TOWARDS AN ECONOMIC VALUATION OF BIODIVERSITY: FRESHWATER ECOSYSTEMS[1]

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Abstract
The valuation of environmental resources and biodiversity as a whole has become an increasingly necessary topic of research as our understanding of the importance and benefits of the healthy functioning of the environment develops. A major shortcoming of current research is that there has been very little advance in the valuation of freshwater biodiversity. The paper examines the socioeconomic importance of biodiversity and outlines the fundamentals of economic valuation thereof. The difficulties associated with the valuation of freshwater ecosystems are outlined and the results of a study presented to the South African Water Research Commission incorporating resource economics into freshwater quality objectives is described. The valuation of freshwater biodiversity is an important and complicated task that needs close attention in future research.

THE INCREASING AWARENESS of the importance of biodiversity for sustainable living has economic implications. Firstly, at the level of individual households and firms, decisions concerning what to consume and what and how to produce goods and services can have important implications for the long-term sustainability of society. Secondly, policy makers need to be persuaded that actions to maintain, let alone that serve to increase biodiversity, are worthy of being 'on the agenda' and deserves the diversion of funds from other social and economic needs of the nation.

The paper is divided into three sections: an overview of the value that humans place on biodiversity; the economic framework that may be used for placing a monetary value on biodiversity; and the resource economics approach to the valuation of freshwater goods and services.

1. SOCIO-ECONOMIC CONTEXT: THE ECONOMIC CONTRIBUTION OF BIODIVERSITY TO SOCIETY

Klaphake *et al.* (2001) present a convincing case for the downside effects of declining biodiversity in that "freshwater ecosystems have experienced a significant loss of their biodiversity due to various human activities (with) around 30% of the fish species threatened, mostly because of habitat destruction…(and) the introduction of alien species, pollution and overexploitation…also (being) important factors…" This has led to as much as 65% of freshwater mammals being threatened; "birds and mammals depending on freshwater have lost their breeding and feeding areas" and as much as 50% of the world's wetlands are estimated to have been lost in 20th Century. On the positive side "attitudes towards the integration of nature protection in water policy have changed and biodiversity loss of freshwater (has) increasingly been perceived as a key challenge…" for at least two reasons. Firstly, it has been recognised that the continued

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alteration of freshwater biodiversity is not sustainable; and secondly, it has been realised that "less modified freshwater ecosystems and the preservation of freshwater biodiversity provides significant economic and social benefits to society" (Klaphake *et al.,* 2001).

The extent to which biodiversity is of value to society is partly indicated by the willingness of governments to sign conventions and to enact legislation to protect or increase biodiversity in the absence of a clear understanding of its value in the market place. Governments have been persuaded that the loss of species could have important implications for discoveries yet to be made. However, the extent to which biodiversity is of value in a quantifiable sense and understanding why greater biological diversity is of greater benefit to society and whether this would come at a cost to, say, increased production of food - what to many has been accepted as 'progress' - is not universally accepted as a given.

Economic contributions made by biodiversity

Heal (2004: 105 – 114) identified four major economic contributions made by biodiversity, namely to: productivity, insurance, genetic knowledge, and to ecosystem services.

It has been demonstrated that increased biodiversity contributes to productivity in plant systems (e.g. increases in biomass from more varieties of grasses); in microbial communities in which greater diversity made for greater stability and robustness in the presence of environmental fluctuations; and in the development of high yielding 'green revolution' agricultural crops (Heal 2004: 106 - 107).

The 'insurance role' of biodiversity flows from the differing resistance of individual varieties of plant and animal life to disease. In the event of a new virus a major disaster may occur where the production of food depends entirely or largely on limited varieties of crops, a situation which has been dramatically demonstrated around the world, such as in the Irish potato famine of the 19th century, crises in rice production in the 1970s, and bovine diseases and avian flu epidemics. Biodiversity can form an important insurance against disaster. The questions that arise from this are:

- How do individual producers and society in the light of possible downside uncertainty make socially efficient choices?
- To what extent has agricultural production led to a change for the better or worse in biodiversity and at what cost?

Biodiversity is a source of genetic knowledge; natural organisms contain properties from which much can be learnt. For example, the knowledge of how the San people of Namibia for centuries have been able to endure long periods without significant sustenance was contained in a root plant, which pharmaceutical firms are exploring as an appetite suppressant.

