example gradual global warming) can push the system over an environmental threshold from an old 'stable state' or regime into a new 'stable state' or regime. Since ecosystems in almost all cases cannot be seen as being stable (constant fluctuation in conditions), a "catastrophic" change from one 'stable state' to another could more aptly be termed a "regime shift" (Scheffer and Carpenter, 2003: 650).

To illustrate the concept of ecological thresholds and catastrophic regime shifts, consider the two extremes: one in which the environment in question has undergone minimal impact and is not under considerable stress (sustainable use); and another where the environment has undergone a large degree of impact. In the first extreme the marginal regime applies as there is a large degree of 'certainty and predictability' associated with small changes in marginal value; in this situation the ecological system follows a similar pattern to the economic system (Limburg *et al.,* 2002: 416). Under these conditions predictability allows a marginal valuation of environmental goods and services based on the preferences of human beings and the scarcity of the resource (Limburg *et al.,* 2002: 416).

At the other extreme the behaviour of the value of the environmental good or service can be described as a 'non-marginal regime', where marginal economic valuation is no longer appropriate, and changes in the marginal value of the resource are large and erratic (Limburg *et al.,* 2002: 417). At this point there is uncertainty regarding the environmental system; it has the potential to transform completely with only marginal changes to the stresses placed upon it. The most classic intuitive example of this is "the straw that broke the camel's back" (Scheffer and Carpenter, 2003: 648)

The difference between these two scenarios can be illustrated by figure 2.2. Figure 2.2 A illustrates the situation where the marginal regime holds and there is a gradual, predictable loss in environmental quality and value. In this situation change can be understood and managed, because any change in quality will be completely predictable. Figure 2.2 B illustrates the situation where the marginal regime no longer holds; it is theorised that close to some "critical threshold" even small changes in the stress on the environment will have significant changes in the value of the environment to the economy (Limburg *et al.*, 2002: 417).

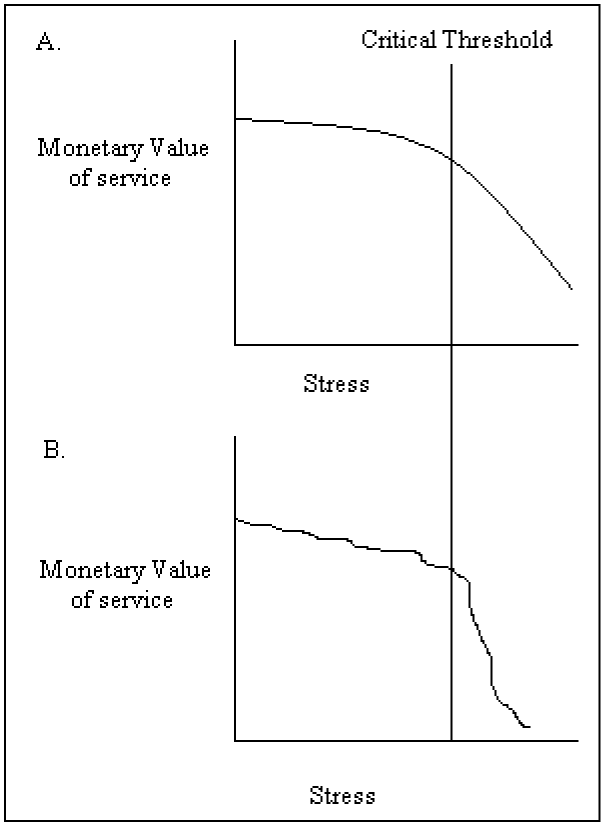

Fig. 2.2: The difference between an environment with a smooth response to stress and an environment with a catastrophic response to stress

Source: Limburg *et al.*, 2002: 417

As an example of an ecosystem reaching a critical threshold and shifting to a new stable regime, Scheffer and Carpenter (2003: 648) present coral reefs in the Caribbean. For years researchers had been studying the reefs, and although a great degree of knowledge regarding the reefs had been generated, researchers had not predicted the sudden and dramatic changes that took place. The reefs transformed into an algal encrusted state, and only once the changes had taken place were researchers able to isolate the probable causes for the transformation. A second example presented by Scheffer and Carpenter (2003: 648) is that of ancient vegetation loss in the Sahara region. A gradual reduction in vegetation in the region was observable followed by a sudden and unprecedented loss in vegetation with no apparent over-arching environmental trigger. These are but two of the examples that Scheffer and Carpenter (2003) use to connect the theory regarding alternative stable states to what has been observed through experimental evidence and sudden events that have taken place in the natural environment. The authors note that similar examples are available for standing water bodies, savannahs, open oceans and lakes.

The theory of regime shifts or shifts in stable states of ecosystems is controversial (Scheffer and Carpenter, 2003: 648). This can most likely be attributed to the inherent unpredictability of such events. Regardless of the level of evidence of regime shifts in varying ecosystems and the conflicting views on the subject, it would appear that the more stress that is placed on an ecosystem, the higher the risk or probability of a shift in the stable state of that ecosystem (Limburg *et al.*, 2002: 417). Due to this unpredictability, the issue deserves consideration in the management and conservation of environmental systems.

Limburg *et al.* (2002: 417) describes a loss in value as a loss in ecosystem goods and services, or deterioration in system functioning. Farber *et al.* (2002: 384) use an example of trees in a catchment to describe how such a threshold could be reached. Trees in a catchment provide the critical service of reducing river flows during storm events to downstream users. If the trees are placed under stress and their numbers are depleting, at some point flood damage would become unacceptable to the downstream users. This is a good example of how social and economic needs can place thresholds on environmental quality. The poor understanding of the way the environment reacts to stress and other factors that may hide the indications that a critical threshold has been reached, such as over-fishing a drastically depleting stock of fish, or considerable time elapsing between storm events, make the identification and prediction of such situations difficult. These problems complicate a marginal pricing regime.

The switch from a marginal pricing regime to a non-marginal pricing regime can be dramatic and irreversible, which can result in a loss of value in of the resource in perpetuity. It therefore follows that the avoidance of such thresholds, or resilience to stress, represents a service with value. Consider the above example of trees in a catchment that moderate stream flows in storm events. Before the critical threshold where flood damage becomes unacceptable (for example: loss of human life, or financial costs beyond some critical level), marginal reductions in the number of trees can be measured in value by the increase in the cost of storm damage, in this case the cost for the environmental service would be the price of property repairs. When the critical threshold is reached and the flood severity becomes unacceptable, the increase in economic loss does not change marginally with increased stress on the catchment and considerable more damage is experienced than in previous storm events. People may even be placed at risk, further increasing the loss in value from a small reduction in ecosystem quality. This point is represented by the critical threshold on fig. 2.3 which shows the relationship between trees per hectare and flood damage severity by the function ‘FF’. Now a monetary measure of value alone may not completely represent the increase in severity of the storm event. For this reason a risk averse society will in all likelihood prefer to maintain some level of tree cover below the critical threshold, at point T on fig. 2.3 for example. This is because of a predicted discontinum in the demand for the protection to flood damage provided by trees in the catchment, in other words there would be a disproportionately higher level of demand for protection at decreasing levels.

The willingness to maintain a certain level of tree cover represents the value placed on the resilience of the ecosystem to not reach the critical threshold where the predictable margin regime no longer holds. Any level of tree cover below point T would represent a marginal loss in welfare because of the increased risk of reaching the threshold level associated with socially unacceptable flooding (Farber *et al.,* 2002: 384).

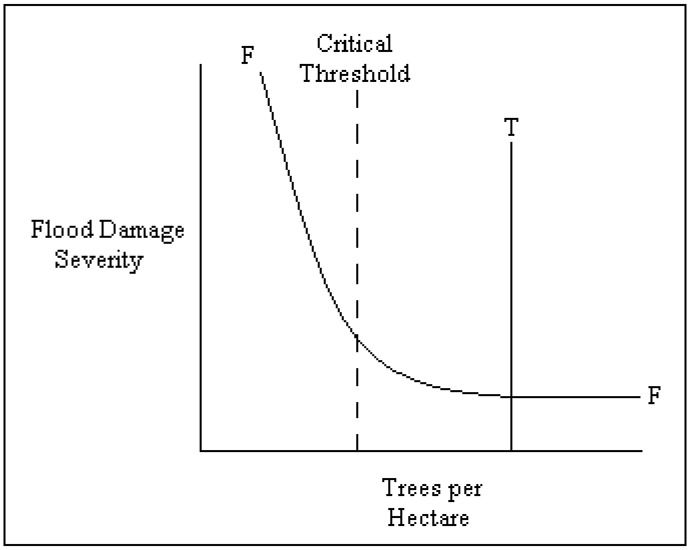

Fig. 2.3: The flood protection value of trees

Source: Farber *et al.*, 2002: 384

Any level of tree cover below point T would mean that society would be willing to pay not only the marginal difference in flood damage for the reduction in tree cover, but also an 'insurance premium' to avoid a massive and possibly irreversible change in environmental quality, i.e. the loss of a system function and hence a loss in welfare (Farber *et al.*, 2002: 384). Using this example Farber *et al.* (2002: 384) distinguish between an efficiency value and a sustainability value of environmental functions. In the marginal region where small changes in tree cover lead to incremental changes in flood damage, efficient decisions can be made on the level of flood damage allowed and the value of trees. When a certain point is reached in the level of tree cover, say point T on figure 2.3 for example, the value of extra trees include a degree of sustainability value because every extra tree reduced the chance of a complete economic and ecological system failure. Sustainability value may be more important than efficiency value because of the possibility of irreversibility. Ecosystems should be managed at levels where they remain both efficient and sustainable in the long run, as opposed to efficient in the short run where only the value of increased flood damage is considered, and not the impending risk of system failure, or an 'unacceptable' threshold being reached.

In the tree example only one service of the ecosystem was considered; in reality the situation is far more complicated and any given ecosystem function may be responsible for a number of environmental goods and services. Another way to look at this is that an array of stresses acting on the environment may have influence on a number of environmental functions. Determining a threshold level for the amount of stress placed on the environment may therefore be an altogether more complex task.

If the case of water hyacinth is considered, one of the most important services it affects is the ability to abstract water from the system because of the reduced yield it causes. In theory it is possible to plot a marginal regime for the value of water until it reaches a socially critical threshold, a point where there is not enough water available to meet the basic needs of the people that it supports. But water yield is not the only environmental service that water hyacinth negatively affects; aquatic systems affected by water hyacinth also provide recreational services for example. If boating is considered, it is conceivable that as the usable surface area diminishes there would be a marginal loss of recreational value. This would continue until a point is reached where boating is no longer possible, the critical threshold. As this point is reached, and beyond a certain point where the sustainability of the service is in question, sustainability value would be included when reducing the amount of water hyacinth.

Figure 2.4 illustrates a situation where more than one critical threshold is included when analysing a single environmental stress, in this case water hyacinth. In part A, before the critical threshold CT 1 is reached, the marginal situation as described previously is experienced, but as CT 1 is approached, an invasion level that does not allow for boating for example, sustainability value is now included in the benefit of clearing, or loss to systems value as a whole. As the invasion continues another critical threshold is reached, CT 2, say for example an increase in water borne disease to a point where an unacceptable number of people are unhealthy (the loss in value could be calculated through medicine expenditure and lost work hours). At this point the sustainability of the resource to maintain a healthy population is in question and a larger degree of sustainability value is included when calculating the total loss to resource value. In figure 2.4 B the amount that the severity of the invasion has increased from a zero invasion level to CT 1, and from CT 1 to CT 2 is equal. This is represented by A and B on figure 2.4 B. The increase in benefit of control or loss of value to the resource has not increased by the same amount. This can be accounted for by successive critical thresholds being reached and an ever increasing level of sustainability value being included into the loss in quality of the resource. This is represented on figure 2.4 B firstly by the increase on the Y axis from P1 to P2 corresponding to an increase of the invasion by the amount A, and secondly by the increase from P2 to P3 corresponding to an increase of the invasion by the amount B.

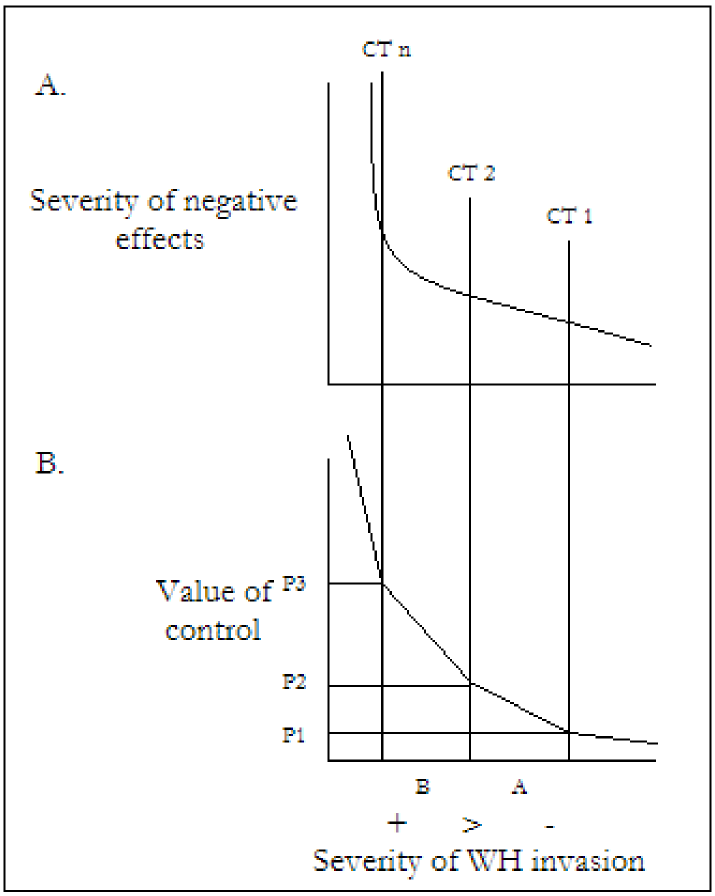

Fig. 2.4: The loss in total resource value when a negative environmental stress affects more than one environmental service (note the severity of the invasion increases as the apex of the X axis is approached)

Because of the apparent increase in the rate at which the value of control (increased environmental degradation) rises it seems logical that the most efficient stage to control an environmental stress would be before it reached a sustainable or critical threshold, even before the possibility of irreversibility is considered. Any further damage to the environment would produce a loss in resource value at an increasing rate where efficiency value is no longer the only consideration. The large benefits to control associated with high levels of environmental degradation may also account for most environmental management programmes being implemented after there has been a considerable amount of stress placed on the system where the greatest benefits can be realised from the mitigation of the control (refer to figure 2.4 B – value of control). It follows that interventionary environmental protection should be preferred, when the costs of control are low, at low levels of stress and the losses to resource value are potentially large and grow at rates that do not fit the marginal regime, as is the case with water hyacinth.

In order to calculate the loss in monetary environmental value, indicated by the value of control on figure 2.4, markets have to exist for all environmental goods and services associated with the resource. In the absence of traditional markets, markets for environmental goods and services have to be created using environmental valuation techniques in order to determine system value, or the cost of environmental degradation, for example the invasion of water hyacinth.

Another consideration is that it is very important to know the various critical threshold levels so that control efforts can be planned and monitored accordingly (Huggett, 2005: 307). According to Huggett (2005: 307), the majority of the literature regarding ecological thresholds views them as catastrophic points in the level of ecosystem quality where the system as a whole experiences a drastic drop in quality, and not as individual points in a series headed to system collapse. For the purpose of an economic valuation of ecosystem functions it is useful to consider a series of identifiable and easily measured acceptable limits for the quality levels of the goods and services that the environment offers, hence enabling clear management goals for conservation. In the more commonly accepted understanding of ecological thresholds, the ‘turning point’ is not as easily identified or predicted and therefore lacks the ability to, in all cases, guide conservation efforts (Huggett, 2005: 307). The reason for the relative obscurity in the traditional understanding of ecological thresholds is mainly that there is a lack of understanding of complex environmental systems (Huggett, 2005: 307); while economic and social thresholds can more easily be identified, although not perfectly due to the limitations discussed. For example, if a certain pre-determined number of people in every hundred in a population experience illness, an observable threshold would be reached.

The valuation of ecological systems is unlikely to be straightforward due to the complex nature of the environment. At abundant levels of environmental goods and services produced in systems that are sustainably exploited, the marginal pricing regime will in some cases hold, and markets with prices that accurately reflect the scarcity of environmental goods and services should be developed. When ecosystems are placed under considerable stress, at some stage, certain critical ecological or economic thresholds may be reached. This would result in a drastic loss of resource value, causing high mitigation costs and highlighting the value of a functioning, resilient ecosystem. The potential economic losses associated with ecological thresholds can be seen as the value of a resilient ecosystem.

CHAPTER THREE: THE VALUE OF BIODIVERSITY

In the previous chapter the value of environmental functions was considered in terms of total resource value, and the way in which resource value changes given certain levels of stress placed on ecosystems, or the increased scarcity of environmental goods and services. One such stress to aquatic ecosystems is the invasion of water hyacinth. Where there is the potential for the loss of biodiversity, as is the case of the invasion of water hyacinth, it is important that a valuation thereof is considered.

The goods and services that are generated through the operation of ecosystem functions are what give environmental resources value in economic terms. The present chapter provides a detailed description of the way in which environmental goods and services derive economic value.

3.1 The Economics of Biodiversity

Much of the emphasis of the conservation and protection of natural resources is focused on the concept of biological diversity, or biodiversity (Weikard, 2002: 20). This may largely be due to the increasing recognition of the negative impacts that human activities have on biodiversity, particularity through habitat destruction (Simpson, 2002: 1). Biodiversity is simply defined as "the total variability of life on earth" (Heywood *et al.*, 1995: 5), or more broadly as the total range and quantity of biological variability, including species numbers and population sizes, at all levels of existence from the genetic level to the species and community levels (Heal, 2004: 106; Simpson, 2002: 2; Fromm, 2000: 303). Biodiversity can be described on different scales, in other words a country's biodiversity can be described as a whole (national biodiversity) or it can be limited to a description at a much smaller scale, like the diversity of different species in a catchment for example. The definition of biodiversity also incorporates interactions between species at different scales. These connections are an important aspect of biodiversity when ecosystem functioning is considered, and therefore ecosystem value.

Because of the complex nature of the natural environment and the varying benefits that are received from biodiversity, the capacity to define biodiversity accurately is limited (Simpson, 2002: 1; Baumgartner, 2005: 2; Weikard, 2002: 20). This largely accounts for the number of definitions of biodiversity, and conflicting views regarding biodiversity and its importance. It also makes its valuation complex. Accurate estimations of the value of biodiversity can only be made when it is known, and there is consensus on, what is being valued (Simpson, 2002: 01). It is important that there is this level of shared and accepted understanding because only then can comparisons and assessments be made regarding total resource value.

Biodiversity is regarded as having value in a number of ways. Firstly, biodiversity has direct benefits to individuals through the direct use of biological resources, for example recreational use of environmental resources (Christie *et al.*, 2004: 11). Secondly, biodiversity has value to individuals through the passive-use of environmental resources, in other words biodiversity has value to individuals through the knowledge of a 'healthy environment' for current benefit, and for the benefit of future generations. Finally, biodiversity can be seen to have value through the facilitation of ecosystem functioning and therefore in the production of ecosystem goods and services (Heal, 2004: 107; Limburg *et al.*, 2002: 417; Dasgupta, 2000: 11), whether or not they are used for current or future consumption. It is therefore clear that there are a number of negative environmental externalities that are prevented through the conservation of biological diversity. These externalities represent an economic value. Biodiversity therefore has significant economic value in the provision of natural resources and in the maintenance of human welfare. It appears that this importance is not well understood and is often neglected.

Various human activities result in environmental degradation, or the decline in biodiversity (Christie *et al.*, 2004: 11). This decline will reduce the value generating capacity of biodiversity, in other words environmental degradation represents a decline in the value of biodiversity. In order to maintain the value generating services facilitated by biodiversity, society needs to adopt strategies or policies to protect the natural environment. If the value of biodiversity could be accurately measured then these policies would not meet opposition based on rational economic decision making, and incentives to conserve biological diversity would exist (for example the increased productivity associated with increased levels of biodiversity in an agricultural environment, discussed later in this chapter).

Dasgupta (2000: 11) provides a good example of the widespread apparent neglect and misunderstanding of the importance of biodiversity. In many emerging economies the environment is seen to take a back seat to development based on the notion that development is the best way to alleviate poverty, and then through poverty alleviation and development, environmental sustainability will be promoted. This empirical observation "give(s) rise to an inverted U-shaped curve relating economic growth and environmental degradation" (Nahman and Antrobus, 2005: 105).

This U-Shaped curve is similar to a theory described by Kuznets in 1955 which hypothesised a theoretical relationship between income per capita and income inequality (Nahman and Antrobus, 2005: 105). The relationship between economic growth and environmental degradation is therefore known as the environmental Kuznets curve (EKC). The EKC hypothesis can be described as follows: in the early stages of a country's economic development and at low levels of income per capita, development is associated with increasing levels of environmental degradation. At a certain point in the time line of economic growth, this trend will reverse and higher levels of income per capita will be associated with increased environmental protection and improvement.

There is however evidence that contradicts the EKZ theory (Stern, 2004: 1426; Dasgupta, 2000: 12). Research indicates that more developed nations in fact have a larger negative environmental impact, and hence the notion that emerging countries pollute now and conserve later does not hold (Panayotou, 1992 in Dasgupta, 2000: 12). The 'develop now and conserve later' development strategy also makes little sense on the grounds of continued economic and environmental sustainability. The reason for this is that the environmental Kuznets curve assumes that environmental degradation will not have an effect on income as it is assumed that "income is an exogenously determined factor" (Stern, 2004: 1426). It is assumed that environmental damage will not affect income, or that the economy is sustainable. This is not however the case. Resources should be exploited at levels that yield the optimal stream of benefits in a time frame that allows for the economy to develop at a pace in line with the diminishing resource base allowing time for specialisation in other fields, and ensuring the continued growth and sustainability of the economy (Dasgupta, 2000: 12). Even with renewable resources, ecological thresholds and the issue of environmental irreversibility must be considered.

Dasgupta (2000: 12) also suggests that the poorest of the poor in any country are those most dependent on the natural resource base and therefore have the most to lose from its depletion. This results in non-pareto optimal outcomes of resource allocation through development and rejects the notion that development that initially disregards the environment is a means towards poverty alleviation and socially optimal resource allocation.

One of the factors contributing to the notion that development through environmental degradation is acceptable, is that of the substitutability of natural resources (Dasgupta, 2000: 12). According to Dasgupta (2000: 13) natural resources can be conserved or replaced through substitution in the following ways: firstly resources can be substituted in consumption through the development of synthetic materials, for example nylon can replace wool; secondly innovation can result in greater efficiency of natural resource use, for example the replacement of the piston by the steam turbine in the early 1900s; and thirdly natural resources can themselves substitute each other, for example natural gas for oil.

The economy can be seen to be the driving force behind substitution; for example in the automobile industry as the price of petrol increases the incentive to find a more efficient fuel is created because of the expected increased profits that are now possible. A large amount of research and development goes into the development of alternative, more abundant, cost effective fuel sources. Evidence of this can be seen by the number of new concept cars that use hydrogen from water or electricity to fuel them. Another example of how a changing economy can make natural resources more viable is the mining industry. As resources become more expensive (oil in this case), it becomes more economically viable to mine new sources or drill at greater depths previously not cost effective. Reserves become viable at an increasing rate as mining techniques improve and it becomes cheaper to drill.

Apart from the fact that substitutes often entail large economic costs (Dasgupta, 2000: 14), is the substitution of natural resources viable in perpetuity? Will there always be another resource or technique readily available for society to continue exploiting the natural resource base in the pursuit of economic growth without sustainability constraints? Daly (1987) has described the biophysical limits to economic growth and the capacity to use environmental resources as a means for production. The natural environment is a finite source of low-entropy natural resources, which are rearranged in the production process. These low-entropy inputs are converted through the production process to high-entropy outputs, and eventually high-entropy waste, for which the earth provides a finite sink. The capacity to continue to substitute environmental goods for each other is therefore limited by the natural environment, both in its capacity to provide inputs for the production process, and as a sink for waste.

Given that there are limits to the extent that mankind is able to exploit the environment for economic growth, there are also moral concerns regarding the depletion of environmental goods and services and the rate at which these are consumed. These concerns also represent limits to economic growth (Daly, 1987: 329). For example, because of the finite nature of the environment there is a contention that conservation (of productive environmental inputs) needs to take place for the benefit of future generations. The need to conserve the natural environment for these reasons represent limits to economic growth in the present, and a limit to the extent that current productive environmental resources can be substituted for other resources with similar attributes.

In this chapter, however, the emphasis is on the economics of biodiversity. Clearly the regime of exploit – substitute – exploit will have a negative impact on biodiversity and is not feasible in perpetuity, and therefore will lead to a reduction in biodiversity value in itself. If the substitutability that diversity offers is considered, it can be seen that this in itself represents an economic value of biodiversity that is diminished as the number of available substitutes decreases (Weikard, 2002: 23).

Although there is no comprehensive widely accepted valuation method for biodiversity, it clearly has value in a number of applications as the substitution examples suggest. Biodiversity conservation therefore can be seen as an investment, and a lack of conservation as a disinvestment, which leads to the deterioration of ecosystem services and therefore entails economic costs (Fromm, 2000: 303). The economic decision of whether or not to conserve biological diversity therefore depends on the associated costs and benefits of protection/lack of protection (Fromm, 2000: 303). In the following section of this chapter the various ways in which it has been identified that biodiversity displays economic value (conversely, where a loss thereof leads to economic costs) will be discussed.

3.2 The Value of Biodiversity

Although a comprehensive definition of biodiversity is still some distance away, it would allow a complete and repeatable technique for valuation. There are some good examples of how biodiversity makes economic contributions and therefore displays economic value, even though in most cases market prices do not display this value. According to Weikard (2002: 23) it is 'unanimously' accepted by society that a greater level of biodiversity is preferred. The challenge therefore is to put these benefits into monetary values. A discussion regarding the economic contributions of biodiversity provides an understanding of the benefits associated with the protection thereof, and the need for methods to assess accurately and comprehensively its non-market and market value. Heal (2004) groups the economic contributions of biodiversity into four categories, namely: biodiversity and productivity, biodiversity and insurance, biodiversity and genetic knowledge, and biodiversity and ecosystem functioning.

- **Biodiversity and Productivity**

Tilman *et al.* (2001: 843) describe the results of a long term experiment conducted over seven years on the effects of diversity on plant growth (productivity). The experiment was conducted over 168 plots each seeded with various different grassland plant species (the number of different species ranged from 1 – 16 species per plot). The relevant growth in terms of aboveground living biomass (primary productivity) and increased total biomass were observed over the experimental period.

It was found that on a year to year basis both the primary productivity and the total biomass increase were highly correlated to the number of species planted on each plot. Beyond this it was found that this relationship strengthened over time indicating that the biodiversity – productivity relationship is not a 'short lived phenomenon' as suggested by some research (e.g. Huston, 1997).

In another study linking the effects of biological diversity to agricultural yield, Yunusa *et al.* (2002) analyse the effects of the introduction of 'shelter-belts' of indigenous vegetation in an area of intensive agriculture, namely the Victorian Riverina bioregion in Australia. Farmers in the region would have to give up some portion of their productive land for the establishment of the shelter-belts, inducing a reduction in yield equal to the amount of land forgone. Beyond this, it is predicted that there will be a further reduction in yield in the remaining crops due to increased competition from the well adapted indigenous vegetation. This reduction in yield is said to be mitigated by a number of direct functions that these shelter-belts provide, namely weed management, and pest and disease control that improve agricultural yield. Beyond this, improved natural biodiversity is also expected to enhance ecological processes such as: the maintenance of soil quality, reduction in erosion, water purification, and carbon sequestration.

Travers (2000: 2), a forestry consultant, comments on the practical implications of research indicating the strong positive relationship between biodiversity and productivity. He argued that an outdated forestry management objective where the main objective was to reduce biodiversity to increase productivity was 'counter productive and unnecessary'. He suggested that maintaining natural biodiversity in forestry systems not only enhanced the productivity of the plantation in the long term, but also enhanced the productivity of commercial vegetation; which lead to a far greater total productivity of the entire system. Recognising not only the commercial benefits of increased biodiversity, but the ecological benefits too, Travers (2000: 03) maintained that the only way to maximise the benefits that are received from the natural environment, is to incorporate them into production decisions. This is a good example of the recognition of the commercial value of biodiversity; however it must be borne in mind that there are non-market benefits to the protection of biodiversity which should be accounted for these production decisions. Consequently, production and commercial profit are not the only sources of value derived through the existence of biodiversity.

Conservation is often seen to be separate from productive agricultural systems, but the commercial value of biodiversity seems to suggest that this may not necessarily be the case. If both conservation efforts and commercial agriculture could harmonise at some minimum level, the evidence suggests that the synthesis will be beneficial for both parties. In a study comparing the biodiversity between protected areas and adjacent rangeland in xeric succulent thicket, Fabricius *et al.* (2003) discovered that although protected areas were successful in protecting those species most vulnerable to heavy grazing, other species that were not successful in the protected areas thrived in the rangelands (mainly reptiles and arthropods). This evidence suggests that there are benefits to having diverse habitats in the promotion of regional species richness, or biodiversity. Small conservation areas could be set aside within regions characterised by commercial agriculture to promote higher levels of biodiversity and hence productivity as a whole.

The research reviewed here are but a few of a number of studies suggesting a strong correlation between species numbers (diversity) and productivity (Heal, 2004: 107), indicating an economic value of biodiversity particularly in the agricultural sector. Diversity also strengthens an ecosystem's resistance (be the ecosystem natural or commercial) to environmental fluctuations, ensuring continued high levels of productivity even in changing conditions, further adding to the productivity value of biodiversity (Baumgartner, 2005: 07; Heal, 2004: 107; Travers, 2000: 02).

Apart from the direct benefits to productivity through increased biodiversity there have been a number of agricultural developments that have been possible through the use of genetic variability of naturally occurring species of commercial plants (Heal, 2004: 107). By using genetic material the yields of rice, barley, soybeans, wheat, cotton and sugarcane have doubled; tomato yields have tripled; and yields of maize, sorghum and potato have increased four-fold (US Congress Office of Technology Assessment, in Heal, 2004: 107). Although estimates of the value of diversity in genetic material are difficult, it is suggested that genetic diversity has led to an increase in the value of US agriculture by $1 billion per year for the last 50 years (assumed to be at current prices but the author made no mention of this) (Heal, 2004: 107). It should however be noted that the value of such banks of varied genetic information is reduced by the development of bio-engineering.

In summary, biodiversity has real economic value through enhanced productivity at three basic levels: firstly, any ecosystem's productivity is positively related to the number of species occuring within that system in terms of both individual plant performance and total biomass accumulation (having both commercial and conservation implications); secondly, biodiversity provides ecosystem functions (water purification, soil erosion prevention etc.) that enhance productivity; and finally, genetic diversity of commercial plant species allows the development of high yield agricultural crops.

- **Biodiversity and Insurance**

The value of biodiversity in the provision of environmental goods and services is a separate issue to the insurance value discussed below, and is dealt with later in the chapter. At this point it is only necessary to consider the benefit of the long term provision of these services and assume that they have value. What is now of concern is their continued provision in the face of environmental shocks.

If the provision of environmental goods and services is viewed to have economic value, and their provision to be uncertain, biodiversity can be viewed as an insurer against uncertainty. In the presence of uncertainty, diversity plays a role in the mitigation of risk to the economic agent affected (Baumgartner, 2005: 02). This can be illustrated by the example of a broker who invests in the stock market, but rather than investing all the funds that he has available in one stock, he will diversify his portfolio to reduce the amount of risk faced (Baumgartner, 2005: 02). Biodiversity is thought to play a similar role in the provision of environmental goods and services. Biodiversity can be seen to enhance a system's capacity to cope with environmental fluctuations, in other words improve its resilience (Heal, 2004: 107). A system with a high level of biodiversity will be able to ensure the long term provision of goods and services even in the face of environmental shocks. In this way biodiversity plays a role as an insurance against environmental shocks. A good example of how a well functioning, diverse ecosystem would have mitigated the effects of an environmental shock is that of the 2004 tsunami. It is thought that the effects of the tsunami would not have been so severe if the coastal mangrove swamps were still intact in Thailand at the time of the event (Doyle, 2006).

A good example of how biodiversity has the potential to play a role as an insurer is illustrated by the biological control of invasive species. When a species becomes invasive, or when the potential for a species to become invasive is identified, one option of control available to environmental managers is that of biological control, or biocontrol. In biocontrol certain species, which are known enemies of the invasive species, and that are native to its place of origin and that are host specific, are released in order to control the spread of the invasive species. Through the destruction of biodiversity, potential biocontrol agents can be lost in the invasive species' place of origin.

The cost of the loss of potential biocontrol agents is difficult, if not impossible to estimate because it is impossible to predict which species will become invasive in the future. It is also difficult to predict the value of biocontrol agents, firstly because of the difficulties in environmental valuation and secondly because it is hard to estimate the losses that are prevented by the early and successful release of a biocontrol agent. Some studies do however indicate the potentially high value of such agents. South Africa spends R11 million annually on the control of water hyacinth (however the amount spent is characterised by under funding; estimates put the minimum amount needed for control at R16 million) (Hughes, 2006). The benefits of a potential control agent that was successful throughout the country would not however be restricted to this figure. The benefits also include the lost use and non-use values of the water resources invaded by water hyacinth, which in all likelihood would exceed the R16 million estimated by Hughes, the National Biological Control Implementation Officer for Working for Water, South Africa (2006) to be currently needed annually for the control of the plant. In a study by McConnachie *et al.* (2003), the benefits of biological control agents for red water fern, *Azolla filiculoides* in South Africa were estimated through survey responses to be in the order of US$ 450 per hectare over a 6 year period, eventually resulting in a 15:1 return on investment into biocontrol over a 15 year period.

Another good illustration of how biodiversity plays an economic role as an insurer is provided by Heal (2004: 108). In the 1970s a new virus, called the 'grassy stunt virus', threatened Asian rice production. This was a particularly severe problem because billions of people throughout the world depend on the rice crop for their day-to-day survival. A strain of crop rice needed to be developed that was resistant to the virus. This was possible because the International Rice Research Institute (IRRI) holds a seed bank of 'different varieties of rice and their near relatives'. The strain of rice that was resistant was a wild rice that was previously not commercially used. The wild rice's gene that was resistant to the virus was isolated and transferred to commercial rice varieties. The new hybrid strain of rice was able to cope with the new virus. What is interesting was that the strain of wild rice that was used was only found in a catchment that had been filled for a hydroelectric power plant.

There are other examples of how the genetic diversity of commercial species that occur in the wild have been able to save food sources in the face of new, threatening disease (Heal, 2004: 108). The potential for disease is augmented by the trend in agriculture to plant large areas with the same crop types, resulting in massive devastation in the face of disease because all the crops of the same variety will be affected. Apart from recent examples of this, agricultural catastrophes dating back to Roman times have been attributed to mono-cropping (Heal, 2004: 108). It therefore seems reasonable to assume that similar events will occur in the future and, thus maintaining some level of genetic diversity will provide insurance against these potentially catastrophic (in terms of human welfare) environmental shocks. In conclusion Heal (2004: 109) states: "Without this (genetic) diversity, we have disarmed unilaterally in the war against our most threatening diseases."

- **Biodiversity and Genetic Knowledge**

Biodiversity is said to have value as a source of knowledge (Heal, 2004: 109). Perhaps the most famous exemplar is to be found in the pharmaceutical industry. In the United States it is estimated that up to 37% of the value of all pharmaceuticals sold annually can be attributed to genetic knowledge of plants and other living organisms.

It would be impossible to put the genetic knowledge value of biodiversity into quantifiable numbers because the potential of this source of information has not yet been completely realised. For example heat resistant enzymes required for culturing in a new biotechnological process were found in the hot springs in the Yellowstone National Park in the United States (Heal, 2004: 109); there is no way that the value of this enzyme could have been predicted before the practical applications of biotechnology were understood. It cannot predict where the sources of genetic knowledge lie that will help society in future technological advances, or the ultimate value of that knowledge until it is fully understood.

From the example it is clear that biodiversity has economic value through the application of genetic knowledge; what remains unclear is a means to quantify this value.

The problem with the lack of predictive capability is that these sources of value, by nature, can in no way be guaranteed, or accounted for. Previous cases where new biological discoveries have led to returns through the use of genetic knowledge should be considered when conserving biodiversity. The opportunity cost to society of the lost potential value through the destruction of biodiversity should, at the very least, be a compelling argument for maintaining the current level of species diversity within any environment.

The economic value of genetic knowledge in biodiversity is not limited to the discovery of new species, but can also apply to the application of existing knowledge of known characteristics of living organisms for commercial purposes. An example of this was provided by Gillespie-White and Garduno (2002) regarding the pharmaceutical application of the Hoodia, which is a succulent plant indigenous to South Africa. For thousands of years the San Tribe in South Africa used the Hoodia as a hunger suppressant. With this knowledge the Council for Scientific and Industrial Research (CSIR) 'developed and patented the active ingredient in the succulent, known as P57'. The drug company Pfizer is currently developing a drug from the active ingredient which is said to be potentially worth millions of dollars. A benefit sharing memorandum of understanding has been established between the CSIR and the San people for the economic benefits arising from the application of the active ingredient P57. The CSIR have recognised the San people as the custodians of the genetic knowledge, and the San people have recognised the importance of the development and protection of P57 to ensure continued economic gains.

Whatever is paid to the San people for any drugs that are developed from the active ingredient could be seen as a willingness to pay for genetic knowledge by large corporations. This looks as if it may be a good starting point in the valuation of the potential economic benefits in the application of the genetic knowledge of biological diversity.

- **Biodiversity and Ecosystem Functioning**

The value of species interactions in the provision of ecological functions:

One of the most important aspects of diversity from an ecological perspective is the "co-existence of species within a habitat defined by the complex relationships of interaction and interdependence" (Fromm, 2000: 309). In other words the survival and functioning of one species depends on the survival of other species, which in turn depend on the survival of yet more species (Fromm, 2000: 309). This concept suggests that a measure of value of a single species is meaningless, because value depends on the inherent complexity and functioning of the ecological system. Loss of diversity that damages existing relationships reducing the productivity of a single valuable species represents a loss in value, even if the valuable species is not directly impacted upon. Norton (1995 in Fromm, 2000: 310) describes this as the 'contributory value' of biodiversity. This quality relies on each organism surviving 'within a web of interactive relationships', hence each species has a value in contributing to the continued survival and functioning of other species. It is this diversity that is often overlooked that can be seen as the 'intermediate goods' in the production of valuable environmental goods and services through the provision of ecological functions (Fromm, 2000: 310).

Examples of how the contributory value of biodiversity has specific tangible commercial implications can be seen in the engineering of genetically resistant food crops discussed earlier in this chapter. The contributory value can be seen as a separate and important aspect of diversity. This is because even though the value generating process is the same, the value of disease resistant crops refers to the value of specific species or genes, whereas the contributory value of biodiversity refers to the value of the interactive structure as a whole. The limitations of the valuation of specific species as indicators of total economic value of ecological functions are well highlighted here. The inability to value biodiversity accurately because of the limited understanding of environmental interactions and processes could not be better emphasised than by the distinction between individual species values and the contributory value of all species within an ecosystem. The potential for double counting should be borne in mind when calculating the value of specific aspects of a system in calculating the value of an environmental function as a whole.

The importance of species and species diversity in the provision of ecological functions:

The importance of species, and their diversity, within ecosystems to provide ecological functions will now be considered. Species and their interactions can be considered as the 'biotic elements of ecosystem structure', which in conjunction with the abiotic elements facilitate the provision of ecosystem functions (Fromm, 2000: 313).

Fromm (2000: 313) uses the example of soil to illustrate this connection. The abiotic components of soil determine the physical and chemical properties of the soil, which in turn determine the biotic components of the soil. The biotic components however have the capacity to alter the abiotic properties of the soil. The processes that take place determine the soil functions, such as the moderation of the hydrological cycle, the renewal of biological diversity and the regulation of global element cycles (carbon, nitrogen, sulphur). To illustrate the importance of the species diversity in soil functioning Fromm (2000: 313) states that "90 percent of matter transformation processes in soil are conducted by the soil flora and fauna (the biological diversity of the soil)".

The soil example illustrates the extreme importance of species in the provision of ecological functions, but does not explicitly identify the importance of the diversity of those species, and in ecology it is assumed that not all species have the same importance in this regard (Fromm, 2000: 313). The contention is that some species may be lost to any ecosystem with only minimal effects on ecological functioning, while the consequences of the loss of others will be severe. The reason for this is that certain groups of species and their interactions are responsible for the provision of ecological functions; these species are known as 'keystone species' (Fromm, 2000: 314). The conclusion that certain species within ecosystems are productively redundant according to Fromm (2000: 314) is 'short-sighted' for the following reason: environmental processes operate under fluctuating environmental conditions, a species that is redundant under certain conditions may become a keystone species under other conditions. As a species becomes extinct a redundant species will take its place to ensure ecosystem functioning. Clearly, as the possibility of this substitutability decreases, the diversity value of the ecosystem as an insurer against unexpected conditions, diminishes.

A lack of scientific knowledge of ecological processes once again hinders an accurate valuation of biodiversity: under stable conditions the species that are currently redundant but will have productive uses in the future are unidentifiable with current levels of understanding. Their true value can therefore not be determined before an environmental shift or impact, but at the same time cannot be denied or ignored, and is therefore important in the consideration of the value of biodiversity.

The concept of keystone species can also be used to highlight the value of specific species and the importance of interactions between species in the provision of ecological functions. Heal (2004: 110) explains how the removal of the kangaroo rat from the Chihuahuan desert led to far reaching changes in the desert ecosystem, with a 'threefold increase in the production of desert grasses'. This illustrates how the loss of a keystone species can negatively impact on the entire functioning of the ecosystem where there are no readily available substitutes for the lost species role in the provision of specific ecological functions. Similarly the introduction of exotic or alien species, such as water hyacinth, can have negative effects through the transformation of the ecosystem and the loss of keystone species (Heal, 2004: 110).

3.3 The Market for Biodiversity?

The pertinent question at this stage is: what is the vale of protecting biodiversity? Biodiversity provides insurance against a changing environment, as biodiversity is depleted its capacity to continue to provide environmental goods and services diminishes. But can these environmental functions be substituted as discussed earlier in this chapter? In some instances this is possible, but at a large financial cost. In these cases it may appear simple to calculate the difference between the costs of environmental conservation (including the opportunity cost of alternative productive land uses, e.g. agriculture) and the cost that would be incurred to substitute all value generating functions of biodiversity.

$$C(sub) - C(cons) > 0 \qquad (1)$$

C(sub) = Cost of substitute

C(cons) = Cost of conservation

(Pearce and Moran, 1994: 14)

If the result of equation 1 is greater than zero (assuming the benefits are the same in both scenarios) then it would make economic sense not to develop the environmental resource, but rather to conserve it (Pearce and Moran, 1994: 14). It is clear that the services offered by biodiversity have large economic value, perhaps best observed through pharmaceutical value and the ability to develop disease resistant food crops. If the opportunity costs of the potential loss of life were these products not developed to be included, the value of conservation would be further increased. The efficient economic decision appears to be to conserve biodiversity, but this is often not the case.

There are four main reasons why conservation is not the chosen outcome: firstly, environmental goods and services are seldom valued in the market and are therefore hard to assign monetary values; secondly, where markets for environmental goods and services do exist they often fail; thirdly, where markets do exist that reflect the value of an environmental good or service, i.e. pharmaceutical or food crop markets, it is difficult to identify the aspects of biodiversity (species/genes) that will be valuable before their productive applications are realised; and finally, the positive externalities associated with biodiversity conservation do not enter into a rational economic agent's decision making process unless there is a mechanism to internalise the benefits that society will enjoy.

In classical microeconomic theory prices are determined in the market and are a representation of trade-offs between scarce goods. In this way goods and services are allocated among consumers, and productive inputs among producers (Gowdy, 1997: 26). Pareto optimality will result through the unhindered exchange of goods in the market under the following assumptions: "(1) participants in the market have all the relevant information about the objects exchanged in the markets, (2) each participant buys or sells a very small portion of the amount being traded, and (3) there are no barriers to entering or leaving the market for any particular good" (Gowdy, 1997: 26). In this framework the value of biodiversity would be calculated by the simple addition of the market prices times the quantities traded of the various valuable goods and services offered by biodiversity. Neoclassical economists recognised some of the imperfections and limitations of classical theory of the market, and started to develop techniques to value goods traded in the market more accurately, and place values on goods not traded in the market, such as contingent valuation and the travel cost method (Gowdy, 1997: 26).

- **Discounting**

Another reason for the omission of environmental values in the determination of prices through shortcomings in classical assumptions is that economists recognise markets in a private context as opposed to a social context. In the following example provided by Pearce and Moran (1994: 13) the problem of agents acting in a private market is well illustrated, as well as the problems of incomplete information and discounting that lead to the market for environmental goods failing.

The example begins with the question of the economic rationale behind land use conversion, which is a major cause of habitat destruction and hence biodiversity loss. The private decision of an economic agent, acting as a profit maximiser, would be whether or not to convert a piece of land that he/she owns. To simplify the example the decision is fixed between maintaining a tropical forest and converting it for agriculture. The individual's economic decision would be based on the relative profitability of the two options (Pearce and Moran, 1994: 13). The profit realised through conservation would be all the potential income of sustainable use of the tropical forest, such as ecotourism or sustainable harvesting, less any costs (see equation 2):

$$B(Sus) - C(Sus) = Profit \qquad (2)$$

B(Sus) = Benefits of sustainable use

C(Sus) = Costs incurred through sustainable use

While the profit realised through agriculture would be expected income through productive activities less any costs incurred (see equation 3):

$$B(Dev) - C(Dev) = Profit \qquad (3)$$

B(Dev) = Benefits of development of land

C(Dev) = Costs incurred through development of land.

For conservation to occur the net benefit (profit) from sustainable use must exceed the net benefit from the development of the land (see equation 4):

$$B(Sus) - C(Sus) - [B(Dev) - C(Dev)] > 0. \qquad (4)$$

(Pearce and Moran, 1994: 14)

A consideration of the stream of benefits with regard to time has to be considered (Pearce and Moran, 1994: 14). It is assumed that people prefer to receive a fixed amount of money now as opposed to the same amount of money later for a number of reasons. At this point the concept of discounting is introduced into the example.