Biodiversity allows for the optimal functioning of ecosystems, the nature of which is not immediately obvious until the removal of key species result in the collapse of the system in its entirety. Even where diversity may not be important at a local level it may nevertheless be vital for the functioning of ecosystems at a regional or global level. O'Keefe and de Moor's (1988) analysis of the increase in the blood-feeding Blackfly population of the Fish River in the Eastern Cape of South Africa following its use as an irrigation canal and the increase in cattle, sheep and goat morbidity is an example of the consequences of a change in water regime leading to the elimination of diversity. Heal (2004: 110) cites the diminution of keystone species leading to the collapse of local ecosystems, such as otters on the Californian coast and Chihuahua desert kangaroo rats as examples, as have the introduction of exotic species led to the transformation of systems, such as in the introduction of the rinderpest virus in East Africa.

What do economists need to understand/know about freshwater ecology to enable an economic analysis of the value of biodiversity?

According to ecologists Armsworth, Kendall and Davis (2004) for a comprehensive economic analysis of the value of biological diversity (biodiversity), a number of criteria and functions need to be understood.

Biodiversity can be measured on three different scales: the species, community and spatial and can only be conserved properly *in situ*, that is, in its natural habitat. An exception to this is that some plant species often survive in artificial or different habitats to their origin.

Humans contribute highly to biodiversity threats by means of habitat loss (conversion of wetlands into grazing or for cropping), harvesting (of fish, plants and water), the introduction of exotic species and climate change.

Current freshwater conservation efforts are focussed on specific species or of areas with a high biodiversity, techniques that are more common in terrestrial habitats. The disappointing level of success of conservation projects in terrestrial habitats, and the inherent differences between terrestrial and freshwater systems is cause for serious concern in adopting this approach to freshwater ecosystems.

Freshwater ecosystems as a whole differ greatly from terrestrial systems as they have had to endure far more frequent and dramatic disturbances and specialist species have had less time to develop (Moss, 2000: 1). It is for this reason that individual organisms are not intricate to the freshwater system and its functioning. The focus of conservation should therefore not be concentrated at the species level but rather on the system as a whole.

Another argument against species specific conservation is the nature of species interactions within the freshwater system (Moss, 2000: 2). The food chain in freshwater systems display 'bottom-up' characteristics placing emphasis on the system functioning as a whole as opposed to individual species protection.

Ecological data is often expensive and difficult to obtain. The species-area relationship model provides an estimate of the number of different species in an area, as long as the size of the sites is similar. This model is seen as robust. It does have several shortcomings though. The fact that a species is found in a site in the present does not necessarily mean that it will be there in the future. In order to make accurate estimates a dynamic model should be used.

The representation of the dynamic processes of a population or community is essential in modelling ecological production. Ecological systems are not static and have many endogenous (interactions etc.) and exogenous factors acting upon them. To make an accurate estimate of how biodiversity is affected, dynamic processes should be quantified. However the current model used excludes three quintessential factors, namely spatial, temporal and individual variation. Spatial variation indicates that, in practise, a population or community will often differ from modelled outcomes. There are many migratory species too and their migratory patterns are not taken into consideration. Temporal variation cannot be modelled as population and community dynamics change erratically over time and cannot be harnessed or quantified. Reproduction timing can also vary, making the estimation of population growth inaccurate if an average is taken.

Economically, the dynamic model is more pertinent as it measures population and community dynamics as opposed to a static pattern. This produces more accurate outcomes, but the dynamic model is also a lot more costly and time intensive.

The models currently used in the process of selecting conservation sites do not reflect the social impact of the project on the affected communities, such as the MARXAN model. This model takes into account the cost of placing a conservation area at a particular site, but not its social impacts.

A shortcoming of conservation is the lack of economic analysis that has been undertaken as conservation issues are interdisciplinary in nature. Conservation planning approaches should specify the desired goals of the conservation efforts. This can lead to the prioritising of different conservation efforts and assist economists in placing a value on the project. The valuation of biodiversity does not take into account how climate change and other exogenous factors will affect it, thus bringing an element of uncertainty and risk. The return on the investment is unclear as it is not certain whether the biodiversity will last due to disturbances. Conserving biodiversity competes with other social investments and interests. Alternative land and water uses and the utilisation of natural resources have high impacts on human livelihood. Most conservation happens in developing countries, in their rural areas. The people living in the rural areas often rely on the natural resources as a source of income and livelihood.
Current protected lands are said to encapsulate only a small proportion of total biodiversity. With natural resources becoming scarcer, justifying the conservation of biodiversity over alternative land uses, such as agriculture, is difficult. Fertile land and space for other development options is very precious.

Different species are valued differently according to human preferences and public interest. Individual species or groups can be considered as surrogates for biodiversity although a shortcoming of the approach is that there is not much evidence that surrogates are in fact good predictors of other components of biodiversity.

Currently conservation is focussed on ecosystem resources with benefits that accrue to human beings in some manner, be it for resource or cultural use. However, with the extinction rate of species expected to be on the increase this century a broader approach must be undertaken. This is easier said than done, as land is needed for human purposes such as agriculture to feed the growing population of the world and for housing. These will ultimately decrease the amount of biodiversity depending on the area.

2 ENVIRONMENTAL AND RESOURCE ECONOMICS AND THE CONSERVATION OF BIODIVERSITY

Modern mainstream Economics and its application to the natural environment, Environmental Economics, is predicated upon the assumption that value is determined by the value that humans place on goods and services. Whereas many resources, that are scarce relative to human wants, are adequately priced in mixed market economies, many environmental resources are not. This is due both to the abundance of the resources, such as sunlight and air, and in some cases water, and their nature as common property, such as the oceans.

Economists concerned with environmental issues, beginning in earnest in the early 1970s, have significantly developed a theoretical framework and methods of determining environmental values, but biodiversity has only relatively recently been picked up on their radar screen. The question that arises is: what do economists need to know about ecosystem functioning in order to place the issue sufficiently within the sights of policy makers to enable the necessary legislative and budget decisions to be made?

Pioneering work on the economics of biodiversity include Swanson's *The International Regulation of Biodiversity* (1994), Simpson, Sedjo and Reid's (1996) work on '*Valuing biodiversity for use in the pharmaceutical industry'* and Heal's *Nature and the Marketplace* (2000) and *Bundling Biodiversity* (2003). The International Conservation Union's, IUCN Business Unit has produced a List of Documents posted on the Biodiversity Economics Library[3]. Of the nearly 400 items only 60 were 'published' while the remainder were unpublished documents (about 260) and presentations (about 60). What is remarkable is that there appeared to be no published works listed that deal specifically with the issue of the economics of freshwater biodiversity.

The 2004 Special Issue of the Journal *Resource and Energy Economics* has made a particularly useful contribution to opening the debate among Economists by bringing together papers focusing on the economic analysis of aspects of biodiversity and a setting out of the understanding of biodiversity by ecological scientists.

What do biologists need to understand to facilitate an economic analysis of freshwater biodiversity?

There are several important areas of 'difficulty' in undertaking economic analyses of freshwater biodiversity. The first difficulty is simply the ability to translate an increase or decrease in biodiversity into a quantifiable effect. In economic terms it requires the establishment of a functional relationship between the extent of biodiversity and a level of benefit and in the case of biodiversity the calculation of the frequency of downside occurrences (i.e. risk). For example, an increase in freshwater pollution that leads to a decrease in biodiversity could be quantified in terms of the ability of the water body to mitigate pollution, which would increase the cost of water purification, or increased pollution could decrease the edible fish catch. Put differently, in what way does the decrease in biodiversity lead to additional costs or a decrease in benefits to society?

Situations in which the benefits of an action and the costs of undertaking the production of goods and services accrue directly to the individual firm or household are relatively easily analysed. These benefits and costs are reaped and borne privately and do not either benefit or harm other members of society. In the case where there are effects external to private households or firms, society either reaps a benefit for which it has not had to bear a cost (e.g. where a land owner increases water flow into a public dam or reduces water pollution, but enjoys no private benefit from the action) or society bears a cost (e.g. when a polluting firm uses a river to dispose of waste at no private cost). In both cases there is a divergence between private benefits and costs and

[3] Access at http://biodiversityeconomics.org

the benefits and costs borne by society as a whole, the problem of 'externalities.' The information needed to undertake a valuation of biodiversity in the presence of externalities requires an identification and quantification, both of the external effects and of the beneficiaries and/or those who bear the cost of maintaining or increasing freshwater diversity.