Discounting facilitates the comparison between losses and gains over varying time periods, and is the process in which society "places a lower value on a future gain or loss as the same gain or loss occurring now" (Pearce *et al.,* 2003: 121). For instance consider the choice of receiving R1 now and R1 at the same time next year - the R1 will be taken now because if it is invested with a bank it will grow at the rate of interest (r) and at the same time next year will be worth R1 + r. Another way of putting this is that R1 next year is the same as R1/(1+r) now, which is the discount factor and 'r' is the discount rate. The discount rate in this case is referred to as the "opportunity cost of capital approach to discounting" and is merely calculated by the determination of the rate of interest earned on money (Pearce and Moran, 1994: 14). Discounting at a constant rate in this fashion is also termed "exponential discounting", because the value of the good in question decreases over time at an exponential rate (Pearce *et al.,* 2003: 123). But the interest rate is not the only reason for discounting. At high rates of inflation money earned at a later state would have to be discounted with the rate of inflation in mind; the individual may be impatient and prefer the money now, this is called "pure time preference discounting"; or the individual may foresee earning a higher income in the future, and the money would therefore seem to be worth more now to the individual. This is called "discounting due to the diminishing marginal utility of income" (Pearce and Moran, 1994: 14). These factors contribute to what is known as the social time preference rate of discounting. The social time preference rate is not easily calculated, but for the purposes of this example what is important is that a positive discount rate exists, in other words money now is preferred to money later. Allowing for the discount rate, equation 4 can now be expressed as:

$$PV[B(Sus) - C(Sus)] - PV[B(Dev) - C(Dev) > 0 \quad (5)$$

PV - Present Value

(Pearce and Moran, 1994: 14)

Examine the effect of the discounting from the individual's viewpoint. Firstly, it is important that it is assumed that the benefits from sustainable use or conservation are not as high initially as development to the individual; this will be further discussed later in the current section. The conversion of the natural landscapes usually results in unsustainable land use and the depletion of nutrients from the soil usually through the introduction of agriculture, and later once the quality of the soil is further depleted, livestock (Pearce and Moran, 1994: 15). The landscape has now been converted from a renewable to a non-renewable resource generating system, and the benefits from the commercial use of the land go down as the landscape is further degraded.

At some point the degradation of the natural environment will become so severe that the restoration of the forest is highly unlikely, introducing the possibility of the irreversibility of the impact resulting from the initial land use conversion (Pearce and Moran, 1994: 15). At this point the ecosystem becomes unable to restore itself or is not able to regenerate through human intervention. The impact results in a loss of productive capacity of the natural ecosystem in perpetuity. The stream of profits from land use conversion now ceases. This can be seen as an environmental threshold with its own economic implications, particularly in terms of the marginal valuation of environmental goods and services and scarcity.

In the case of the sustainable use of the forest, the initial benefits are less than what is expected from the conversion of the land, for say agriculture, but the stream of benefits would last far longer through sustainable use, suggesting that conservation will be preferred (Pearce and Moran, 1994: 15). Discounting describes why this is not the case. Figure 3.1 illustrates why discounting causes the market for environmental goods and services to fail.

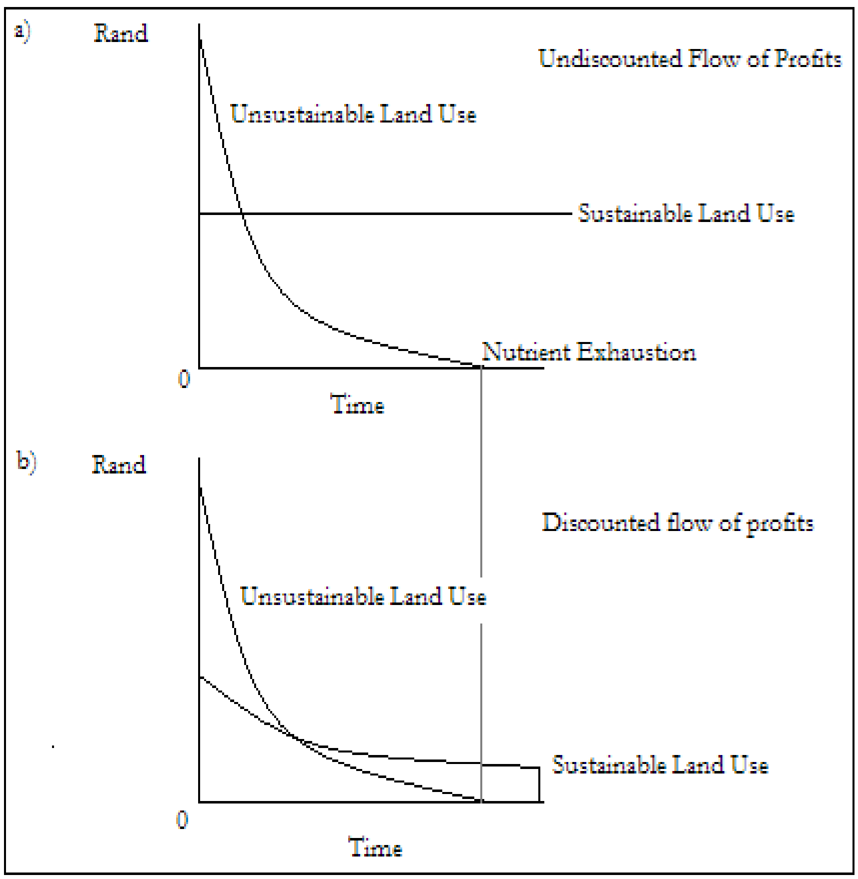

Figure 3.1: The difference between the discounted and undiscounted flow of profits from both the sustainable and unsustainable use of natural resources

Source: Pearce and Moran, 1994: 16

Figure 3.1 a) shows the decision that would confront the land owner if the time preference of money (discounting) was not taken into account. As can be seen, the expected profits from the unsustainable land use start to decrease over time as the resources quality levels (nutrients, etc) start to deplete. No further profit is expected at the point of nutrient exhaustion. The benefits of sustainable land use, although less than the benefits from unsustainable land use initially, last as long as the resource is used in a sustainable fashion (Pearce and Moran, 1994: 16).

Figure 3.1 b) shows why discounting causes the unsustainable land use to be preferred to a rational agent seeking to maximise profits. The streams of expected benefits from both sustainable and unsustainable land use diminish over time because of the effects of discounting. The present value of the two options is the area under their respective curves on the graph (Rand x Time); if the area under the unsustainable land use curve exceeds the area under the sustainable land use curve, the unsustainable land use will be preferred (Pearce and Moran, 1994: 16).

Contemporary research suggests that the discounting of the benefits received from environmental goods and services is not as simple as it appears in the previous example. Indeed the concept of discounting is met with concern from environmentalists when the value of the stream of benefits from productive natural resources is reduced to trivial amounts through discounting (Hoel and Sterner, 2006: 1). Essentially the problem lies in the contention that discounting seems to be "inconsistent with the spirit of sustainable development" where more concern is given to the welfare of future generations (Pearce *et al.*, 2003: 124). The 'spirit' of sustainable development referred to here is that a higher value is placed on the welfare of future generations than previously, or that future generations' welfare should not be discounted at traditional rates. A reduction in the discount rate will have the effect of increased saving and investment (Pearce *et al.*, 2003: 123), and since the conservation of biodiversity can be seen as an investment (because of the potential value of biodiversity not yet realised), the reduction of discount rates for environmental goods and services should have the effect of promoting conservation.

Consider the concept of scarcity, and the effect of increased scarcity on prices of goods and services. The discounting of environmental goods and services is calculated assuming the relative prices of environmental goods and services remain constant over time. This is however not the case because as environmental goods and services become more scarce their relative price will increase (exponentially) (Hoel and Sterner, 2006: 2). This would initially counteract the effects, and even reverse the effects of discounting depending on the relative strength of the two opposing forces – namely discounting and a rise in price of the resource in question relative to all other goods in the market.

Recent evidence suggests that people do not discount future gains or losses at a constant 'exponential rate', but rather at lower rates over time, or that future funds are discounted at a 'hyperbolic rate' (Pearce *et al.,* 2003: 126). This would to a certain extent reduce the negative effects of discounting; however, to construct a discount rate regime that varied over time is very complicated and open to criticism. In a formal application of discount rates based on the uncertainty of the future state of the economy (and hence interest rates), Martin Weitzman was however able to construct a hyperbolic discount rate that declines over time (as uncertainty increases) (Pearce *et al.,* 2003: 129). The effect of this formal application is that there is a theoretical construct available that in some way describes the way rational economic agents are observed to behave. A discount rate that decreases over time as uncertainty increases would make environmentally conscious resource use decisions seem more favourable because these projects are generally characterised as long-term investments.

- **Environmental Conservation, Discounting and Society**

Consider the first classical assumption of price formation as mentioned previously; that the agent has all the relevant information about the goods being traded in the market (Gowdy, 1997: 26). It would appear that even in ideal circumstances the agent has imperfect information about the good being traded, which is in this case essentially biodiversity, let alone the cost of the negative impacts on biodiversity incurred by society as a whole. The value of biodiversity is at best unpredictable given the current level of scientific understanding, and even if there are private benefits to the landowner through conservation and sustainable use, like increased productivity, it is unlikely the landowner would consider this in his/her profit maximising decision. Consider equation 5, if the net benefits from conservation exceed the benefits from alternative land uses conservation will be preferred, and this seems likely given the high value of biodiversity as discussed. However, due to the problem of incomplete information (limited level of scientific understanding and lack of accurate environmental valuation) not all the benefits from conserved biodiversity are included in the agent's decision making process. And the benefits that are expected from conservation of biodiversity that do enter into the decision making process are discounted, as the benefits are not realised until some time in the future. The inefficient decision, taking all information into account, is therefore taken.

Up to this point the decision from a private agent's viewpoint only has been considered, but the benefits of biodiversity conservation are more far-reaching than the individual economic agent. The benefits to conservation are spread throughout society but do not come into the private decision making process. Once again consider equation 5; if the benefits to society were to be included in this equation this would further inflate the value of sustainable land use, in other words the social benefit exceeds the private benefit of conservation. The converse of this is that the private costs through unsustainable land use [C(Dev)] are far smaller than the social costs of the decision. This illustrates the concept of externalities in the market for environmental goods and services. If the social costs and benefits were included in the decision making process, in other words the market has been corrected for the existence of externalities, it seems far more likely that the sustainable option would be preferred. The market for the conservation of biodiversity fails because of positive environmental externalities that are not able to be internalised by the private decision maker. There is a role for the government to correct these problems by introducing taxes on those who undertake unsustainable land use practices to discourage such practices, and subsidies for those who conserve to promote sustainable practices, hence introducing a societal aspect to the individual's profit maximising decision (Matthews and Lave, 2000: 1391).

Section 56(1) of South Africa's National Water Act (No. 36 of 1998) provides a good example of how tax based incentives could be implemented to reduce environmental damage. The focus of the pricing strategy is on waste discharges and is based on the 'polluter pays principle' (DWAF, 1998: 26), it can therefore be seen as an incentive to polluters to reduce negative environmental impacts. The strategy's stated goals are as follows: "to promote the sustainable development and efficient use of water resources; to promote the internalisation of environmental costs by waste discharges; to recover costs associated with mitigating resource quality impacts of waste discharge; and to create financial incentives for waste discharges to reduce waste and use water resources in a more optimal manner" (DWAF, 1998: 26). Polluters are expected to pay a waste discharge rate dependent on the quantity of waste discharged. These charges are to form part of an "integrated approach to manage resource quality problems in a catchment" (DWAF, 1998: 26). The rate that polluters pay will be based on either an incentive charge or a mitigation charge (DWAF, 1998: 27). Where specific resource quality requirements are the main goals and it is assumed that polluters can reduce waste cost effectively, the incentive charge will be implemented. In this way the incentive is created for polluters to reduce waste, and therefore pay less, by adopting more environmentally friendly technology and at the same time meeting resource quality objectives. The mitigation charge is preferred when it is assumed that cleaner technology is too expensive to adopt (in other words more expensive than the incentive charge) and the costs of mitigation are easily calculated.

In this way it can be seen that the South African Department of Water Affairs and Forestry (DWAF) is introducing a pollution tax in an attempt to correct for negative environmental externalities incurred by waste dischargers to the South African water resource. In other words DWAF is introducing social considerations into the private economic decision making process. But both the incentive charge and the mitigation charge imply a large extent of administration on behalf of the management agency for each catchment, implying fiscal inefficiency. The former would require constant monitoring of levels of waste discharge and the latter charge not only assumes that all the costs of the environmental impact are mitigated, but that all the costs of mitigation can be accurately calculated.

Tax based environmental incentives and disincentives are used in various forms and achieve varying levels of success; the success is often limited by the capacity of the governing body to monitor negative environmental impacts, and the ability to value the cost to society of those impacts or the benefits incurred through the promotion of efficient environmental and economic decisions. The question of accurate environmental valuation once again comes to the fore when attempting to include social costs of environmental impacts in the private economic decision making process.

3.4 Conclusion

From the overwhelming evidence which supports the notion that biodiversity has economic value, it can be assumed that a loss can be associated with economic costs. However, to date there has been no comprehensive valuation of biodiversity that has been developed, largely due to the limited level of understanding of biodiversity, and its value generating functions. Large scale macro valuations of biodiversity are often attempted, for example 'the world's plant species are worth X', or 'the value of all mammals is Y'. These valuations are merely estimates or best guesses, and detract from meaningful environmental valuations that draw from well executed research and provide a starting point for an accurate, repeatable valuation technique of biodiversity. Macro valuations serve only as a shock technique and are of no real academic value; perhaps the concept of the valuation of biodiversity is only useful at small scales where the benefits from conservation are measurable and tangible. The value of biodiversity is nevertheless clear and needs careful consideration when choosing whether or not to conserve or develop. The recognition of the value of biodiversity does not automatically dismiss the need for development, but rather can be seen as a means to strengthen the argument for conservation and sustainable development.

In this chapter it was argued that environmental goods and services have economic value. However this value is not simple to express in monetary terms, mainly because markets for environmental goods and services seldom exist, and where they do they are often imperfect. For this reason methods have been developed that attempt to capture the value of environmental goods and services in economic terms. Chapter 4 critically reviews the method used to determine the value of environmental goods and services in this thesis, the contingent valuation method.

CHAPTER FOUR: THE CONTINGENT VALUATION METHOD

4.1 Introduction

On 24 March, 1989 the Exxon Valdez oil tanker left the port of Valdez, Alaska and began its journey along the Valdez Narrows *en route* to the Prince William Sound (Carson *et al.,* 2003: 257). In the early hours of the following morning the oil tanker diverted from its intended shipping route to avoid icebergs and ran aground on the Bligh Reef in the Prince William Sound (Page and Gilfillan, 2004). The crew did not realise how much they had deviated from their designated course (Carson *et al.,* 2003: 257). This resulted in the release of 37 000 tons of crude oil, only 20% of the total amount the tanker was carrying, largely due to the subsequent salvage effort (Page and Gilfillan, 2004). Although this spill was significant, it only ranked as the 54th worst worldwide (as of 1993) in terms of the amount of oil released. It was however the largest in United States (US) history and was perceived by the public to be one of the worst environmental disasters in US history (Carson *et al.,* 2003: 257). The true environmental impact of the disaster has however been questioned (Page and Gilfillan, 2004). The extent of the impact is important because if it can be completely mitigated there is no long term loss in passive use or non-use value, but what is of concern is that there was a 'perceived' loss in non-use value to the public through the immediate environmental damage of the disaster. Are these types of losses valid in terms of liability for the costs incurred through an environmental impact, and how is it possible measure them?

The contingent valuation method has been used to estimate the passive use value of environmental goods and services for approximately the last 40 years (30 years prior to 1993) (Arrow *et al.,* 1993: 04), but a high level of interest and debate was sparked by the running aground of the Exxon Valdez and the court action that followed (Carson *et al.,* 2003: 258). Although the debate is most heated regarding the technique used to measure passive use values (contingent valuation), the "conceptual underpinnings" of passive use are also questioned. In a court action at a similar time to the Exxon Valdez oil spill, The State of Ohio v. The Department of the Interior, it was ruled that lost passive use values could be included in environmental damage assessments and could be measured using contingent valuation (Arrow *et al.,* 1993: 05). Following this the Oil Pollution Act of

1990 and the regulations of the National Oceanic and Atmospheric Administration (NOAA) both allowed for the inclusion of passive use values in compensable environmental damage assessments (Carson *et al.,* 2003: 258). The primary method of passive use value calculation, contingent valuation (CV), was confronted by the following major criticisms (amongst others): CV studies elicit valuation responses that are not consistent with rational choice; respondents do not understand what they are being asked; and respondents do not take the exercise seriously because their responses are not binding (Arrow *et al.,* 1993: 05).

These criticisms reached a climax in the publication of an "Exxon sponsored conference volume" that sought to challenge the assumptions of the proponents of natural resource damage regulations (Carson *et al.,* 2003: 259). In response to these criticisms the NOAA established a panel led by Kenneth Arrow and Robert Solow to assess the validility of CV studies (Carson *et al.,* 2003: 259). The panel produced a report containing the various criticisms of the CV method, issues regarding the design of CV studies and their guidelines for future CV studies (Arrow *et al.,* 1993: 05). Since this report contemporary research has suggested improvements and amendments to the recommendations of the panel set up by the NOAA. The recommendations of the NOAA panel and the subsequent advances in the design of the CV method will be discussed in the remainder of this chapter.

4.2 The Contingent Valuation Method

When calculating the cost of an environmental impact on a natural resource some of the losses can be derived through the "information revealed in market transactions" (Arrow *et al.,* 1993: 01), for example if a fire destroys a forest and thereby reduces a local community's ability to generate income through the sustainable use and sale of timber, their losses can be calculated by assessing the reduction in timber collection as a result of the fire multiplied by the market price for the wood, less any costs. If the forest also attracts a level of ecotourism then the losses of local hotels, lodges and other associated facilities can be calculated by the difference in generated income after the disaster compared to a normal season. Even the losses that are incurred by people that use the forest for recreational activities can be calculated, albeit in a more complicated fashion. An example of this would be the extra costs associated with people having to travel further to walk their dog in a forest which derives the same level of utility for them as the destroyed forest. As discussed in Chapter 1, Total Economic Value consists of use and non-use or passive values. The values described above are examples of use values (Arrow *et al.,* 1993: 01) which can generally be elicited through market transactions. The loss in use value is restricted to those who actively use the resource, while the loss in non-use value is not. Continuing from the forest fire example, if there was a site in the forest that had religious significance there may be people that value its existence without ever laying eyes on the site let alone making active use of it. This is known as existence value and forms a major part of non-use value (Arrow *et al.,* 1993: 02).

Before the Exxon Valdez spill the term 'non-use value' was not common to economists that did not have experience in the field of cost-benefit analysis of the effects of negative environmental impacts or environmental risk (Carson *et al.,* 2003: 257). When it became evident that the State of Alaska and the US Federal Government intended to claim for the lost non-use value caused by the Exxon Valdez, this trend changed and a large amount of interest started to emerge regarding the "conceptual underpinnings and estimation techniques" of non-use values (Carson *et al.,* 2003: 258).

A 1989 US court ruling of Ohio v. The US Department of the Interior further influenced the increased level of interest in non-use environmental values (Carson *et al.,* 2003: 258). The two main outcomes of the ruling concerning The Department of Interior's (DOI) regulations regarding non-use value damage assessments were that: non-use values are compensable; and the DOI's list of damage assessment techniques which placed contingent valuation as the least preferred was not justified.

Stated preference techniques, such as contingent valuation, are recognised as the only methods available to elicit non-use environmental values (Carson *et al.,* 2003: 258). Use values can be elicited through valuation techniques that use market transactions to identify the worth of the environment to the people that use it, but the existence of non-use values is not dependent on the actual use of the resource. There are therefore no observable market activities upon which to base valuations. It can therefore be said that non-use values leave no "behavioural trace" (Carson *et al.,* 2003: 258). Contingent valuation attempts to create this "missing market" by asking what people are willing to pay (WTP) or less often willing to accept (WTA) for given changes to the quantity or quality of the resource being valued (Carson *et al.*, 2003: 258). In this way respondents have the opportunity to make a choice regarding how much they are willing to buy (or sell) the benefits that they receive from a particular environmental amenity (Carson *et al.*, 2003: 258).

4.3 Developments in Contingent Valuation Theory

An issue that makes the problems associated with the contingent valuation method a topic of particular concern is that it is very difficult, and often subjective, to validate the results obtained (Arrow *et al.*, 1993: 06; Smith and Osborne, 1996: 288). It must however be noted that this problem is not unique to the CV method, indeed it would be difficult to validate the results obtained of any method that values the passive use of environmental resources (Arrow *et al.*, 1993: 07). This is because of the lack of conventional economic markets for passive use values, and hence the need for accurate valuation methods that create an artificial market (as discussed previously in this chapter).

- **Elicitation Formats**

The term 'contingent valuation' arose because the method requires the respondent to make a valuation contingent on a described hypothetical future event occurring, for example a forest fire or an oil spill (Carson *et al.*, 2003: 258; Arrow *et al.*, 1993: 03). Respondents are provided with some specific information regarding the "extent and nature" of an event and questions designed to elicit their WTP to prevent such an event or their WTA compensation should such an event take place (Arrow *et al.*, 1993: 03). According to Arrow *et al*. (1993: 03), the WTP or WTA question is posed in a number of ways: firstly, it can be asked by means of an open ended question whereby respondents are asked how much they are WTP or WTA. This can take a number of forms, for example, offering respondents payment cards where a number of values are presented to choose from including the option for the respondent's own valuation; secondly, a series of valuation questions can be asked of the respondent; each question in the series is dependent on the respondent's previous answer, for example, the respondent can be asked if he/she is willing to pay R10 to avoid environmental damage. If the answer is positive the questions continue with a set increase in WTP until a negative answer is given. The respondent's WTP can now be observed as the range between the last amount which received a positive response and the amount which resulted in a negative response (e.g. between R50 and R60); and finally, the WTP/WTA question can take the form of a "hypothetical referendum" where respondents are informed of how much they would have to pay to prevent a certain event occurring or how much they would be given in the case of that event occurring, the respondent would reveal his/her WTP/WTA with a simple "yes" or "no" answer.

By asking respondents' WTP or WTA, the contingent valuation method is calculating the respondents' 'Hicksian consumer surplus', either their compensating variation (WTA) or their equivalent variation (WTP) as a result of the change in the quantity or quality of the provision of the public good in question (Venkatachalam, 2004: 92). Even though it seems to makes sense that if researchers are trying to assess the cost of a potential negative environmental disaster they would want to know how much people would be willing to accept in compensation, the majority of contingent valuation studies ask respondents to estimate an amount that they would be willing to pay (Arrow *et al.,* 1993: 04; Carson *et al.,* 2003: 258).

It may even seem irrational to ask respondents how much they are willing to pay to prevent an event occurring if the potential costs of that event is what is being calculated. The reason for this choice in survey design is that it is assumed that people tend to overestimate an amount which they assume that they might receive, while it is expected that people will give their lowest bound valuation estimate if they believe that they will have to pay for the stated benefits of the proposed programme (Arrow *et al.,* 1993: 04). The reason that people are expected to give their lowest bound valuation for WTP can be explained by the income effect and the substitution effect (Venkatachalam, 2004: 93). The income effect plays a role in the divergence between WTP and WTA by the presence of an income constraint with WTP, and the absence of an income constraint with WTA (Venkatachalam, 2004: 93). According to Venkatachalam (2004: 94), WTA will also be an exaggerated valuation if there are a large number of substitutes available (substitution effect), because respondents are more likely to give a true reflection of value when faced with substitutes if they believe they will be made to pay for the benefits in question.

An interesting observation that Venkatachalam (2004: 95) makes is that, because of the divergence between WTP and WTA, either one of the valuation mechanisms (or both) is wrong, or the theory is wrong. This is because it is assumed that each consumer or respondent has a compensating value (WTP or WTA) based on his/her preferences for the perceived loss in utility of the described situation. There is therefore an accurate value measure that the contingent valuation method seeks to determine. The conservative estimation of value (WTP) is therefore preferred to increase the validity of the valuation exercise by “eliminating extreme responses” (Arrow *et al.,* 1993: 52). For this reason, in the remainder of this chapter, valuation questions will only be referred to as WTP questions, except where distinction between WTP and WTA is necessary for the analysis of the contingent valuation (CV) method.

- **Hypothetical Bias**

The problem of respondents overestimating WTP can be described as that of hypothetical bias. The main concern is that respondents will tend to overestimate their WTP in hypothetical valuation scenarios (Harrison and Rutstrom, 1999: 01). This can be explained quite logically: if a respondent’s higher valuation leads to a greater chance of the provision of the good in question, but the respondent will never be made to pay for it, it makes sense to overstate his/her valuation; or if the provision of an existing good is being valued it makes sense for respondents to give a higher hypothetical WTP, to ensure the continued provision of that good (Harrison and Rutstrom, 1999: 01), this can be referred to as strategic bias. According to Harrison and Rutstrom (1999: 02) there is a need to investigate this problem particularly in the case of contingent valuation because of the importance of the results of such studies; and if the extent of the problem is known it is possible to determine how relevant it is. In other words, there is a need to investigate how accurately CV predicts actual payments of respondents for environmental goods and services (Veisten and Navrud, 2006: 735).

When valuing environmental resources that mainly consist of direct use values as opposed to passive use values it is possible to validate results with revealed preference methods of valuation that use market values to indicate people's actual payment for these goods and services (Veisten and Navrud, 2006: 735). For this reason critics of the CV method have concentrated on studies that have focused on the valuation of passive use values of environmental resources, which are altogether more complicated to validate (Veisten and Navrud, 2006: 735).

One method available to test the validility of the CV method (or any other method that creates a market for passive use value) would be to offer the same sample, or a suitably similar sample to the one in which the CV study was undertaken, an opportunity to pay for the environmental good being valued (Arrow *et al.,* 1993: 07). The results of the CV survey can now be compared to the "real" results (Arrow *et al.,* 1993: 07). This is not to say that the results from actual payment are expected to match the CV. One of the reasons for this is the "free-rider" problem, which will result in an under estimation of actual payment for environmental resources due to their perceived nature as public goods (Veisten and Navrud, 2006: 736). The free-rider problem does not exist in hypothetical surveys because people are not bound to their stated valuation; there is therefore no incentive to free ride on the benefits of other individuals' payments. The challenge is to value such goods in a private context to reveal actual payments, and ultimately calibrating the difference between valuation that is expected to be over estimated (WTP) and the valuation that is expected to be under estimated (actual payment). For this comparison it is important that the relative bias to over and under estimate payment are identified, and where possible, reduced (Veisten and Navrud, 2006: 736).

A number of studies have been undertaken to identify hypothetical bias in CV studies compared to actual payments (Arrow *et al.,* 1993: 07; Harrison and Rutstrom, 1999: 03). One such study was presented as a review of previous literature by Veisten and Navrud (2006: 738), who made the following observations: 'induced truth telling mechanisms' are able to reduce the incentive to over estimate WTP in CV surveys; and that open ended valuation questions result in a lower over estimation of WTP than dichotomous choice valuation questions.

The CV exercise used in the study by Veisten and Navrud (2006) was a valuation of natural forests in Norway that are largely inaccessible to the public, and therefore are perceived to consist mainly of passive use value. Respondents were split into two sample groups to test an induced truth telling mechanism for WTP, namely an invoice for payment sent with the questionnaire to sample group B, and an invoice for payment sent one week after completion of the questionnaire to sample group A. It was expected that sample group B would have had a more realistic estimation of WTP based on the expectation of actual payment. Within the two sample groups some respondents were presented with a dichotomous choice and others open ended valuation questions.

Sample group A (who were sent the invoice for WTP one week after the completion of the CV exercise) only had a significant difference in actual payment to sample group B when the WTP question was posed as a dichotomous choice question and not as an open ended question (Veisten and Navrud, 2006: 746). There was however no significant difference in WTP in sample group B between those respondents who were presented the dichotomous choice and those who were presented the open ended WTP question.

Veisten and Navrud (2006: 750) concluded that 'the truth telling mechanism' can aid in bringing WTP closer to actual payment if the elicitation format is that of dichotomous choice. The authors observe that although a large disparity was found between WTP of all elicitation techniques and actual payments the difference is not solely due to the 'over riding' problem (incentive to over estimate willingness to pay in the belief that the over estimation will strengthen the argument for the protection of the good being valued) and the warm glow effects (moral satisfaction of giving) associated with over estimated hypothetical valuations, but also due to the free riding problem when respondents are asked to make actual payments (Veisten and Navrud, 2006: 750). The actual payments are therefore an under estimate of the true value respondents place on public goods, while the hypothetical valuations are over estimates. The calculation of hypothetical CV and the observation of actual payments are therefore said to "bound true WTP", and are therefore useful in policy analysis (Veisten and Navrud, 2006: 750). The challenge is therefore to reduce over riding and free riding to reduce the extent of the bound that holds true willingness to pay, hence delivering a more meaningful and accurate tool for policy decisions (Veisten and Navrud, 2006: 750).

Although the majority of the literature on hypothetical bias provides evidence of the presence, and in some cases the strong presence, thereof (Harrison and Rutstrom, 1999; Venkatachalam, 2004), more work by Murphy *et al.* (2005) suggests, using a meta-analysis, that hypothetical bias is not as prevalent as previously thought.

In the meta-analysis, to test for the presence of hypothetical bias, three criteria were used for selecting studies on hypothetical bias to be included (Murphy et al., 2005: 316). The criteria are as follows: only WTP studies were included (because of the lack of evidence on WTA); both hypothetical values and actual values had to be elicited using the same mechanism (due to the reported differences in WTP resulting from different payment methods); and dichotomous choice surveys with no monetary estimates of WTP were not included in the analysis. Fifty-nine studies were identified that tested the extent of the problem of hypothetical bias, but once these three criteria were applied only 28 studies were included into the meta-analysis.

From the meta-analysis Murphy *et al.* (2005) concluded that statistical calibration of survey results can in some cases be used to correct for hypothetical bias, with 70% of the calibration factors being below a factor of two. This is noteworthy because the NOAA panel recommended a calibration factor of two (Murphy *et al.,* 2005: 320). However, the calibration factors of the remaining 30% of the observations in some cases vastly exceeded two skewing the econometric analysis. This highlights the potential of some outlying observations biasing the conclusions that are drawn (Murphy *et al.,* 2005: 322). It is suggested that this could explain some of the conclusions that have been drawn from previous studies, highlighting the importance of the problem of hypothetical bias (for example: List and Gallet, 2001; and Harrison and Rutstrom, 1999). Murphy *et al.* (2005: 322) conclude that although there does appear to be a positive correlation between hypothetical values and hypothetical bias, the extent of the problem does not appear to be as significant or unpredictable as conventionally thought. Furthermore questionnaire design may have a significant role to play in reducing hypothetical bias, but this role is difficult to identify because of the difficulties associated with using dummy variables in statistical analysis.

If the level of hypothetical bias can be determined, statistical methods or statistical calibration can be used to eliminate this bias (Veisten and Navrud, 2006; Murphy *et al.,* 2005). But can the level of hypothetical bias be accurately predicted? What is important is not the size of the hypothetical bias, but rather its predictability

(Harrison, 2006: 146). It would not matter if a watch was 10 minutes or 6 hours slow, what would be important is the information regarding how slow the watch was to determine the correct time (Harrison, 2006: 146). So how is it possible to determine how slow the CV watch is? One method is to conduct laboratory experiments of a sample of the population prior to the CV. If the level of hypothetical bias can be predicted in laboratory experiments the results of a broader CV can be statistically calibrated for hypothetical bias (Harrison, 2006: 146). This is not however a certainty, especially for goods that are not realistically delivered, or whose value consists largely of passive use value, as is the case for most public goods (Schlapfer *et al.,* 2005: 145; Harrison, 2006: 146).

Questionnaire design or instrumental calibration may have an important role to play with regard to reducing hypothetical bias (Harrison, 2006: 136). It is possible that respondents do not fully understand the valuation questions that are being posed to them. For example, asking a respondent if they would be willing to pay for a good may be interpreted as a question asking if they would be willing to pay for that good at some stage in the future, but by asking a respondent to directly pay for the good is clearly a question of here and now (Harrison, 2006: 137). The situation where "no means no, but yes may also mean no" was described, and it was suggested that it may have been a cause of hypothetical bias in environmental valuation. One way to eliminate some of this bias would be to pose questions to respondents after their WTP valuation regarding their level of certainty over their responses, and only accepting those responses that display an adequate level of certainty over their valuation as a 'yes' vote (Harrison, 2006: 137).

Harrison (2006: 138) describes the situation where researchers remind respondents of budget constraints within the questionnaire as "cheap talk". What role does cheap talk have in reducing hypothetical bias? For this Harrison (2006: 139) makes the differentiation between 'heavy cheap talk' and 'light cheap talk'. Light cheap talk reminds respondents of budget constraints and the hypothetical nature of the questionnaire, while heavy cheap talk reminds respondents of budget constraints and explains the problem of hypothetical bias in detail. Experimental evidence suggests that heavy cheap talk reduces hypothetical bias to the same level as actual payments, in effect eliminating hypothetical bias (Harrison, 2006: 139). These results have not been unanimously confirmed (List, 2001: 1505), and there are concerns that heavy cheap talk tells respondents that the good being valued is worth more than they think (Harrison, 2006: 139). For these reasons heavy cheap talk should not be viewed as a miracle cure for hypothetical bias (Harrison, 2006: 139).

Another method to correct for hypothetical bias is presented by Schlapfer *et al.* (2005) who suggest that hypothetical bias in stated WTP can be corrected by a referendum or vote for the provision of the same commodity. In a vote for the provision of a public good voters are essentially stating whether or not they have a positive WTP for the commodity in question, because payment for that (public) good comes out of taxes (Schlapfer *et al.,* 2005: 147). The WTP results obtained from a CV exercise conducted over the same population are then compared to the referendum results for the same commodity. Assume that z% of the voter population reject the proposal for the provision of the public good in question, the z^{th} percentile voter is therefore assumed to be indifferent regarding the provision of that good (Schlapfer *et al.,* 2005: 148). The voters implied WTP (change in tax payment) is then inferred from the same percentile WTP value from the CV exercise. The calibration factor is then as follows:

Calibration Factor = Implied WTP / Stated WTP

(Schlapfer *et al.*, 2005: 148)

Consider a numerical example, adapted from Schlapfer *et al.* (2005: 148), to explain the mechanism. Assume that there is a local referendum conducted over 1000 people in Grahamstown for an upgrade of the Makana Botanical Gardens in the city. R500 000 is required for the improvement of the Gardens, in other words R500 is required from each voter if all votes are positive. A WTP study is conducted over the same population and it is determined that there is a total WTP of R1 million for the improvements. Only 56% of the voters however vote for the improvements to the gardens (have a positive WTP). The 44^{th} percentile voter is therefore indifferent regarding payment for the improvements. This voter's WTP therefore equals the tax increase. Now comparing this to the WTP results assume the 44^{th} percentile WTP was R750. The calibration factor therefore is: R500/R750 = 0.667. The calibrated aggregate

WTP is therefore: R1 million * 0.667 = R667 000. The total WTP is now corrected for hypothetical bias.

Although there is a large amount of research and literature regarding the presence of hypothetical bias there is no consensus on the degree to which it affects stated preference valuation, and hence methods to calibrate for it (Murphy *et al.*, 2005: 313; Harrison, 2006: 126; Schlapfer *et al.*, 2005: 150). What is of importance is not the amount of bias that is generated, but rather its predictability (Harrison, 2006: 150). If the extent of hypothetical bias can be accurately predicted, it can be calibrated for. Recent suggestions such as the voter calibration as outlined by Schlapfer *et al.* (2005) are as yet untested, but if they do present similar calibration factors over a number of studies within sufficiently narrow bounds, the first steps towards the identification and accurate calibration for hypothetical bias have been made.

- **Inconsistency with Rational Choice**

It has been argued that the results of some CV studies are inconsistent with rational choice (Arrow *et al.*, 1993: 10). Rationality requires respondents to answer WTP questions in a way that displays a level of consistency with rational everyday real world economic behaviour. For example, respondents are expected to be willing to pay more for more of a good, but at a (gradually) decreasing rate, and that the sample's WTP should be positively related to income (Arrow *et al.*, 1993: 10). Where this is not the case CV studies are suffering from the problem of the embedding or scope effect (Venkatachalam, 2004: 95). Although the embedding effect has been referred to by a number of different names (scope effect, part-whole bias, disaggregation bias, sub-additivity effect, etc.) it essentially describes the situation where a good is valued differently when it is valued on its own (embedded good) compared to when it is valued in a group of amenities (inclusive good) (Venkatachalam, 2004: 96). Another way to describe the embedding effect is when the WTP for a specific good does not differ significantly from the WTP for a "more inclusive good" (Venkatachalam, 2004: 95).

Starting in the late 1980s evidence of the embedding effect started to emerge (Venkatachalam, 2004: 96). Kahneman (1986) (in Venkatachalam, 2004: 95) conducted a CV study for the protection of fish in lakes in Ontario in the United States of America.

It was found that the WTP for the protection of fish in the lakes of a small area in Ontario was almost the same as for the whole of Ontario, providing evidence of the embedding effect.

Kahneman and Knetsch (1992) subsequently sought to identify evidence of the embedding effect both for a public good and for temporal effects. In order to do this the authors conducted a telephonic survey to three groups of respondents asking them to value varying levels of environmental services including the provision of emergency services for environmental disasters. Using the median WTP values for the three goods that increased in inclusiveness it was concluded that there is no significant difference in the valuation of pubic goods that display varying levels of inclusivity (Kahneman and Knetsch, 1992: 62). Furthermore it was therefore concluded that CV valuations for public goods are subject to the problem of embedding. In other words, respondents do not act in a way that economic theory would predict.

The question of temporal embedding is essentially the question of whether or not there will be significant differences between WTP valuations of respondents making a one-time payment or a long-term commitment to a series of payments for a good (Kahneman and Knetsch, 1992: 62). The assumption was made that since respondents appear to behave irrationally when valuing goods that vary in inclusivity, the same could be expected for respondents that are valuing goods on different time scales. To investigate temporal embedding, respondents were then asked at random to either make a one-time payment or a commitment to a series of payments. The medians of the WTP were similar for both payment schedules, leading to the conclusion that respondents did not distinguish between payments with vastly different present values (Kahneman and Knetsch, 1992: 63).

From these results Kahneman and Knetsch (1992: 63) conclude that there needs to be some level of experimental control for values elicited through CV studies, if indeed the CV method is able to be manipulated in such a way as to avoid the problem of embedding. Kahneman and Knetsch (1992: 64) offer the hypothesis that respondents are in fact valuing another ‘good’ in WTP valuations. The good in this case is a sense of moral satisfaction, or “warm glow of giving”. It is suggested that the moral satisfaction may be similar for an inclusive good and an embedded good. To investigate this hypothesis Kahnaman and Knetsch (1992: 65) chose 14 goods for a telephone survey presented to four groups of respondents. The 14 groups of goods were split into an embedded good and an inclusive good, for example famine relief in Ethiopia vs. famine relief in Africa. The first two groups of respondents were asked to judge the level of satisfaction that they would receive from the embedded good (respondent group 1) and the inclusive good (respondent group 2) independently. The second two groups of respondents were asked to value the goods in question (respondent groups 3 and 4). The level of satisfaction gained by contributing to the good and the valuations were then compared. Kahnaman and Knetsch (1992: 67) concluded that, if the inclusiveness of a group of goods does not increase the level of moral satisfaction for contributing to that good, there is little effect on WTP for a more inclusive good as compared to an embedded good. An interesting extension of this can be applied to the WTP/WTA debate. WTA has been rejected by CV designers because of the belief that respondents will base their WTA valuations on moral concerns (unrealistically high 'acceptance' value for the extinction of a species for example) (Kahnaman and Knetsch, 1992: 69). But if concerns, such as the moral satisfaction of giving to a 'good' cause, are associated with WTP, then surely WTP in CV exercises should be rejected on similar grounds (Kahnaman and Knetsch, 1992: 69)? The paper by Kahnaman and Knetsch (1992) is clearly a damming view of the theoretical underpinnings of the CV method, this view has however been challenged.

In response to the conclusions drawn by Kahnaman and Knetsch (1992), Harrison (1992) outlined a number of criticisms for their evidence of embedding for various levels of inclusivity of a public good. Firstly, for the conclusions of Kahnaman and Knetsch (1992) to stand it must be assumed that for every constituent part of the public good being valued there is a positive WTP, and that the various aspects of the inclusive good are not substitutes. If these assumptions do not stand, the results of the study can be explained by rational economic behaviour, and not by irrational behaviour such as embedding.

Harrison (1992: 251) rejects the method of statistical analysis used by Kahnaman and Knetsch (1992) and when the data is rearranged, a different set of conclusions may be drawn. From the rearranged data used by Harrison (1992: 254) it was shown that the mean WTP for the three goods valued that an increase in inclusivity does differ significantly. Respondents appear to have participated in a manner consistent with economic theory, the reverse of the conclusions drawn from the data by Kahnaman and Knetsch (1992).

Regardless of the interpretation of the data used by Kahnaman and Knetsch (1992) there are further criticisms of the conclusions drawn (Harrison, 1992: 253). It has to be assumed by Kahnaman and Knetsch (1992) that the interviewer has made it clear to respondents what it is that they are being required to value. It is Harrison's (1992: 253) opinion that they have not. Because respondents were asked to value the goods in a telephone survey it is realistic to assume that they were not making detailed notes of the good that they were valuing. The descriptions of the goods that were being valued in Kahnaman and Knetsch (1992) were very similar (all three descriptions begin with the statement "This survey focuses on environmental services…") with incremental changes in the level of inclusivity. Because respondents did not have time to comprehend exactly what they were valuing it is plausible that they were all merely valuing environmental services (Harrison, 1992: 253). This confusion that seems apparent is generally avoided and tested for by CV practitioners (Harrison, 1992: 254). Subjects may indeed have viewed all three goods as being identical (Harrison, 1992: 254).

Another explanation for the apparent similarity of the valuation of goods that is presented by Kahnaman and Knetsch (1992) is as follows: perhaps people have a 'budget' for say, environmental services, and they are willing to spend this budget. They then commit to one aspect of environmental services as opposed to an increment of the budget simply because no one is asking them to pay for the other aspects of environmental services. But when respondents are asked to value other aspects of environmental services they have to adjust their hypothetical consumption in response to the additional spending they are now confronted by. This may even be an indication that respondents are behaving rationally in the face of limited budgets. Additional spending for one group of goods should correspond with a decrease in spending in another group of goods, especially if the goods are seen as substitutes. A way to test this would be to ask two groups of respondents from the same population to value two unrelated goods, and a third to value the two unrelated goods together. Any evidence of embedding in this case would have interesting implications for CV theory.

Similarly, Hanemann (1994: 36) rejected a theory presented by Diamond that subsequent provision of similar goods should yield valuation estimates by CV respondents which increase “more than proportionally” to their increase in provision; based on empirical evidence Diamond concluded that this was not the case, and therefore rejected the CV method. Hanemann (1994: 36) however argues that this assumption is incorrect, especially when the ‘similar goods’ can be seen as substitutes, which is likely. It can be expected that individuals will value increasing levels of the provision of similar goods at declining rates because of “diminishing marginal rates of substitution” and “substitution effects” (Hanemann, 1994: 36).

With regard to the hypothesis that WTP for public goods displays some level of WTP for moral satisfaction presented by Kahneman and Knetsch (1992), Harrison (1992: 256) rejects this on two grounds. Firstly, Kahneman and Knetsch’s (1992) statistical analysis of the collected data is once again rejected by Harrison (1992: 256), and secondly, regardless of the rejection of the statistical analysis, he points out that the grading of moral satisfaction used by Kahnaman and Knetsch (1992) has no real meaning since respondents were asked nothing about the level of moral satisfaction that they would receive for making payments for various goods, but rather just the satisfaction that they would receive. According to Harrison (1992: 256) this is an important distinction.

In a subsequent paper Hanemann (1994: 33) discussed the apparent effect of moral satisfaction, or “warm glow”, as described by critics of the CV method such as Diamond and Hausman (1994). Critics such as these argued that respondents to CV surveys did not offer valuations that were in line with their true economic preferences because of the “warm glow” effect. This was however contested by Hanemann (1994: 33) on the grounds that individuals’ valuations should be based on whatever standards relevant to them, regardless of their motives. It would seem rational, for example, for parents to value government policies that support subsidised education more highly than individuals who do not have children. Furthermore, it would seem irrational to reject these valuations because they are based on selfish grounds, individuals valuations are made up of whatever considerations they see fit. The conclusion which had previously been made, that CV studies are unreliable because individuals make valuations on their own “purely selfish grounds”, is therefore rejected by Hanemann (1994: 33).

It is therefore evident that there are conflicting conclusions regarding the presence of the embedding effect, and the effect of moral satisfaction on WTP. To get a better picture of the extent and nature of the embedding effect it is necessary to consider what the research is saying collectively (Venkatachalam, 2004: 98). One such study was conducted by Smith and Osborne (1996), in which they use a meta-analysis of five different CV studies all valuing air quality associated with visual improvements to US national parks. By only including studies that valued air quality and visibility with some respondents that were on site and others that were a considerable distance from the park, the meta-analysis was able to cover both use and non-use values of the visual improvements. The goal of the study was not simply to display statistical differences between valuations of varying amounts of the same commodity, but that the differences were “consistent with economic intuition” which is “context dependent”. This is viewed as an important aspect when assessing the level of consistency with conventional economic thought. For example, if the goods are seen as substitutes small changes for the inclusive valuation would be expected.

Smith and Osborne (1996: 290) used five studies that valued change in air quality as a change in visible range based on similar methods. Each of these studies used photographs to convey to respondents what they were being asked to value. It was considered to be important to convey in the clearest possible manner to respondents as much information about the good being valued as possible in the absence of experience in the purchase of the good being valued, so that respondents may make informed and realistic valuation estimates (Harrison, 1992: 253; Smith and Osborne, 1996: 289; Carson *et al.*, 2000: 179). Problems associated with information effects, discussed in the following section of this chapter, should however also be considered.

The results of the meta-analysis found that there was a significant positive relationship between WTP and the extent of the visual improvements, which was indeed consistent with rational economic behaviour (Smith and Osborne, 1996: 300).

The study by Smith and Osborne (1996) showed that the CV method can produce reliable results that are both ‘statistically significant and economically plausible’ when valuing both use and non-use environmental values (Venkatachalam, 2004: 99). Although there are studies such as this one, that appear to vindicate the CV method, the host of research finding evidence of the embedding effect cannot be ignored (Venkatachalam, 2004: 99; Smith, 2005: 525; Diamond and Hausman, 1994: 62).

After observing evidence of the embedding effect, Diamond and Hausman (1994: 62) took a strongly critical view on the reliability of CV studies. They suggested that the reason for the embedding effect was the lack of information on what was being valued, a problem that is inherent in short surveys that aim to evaluate obscure goods and services. Respondents may have very little idea what it is they are in fact valuing, causing inconsistencies in CV results (Arrow *et al.*, 1993: 12; Diamond and Hausman, 1994: 62).

The proponents of the CV method argue that results suggesting the presence of the embedding effect in CV studies are mainly due to flawed methods in which the surveys were conducted (Venkatachalam, 2004: 100). The problem may in fact lie in the level of information transferred to respondents in the conventional approach to the CV method (Harrison, 1992: 253). Hammitt and Graham (1999) and subsequently Corso *et al*. (2001) found that the embedding problem could be reduced or even eliminated if more information was effectively communicated to respondents.