A further difficulty arises where the good or ecosystem service is one from which it would not be possible to exclude someone from using it, namely a 'public good.' In the environmental sphere examples of public goods are public parks and biodiversity (Heal, 2004: 113). Private markets do not usually produce efficient amounts of public goods and services because once produced it is difficult or impossible to make people pay for them. The remedy for an insufficient production of public goods, such as biodiversity, is for governments to produce the goods or to provide incentives for their production. This gives rise to the necessity for placing a value on biodiversity in order to have the issue placed 'onto the agenda.' Heal (2001, 2003) provides some interesting examples of markets producing at adequate levels by effectively integrating conservation and development via tourism.

Economic Assessment of Biodiversity

Environmental Economists recognise that Total Economic Value (TEV) consists of the use value of goods and services and of non-use values. Use value is simply that satisfaction that is gained from the commodity in the consumption of it, whether in the short term, such as food, or in the longer term, such as housing and durable goods, or even from the option of use at a later stage, called option value.

It has been argued by some that use value should be further categorised into direct and indirect use value, with the latter including ecosystem services such as water and nutrient recycling and carbon sequestration (e.g. Blignaut and de Witt, 2004: 56). Direct use value itself may be divided into direct consumption (typical market goods and services) and the value of non-consumptive uses such sunshine and recreation.

Non-use values may be derived from the knowledge that something will exist at some time in the future, usually called existence value, but what some prefer to think of both existence and bequest values. In the latter case, people place a value on an asset, which could include biodiversity, because they wish others to be able to enjoy it at some time in the future.

In its simplest form then, *Total Economic Value* (TEV) can be thought of as consisting of the aggregate of *Use Value* plus *Option Value* plus *Existence Value*. In the case of 'use value' market prices would be the chief source of determining value, having made whatever correction would be required to take account of interventions in the price, such as in the form of taxes or subsidies. In the case of durable assets it is also necessary to account for consumption taking place over an extended period of time by reducing the expected future flow of services to a present value equivalent. Not all resources consumed though, are priced in the market. In cases where resources are abundant relative to consumption the market value may be extremely low or even zero, such as the consumption of sunshine. Other services may only have an indirect 'price' such as a good view, or an unpolluted freshwater lake used for recreation purposes. Deriving a value in these circumstances is much more difficult.[4]

Option and Existence values present understandable difficulties. Deriving the value of an option for the use of a lake, a river or an estuary would require a potential consumer to estimate the amount that he or she would be willing to pay (WTP) for potential future use. In the case of existence values a similar problem is faced. It is well known however, that many people are willing to donate money to a 'Save the X' (Whale, Panda, Bear, Shark…) campaign for the use or enjoyment by later generations (and thus contains an element of 'bequest value').

In many studies the existence value has been found to be greater than the use value. For example, Pearce (1991) found that the existence value placed on the Grand Canyon exceeded the use value. The methods used to determine non-market values have developed significantly over the past three decades, but are not without controversy or easily used or come at a significant cost.

As was noted earlier, mainstream economics determines value relative to that placed on an asset by humans. Some economists have questioned the rationality of the *homo economicus* foundation of economics and have argued that intrinsic values, which are independent of the values perceived by humans, could be assigned to certain species such as owls (Erikson, 2000). Along these lines Heywood and Watson (1995) proposed that Total Value should be reformulated to include Non Human Value (NHV) in addition to Total Economic Value (TEV), but this is not a concept that has been very widely accepted by economists because of the likelihood of double counting, and also from an environmental ethical viewpoint it would be difficult to develop a clear argument for one species over another.

The approach to measuring the economics of biodiversity would be an application of Benefit-Cost Analysis, which will not be elaborated upon here.[5] What biodiversity economics does recognise is the difference in incidence of benefits and costs of biodiversity protection between different parts of society (Chapman, 2000: 275). A weakness of economic valuation is that most methods are estimates of specific values such as recreation, landscape and existence values rather than TEV.

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[4] In the context of conservation, the use of traditional exponential discounting (e.g. 7% p.a. compound over a period of 25 years) for choices that need to be evaluated over long time horizons, has recently been questioned by behavioural economists who postulate that individuals' discount rates decline with increasing time (i.e. a hyperbolic discounting of the value of a conservation project is more realistic) (Heal, 2004: 113).