Desvousges *et al*. (1993) conducted a study valuing small oil spills vs. large oil spills, and the percentage loss of migratory water birds in various contingent valuation exercises. The conclusion arrived at was that respondents do not elicit reliable estimates of value based on changes of scale in the provision of that good. However, these results were also challenged on the basis of survey design, more specifically the level of information that respondents had to base valuation decisions on, what may have seemed to be very small incremental changes in numbers of bird losses (a change in bird numbers of between 0% and 2%), or size of oil spills (Hausman, 1993: 162). It is argued that respondents struggled to comprehend changes in the quantities of the goods being offered, mainly because of the lack of experience in valuing such goods.

It has therefore been suggested that when there has been evidence of embedding in the CV method this can largely be attributed to improper design of CV surveys and the inability of respondents to comprehend the information that is being presented to them (Venkatachalam, 2004: 102). Some of the mechanisms that can be used to reduce or eliminate the occurrence of the embedding effect include: "describing the larger and smaller commodities, and then asking respondents to focus their attention on the smaller commodity; using maps and photographs to describe the scenario, debriefing, providing opportunity to respondents to revise the bids; etc." (Venkatachalam, 2004: 102). Respondents should also be given the opportunity to analyse the information that is being presented to them as opposed to surveys that put respondents on the spot, such as stopping patrons in a mall for example (Venkatachalam, 2004: 100). One way that this might be possible, whilst still eliminating interviewer effects and the associated problems with mail-in surveys, is the use of the 'drop and collect' method described in the method section of this thesis.

- **Information Effects**

The amount of information that is presented in a contingent valuation survey has been observed to influence willingness to pay in both a positive and negative fashion (Bateman and Mawby, 2004: 49; Venkatachalam, 2004: 103; Vatn, 2004: 05; Smith and Osborne, 1996: 290; Hausman, 1993: 162). Information effects are strongest when respondents do not have a high degree of experience in the pricing of the good being valued (as is the case for most public goods where there is a high non-use value element) (Bateman and Mawby, 2004: 49). Information is therefore assumed to have a weaker effect on WTP when respondents have experience in the valuation of the good. In this sense CV surveys attempt to convey the information that respondents would consider in the everyday valuation of goods traded in the market. It therefore seems apparent that positive information regarding the attributes of the good being valued would increase the stated WTP, while negative information should decrease WTP (Bateman and Mawby, 2004: 49). In the same way positive information about complements should increase WTP of the good in question, while positive information about substitutes should decrease stated WTP.

The information effects above can be described as the value-enhancing element of the scenario presented in CV surveys, which are descriptions, either positive or negative, of the good being valued (for example, the problems associated with the introduction of an invasive species) (). Value neutral elements are pictures or diagrams to describe situations without the use of emotive language (for example, a picture of a river invaded by water hyacinth when valuing its control). According to Venkatachalam (2004) the value enhancing elements of a CV survey are: "a) the information about the good being valued; b) the budget constraints and other people's CV values; and c) the information about the related environmental goods that are supposed to affect the WTP values for the good under consideration."

To investigate the effect of the reminder of substitute and complementary environmental goods on WTP, Whitehead and Bloemquist (1991) conducted a CV study on a wetland in Western Kentucky to establish its perceived value. Three different surveys were designed: the first reminded respondents of substitutes for the wetland, the second complements, and the third neither. The result was that information regarding substitutes decreased WTP while information regarding complements increased WTP.

According to the report for the NOAA on contingent valuation budget constraints and a reminder of substitutes should be included in contingent valuation studies because of this observed effect of information on respondents (Arrow *et al.,* 1993). In order to investigate these recommendations Loomis *et al*. (1994: 500) conducted CV studies both with and without these two recommendations, where most of the other recommendations of the panel are strictly followed. The CV studies sought to determine the general public of western Oregon's perceived value to reduce forest fires in old growth areas in the region. Because of the relatively small amount of remaining old growth areas and the realisation of their ecological importance, a large portion of these areas are under state protection.

Two CV postal surveys were sent out to the public of Oregon, the second only differing from the first in that a reminder of substitutes and budget constraints was included. A very similar response rate was achieved for both groups of respondents. Following a statistical analysis of responses it was concluded that there was no statistical difference in WTP between the two groups, in other words, the hypothesis that a reminder of budget constraints and substitute goods affects WTP is rejected. Loomis *et al*. (1994) provide a number of explanations for the observed similarity in WTP between the two groups of respondents. Firstly, it is possible that respondents already consider budget constraints and substitute goods when valuing environmental resources; so there would therefore be no need to remind respondents of these issues as recommended by the NOAA panel. Secondly, respondents may not elicit a true reflection of WTP because they do not consider the survey as a real world valuation; respondents therefore do not consider budget constraints and substitutes. And finally, it is suggested that respondents lack the required experience to value environmental goods and services such as fire protection and therefore are not able to make a real world valuation, let alone consider budget constraints and alternatives.

With reference to their previous research, Whitehead and Bloemquist (1995) comment on the conclusions drawn from the study by Loomis *et al.* (1994). After reworking the statistics of the wetlands valuation so that that results were comparable to those drawn by Loomis *et al.* (1994), Whitehead and Bloemquist (1995) confirmed the conclusions drawn from their previous study, stating that information regarding substitutes does affect WTP. The authors suggested that the respondents to the Loomis *et al.* (1994) study had some knowledge of the good being valued and therefore may have had a better knowledge base to make accurate valuation estimates, and therefore were already able to consider substitutes and budget constraints without reminders. This was however not the case in the wetland valuation as few respondents had any prior knowledge. It is therefore suggested that reminders of budget constraints and substitutes is only really important when unfamiliar goods are being valued by the public.

It is apparent that when respondents do not have experience valuing environmental goods and services an inclusion of a reminder of substitutes and budget constraints affects WTP negatively. The converse of this is that people who have little understanding of the good being valued tend to inflate WTP. From the research conducted by Loomis *et al.* (1994) it is apparent that when respondents do have prior knowledge of the good being valued and reminders are included, it has little or no effect on WTP. These results tend to confirm and highlight the importance of the recommendations of the NOAA panel when trying to arrive at an accurate estimation of WTP. From the evidence that information regarding substitutes and budget constraints does not affect WTP when respondents do have prior knowledge of the good being valued, the reminder should be included in all CV studies in an attempt to make the level of experience and knowledge more homogeneous throughout the sample group.

In a more recent study to investigate the effect of increased levels of information, Bateman and Mawby (2004) undertook a CV study that measured the value of a woodland in the United Kingdom using two surveys that varied in the level of information. In the 'high information' survey respondents were informed about some of the species that relied on the woodland habitat (complementary goods), and were presented a map of the woodland that clearly indicated walking routes and the Woodland Art Centre. In this way both value enhancing information and value neutral information was added to the 'low information' survey to remind respondents of both the use and non-use values associated with the woodland. The result of this study was that, as predicted, an increased level of information presented to respondents both substantially and statistically significantly increases WTP.

According to the NOAA panel a conservative estimate of WTP is preferred (Arrow *et al.*, 1993). So should information regarding complementary goods be included in CV studies? Surely what is optimum is an accurate measurement as opposed to a conservative estimate. The question is when complementary goods are included (such as wildlife that relies on a woodland for survival) in a CV study, do they drive WTP to a more accurate level or inflate WTP? It does not seem so far fetched, particularly in the Bateman and Mawby (2004) study, in which respondents are in fact including the other goods described in the survey in their valuation, biasing WTP for the woodland. This differs from the situation where budget constraints and substitutes are included as reminders because it seems plausible that these encourage respondents to behave in a more economically rational way, and therefore produce reliable WTP responses.

In summary, it seems apparent that the higher the level of knowledge of respondents, the less strong the effect of additional information will be. Positive information and information regarding complementary goods drives up WTP; while negative information and information regarding substitutes tends to reduce WTP. Further research is required to identify the optimum level of information to be included in CV studies (Venkatachalam, 2004: 105).

In this chapter the theoretical background to the contingent valuation method was discussed and critically analysed. In the following chapters the method is used to value the control of water hyacinth on the Nahoon River in East London, South Africa.

CHAPTER FIVE: METHOD

5.1 Aim of the Study

There is increasing recognition of the importance of invasive species control in South Africa. Invasive aquatic species are of particular concern because of the threat posed to South Africa's water resource, and hence to the socioeconomic development of southern Africa as a whole (Cilliers *et al.*, 2003: 161; Gorgens and Wilgen, 2004: 27). Water hyacinth is one such aquatic invasive species.

Not only are the problems associated with the invasion of water hyacinth well documented, water hyacinth has established itself in fresh water bodies throughout South Africa, making it one of the most important invasive species facing the natural environment (Macdonald, 2004: 22; Gorgens and Wilgen, 2004: 27). Substantial, but not adequate, funds are spent on controlling water hyacinth (Hill, 2006: Pers comm.). The relative cost effectiveness of control programmes is therefore an important issue in policy development.

The aim of this study is to assess the relative cost effectiveness of the money being spent on the control of water hyacinth. For this it is necessary to undertake a comprehensive analysis of both the costs and the benefits of control. A cost-benefit analysis is then possible for the control of water hyacinth.

5.2 The Benefits of the Control of Water Hyacinth

The benefits of the control of water hyacinth can be seen as the costs that would have been incurred if no control were to take place. To calculate these environmental costs it is necessary to consider the concept of Total Economic Value or TEV. The TEV of environmental resources (such as fresh water resources) is made up of both use and non-use values. Depending on the socioeconomic environment surrounding the area affected by the invasion of water hyacinth, use and non-use environmental values will have varying relative importance. For example in a rural context where the infected water resource is used for sustenance it is expected that direct use values will make up the majority of TEV, while in an urban setting it is expected that indirect use, and non-use values will play a more important role. Examples of this are the appreciation of a view or the existence values that respondents in an urban environment might have for the resource in question (the value associated with the knowledge of a healthy environment).

This study focuses on the economic effects of the invasion of water hyacinth in an urban setting, namely the Nahoon River community in East London, South Africa.

5.3 Calculating the Benefits of the Control of Water Hyacinth – Environmental Valuation Methods

Price can be used as a measure of value for most market goods, since a product's price represents people's willingness to pay for that good (Clinch, 2000: 4). There are seldom markets for environmental goods, and where markets do exist they are imperfect and prices are normally distorted (Kaiser and Roumasset, 2002: 2). There are therefore no prices that will reflect a benefit to society for the improvements of environmental resources or social costs of environmental degradation (Clinch, 2000: 4). It is therefore necessary to utilise the various techniques that have been developed to measure such non-market improvements or damages. When attempting to value elements of the environment for cost-benefit analysis when assessing an environmental policy, or when merely attempting to value an aspect of the environment to form an estimation of asset value, it is necessary to use such valuation techniques, which will be discussed in the section that follows.

The two main categories of non-market valuation techniques are: stated preference methods, which are the only methods available to measure passive or non-use environmental values, and revealed preference methods, which try to attach an environmental value to a good that is valued in the market (Willis, 2002: 636).

Revealed preference methods use existing data to derive actual human behaviour with regard to environmental valuation. This is mainly when the price of a good is influenced by environmental quality (Clinch, 2000: 9). This valuation is done by identifying and isolating the proportion that the environment affects the price of a good that has a market (Clinch, 2000: 9). Two of the most popular revealed preference methods are the Hedonic Pricing Method (HPM), also known as the Hedonic Valuation Method, and the Travel Cost Method.

The Hedonic Pricing Method uses the prices of market substitutes (property prices) to find the value of parts of the environment (Beder, 1997: 93). Most goods' price in the market depends on a number of attributes, for example when people go out looking for a new pair of sports shoes they consider the brand, the colour, their durability and their versatility. In the same way houses are valued according to the attributes that they offer (McConnell and Walls, 2005: 6). It is assumed that part of the value of a house depends on its surrounding environment (Clinch, 2000: 9). To value the environmental amenity in question all the variables that determine the value of a house need to be identified, the effect that the environment has on this value then needs to be isolated and quantified (Clinch, 2000: 9).

The Travel Cost Method is used to place a market value on goods and services that are not generally bought and sold in the traditional market (Karasin, 1998: 1). These are usually recreational or environmental resources that people have to spend significant amounts of money to experience. Individuals weigh up the costs of a recreational visit against the benefits that will be gained from the visit and act in a way that represents the personal value for the recreational service in question (DEH, 1995: 2).

The Travel Cost Method is a method of environmental valuation whereby the costs that people incur from travelling to environmental amenities is calculated to represent society's willingness to pay for that amenity. Data on the expenses that individuals are faced with is determined by the use of a survey (DEH, 1995: 2). The expenses that are included range from food expenses on the visit to forgone income that is experienced due to the time taken off productive activities (DEH, 1995:2). The idea behind the Travel Cost Method is that even though the service does not have a specific value, or if the service's market value underestimates the true value, the costs incurred by individuals travelling to the site can be used as surrogate prices for that service (Karasin, 1998: 1). This makes it possible to estimate a demand curve for the environmental amenity in question.

The major shortcoming of revealed preference techniques of environmental valuation is that they are not able to measure non-use environmental values. Revealed preference techniques are therefore not feasible methods of environmental valuation for the purposes of this research. The only mechanisms available to estimate TEV, including non-use value, are stated preference methods.

Stated preference methods are also known as direct valuation techniques that ask participants to place a value on an environmental good or service (Clinch, 2000: 10). Stated preference methods try to calculate intended behaviour of society faced with some event occurring (Willis, 2002: 636). Stated preference techniques are important as revealed preference techniques are not capable of measuring all environmental values, for example goods that do not yet exist or goods where no market value exists (Willis, 2002: 636). Two techniques can be used to measure stated preferences, namely: contingent valuation (including contingent ranking exercises) and stated choice, which is also referred to as choice experiments or conjoint analysis (Willis, 2002: 636).

The contingent valuation method (CVM) is said to provide a 'holistic' valuation of an environmental good or service (Willis, 2002: 641). The limitation of this is that researchers cannot isolate the value that individuals place on particular aspects of the project in question. It is often the case that in the policy making process planners need to make decisions on where to concentrate environmental improvements within a proposed action (Willis, 2002: 641). For example, if there was a proposal to conserve an environmentally sensitive stretch of coastline, information is not only required about the good as a whole (the stretch of coastline), but also the specific features that need close attention (e.g. sand dune preservation). The stated choice method provides the tools for researchers to identify these specific preferences within a proposed project (Willis, 2002: 640), and is therefore a more focused method of environmental valuation.

As described by Willis (2002: 642), the stated choice method of valuation is structured as follows: respondents are presented with a set of choices, where each choice provides a different set of environmental attribute combinations at different prices for a proposed project. Respondents are either asked to make a choice of one option or to rank options as they see fit.

There is a debate over which environmental valuation method is superior (contingent valuation or stated choice) (Bennett, 1996: 186). According to Mogas *et al.* (2002: 3) the stated choice method allows participants to identify tradeoffs between different attributes, including money. If money is included in this assessment then the marginal value of each attribute can be assessed (Mogas *et al.*, 2002: 3). The advantage discussed by Mogas *et al.* (2002: 3) and highlighted by Willis (2002) can be weighed up against the disadvantages of the stated choice method as explained by Adamowicz and Boxal (2001: 68), namely that: "the presence of strategic behaviour in respondent choice, the design of the experiments, fatigue, learning and complexity that still require research effort." There is little evidence that one method is better than the other. Literature merely suggests that the choice method offers some advantages over the CVM (Mogas *et al.*, 2002: 4). However, in an analysis of the similarity of the results that the various methods obtain, Mogas *et al.* (2002: 4) found that the results of both the CVM and the stated choice method to be statistically similar. The latter method however, made it easier for researchers to understand the responses of participants, and yielded greater value estimates for environmental amenities. This is not ideal because a conservative estimate of environmental value is preferred when results cannot be compared with real world scenarios and there is an element of uncertainty regarding the accuracy of results. Further research is required to test the accuracy of stated choice method, especially when valuing public goods where there are no market values with which to compare results.

Because of the extensive literature (for example: Harrison, 1992; Arrow *et al.*, 1993; Carson *et al.*, 2000; Venkatachalam, 2004) regarding the theoretical underpinnings of the contingent valuation method and because of the need for a holistic valuation of the resource in question, the Contingent Valuation Method was selected for this study in order to estimate the benefits associated with the control of water hyacinth. The main debates and criticisms regarding the CVM were extensively discussed in the previous chapter of this thesis.

5.4 The Pilot Study

The aim of the pilot study was to test the willingness to pay (WTP) questionnaire designed to conduct the contingent valuation (CV) of the benefits associated with the control of water hyacinth to residents of an urban area affected by the problems associated with its invasion. Pre-testing and careful planning is considered an essential aspect of contingent valuation studies (Arrow *et al.,* 1993: 31).

- **The Questionnaire**

The questionnaire was finalised after a number of drafts were drawn up and amended through careful review. Since the contingent valuation method has been criticised for exaggerating environmental values, guidelines for its correct application have over the years been developed, and it is accepted as a starting point for litigation in the United States if the guidelines are followed (Carson *et al.,* 2003: 258). The Guidelines as set out by the National Oceanic and Atmospheric Association (NOAA) (Arrow *et al.,* 1993) were followed where possible, and where contemporary research has suggested shortcoming of the findings contained in the report, alternative research strategies were adopted.

The introduction to the questionnaire (as can be seen in appendix 2) consisted of a black and white diagram of the plant (water hyacinth). The black and white diagram as opposed to a picture was chosen so that respondents would merely recognise the plant if they had encountered it before and not form an opinion of the plant, positive or negative, based on a picture. According to Arrow *et al*. (1993: 55) photographs are useful tools to explain to respondents the good which is being valued, but must not induce any bias in the process.

According to the NOAA panel on contingent valuation, personal interviews are preferred to mail-in surveys because people with a bias towards the value of the good being valued are more likely to respond to the survey (Arrow *et al.,* 1993: 30). It was however decided that respondents would be allowed to complete the survey at their leisure, within the following 24 hours. The introduction then indicated that someone would be around the following day to collect the completed questionnaire and that if respondents had any questions they could ask them then. This was in recognition of the importance of limiting the rate of non-response and the avoidance of interviewer effects (Arrow *et al.*, 1993: 30). It was assumed that if people did not feel pressured into an immediate response there would be more people willing to partake in the survey. It was also indicated that the questionnaire was completely anonymously so that respondents did not assume any incentive to under or over estimate WTP. The anonymity of the questionnaire may however have contributed to hypothetical bias because of the problem of free-riding (Veisten and Navrud, 2006: 750).

The questionnaire was then divided into three sections (attached as Appendix 2): section one sought to determine people's knowledge of the problem and the extent to which they were affected by the invasion of water hyacinth; section two consisted of the WTP question; and section three elicited socioeconomic data of respondents to check for any effects on WTP.

In section one, before any information was given regarding the problems associated with water hyacinth so not to introduce bias, respondents were asked: the distance they lived from the river, if they had noticed water hyacinth, if they considered it to be a problem, if they had noticed an increase in the occurrence of the plant, and if they had incurred any direct monetary costs because of the plant. The aim of this section was to establish the level of knowledge of respondents of the problems associated with water hyacinth.

In section two some of the problems associated with the invasion of water hyacinth were presented to respondents, and respondents were told that it would be possible to reduce the plant invasion by 80%. A black and white diagram that indicated this reduction was provided as an explanatory device. One of the biggest problems when valuing public goods is the lack of experience respondents have in their valuation, the reliability and accuracy can be improved by providing information that would be available to respondents if they had experience purchasing the good (Harrison, 1992: 253; Smith and Osborne, 1996: 289; and Carson *et al.*, 2000: 179). Caution was taken not to provide too much negative information as this might positively affect WTP (Bateman and Mawby, 2004: 49).

The payment vehicle was then described: it would consist of a monthly addition in municipal rates that would go directly to the control of water hyacinth. It is necessary in these studies that respondents believe the payment vehicle and that it is familiar so that the contingent market is accepted (Arrow *et al.,* 1993: 42). It was also conveyed that for the local municipality to spend money on the control of water hyacinth less would be available for other services such as ‘housing or education’, reminding respondents of budget constraints. The reminder of respondents’ budget constraints was emphasised as an important aspect of WTP questions so that responses were as realistic as possible (Arrow *et al.,* 1993: 42). Once again this is in recognition that people have little experience in valuing public goods, and in real world valuation scenarios people are faced with budget constraints (Loomis *et al.,* 1994). Because of this lack of experience and the hypothetical nature of the survey, the budget constraint was included. The less experience respondents have in the valuation of a good, the more a reminder of a budget constraint is expected to reduce WTP (Loomis *et al.,* 1994).

Respondents were then presented a payment card with values ranging from R0 to R50 as increases in monthly municipal rates. Respondents were asked to make their WTP decision based on this card. An option for the respondent to state his/her own value was also offered on the card. The WTP question was presented as follows: “From the payment card below, please select the maximum that you would be willing to pay for an 80% clearing of water hyacinth taking into account your monthly household expenditure: (There is an option to choose another amount if none of the following are applicable.)”. According to the panel established by the NOAA on CV the best value elicitation format, or the format that yields the most conservative WTP responses, is the referendum format (Arrow *et al.,* 1993: 18). However recent research has indicated that this may not be the case. It has been suggested that open-ended WTP questions tend to induce a lower level of hypothetical bias than closed-ended valuation (Ready *et al.,* 2001; Brown *et al.,* 1996). It has also been suggested that respondents are more certain of their responses in open-ended valuation questions, as is the case in the use of payment cards (Ready *et al.,* 2001)

At the end of section two, respondents were asked questions designed to determine the reason for their stated WTP, and their level of confidence of the accuracy of the values. These questions are designed to give an indication of any problems with the CV survey, like the non-acceptance of the payment vehicle. This was recommended by the report for the NOAA (Arrow *et al.,* 1993: 57).

Section three consisted of a number of socioeconomic questions regarding people's age, language, race, sex, education, occupation and income as recommended by the report for the NOAA (Arrow *et al.*, 1993: 35). The main aims of this section was to check the consistency of responses, in other words, to check if income was positively related to WTP as economic theory predicts, and to identify different WTP patterns amongst various socioeconomic groups. In the Nahoon River study this data proved very useful in confirming the homogeneity of the two different study groups.

- **Study Site**

The town in which the pilot study took place was Parys. It is a small town with a population of about 43 000 people, located in the northern Free State on the banks of the Vaal River. It is well documented to have a problem with the invasion of water hyacinth (Littleford, 2006). The town is situated just over 100km south of Johannesburg which makes it a popular weekend getaway. This has become a major driving force behind the small town's economy. The site was selected because of the similarities between the Parys study area and the East London suburbs of Abbottsford and Dorchester Heights surveyed in the main phase of the study.

The study was undertaken during the period 15 – 19 May 2006. Two researchers went from 'door to door' to homes situated within 500m of the river (homes on the river side of Bree Street and Loop Street). Residents were selected randomly within this area to complete the questionnaire on their own, which was collected the following day. Each respondent was personally consulted as it was assumed that if the questionnaire was merely left in the letter box, only concerned parties would respond, exaggerating the WTP. The majority (approximately 80%) of people issued questionnaires completed the survey (however, a number declined to accept a questionnaire without reading the background information).

- **Pilot Study Results**

For the pilot study a target sample size of 40 respondents was expected, which was achieved. Of the 40 respondents, 22 (55%) indicated that they had a 'zero' WTP for the control of water hyacinth. This is a very high percentage and can be attributed to a number of factors. Firstly, 12 of the respondents indicated that they would not be willing to pay because they believed that the local municipality would not spend the money on the problem. Issues such as local corruption within the municipality, exorbitant local government salaries and general mistrust of the local municipality were all issues cited within the questionnaires. These respondents were essentially not reflecting that they would not be willing to pay for the control of water hyacinth, but rather highlighting issues with the payment vehicle, in other words, respondents were not accepting the contingent market. Some respondents even mentioned that if money was to go directly to a private institution to pay for the problem they would be interested in supporting such projects. This highlighted work that needed to be done to better design the payment vehicle in future studies. The payment vehicle needed to be believable, but respondents also needed to believe the money would go directly to alleviate the problem so that an accurate WTP may be elicited in future studies.

The 12 respondents that explicitly stated problems with the payment vehicle (municipal mistrust) were excluded from the WTP analysis (but were included in the socioeconomic analysis), leaving a sample size of 28. With these 12 removed (refer to table 5.1, below), 36% of respondents (10) had a 'zero' WTP, still a significantly high percentage. The average WTP of the remaining 28 respondents was R10.33 per month (R123.96 annually[1]). The median WTP response was R10 (15% of respondents), which was 0.07% of average household income (R14 643).

[1] The annual average WTP of R123.96 is equal to €12.68, US$17.29, and £8.59 (31 August 2007).

Table 5.1: Summary of WTP results for the Vaal River pilot study

	WTP
Yes	18 (64%)
No	10 (36%)
Average	R10.33
Median	R10
Annual	R123.96
Percent H/H income	0.0007%

Table 5.2: Summary of background information for the Vaal River pilot study

VPS1	**Yes %**	**No %**
Accept payment vehicle (40)	70 (28)	30 (12)
Noticed water hyacinth (40)	97.5 (39)	2.5 (1)
Think WH a problem (40)	85 (34)	15 (6)
Benefits to clearing? (40)	80 (32)	20 (8)
Direct costs incurred? (40)	80 (32)	20 (8)
WTP? (28)	64.3 (18)	35.7 (10)
Noticed an increase in WH? (40)	45 (18)	55 (22)

Note: ( ) indicates absolute numbers

As indicated in table 5.2, twenty-two respondents (55%) indicated in section one of the questionnaire that they had not noticed an increase in water hyacinth, and that it had not been a pressing problem in the immediate weeks leading up to the study because the Vaal River had recently come down in flood, clearing the section of the river that is banked by Parys of almost all water hyacinth. It is plausible that one of the main reasons for the remaining high percentage of 'zero' responses, although this was not explicitly reflected in the questions regarding the reasons for respondents' stated WTP.

Another interesting point that emerged from the statistical analysis was that the distance people lived from the water and the level of knowledge of the problems associated with water hyacinth did not significantly influence willingness to pay and even suggested that they had a negative influence on WTP. This may be further evidence that the contingent market was not accepted (payment vehicle problems) or may provide evidence of a further observation from the research, namely, it became evident that a large portion of residents of Parys were very unhappy with the quality and management of the Vaal River especially in their area. It appeared that very few people were able, or were prepared, to use the river in its current state for recreational purposes or for any other reason. The public good in question (the Vaal River and associated attributes) appears to have little value to the residents of Parys in its current management state. Some respondents even indicated that they could not fish recreationally in the river due to water quality issues even though they had the desire to do so. This may have contributed to the low observed WTP and the high R0 response rate. Beyond this water hyacinth did not seem to be high on the list of mentioned problems associated with the river's quality. In the Nahoon River study it proved beneficial to include questions that more accurately determined the use and non-use values of the resource to respondents.

- **Regression Results and Analysis**

Table 5.3: WTP for the eradication of water hyacinth along the Vaal River: Pilot study 2006 – multiple log-linear regression results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.23	1.23	4.23	0.00
Benefits to clearing	0.85	0.56	1.51	0.16
Noticed a problem	-0.73	0.43	-1.67	0.12
Education	-0.50	0.27	-1.84	0.09
Income	4.26E-05	1.80E-05	2.36	0.03
Race	-1.01	0.46	-2.18	0.05
Sex	-0.18	0.41	-0.45	0.65
Age	0.24	0.15	1.55	0.15
R-squared	0.49	**F-statistic**		1.42
Adjusted R-squared	0.14	**Prob(F-statistic)**		0.29
S.E. of regression	0.50			

The White Heteroskedasticity-Consistent Standard Errors and Covariance log-linear model was used, and run with the ordinary least squares method. In order to deal with zero responses, which accounted for 36% of the sample (10 respondents), a constant of one was added to the WTP amount. Since the log of one is zero, this allowed the inclusion of zero responses without altering the results.

From the adjusted R^2 statistic it can be deduced that 15% of the change in WTP can be accounted for by the model. The low F statistic shows that the overall regression was not very significant, which can be expected with small sample sizes. A larger sample size was planned for the Nahoon River study.

Respondents were asked to class their level of education and income within a number of given brackets. The level of education was coded from 1 to 6 (the number of brackets available) and the level of income was coded as a mean of the bracket chosen, except for the first and last bracket (i.e. less than R10 000 per month or more than R50 000 per month), which were given values of R9 000 and R51 000 respectively. The "noticed a problem" variable indicates the effect of respondents being aware of the problems associated with the invasion of water hyacinth and was coded as a dummy variable, given the value of one if the respondent was aware of the problems, and zero if the respondent was not aware of the problems. Race (only two race groups participated in survey) and sex were also coded as dummy variables, people of European origin were given the code of one and people of African origin were given the code of zero, and males were coded as one and females as zero.

Both income and race were found to be significant at the 5% level, albeit only slightly, namely, for a R1.00 increase in income WTP would increase by 4.26×10^{-5} %, and people of African origin were more likely to have a higher WTP at a rate of 1.02%. Because of the very small income coefficient, not much can be made of its significance; however, it did suggest some internal consistency with regards to income and willingness to pay because it was expected that income would be positively related to WTP. That race was found to be significant was not paid much attention because 39 out of the 40 respondents were of European origin (97.5%). Although education did appear to be significant at the 10% level, it appeared to have a negative relationship with WTP (an increase in education level would lead to a 0.5% decrease in WTP per level), which was not expected because it was assumed that respondents with a higher level of education would have a greater awareness of the benefits associated with the control of invasive species. It was also interesting to note that the variable concerning the awareness of the problems associated with the invasion of water hyacinth was almost significant at the 10% level, however the coefficient suggested a negative effect on WTP (that a respondent was aware of the problems associated with the invasion of water hyacinth decreased WTP by 0.85%).

- **Observations from The Pilot Study**

The pilot study proved an invaluable tool in the development of the Nahoon River study questionnaire. It made the observation clear that thought had to be put into the way the payment vehicle was presented to respondents. It also became apparent that questions that sought to determine the use value of the resource should be posed, in detail, to get an accurate picture of how and why respondents value the resource in question.

5.5 The Nahoon River Study

Upon completion and careful analysis of the results of the Vaal River pilot study, the first phase of a contingent valuation of the benefits associated with the control of water hyacinth on the Nahoon River was undertaken early in September 2006, and the second in early February 2007. The goal of the study was not only to estimate a WTP for the control of water hyacinth, but to gain a broader understanding of the values associated with the Nahoon River to the residents of Abbottsford and Dorchester Heights in East London. Shortly before the first phase of the study, heavy rains had washed the majority of water hyacinth out of the Nahoon River, and based on past experience the water hyacinth was expected to re-establish early the following year in the months prior to the second phase of the study (Hill, 2006: Pers comm.). This presented the opportunity to test for any significant difference in WTP based on the amount of water hyacinth on the Nahoon River, whilst increasing the sample size of the relatively small population. The amount of water hyacinth had increased from small clumps around tree stumps in September 2006 to mats of approximately 10m x 10m in their largest extent in February 2007.

- **The Questionnaire**

The questionnaire was amended from that used in the Vaal River pilot study based on observations made, and lessons learned from that study. The Nahoon River study questionnaire is included as appendix 3.

The "24 hour drop off and collect" system that was used in the pilot study was perceived as a success because of the high percentage of respondents that accepted the survey completed it, and was therefore used in the subsequent study. The "24 hour drop off and collect" system was also expected to reduce, if not eliminate, interviewer effects and reduce the bias of only interested parties responding as in 'mail-in surveys', whilst allowing sufficient time for respondents to consider their responses as opposed to "on the spot" interviews that tend to rush respondents. The introduction was simplified marginally to improve the ease of reading, and the question of how far the household was from the river was posed to respondents rather than being completed by the interviewer to improve the accuracy of these results. This followed from the pilot study in which it was found that interviewers found it difficult to judge the distance to the river from the roadside. Respondents were informed in the introduction that the questionnaire was anonymous.

It was identified that to gain a better understanding of what constituted the value of the resource to respondents, questions relating to how and how often people made use of the river were included in section one. Questions relating to the environmental awareness of respondents were also included to help to gauge non-use values.

One of the major shortcomings of the original questionnaire used in the Vaal River pilot study was the non-acceptance of the payment vehicle by respondents. In section two of the Nahoon River survey it was suggested to respondents that their contribution to the control of water hyacinth would be made to a privately managed organisation, namely, 'Working for Water', an initiative of the Department of Water Affairs and Forestry for the eradication of invasive weeds, and that the funds would go directly towards solving the problem. The payment vehicle in the Vaal River study indicated that funds would go to local government, which was largely rejected. This amendment was made in recognition of the importance of the acceptance of the payment market by respondents (Arrow *et al.*, 1993: 42). A shortcoming of the selection of

Working for Water as the payment vehicle is the possibility of the embedding problem. It is plausible that respondents may inflate an estimation of the contribution that they would be prepared to make to the organisation for the control of water hyacinth with the inclusion of a valuation for job creation and the control of other invasive species (for which the organisation is widely recognised). It is however clear in the questionnaire that the valuation is specifically for the control of water hyacinth on the Nahoon River. It should also be noted that this payment mechanism produced less bias than the mechanism used in the Vaal River pilot study.

As in the pilot study, respondents were reminded of the budget constraints that they faced. The WTP question was posed to respondents by use of a payment card as in the pilot study.

The socioeconomic questions posed in section three of the pilot study remained largely unchanged.

- **Study Site**

The study was conducted in two suburbs of the Nahoon area in East London called Abbottsford and Dorchester Heights (27°57’05’’ E, 32°59’05’’S). They are small adjacent suburbs that border the Nahoon River, which appear to be characteristic of most suburbs situated along the river. What is however unique to these suburbs is that the quality of the water is ideal for the spread of water hyacinth. The problems associated with the invasion of water hyacinth on the Nahoon River have been documented since January 2005 (Stapelberg, 2007), which include a reduction in recreational use of the river, a perceived increase in mosquitoes, and a reduction in value of property (Hill, 2006).

The East London area receives most of its annual rainfall in spring (between 500mm and 1000mm) (Bruton and Gess, 1998: 47). There is a high amount of surface runoff and therefore when it rains heavily, the Nahoon River does sometimes come down in flood, washing most of the water hyacinth onto surrounding beaches (most recent occurrence: 11 November 2006).

- **The Study**

The first phase of the study was undertaken over the period of 7 - 10 September 2006, and the second phase of the study was conducted over the period 11 - 14 February 2007. Two researchers went from 'door to door' to drop off and then collect questionnaires from households in Abbottsford and Dorchester Heights within 1km of the Nahoon River. Due to time constraints, eight streets were randomly selected to be surveyed (four in the first phase of the study, and four in the second). Streets in both phases of the study were selected of similar socio-economic characteristics (at the discretion of the researcher, and where ever possible all the households on each street were sampled. Disregarding the homes whose residents were persistently unavailable, 76 households were asked to complete the survey in the first phase of the study, of which 64 did so; and in the second phase of the study 84 households were asked to complete the survey, of which 68 did so. This resulted in an 84% response rate for the first phase of the study, an 81% response rate for the second phase of the study, and an 82.5% response rate for the entire study (160 issued/132 received); exceeding the response rate of the contingent valuation undertaken for the damages caused by the Exxon Valdez by almost 10%, and response rates achieved by "the best (American) academic surveys such as the University of Michigan's American National Election Surveys and the University of Chicago's General Social Survey" (Carson *et al.*, 2003: 270). This presents a strong argument for the use of the "24 hour drop off and collect" system.

The sample size of 132 respondents is relatively small for a study of this nature. If the study was continued from this 'preliminary' phase the validity of the results would be strengthened.

- **Data Coding**

The socioeconomic data was coded as follows: sex was a dummy variable with females being represented by a zero and males one; education was coded in the five categories that respondents were asked to grade their education, with one indicating a primary school education and five indicating education to a tertiary level, a dummy variable was also included indicating tertiary education, and was coded as a one for a respondent with tertiary education and zero for a respondent with no tertiary education;

occupation was also coded in the categories posed to respondents, with one indicating a ‘professional’ occupation and seven indicating that the respondent was unemployed (not including househusbands/wives); distance from the river (distance) was recorded in metres; age was recorded in categories, with one representing a respondent that was between 20 and 30 years old, and five indicating that the respondent was older than 60 years old; language and race were also coded as dummy variables with English and people of European origin given the code of zero, and all other languages and people of other race groups (African and mixed origin people) given the code of one. Income was also recorded in categories, with one corresponding to a household income of less than R10 000 a month and six corresponding to an income exceeding R50 000 a month.

In the following chapter the results of the WTP study at the Nahoon River are presented.

CHAPTER SIX: RESULTS

6.1 Results

In the first phase of the Nahoon River study sixty-four surveys were completed and sixty-eight surveys were completed in the second phase. Of the returned surveys, 18 and 17 respectively of the respondents indicated that they would not be willing to pay for the control of water hyacinth, as it should be a responsibility of the government (refer to table 6.1). It is understandable that respondents would respond in this way due to the public nature of the good in question. However, it does not necessarily indicate that these respondents did not value the benefits of the river, but rather that they thought that these costs should be incurred by the government. These respondents were considered to have rejected the payment vehicle. For this reason they were not included in the statistical analysis (leaving a sample size of 46 and 51 respondents respectively), but they were included in the socioeconomic analysis and the analysis of the qualitative responses because their WTP views had no bearing on these results. The percentage of respondents rejecting the payment vehicle was however an improvement on the issue as experienced in the pilot study.

The regression results for all the variables tested in the study are included as appendix 4d.

6.2 Socioeconomic and WTP Results Analysis

Table 6.1: Summary of WTP and WTP background question responses

Nahoon	% Yes N1	R Size N1	% Yes N2	R Size N2
Accept payment vehicle	72	46 (64)	75	51 (68)
Noticed water hyacinth (WH)	92	59 (64)	96	65 (68)
Think WH a problem	80	51 (64)	90	61 (68)
Increase in WH?	67	43 (64)	87	59 (68)
Benefits to clearing?	70	45 (64)	69	47 (68)
Direct costs incurred?	8	5 (64)	12	8 (68)
Recreational activities?	66	42 (64)	75	51 (68)
Recreational activities done often?	33	21 (64)	29	20 (68)
Recreational activities affected?	42	27 (64)	65	44 (68)
Environmental programmes?	70	45 (64)	71	48 (68)
Environmental groups?	3	2 (64)	10	7 (68)
WTP?	59	38 (64)	57	39 (68)
WTP?	76	35 (46)	76	39 (51)
Government should pay?	28	18 (64)	25	17 (68)
Very sure?	59	27 (46)	53	27 (51)

Note: WH = Water Hyacinth

R Size = Response Size (absolute)

( ) = Sample Size

In both phase 1 and 2 of the Nahoon River study over 70% of respondents accepted the payment vehicle; there are no expected or observable differences in this figure between the two phases. The percentage of respondents having noticed water hyacinth increased from 92% to 96% between phase 1 and 2 of the study. The small increase could be explained by an increase in water hyacinth, but this is unlikely due to the proximity of respondents to the river and the time period that water hyacinth has been documented to be a problem on the Nahoon River, suggesting that most people in the area would be aware of the problem. What was interesting was the substantial increase in the percentage of respondents that noticed an increase in the levels of water hyacinth (67% to 87%); this is consistent with the observable increase between the two phases of the study.

There was also an increase in the percentage of respondents that believed that water hyacinth was a problem, which was expected due to the increase in the number of plants on the Nahoon River between phase 1 and 2 of the study. There was however a very small difference in people feeling that they would benefit from the control of water hyacinth (70% to 69%). The lack in observable difference between the two samples in this regard is most likely because the amount water hyacinth does not affect the number of people who feel that they would benefit from its control, in other words it is the knowledge of the problem (non-use values) as opposed to the levels of water hyacinth (use values) that lead to benefit being derived from its control (as later confirmed by the regression results). This may also be an example of the difficulties that are experienced in contingent valuation in attempting to measure changes in value for small changes in the resource being valued (refer to the embedding problem in the contingent valuation chapter).

An increase was experienced in the number of respondents that had incurred costs (in forgone time) due to the invasion of water hyacinth between the two samples; this was also expected due to the increase of its invasion levels. The most common form of direct cost documented by respondents was private mechanical clearing of the weed.

In terms of recreational activities, there was an increase in the number of respondents that used the river for recreational activities (66% to 75%). There was also a large increase in the number of people that felt that the recreational activities that they use the river for are affected by water hyacinth (42% to 65%).

There was no difference between the two samples of the number of people who watch environmental programmes (this was expected as the amount of water hyacinth on the river should not affect this), indicating that the two samples are comparable. There was however an increase in the number of people that belong to environmental groups (3% to 10%), which can most likely be explained by a more environmentally aware sample (supported by the increase in the number of respondents who used the river for recreational activities, however, this may simply be due to the second phase of the study immediately following a holiday period). That people belonged to environmental groups did not have a significant effect on WTP (appendix 4d).

Table 6.2: Summary of socioeconomic profile of Nahoon Respondents, September 2006 and February 2007

	Nahoon1 (%)	**Nahoon2 (%)**
Monthly Income		
<10 000	31	34
10 000 - 20 000	42	40
21 000 - 30 000	22	18
31 000 - 40 000	5	6
41 000 - 50 000	0	3
>50 000	0	0
Occupation		
Professional	26	31
White collar worker	25	25
Service person	9	10
Blue collar worker	11	6
Student	0	0
Housewife/husband	11	0
Retired	5	7
Self employed	11	21
Unemployed	2	0
Age		
21 - 30	8	4
31 - 40	31	37
41 - 50	36	26
51 - 60	20	22
61 - 70	2	6
>70	3	4
Sex		
Male	58	60
Female	42	40
Race		
White	83	91
Black	13	9
Indian	3	0
Colored	2	0
Other	0	0
Education		
Primary school	0	0
Grade 8	0	1
Grade 10	2	1
Matric	45	51
Tertiary	53	46

The median income category per household, after tax for both samples was between R10 000 and R20 000 per month (42% and 40% of the sample). The only observable difference was the increase (5% to 9%) in 'high' income (x > R31 000) earners in the second phase of the study.

The majority of respondents were 'professionals' and 'white collar workers' (51% and 56%) in both phases of the study. The only marked difference between the two samples was the increase (11% to 21%) in respondents who are self employed in the second phase of the study.

The vast majority of respondents in both phases of the study were between the age of 31 years and 60 years (87% and 85%).

In both phases of the study about 60% of respondents were male (58% and 60%), and the vast majority of respondents were white (83% and 91%). The uniformity in terms of race can be explained by the current socioeconomic distribution in South Africa.

Almost 100% of respondents had received an education of matric or above, with about 50% of respondents having achieved a tertiary education. A slightly smaller percentage of respondents had received a tertiary education in the second phase of the study.

6.3 Regression Results and Analysis

Table 6.3: Log-linear regression results for Nahoon River Phase 1 and 2 independently

VARIABLE	PHASE 1	PHASE 2
C	-0.59	-1.16**
Increase	0.18	0.85**
Problem	0.56	0.42
Benefit	-0.11	1.11**
Affected	0.70**	0.05
Envprog	0.85**	0.69**
Sure	0.99**	0.01
Y	0.33**	0.52**
R-Squared	0.74	0.76
Adjusted R-Squared	0.70	0.72
S.E. of regression	0.76	0.77
F-statistic	15.73	19.73
(Prob) F-statistic	0.00	0.00

Explanation of Variables:

C - Constant

Problem - Respondents think the presence of water hyacinth is a problem – 1 if yes; 0 otherwise

Benefit - Respondents expect to benefit from the control of water hyacinth – 1 if yes; 0 otherwise

Affected - Recreational activities affected by water hyacinth – 1 if yes; 0 otherwise

Envprog - Respondents watch environmental programmes on TV – 1 if yes; 0 otherwise

Sure - Respondents are very sure of their responses provided – 1 if yes; 0 otherwise

Y - Income – In income categories described

* - Significant at the 10% level of significance

** - Significant at the 5% level of significance

The econometric model used for the analysis of phase 1 and 2 independently was: **log (WTP + 1) = f (c, increase, problem, benefit, affected, envprog, sure, Y)**. The a priori expectations were as follows: if a respondent had noticed an increase in water hyacinth a positive effect on WTP was expected; if respondents thought that the presence of water hyacinth was a problem this was expected to positively influence WTP; respondents who expected to receive a benefit from the control of water hyacinth were assumed to have a higher WTP for its control; if respondents watched environmental programmes on TV it was expected that they would have a greater awareness of environmental concerns, positively influencing WTP; the sign for the co-efficients of all the above were therefore expected to be positive because of their positive influence on WTP. It was impossible to predict what affect the level of certainty would have on WTP. WTP was expected to increase with an increase in income bracket, it was therefore expected, and important for the consistency of the model that the sign for the co-efficients of this variable was positive in both phases of the study, which it was.

The White Heteroskedasticity-Consistant Standard Errors and Covariance log-linear model was used, and run with the ordinary least squares method. In order to deal with zero responses, which accounted for 24% of the responses in both phases of the study (refer to table 6.1), a constant was added to the WTP amount (one). Since the log of one is zero, this allowed for the inclusion of zero responses without altering the results.

From the adjusted R^2 statistics in table 6.3 it can be seen that 70% of the variation in WTP can be accounted for by the model for phase 1, and 72% for phase 2. The high F statistic for both phases of the study shows that the overall regressions were significant at the one percent level of significance.

From the *a priori* expectations mentioned previously and with reference to table 6.3, it can be seen that the only variable that did not have the expected effect on WTP was if respondents felt that they would benefit from the control of water hyacinth in phase 1. This variable did however have a significant positive effect on WTP in phase 2, and when both phases are combined the expected effect on WTP prevailed with the larger sample size.

The only variable that was significant in the regression results of both phase 1 and 2 of the study independently (table 63), was that people watched environmental programmes on TV. This suggested that it was the non-use value as opposed to the use value that made up the majority of WTP.

That respondents had incurred direct costs due to water hyacinth did not have a significant effect on WTP in both phases of the study. This increase was therefore not included in the cost-benefit analysis.

Table 6.4: Regression results for the Nahoon River Study – Phase 1 and 2 combined

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.00	0.29	-3.42	0.00
PROBLEM	0.69	0.27	2.51	0.01
BENEFIT	0.83	0.22	3.71	0.00
AFFECTED	0.34	0.19	1.74	0.08
ENVPROG	0.90	0.21	4.10	0.00
P2	0.10	0.17	0.60	0.54
Y	0.58	0.09	6.09	0.00
R-squared	0.68	**F-statistic**		32.40
Adjusted R-squared	0.66	**Prob(F-statistic)**		0.00
S.E. of regression	0.83			

Note: Explanation of variables for table 6.3 applies to this table, with the inclusion of the of the variable 'P2' indicating that the respondent took part in the second phase of the study.

As in the analysis of the results of phases 1 and 2 independently, the White Heteroskedasticity-Consistant Standard Errors and Covariance log-linear model was used to analyse the results of phase 1 and 2 combined, and run with the ordinary least squares method.

From the adjusted R^2 statistic in table 6.4 it can be seen that 66% of the variation in WTP was accounted for by the model. The high F statistic of the study indicates the overall regressions were significant at the one percent level of significance.

Other statistical methods were tried (linear regression, probit regression, and logit regression), but did not result in as many significant variables in the regression. The results of these are included in appendix 4 a-c.

There was a significant positive effect on WTP (table 6.3) if respondents felt that they would benefit from the control of water hyacinth in the second phase of the study. This effect was not experienced in the analysis of the results of the first phase of the study. However when both samples were joined this variable had a significant positive effect on WTP (table 6.4).