[5] Both a physical linkage approach and behavioural linkage approaches to estimation would be used. The former seeks to link the damage (or benefit) from decreasing (or increasing) biodiversity to the monetary value to humans. The latter approach uses indirect and direct approaches to the estimation of benefits including the Averting Expenditure, Travel Cost and Contingent Valuation Methods, of which the last mentioned method would be an important technique in measuring the impacts of freshwater biodiversity changes.

3. RESOURCE ECONOMICS APPROACH TO THE VALUATION OF FRESHWATER GOODS AND SERVICES

In a paper prepared for the South African Water Research Commission (WRC) Mander *et al*. (2002) outline a resource economics approach to determining the Freshwater Ecological Reserve. The 'reserve' is described as "The water required to meet peoples' basic domestic needs and the needs of the environment" by the National Water Act 36 of 1998. While the reserve sets out the ecological requirements for rivers, estuaries, wetlands and groundwater the study was focused on rivers.

There is said to be a lack of data concerning the value of rivers to society, while the benefits of water abstraction are easily calculated and have been calculated in previous studies. The project was therefore focused on the valuation of ecosystem goods and services, excluding the benefits of water abstraction, as a basis for economic analysis.

An understanding of the range of ecosystem services available can help stakeholders understand that there other river users that rely on the resource for economic, cultural and environmental reasons and that tradeoffs have to be made for the efficient use of the system. Benefits range from 'a place to catch fish' to 'a system that mitigates floods', clearly a large variation in stakeholder needs.

Various Resource Quality Objectives (RQO) are set for specific desired management classes of rivers (a set of pre determined minimum quality levels for specific river reaches). Stakeholders have different perceptions of what these minimum quality levels involve, for example access to specific water volumes versus a certain level of functional ability of the system as a whole. Due to this limited level of understanding of different management classes, stakeholders are unsure what each class allows in terms of the level of ecosystem goods and services other users are able to enjoy, while they generally have a good grasp of what benefits they expect. River ecosystem goods and services provide a 'common currency' in terms of ecosystem functionality, and hence biodiversity, which is said to be directly positively related to the level of river health. A focus on river ecosystem goods and services can therefore provide a basis for the common understanding of the desired management class and level of functionality.

The study provided for the WRC uses both primary and secondary data in a number of techniques to value the freshwater goods and services supplied by the Crocodile River catchment in South Africa. A number of assumptions were made in the cost and benefit calculations due to the inherent difficulties in environmental valuation studies. The goods and services valued displayed direct and indirect use values, non-use benefits were not included in the survey. This is perhaps due to the subjectivity and difficulty in non-use price calculations.

The information obtained however proved useful in: ranking the importance of the various freshwater goods and services, calculating the magnitude of value associated various quality levels (and therefore management classes), where the benefits were being distributed and in which reaches there was a high demand. These values that are associated with the current river condition, and clearly play an important role in local and regional economies, can inform decisions in setting the ecological reserve, management class and resource quality objectives. The calculated values can also prove instrumental in attempting to make tradeoffs between different river uses.

The method used by Mander *et al*. (2002) provide a useful assessment on the relative values of the freshwater goods and services that most directly affect human consumption incorporating both use and non-use values, and can be useful in decisions regarding river quality management. Although important functions of the river that are good indications of river condition are valued and incorporated this study does not provide a valuation of freshwater biodiversity as a whole. The study does however go a long way in developing a technique to incorporate economic considerations in policy decisions concerning freshwater use and conservation.

CONCLUSION

The earth's natural resources provide important services, quite apart from food and fibre, through the mitigation of pollution and the stabilisation of climate, services that are recognised to have an economic value. However, the economics of biodiversity is not yet well understood and apparently little has been written specifically on the economics of freshwater biodiversity. This may be a function of how much is known about the biological and ecological effects of differing levels of freshwater biodiversity, or simply that to date few economists have been interacting with freshwater scientists. A weakness of economic valuation is that estimates are generally site or location specific and do not evaluate ecosystems as a whole, which implies that holistic valuations are still some way off.

A better understanding of the functional relationship between biodiversity and economically important ecosystem services would allow a clearer estimation of the value of biodiversity conservation (Heal, 2004: 113). The operational question as posed by Heal (2004) is: "How much of biodiversity (do) we need to conserve to attain (the) goal" of maintaining important ecosystem services and biogeochemical cycles?

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