The distance that people lived from the banks of the Nahoon River did not have a significant effect on WTP. There are two possible explanations for this result: firstly, because of the location of Abbottsford and Dorchester Heights, perhaps the sample all lived too close to the river for there to be any difference in use value of the river; and secondly, if use values were not as important as non-use values to the population, location to the river would not have been very important to WTP. If the latter was the case it would suggest that the WTP of the sample may be applicable to a far broader section of the East London population, specifically if non-use values make up the majority of WTP.

There was no significant positive effect on WTP if respondents had noticed an increase in the level of water hyacinth or if they had noticed water hyacinth at all on the Nahoon River (appendix 4d), suggesting that there would be no difference in WTP between the two phases of the study. This was the case as there was no significant effect on WTP in the second phase of the study when there were greater levels of water hyacinth present (P2 on table 6.4). This tended to confirm the notion that it was the non-use values that make up the majority of WTP, or that the marginal change (refer to section 5.5) in the amount of water hyacinth was too small to affect WTP.

Some of the increase in the amount of people that felt that water hyacinth affected their recreational activities is most likely to be accounted for by the increase in respondents that use the river for recreational purposes (table 6.1); however, the increase in number of people affected (23%) cannot solely be accounted for by this increase (9%). It therefore suggests that the increase in water hyacinth can account for some of this rise. However, it appears that this had a relatively small effect on WTP and the fact that water hyacinth affected recreational activities was not even significant in the second phase of the study (table 6.3). However, recreational activities being affected by the presence of water hyacinth did have a significant positive effect (at the 10% level) on WTP when both phases are combined (table 6.4); holding all things constant, a person who felt that their recreational activities were affected by water hyacinth would have a higher WTP by 0.35%. However, merely using the river for recreational activities did not have an effect on WTP, nor did the frequency that the river is used have an effect. If it were the use values that were most important to WTP it would be expected that these variables would have a significant positive effect on WTP. That there was a weak positive effect on WTP if recreational activities were affected by water hyacinth did however indicate that WTP was not solely made up of non-use values, but the positive effect on WTP was the least strong of all the significant variables suggesting that non-use values make up the majority of WTP.

A person who felt that they would benefit from the control of water hyacinth, holding all else constant, would have a higher WTP by 83%. It makes sense that since people feel that they would benefit, or gain some form of utility, from the control of water hyacinth they would be willing to pay more. That this variable, coupled with the variable indicating that respondents were aware of the problems associated with water hyacinth (who, holding all else constant, would have a higher WTP by 70%), was significant (both at the 5% level of significance) suggests some level of internal consistency with the model. It indicated that respondents based their valuation judgements on rational economic decision making. A person who is not expected to gain utility from the control of water hyacinth is not expected to have a positive WTP.

Respondents did however indicate that the utility that would be gained from the control of water hyacinth would not be made up solely from its physical removal and the use values associated with its removal, but also from the knowledge of a healthier environment. The reason for this deduction is that the strongest positive and significant effect on WTP was that respondents who watched environmental programmes on TV, holding all else constant, had a higher WTP by 90%. This suggested that the benefits that respondents expect and are willing to pay for came from the *knowledge of the problems* associated with the invasion of water hyacinth and their *concern* for the environment. To a smaller extent respondents expected to benefit from the problems associated with water hyacinth impacting on their recreational activities.

That the knowledge of the problems associated with the invasion of water hyacinth did have a positive effect on WTP suggested that if more information was conveyed to respondents about the good being valued, reported WTP may have been an even more accurate reflection of true WTP. That a prior knowledge of the problems associated with the invasion of water hyacinth did have a significant positive effect on WTP suggests that the Nahoon River study may have been largely free of information bias, as this variable was not expected to be significant if the information presented in the questionnaire significantly affected peoples' WTP.

Another interesting point that emerged from the statistical analysis was that if respondents were very sure of their WTP answers ('sure' on appendix 4d, recorded as a dummy variable, coded as 1 for respondents who were 'very sure' of their WTP answers, which accounted for 56% of the sample, and 0 for all other respondents), WTP would increase by 40% holding everything else constant (significant at the 10% level). Respondents that were unsure of their responses appear to have given a more conservative estimation of their WTP. It seems logical that respondents with a better knowledge of the problems associated with water hyacinth would be able to make better valuation assessments and were therefore 'very sure' of their responses. This may explain the reason for the positive effect on WTP of very sure respondents.

Income had a significant positive effect on WTP (1% level of significance). From table 6.4 it can be seen that an increase in income of one category will result in a 58% increase in WTP. This was also an indication that people were making 'real' decisions.

6.4 Benefits Results Summary

Table 6.5: Summary of WTP results

WTP	**Nahoon1 (46)**	**Nahoon2 (51)**
Yes	35 (76.0%)	39 (76.5%)
No	11 (23.0%)	12 (23.5%)
Average	R17.76	R20.98
Annual	R213.12	251.76
Percent H/H income (%)	0.8	0.9

Referring to table 6.1, of the remaining 46 respondents 35 indicated a positive WTP, at an average of R17.76 per month in the first phase of the study, while in the second phase of the study of the 51 respondents that accepted the payment vehicle, 39 indicated a positive WTP at an average of R20.98 per month (R251.76 per year[1]). Taking the mid point of the various income groups (refer to table 6.4) the average annual household income was R271 296 and R268 704 per year after tax for the two samples respectively. It is calculated that two sample populations of the residents of Abbottsford and Dorchester Heights were willing to contribute 0.8% in the first phase of the study (sample population 1) and 0.9% in the second phase of the study (sample population 2) of their annual income towards the control of water hyacinth.

The consistency of the socioeconomic results of the study gives strength to the argument that both phases of the study tested the responses of a single population. Due to the proximity of both phases of the study this was expected.

The results presented are largely restricted to the study site; however, they can be interpolated to give a broad estimate of the relative cost effectiveness of control programmes throughout South Africa, particularly in urban environments. In the following section conclusions are drawn, and recommendations are made from the results presented.

6.5 Calculation of the Costs of Integrated Water Hyacinth Control

In order to accurately assess the long term costs of continued integrated control of water hyacinth a case study was undertaken at the Enseleni System in northern KwaZulu-Natal where the continued invasion of water hyacinth and the cost of its integrated control has been documented (van Wyk and van Wilgen, 2002).

On a research trip to Enseleni Park the average cost of integrated control over the last 10 years (1997 – 2007) was calculated. The park manager, Mr Roy Jones, has comprehensive records of all expenses related to control over the period, making a calculation of this nature possible.

The costs of integrated control at the Enseleni System are calculated to be on average (over the period 1997 – 2007) R38 350 annually (corrected for 2007 prices).

[1] The annual average WTP of R251.76 is equal to €25.24, US$34.82, and £17.16 (11 July 2007).

6.6 The Cost of Control at the Nahoon River

In a study to assess the relative cost effectiveness of the various control options available for water hyacinth excluding the mechanical control option (which is seen to be cost ineffective when compared to other control options - herbicidal, biological and integrated control), van Wyk and van Wilgen (2002) conclude that integrated control (on the Enseleni River) is the most cost effective control option for water hyacinth, followed by biological and then herbicidal control. Although biological control has been attempted on the Nahoon River (a small population of one control species was released), it has not been successful (Hill, 2006). This is mainly due to a lack of commitment to an integrated or biological control programme for water hyacinth on the Nahoon River, and a decision by the Buffalo City Municipality (local governing authority) to take the herbicidal approach to control. An integrated control approach such as that on the Enseleni River (herbicidal and biological control) is therefore not as yet possible. In this case therefore, the costs of control of water hyacinth have to be assessed based on the cost of an herbicidal control approach. With a commitment from the Buffalo City Municipality to pursue an integrated approach to control, and further research into an effective biological control agent that is able to cope with the climatic conditions at the Nahoon River, the cost effectiveness of funds spent on control would be increased.

In 2005, Mr Stapelberg, chairman of the riverside rate payers association in Abbottsford and Dorchester Heights (Nahoon River suburbs), got three quotes for the (herbicidal) control of water hyacinth on the Nahoon River. All three quotes were done by independent companies for the eradication of water hyacinth during its growing season (September to March) each year. The quotes ranged from R50 668 and R53 220 annually (converted to 2007 prices). The annual cost of control will be assumed to be the most expensive quotation, i.e. R53 220. No quotation was employed, so the most expensive quotation was selected in order to minimise the chance of cost-benefit ratios being inflated by in-accurate cost estimates.

6.7 Cost-Benefit Analysis for the Control of Water Hyacinth on the Nahoon River

Table 6.6 Cost-benefit ratio for the control of water hyacinth on the Nahoon River

	Herbicidal Control	Integrated Control
Cost of Control	R53 220	R38 350
Benefit from control	R223 608	R223 608
Benefit/Cost Ration	4.2:1	5.8:1

The average annual WTP for the control of water hyacinth on the Nahoon River to the residents of Abbottsford and Dorchester Heights in East London is R251.76 (US$34.89) per household. In addition to these potential benefits received by the residents of Abbottsford and Dorchester Heights for the control of water hyacinth there will also be a decrease in the annual amount of water evapotranspiration through the plants out of the river of 222 000m^3 (24 hectares invaded, for 6 months of the year = 12 hectares, resulting in 18 500m^3 of water loss through evapotranspiration per hectare per annum) (van Wyk and van Wilgen, 2002). The reduction in water loss would result in water to the value of R22 200 (US$3 070.54) (R0.10 per m^3) being saved annually through its control (van Wyk and van Wilgen, 2002).

Another study by Hosking and Du Preez (2004) sought to determine the value of water in similar water bodies for conservation projects in South Africa. Using the marginal cost pricing method, the price of a unit of water is equal to the marginal cost of supplying the last unit of water; they valued water at between R0.57 per m^3 and R0.89 per m^3 to urban water users in South Africa. However the conservative estimate chosen by van Wyk and van Wilgen (2002) of R0.10 per m^3 has been used for the cost benefit analysis presented in this thesis.

Given that there are approximately 800 households in Abbottsford and Dorchester Heights (Stapelberg, 2007), the annual WTP for the area is R201 408 (US$27 857.26). When this amount is combined with the gains from reduced evapotranspiration, economic benefits from the control of water hyacinth on the Nahoon River of R223 608 (US$30

927.80) are expected annually. When the benefits are compared to the cost of herbicidal control (table 6.6), the benefit to cost ratio is 4.2:1 annually.

The annual cost of the successful integrated control programme at the Enseleni River, KwaZulu-Natal, South Africa is on average R38 350 (US$5 304.29) (Jones, 2006). The area on the river invaded by water hyacinth is larger than on the Nahoon River, but because the control of water hyacinth displays positive economies of scale (the cost of control would not come down proportionately to the amount of hectares under control because certain costs remain unchanged) the annual cost of the integrated control programme at Enseleni will be taken as the outside limit for the costs of an integrated control programme at the Nahoon River. When the benefits of control on the Nahoon River are compared to the costs of an integrated control approach (table 6.6), the benefit to cost ratio is 5.8:1 annually.

Water hyacinth has some productive uses, namely: feed for cattle, sheep and pigs; mulch and compost for food production; fibre for paper making; weaving baskets or mats; as a wood substitute for furniture; biological filtration; and the production of methane. Large scale processing is seldom commercially viable as the plant is 96% water, and therefore very expensive to harvest (Wise *et al.,* 2007: 16). It is possible on a small scale, but should be discouraged because it could lead to spread. Water hyacinth is not used for any productive applications on the Nahoon River, and therefore does not enter the cost-benefit analysis.

6.8 Conclusion

From the results presented in this chapter, and the proceeding cost-benefit analysis, it is concluded that the economic benefits of the control of water hyacinth outweigh the costs thereof, even when the most expensive method of control is employed. In the following chapter the results from this study are discussed in more detail, and their broader implications are considered.

CHAPTER SEVEN: SUMMARY AND CONCLUSIONS

7.1 Goals of the Study

The aim of this study was to conduct a cost-benefit analysis for the control of water hyacinth at an urban site in South Africa. The purpose of this was to investigate the cost effectiveness of funds that are spent on the control of invasive species, specifically water hyacinth. Coupled with knowledge of the extent and severity of the problems associated with the spread of water hyacinth, an estimation of the cost effectiveness of funds spent on its control would enable meaningful policy recommendations regarding the optimum amount of money spent on invasive species similar to water hyacinth.

As mentioned previously, the problems associated with the invasion of water hyacinth are not unique, as water hyacinth is but one of a number of invasive aquatic plant species in southern Africa, and limited funds have to be distributed amongst a number of priorities in the control of invasive species (and indeed the host of other challenges facing South Africa's socioeconomic development). Therefore although policy recommendations can be made, they have to be put in the context of differing agendas competing for limited funds. This research in no way attempted to analyse the relative importance of the competing agendas at either an environmental or a socioeconomic level, but rather sought to determine the relative cost effectiveness of funds should they be spent on the control of water hyacinth. However, an indication that funds spent on this problem would be cost effective provides a strong argument for the allocation of resources for control, on the basis of the expected positive return on investment and the public nature of the service.

7.2 Benefits to Control

- **Use and Non-Use Values**

The use values that an environmental resource presents to rural communities are generally more tangible than those in an urban context, because they are more easily compared to goods traded in the market. This is because the majority of use values in a rural context can be described as direct use values, where the benefits are generally of a material nature. On the other hand, urban use values of environmental resources such as the Nahoon River are generally of a more indirect nature, for example recreational use or the appreciation of a 'good view', environmental goods and services that are more difficult to compare to goods traded in the market. For this reason techniques, such as contingent valuation, need to be applied that place a financial value on such goods and services. One challenge of environmental valuation is that respondents' WTP is made up of both use values (both direct and indirect) and non-use values, however, background questions in contingent valuation surveys attempt to indicate what portion of respondents' WTP lies in each valuation category. In this way the contingent valuation method not only identifies how respondents value environmental goods and services (use vs. non-use value), but it also attaches prices to the goods and services that are not easily valued in the market.

In the Nahoon River study background questions indicated that the majority of respondents' WTP was made up of non-use values, suggesting that in similar urban contexts it is the non-use values as opposed to the use values that make up the majority of WTP.

It was interesting to note that there was no significant effect on WTP for respondents surveyed in the second phase of the study (P2 on table 6.2). This suggested that an increase in water hyacinth on the Nahoon River similar to that described (section 5.5) did not have a statistically significant effect on WTP even though there was an increase in mean WTP between the two samples. One way to interpret this was that most respondents had not noticed the increase of water hyacinth, which would be consistent with the conclusion that it was the non-use as opposed to the use values that make up the majority of WTP to the residents of Abbottsford and Dorchester Heights. Another interpretation is that with marginal increases in water hyacinth, far from an environmental threshold (such as the collapse of an environmental system) there are only very small marginal increases in WTP. As an environmental system approaches a threshold, marginal changes in WTP are expected to increase exponentially the closer the system approaches that threshold. Further research at the same study site when levels of water hyacinth are close to choking the entire Nahoon system would shed more light on this hypothesis.

7.3 Broader Implications of Cost-Benefit Analysis Outcomes

- **Decision Rule**

The benefits to the control are a measure of total economic value for the control of water hyacinth on the Nahoon River, in other words it is a measure of the net social benefits to control (use and non-use value). The decision rule is defined as follows: "If the net social benefits (NSB) from not controlling the invasive species are less than those from controlling the invasive species (including the costs of control, Cj), then control option j should be adopted, otherwise not" (Wise *et al.,* 2007: 37).

This can also be represented algebraically as:

If $NSB_{j=0} \leq NSB_{j>0} - C_{j>0}$ adopt control option j > 0

If $NSB_{j=0} \geq NSB_{j>0} - C_{j>0}$ allow species to spread (i.e., j = 0 or 'no control)

(Wise *et al.,* 2007: 37)

There are no obvious net social benefits to allowing water hyacinth to spread on the Nahoon River, and the decision rule for controlling water hyacinth on the Nahoon River can therefore be written as follows: (j^h = herbicidal control programme)

R0 ($NSB_{j=0}$) ≤ R136 976 (NSB_{jh}) - R52 264 (C_{jh})

Based on the decision rule, the optimal decision as to whether or not to control water hyacinth on the Nahoon River would be to adopt the herbicidal control programme, and not allow water hyacinth to spread.

- **Benefit Transfer**

It is clear that the benefits of the control of water hyacinth to the residents surrounding the Nahoon River exceed the costs of its control. In order to make deductions on a broader scale from the results presented, it is necessary to assess the extent to which they can be extrapolated for all urban areas affected by the invasion of water hyacinth in South Africa. The results from the pilot study on the Vaal River indicate that this would not be possible in all urban contexts. However, this research does indicate that in urban environments similar to that surrounding the Nahoon River, residents do tend to value the control of water hyacinth, and this valuation is predominantly based on the benefit that respondents acquire through the knowledge of a 'healthy' environment, or the non-use value of the resource.

This research not only indicates the relative cost effectiveness of funds should they be spent controlling water hyacinth in an urban environment, but it also provides a strong argument for the prevention of the spread of water hyacinth (and similar invasive species) in urban ecosystems. It is apparent that residents in an urban setting value healthy ecosystems, and have a positive WTP for the prevention (and control) of invasive species. The benefits to control in this context outweigh the costs.

- **Is Money Spent on the Problem 'Money Well Spent'?**

This research indicates that the benefits to the control of water hyacinth in an urban context are positive, even if the most expensive option for control is employed. There is also a host of literature to support the statement that funds spent on the control of water hyacinth in a rural context are cost effective (for example: van Wyk and van Wilgen, 2002; Wise *et al.*, 2007; De Groote *et al.*, 2003). That in most cases, regardless of the method of control, the money spent on control is cost effective, provides a strong argument that the R11 million (Hughes, 2006) spent annually in South Africa for the control of water hyacinth is money well spent, or at least that the funds are cost effective given the current methods of control. However, cost efficient methods of control (such as integrated control) improve the relative cost effectiveness of funds spent (van Wyk and van Wilgen, 2002). This indicates that a shif from what appears to be the current dominant strategy for the control of water hyacinth to most management bodies in South Africa, namely herbicidal control (Hill, 2006), to integrated methods, would be beneficial.

- **Are Biological Invasions Valued in a Rational Manner?**

A substantial portion (≈ 25%) of respondents in both phases of the Nahoon River study indicated that they would not be willing to pay for the control of water hyacinth due to the fact that they thought that it should be the government's responsibility. These respondents were not indicating that they did not value the resource positively, rather that they rejected the contingent market, protesting about being liable for payment. Indeed some respondents felt that the funds should be made available through the rates and taxes that *they* pay on a monthly basis, indicating they valued the resource positively. These respondents were therefore not included as 'zero' responses, but rather left out of the WTP analysis. This issue highlights the challenges associated with presenting an appropriate payment vehicle to respondents in surveys such as the one presented here.

The threats of invasive species have to be taken seriously as they are a major threat to South Africa's fresh water resource. This threat has serious implications for the socioeconomic development of South Africa as a whole, and therefore should be treated as a priority for both individuals and government alike. There is much controversy from all spheres as to who should bear the responsibility for the costs of control of invasive species (Hill, 2006; Stapelberg, 2007). This research does not attempt to make a judgement regarding where the responsibility of control of invasive species should lie, but rather to indicate what the benefits to control are (costs of no control), and how cost effective funds would be if they were employed to control invasive species such as water hyacinth. The positive valuation of the control of water hyacinth does however indicate that it displays public good characteristics, creating an argument for public spending on the problem. The cost effectiveness of spending on control, as indicated by this research, indicates that public spending would yield positive returns as a social investment in terms of expected welfare gains.

7.6 Conclusion

Environmental resources have economic value through the goods and services that they provide for society for current or future consumption. However tangible or intangible this economic value may be, it is often difficult to quantify. For this reason methods have been developed that attach monetary values to environmental goods and services. These methods enable cost-benefit analysis for monies spent on the improvement of environmental resources that traditionally would not be able to be quantified in financial terms. The assessment of the cost effectiveness of funds that are spent facilitates effective policy decisions which are able to benefit society as a whole.

The contingent valuation method has proven a useful tool in this research to determine the scope and scale of how respondents in an urban context value the control of water hyacinth on an aquatic system such as the Nahoon River in East London. The method not only provided a mechanism to quantify the value of environmental goods and services that are difficult to compare to goods traded in the market, but also a mechanism to determine which goods and services make up the majority of the value of environmental resources to urban populations. The distinction between an urban and a rural population is necessary here because it is assumed that populations in different socioeconomic settings will value environmental resources differently.

From the results of this research it can be seen that there are economic benefits to the control of water hyacinth in an urban context. Based on the calculation of the costs of control for water hyacinth it is deducted that the money spent on the problem is cost effective, with a return on investment of more than 4:1 even when the most expensive methods of control are employed (refer to table 6.6). The converse of this is that by not spending money on the control of water hyacinth and allowing the plant to invade water resources, economic losses are experienced, which are less tangible (however real) in urban contexts. The following conclusions can therefore be drawn: money spent on the control of water hyacinth in heavily residential urban environments characterised by a high level of invasion is cost effective, in that there is a positive return on investment regardless of the method employed for control; and environmental costs (economic losses) are experienced when continued invasion is allowed, on aquatic resources in urban environments similar to that of the Nahoon River.

These results therefore not only provide a strong argument for the investment of funds for the control of water hyacinth in areas that are already invaded, but it also makes a strong argument for measures that seek to prevent the introduction and spread of water hyacinth into areas that are traditionally free of invasive species.

When the results of this research are considered in conjunction with previous research, which has indentified benefits to the control of water hyacinth in rural contexts (for example: Wise *et al.*, 2007; De Groote *et al.*, 2003), an insight into the full scope of the potential economic benefits from its control is possible. Future research that quantifies the benefits of control to both rural and urban socioeconomic environments on a national scale would give an indication of the economic losses that are currently experienced by allowing the continued existence and spread of water hyacinth, the potential losses from the increased spread of water hyacinth, and the economic benefits that are possible through its control nationally.

The research provided in this thesis presents an indication of the potential benefits from the control of water hyacinth in urban environments. Furthermore, it suggests that although there may be an apparent low direct use value for environmental resources in urban environments, other benefits that are gained by resident populations make up a substantial share of resource value.

These results provide a justification for the funds that are devoted to the control of water hyacinth, providing an argument for the continued expenditure for its control, and for continued research into more cost effective methods of control, such as biological control.

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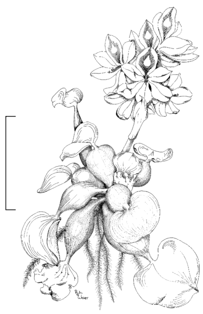
- **APPENDIX ONE: LIST OF FUNCTIONS**

	FUNCTIONS	ECOSYSTEM PROCESSES & COMPONENTS	GOODS AND SERVICES (examples)
	Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO2/O2 balance, ozone layer, etc.)	1.1 UVb-protection by O3 (preventing disease) 1.2 Maintenance of (good) air quality 1.3 Influence on climate (see also function 2.)
2	Climate regulation	Influence of land cover and biol. mediated processes (e.g. DMS-production) on climate	Maintenance of a favorable climate (temp., precipitation, etc) for, for example, human habitation, health, cultivation
3	Disturbance prevention	Influence of ecosystem structure on dampening env. disturbances	3.1 Storm protection (e.g. by coral reefs) 3.2 Flood prevention (e.g. by wetlands and forests)
4	Water regulation	Role of land cover in regulating runoff & river discharge	4.1 Drainage and natural irrigation 4.2 Medium for transport
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers)	Provision of water for consumptive use (e.g. drinking, irrigation and industrial use)
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	6.1 Maintenance of arable land 6.2 Prevention of damage from erosion/siltation
7	Soil formation	Weathering of rock, accumulation of organic matter	7.1 Maintenance of productivity on arable land 7.2 Maintenance of natural productive soils
8	Nutrient regulation	Role of biota in storage and re-cyling of nutrients (eg.N,P&S)	Maintenance of healthy soils and productive ecosystems
9	Waste treatment	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	9.1 Pollution control/detoxification 9.2 Filtering of dust particles 9.3 Abatement of noise pollution
10	Pollination	Role of biota in movement of floral gametes	10.1 Pollination of wild plant species 10.2 Pollination of crops
11	Biological control	Population control through trophic-dynamic relations	11.1 Control of pests and diseases 11.2 Reduction of herbivory (crop damage)
	Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological & genetic diversity (and thus the basis for most other functions)
13	Nursery Function	Suitable reproduction habitat	Maintenance of commercially harvested species
	Production Functions	*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	14.1 Hunting, gathering of fish, game, fruits, etc. 14.2 Small-scale subsistence farming & aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	15.1 Building & Manufacturing (e.g. lumber, skins) 15.2 Fuel and energy (e.g. fuel wood, organic matter) 15.3 Fodder and fertilizer (e.g. krill, leaves, litter).
16	Genetic resources	Genetic material and evolution in wild plants and animals	16.1 Improve crop resistance to pathogens & pests, 16.2 Other applications (e.g. health care)
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	17.1 Drugs and pharmaceuticals 17.2 Chemical models & tools 17.3 Test- and essay organisms
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration & souvenirs (e.g. furs, feathers, ivory, orchids, butterflies, aquarium fish, shells, etc.)
	Information Functions	*Providing opportunities for cognitive development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery (scenic roads, housing , etc.)
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural & artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architect., advertising, etc
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	Science & Education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Source: Groot *et al.* (2002: 396)

- **APPENDIX TWO: VAAL RIVER PILOT STUDY QUESTIONNAIRE**



RHODES UNIVERSITY
Where leaders learn

Willingness to Pay Survey for the Benefits of the Control of Water Hyacinth to Residential Areas of the Vaal River

This survey is designed to gather information about how much you value the functioning of the Vaal River. It will take approximately 15 minutes and it would be greatly appreciated if you would complete it. Someone will be around to fetch it tomorrow at approximately the same time as it was dropped off, so if you do have any questions please don't hesitate to ask then. This survey is completely anonymous and the results will be used for research purposes only. Your household has been selected randomly due to its location with regard to the Vaal River.

Interviewer: ____

Interview number: ______________________

Metres from water (approx.): ________________

To take part in this survey it is important that you are at least 18 years old due to the fact that some of the questions are about taxes and income. Are you at least 18 years old?

☐ Yes ☐ No

(If yes, continue…….)

As you probably already know, there is a species of aquatic plant living on the Vaal River called water hyacinth.

1.1 Have you noticed any water hyacinth on the Vaal River?

☐ Yes ☐ No

1.2 If yes, have you noticed an increase in the amount of water hyacinth in the Vaal River in the past year?

☐ Yes ☐ No

1.3 Do you think that the presence of water hyacinth is a problem?

☐ Yes ☐ No

1.4 If yes, why do you think water hyacinth is problematic?

- ____

1.5 Can you think of any benefits that you would receive from the clearing of water hyacinth?

☐ Yes ☐ No

1.6 Has water hyacinth cost you or anyone else in your household, any money directly? (e.g. boat engine damage, have to travel further for recreational purposes, less people at guest lodge etc.)

☐ Yes ☐ No (If no, go to section 2…)

1.7 If yes, please describe:

- ____

  ____

  ____

1.8 Approximately how much was spent?

- ____

2. Willingness to Pay

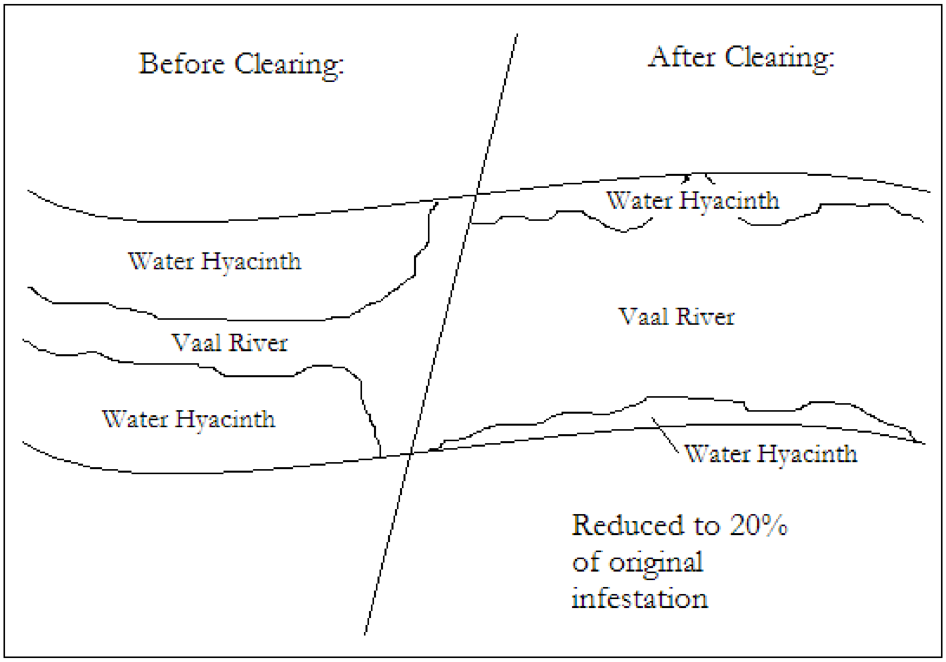
The next section of this survey is designed to measure the value to you of the benefit of the control of water hyacinth through your willingness to pay tax to support clearing projects in your area. Clearing at other invasion sites has been successful, and an 80% reduction in the plant is possible on the river. As you might already know, a portion of your municipal water tax already goes to the clearing of invasive aquatic species

Some of the problems already experienced with water hyacinth that are preventable through control are as follows:

- Poor quality drinking water
- Less drinking water/water for irrigation
- More human diseases in the water
- The siltation of rivers and dams
- Less area for recreational purposes
- Less plants and animals
- Broken farm equipment (pumps)

In South Africa there are a number of things that are necessary for the municipality to spend monthly local municipal rates on, and some of them are regarded as more important than the preservation of our aquatic resource. By spending more on housing or education, for example, less would be available for the control of water hyacinth and the invasive species would be allowed to spread further.

In the next question you are going to be asked to choose an amount that you would be willing to pay extra in monthly municipal rates for an 80% reduction (refer to diagram below) in the amount of water hyacinth on the Vaal River.



From the payment card below, please select the maximum that you would be willing to pay for an 80% clearing of water hyacinth taking into account your monthly household expenditure: (There is an option to choose another amount if none of the following are applicable.)

- ________________________________

R0	R2	R5
R7	R10	R15
R20	R30	R50
Other… Please Specify		

2.1 If you indicated a positive willingness to pay (i.e. more than R0)…

Why are you willing to pay for the clearing of water hyacinth?

- ____

____

____

2.2 If you chose R0…

Why are you not willing to pay for the clearing of water hyacinth?

- The government should pay for these types of problems ☐
- I don't use the river enough to have to pay for the control of water hyacinth ☐
- I don't believe that it is an important enough issue for the government to spend tax money on ☐
  I don't believe the money would be spent on the problem ☐
- Other (please specify):__________________________________

____

For all:

2.3 How sure are you that your answers have shown your accurate willingness to pay for the clearing of water hyacinth?

☐ Not at all sure ☐ Fairly sure ☐ Very sure

3. Information about you….

The final questions are designed to get some details about you. Please remember that the survey is completely anonymous and the results are to be used for research purposes only. Please also be aware that the survey is completely non-discriminatory and the information that you are about to give merely helps in the interpretation of the results.

3.1 How old are you?

- ____________________

3.2 What is your home language?

☐ English ☐ Afrikaans ☐ Xhosa ☐ Other:_________________

3.3 What is your race group?
☐ Black ☐ White ☐ Coloured ☐ Indian
☐ Other: _________________

3.4 Are you male or female?
☐ Male ☐ Female

3.5 How many years of education have you had?

Primary school up to grade 7 = 7 years	☐
Grade 8 = 8 years	☐
Grade 10 = 10 years	☐
Matric (Grade 12) = 12 years	☐
Tertiary education	☐

3.6 What is your job at the moment?

Professional (Doctor, business person, lecturer, etc.)	☐
White collar worker (secretary, clerk, shop assistant, etc.)	☐
Service person (Police, army, navy, air force, nurse, etc.)	☐
Blue collar worker (Builder, cook, cleaner, security guard, etc.)	☐
Student	☐
Housewife/husband	☐
Retired	☐
Self employed	☐
Unemployed	☐

3.7 What is your normal monthly income for your whole household, after tax?

- < R10 000 ☐
- R10 000 – R20 000 ☐
- R20 001 – R30 000 ☐
- R30 001 – R40 000 ☐
- R40 001 – R50 000 ☐
- > R50 000 ☐

3.8 How many people are in your household including dependants?

- ______________________

4. Thank you very much for your time. Are there any other comments that you would like to mention about the invasion of water hyacinth?

- ____

  ____

  ____

- **APPENDIX THREE: NAHOON RIVER STUDY QUESTIONNAIRE**

RHODES UNIVERSITY
Where leaders learn

Willingness to Pay Survey for the Benefits of the Control of Water Hyacinth to Residential Areas of the Nahoon River

This survey has been funded by the Working for Water programme, and is designed to gather information about how you value the Nahoon River. It will take approximately 5 minutes and it would be greatly appreciated if you would complete it. Someone will be around to fetch it tomorrow at about the same time as it was dropped off, so if you do have any questions please don't hesitate to ask then. This survey is completely anonymous and the results will be used for research purposes only. Your household has been selected randomly due to its location with regard to the Nahoon River.

There are no right or wrong answers to the questions in this survey. It is just meant to find out what your opinions are.

To take part in this survey it is important that you are at least 18 years old due to the fact that some of the questions are about taxes and income. Are you at least 18 years old?

☐ Yes ☐ No

(If yes, continue…….)

Approximately how many metres do you live from the Nahoon River? ________________

As you probably already know, there is a species of aquatic plant living on the Nahoon River called water hyacinth.

1.1 Have you noticed any water hyacinth on the Nahoon River?

☐ Yes ☐ No

1.2 If yes, have you noticed an increase in the amount of water hyacinth in the Nahoon River in the past year?

☐ Yes ☐ No

1.3 Do you think that the presence of water hyacinth is a problem?

☐ Yes ☐ No

1.4 If yes, why do you think water hyacinth is problematic?

- ____

1.5 Can you think of any benefits that you would receive from the clearing of water hyacinth?

☐ Yes ☐ No

1.6 Has water hyacinth cost you or anyone else in your household, any money directly? (e.g. boat engine damage, have to travel further for recreational purposes, less people at guest lodge etc.)

☐ Yes ☐ No (If no, go to 1.9…)

1.7 If yes, please describe:

- ____

1.8 Approximately how much was spent?

- ____

1.9 Do you use the river for any recreational activities (walking on banks, fishing, swimming etc.)?

☐ Yes ☐ No

1.10 If yes, what sort of recreational activities do you use the river for?

- ____

1.11 About how often do you use the river?

Once a month ☐
Twice a month ☐
Once a week ☐
Twice a week ☐
More often (please specify) ______________________________

1.12 Do you feel that these activities are affected by the presence of water hyacinth?

☐ Yes ☐ No

1.13 Do you watch any programmes on TV that deal with environmental issues?

☐ Yes ☐ No

1.14 Do you belong to any environmental groups, or have you made any donations to such groups in the past year (e.g. do you own a 'Wild Card' offered by the South African National Parks Board?)

☐ Yes ☐ No

2. Willingness to Pay

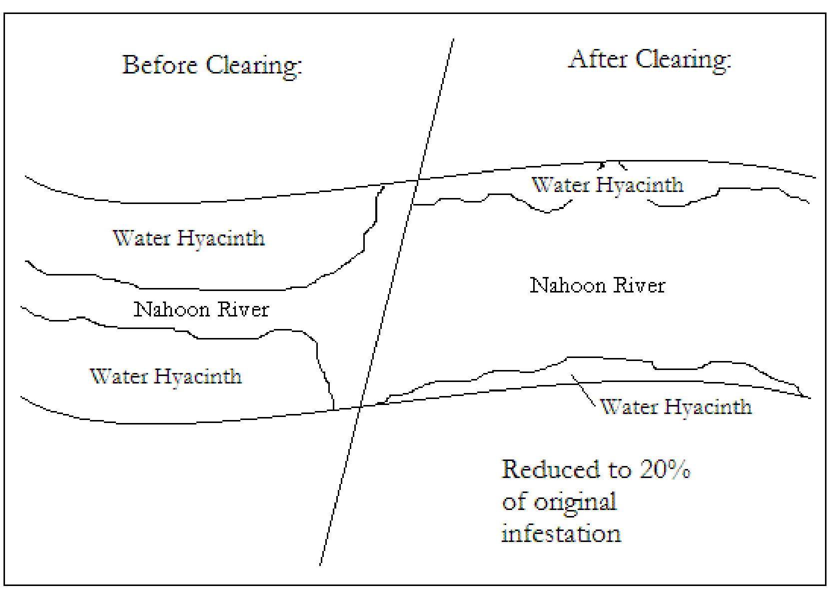
The next section of this survey is designed to measure the value to you of controlling water hyacinth through your willingness to pay a fee to support Working for Water in clearing water hyacinth in your area. Clearing at other invasion sites has been successful, and an 80% reduction in the plant is possible on the river (as shown in the map below). As you might know, a portion of your municipal water tax already goes to the clearing of invasive aquatic species, but with additional funds faster and more effective control is possible.

Some of the problems already experienced with water hyacinth that are preventable through the control are as follows:

- Poor quality drinking water
- Less drinking water/water for irrigation
- More human diseases in the water
- The siltation of rivers and dams
- Less area for recreational purposes
- Fewer plants and animals
- Broken farm equipment (pumps)

But, there are lots of things that you can choose to spend your monthly budget on and some of them you may regard as more important than clearing water hyacinth.

In the next question you are going to be asked to choose an amount that you would be willing to pay as a monthly donation to the Working for Water organisation in your area for an 80% reduction in the amount of water hyacinth on the Nahoon River. These funds would be privately managed and would go directly towards clearing programmes in your area.



From the payment card below, please select the maximum that you would be willing to pay for an 80% clearing of water hyacinth taking into account your monthly household spending: (There is an option to choose another amount if none of the following are applicable.)

R0	R2	R5
R7	R10	R15
R20	R30	R50
Other…Please Specify R____		

2.1 If you indicated a positive willingness to pay (i.e. more than R0)…

Why are you willing to pay for the clearing of water hyacinth?

- ____

  ____

2.2 If you chose R0…

Why are you not willing to pay for the clearing of water hyacinth?

- The government should pay for these types of problems ☐
- I don't use the river enough to have to pay for the control of water hyacinth ☐
- I don't believe the money would be spent on the problem ☐
- Other (please specify):________________________________

  ____

For all:

2.3 How sure are you that your answers have shown your accurate willingness to pay for the clearing of water hyacinth?
☐ Not at all sure ☐ Fairly sure ☐ Very sure

3. Information about you….

The final questions are designed to get some details about you. Please remember that the survey is completely anonymous and the results are to be used for research purposes only.

Please also be aware that the survey is completely non-discriminatory and the information that you are about to give merely helps in the interpretation of the results.

3.1 How old are you?

- ____________________

3.2 What is your home language?

☐ English ☐ Afrikaans ☐ Xhosa ☐ Other:__________________

3.3 What is your race group?
☐ Black ☐ White ☐ Coloured ☐ Indian
☐ Other: __________________

3.4 Are you male or female?
☐ Male ☐ Female

3.5 How many years of education have you had?

Primary school up to grade 7 = 7 years	☐
Grade 8 = 8 years	☐
Grade 10 = 10 years	☐
Matric (Grade 12) = 12 years	☐
Tertiary education	☐

3.6 What is your job at the moment?

Professional (Doctor, business person, lecturer, etc.)	☐
White collar worker (secretary, clerk, shop assistant, etc.)	☐
Service person (Police, army, navy, air force, nurse, etc.)	☐
Blue collar worker (Builder, cook, cleaner, security guard, etc.)	☐
Student	☐
Housewife/husband	☐
Retired	☐
Self employed	☐
Unemployed	☐

Other (please specify): ____________________________________

3.7 What is your normal monthly income for your whole household, after tax?

- < R10 000 ☐
- R10 001 – R20 000 ☐
- R20 001 – R30 000 ☐
- R30 001 – R40 000 ☐
- R40 001 – R50 000 ☐
- > R50 000 ☐

3.8 How many people are in your household including dependants?

- ____________________

4. Thank you very much for your time. Are there any other comments that you would like to mention about the invasion of water hyacinth?

- ____

  ____

  ____

- **APPENDIX FOUR: REGRESSION RESULTS**

Appendix 4a: Linear Regression Results for Nahoon River Study – Phase 1 and 2 all variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-13.42205	7.617119	-1.762090	0.0820
DISTANCE	-0.004528	0.005596	-0.809212	0.4209
NOTICED	-8.064268	7.044882	-1.144699	0.2558
INCREASE	4.279119	4.144761	1.032416	0.3051
PROBLEM	2.425681	4.817632	0.503501	0.6160
BENEFIT	5.907342	3.632635	1.626186	0.1079
DIRECT	8.620214	4.910043	1.755629	0.0831
REC	0.890581	4.576808	0.194586	0.8462
OFTEN	-0.381633	3.631744	-0.105083	0.9166
AFFECTED	2.160803	3.882386	0.556566	0.5794
ENVPROG	3.486678	3.615108	0.964474	0.3378
ENVGRP	8.333485	5.439310	1.532085	0.1295
SURE	2.307702	3.302922	0.698685	0.4868
P2	3.310610	2.954372	1.120580	0.2659
TERTIARY	-2.851495	2.958183	-0.963935	0.3381
RACE	-5.046914	5.658532	-0.891912	0.3752
LANG	4.850039	4.427923	1.095330	0.2767
SEX	2.258180	2.725336	0.828588	0.4099
Y	10.96232	1.655113	6.623305	0.0000
R-squared	0.676770	F-statistic		9.073027
Adjusted R-squared	0.602179	Prob(F-statistic)		0.000000
S.E. of regression	12.48087			

Appendix 4b: Probit Regression Results for Nahoon River Study – Phase 1 and 2 all variables

VARIABLE	COEFFICIENT	STD. ERROR	Z-STATISTIC	PROB.
C	-4.393921	2.366754	-1.856518	0.0634
DISTANCE	-0.001867	0.001235	-1.511373	0.1307
NOTICED	0.871738	1.812658	0.480917	0.6306
INCREASE	0.771194	0.945321	0.815801	0.4146
PROBLEM	0.743377	0.973325	0.763750	0.4450
BENEFIT	1.122427	0.721709	1.555235	0.1199
DIRECT	5.786667	17030141	3.40E-07	1.0000
REC	-1.396464	1.138759	-1.226303	0.2201
OFTEN	0.131510	1.085779	0.121121	0.9036
AFFECTED	1.348400	0.978058	1.378650	0.1680
ENVPROG	3.019035	1.224187	2.466155	0.0137
ENVGRP	5.373598	21659508	2.48E-07	1.0000
SURE	1.482324	0.905981	1.636154	0.1018
P2	0.900713	0.761815	1.182325	0.2371
TERTIARY	-0.245309	0.888943	-0.275956	0.7826
RACE	2.570841	1.736381	1.480575	0.1387
LANG	0.621277	0.907473	0.684623	0.4936
SEX	-0.822852	0.703527	-1.169611	0.2422
Y	0.582971	0.572565	1.018175	0.3086
Mean dependent var	0.762887	**S.D. dependent var**		0.427522
S.E. of regression	0.261953	**Akaike info criterion**		0.723902
Sum squared resid	5.352309	**Schwarz criterion**		1.228227
Log likelihood	-16.10925	**Hannan-Quinn criter.**		0.927826
Restr. log likelihood	-53.12978	**Avg. log likelihood**		-0.166075
LR statistic (18 df)	74.04106	**McFadden R-squared**		0.696794
Probability(LR stat)	9.25E-09			
Obs with Dep=0	23	**Total obs**		97
Obs with Dep=1	74			

Appendix 4c: Logit Regression Results for Nahoon River Study – Phase 1 and 2 all variables

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-8.070531	4.343563	-1.858044	0.0632
DISTANCE	-0.003033	0.002211	-1.372139	0.1700
NOTICED	1.506480	3.250156	0.463510	0.6430
INCREASE	1.291315	1.666131	0.775038	0.4383
PROBLEM	1.646330	1.867132	0.881743	0.3779
BENEFIT	1.925790	1.289370	1.493590	0.1353
DIRECT	29.25391	15885990	1.84E-06	1.0000
REC	-2.475255	1.920845	-1.288628	0.1975
OFTEN	0.081851	1.988475	0.041162	0.9672
AFFECTED	2.453068	1.729251	1.418573	0.1560
ENVPROG	5.545318	2.215794	2.502633	0.0123
ENVGRP	27.96059	17750323	1.58E-06	1.0000
SURE	2.799658	1.652357	1.694342	0.0902
P2	1.500474	1.337029	1.122245	0.2618
TERTIARY	-0.432781	1.576575	-0.274507	0.7837
RACE	4.384791	3.169315	1.383514	0.1665
LANG	1.333717	1.526047	0.873968	0.3821
SEX	-1.369186	1.231814	-1.111520	0.2663
Y	0.928214	0.981038	0.946155	0.3441
Mean dependent var	0.762887	**S.D. dependent var**		0.427522
S.E. of regression	0.257043	**Akaike info criterion**		0.726210
Sum squared resid	5.153535	**Schwarz criterion**		1.230535
Log likelihood	-16.22117	**Hannan-Quinn criter.**		0.930134
Restr. log likelihood	-53.12978	**Avg. log likelihood**		-0.167229
LR statistic (18 df)	73.81722	**McFadden R-squared**		0.694688
Probability(LR stat)	1.01E-08			
Obs with Dep=0	23	**Total obs**		97
Obs with Dep=1	74			

Appendix 4d: Log-Linear Regression Results for Nahoon River Study – Phase 1 and 2 all variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.797225	0.525825	-1.516142	0.1335
DISTANCE	-0.000456	0.000386	-1.181191	0.2411
NOTICED	-0.098355	0.486322	-0.202242	0.8403
INCREASE	0.339005	0.286121	1.184829	0.2397
PROBLEM	0.488184	0.332571	1.467910	0.1461
BENEFIT	0.650356	0.250768	2.593454	0.0113
DIRECT	0.041977	0.338950	0.123843	0.9018
REC	0.059040	0.315946	0.186869	0.8522
OFTEN	-0.207320	0.250707	-0.826942	0.4108
AFFECTED	0.360787	0.268009	1.346174	0.1821
ENVPROG	0.914927	0.249558	3.666187	0.0004
ENVGRP	0.119345	0.375486	0.317842	0.7515
SURE	0.394812	0.228007	1.731575	0.0873
P2	0.104283	0.203946	0.511324	0.6106
TERTIARY	0.038567	0.204209	0.188859	0.8507
RACE	0.305656	0.390620	0.782490	0.4363
LANG	0.105104	0.305668	0.343849	0.7319
SEX	-0.054682	0.188135	-0.290651	0.7721
Y	0.497136	0.114256	4.351079	0.0000
R-squared	0.707966	**F-statistic**		10.50513
Adjusted R-squared	0.640574	**Prob(F-statistic)**		0.000000
S.E. of regression	0.861579			