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Economic Valuation of Ecosystem Services: The Case of Lake Elliðavatn and Lake Vífilsstaðavatn

Halla Margrét Jóhannesdóttir

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Hagfræðideild Háskóla Íslands

Leiðbeinendur: Brynhildur Davíðsdóttir og Daði Már Kristófersson

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Ritgerð til M.S.-prófs

Halla Margrét Jóhannesdóttir

Kt.: 060783-2929

Leiðbeinendur: Brynhildur Davíðsdóttir og Daði Már Kristófersson

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Abstract

Managing the environment is a complicated task constantly faced by decision-makers in all the world´s communities. In Iceland heated debates have been going on over the recent years concerning whether natural areas should be industrially developed or protected for recreational purposes. The aim of this paper is to bring another perspective to the Icelandic debate, an economic valuation of ecosystem services. The term "ecosystem services" refers to the benefits human population derives from ecosystems. The ecosystem services provided by two lakes in the capital area of Iceland, Lake Elliðavatn and Lake Vífilsstaðavatn were assessed according to the categorization scheme of the Millennium Ecosystem Assessment (MEA) published in 2005. The MEA classifies ecosystem services into four categories; provisioning services, regulating services, cultural services and supporting services. Services from each category were identified and valued with economic valuation methods; market price, defensive behavior, travel cost and factor income. The final result is that the annual value of ecosystem services provided by Lake Elliðavatn in 2009 is in the range of ISK 83.263.647 - 101.308.524 (constant ISK 2009). For Lake Vífilsstaðavatn this value is in the range of ISK 5.713.925 - 5.981.560 (constant ISK 2009). It was concluded that although an economic valuation of ecosystem services can only serve as an indicator of a potential value of the ecosystem services provision, it still provides an important contribution to the debate of environmental manament in Iceland.

Ágrip

Umræða um nýtingu lands, verndun náttúruverðmæta og efnahagslega framþróun hefur farið sífellt hærra í samfélögum bæði erlendis og hérlendis síðastliðin ár. Aukinn áhugi á sjálfbærri þróun og skynsamlegri nýtingu náttúruauðlinda kallar á breytingar og ný viðmið þegar kemur að því að meta hvenær er í lagi að raska landi fyrir efnahagslega framþróun og hvenær fórnarkostnaður er of mikill. Markmið þessarar ritgerðar er að koma fram með nýtt sjónarhorn í umræðuna um nýtingu lands á Íslandi, hagrænt mat á þjónustu vistkerfa. Hugtakið „vistkerfisþjónusta“ vísar til þess samfélagslega ábata sem menn njóta af vistkerfum náttúrunnar. Hér eru metnir þeir þjónustuþættir sem vistkerfi vatnanna Elliðavatns og Vífilsstaðavatns á Höfuðborgarsvæðinu veita nærliggjandi samfélagi og hagrænt virði þeirra áætlað.

Notast var við flokkun sem sett var fram í Þúsaldarmatinu á þjónustu vistkerfa sem birt var 2005. Meginflokkarnir eru fjórir, þjónusta sem veitir beinar afurðir eins og fisk eða rafmagn, þjónusta sem temprar ýmsa náttúrlega eða ónáttúrulega ferla svo sem vatnsflæði eða mengun, menningarleg þjónusta og svo stuðningsþjónusta svo sem hringrás næringarefna. Vistkerfisþjónustur úr hverjum flokki voru metnar og virði valdra þjónustuþátta áætlað með hagrænum aðferðum svo sem markaðsvirði, varnarkostnaði, ferðakostnaði og þáttatekjum. Lokaniðurstöður hljómuðu upp á 83.263.647 - 101.308.524 krónur (ISK 2009) fyrir árlega þjónustu Elliðavatns árið 2009 og 5.713.925 - 5.981.560 krónur (ISK 2009) fyrir árlega þjónustu Vífilsstaðavatns árið 2009. Lokaályktanir rannsóknarinnar eru að þrátt fyrir að hagrænt mat á þjónustu vistkerfa geti eingöngu gefið vísbendingu um virði slíkrar þjónustu gefur það samt sem áður nýtt sjónarhorn og er þar af leiðandi mikilvægt innlegg í umræðu um nýtingu lands á Íslandi.

Formáli

Ritgerð þessi er til 60 ECTS eininga og var lokaverkefni höfundar til meistaraprófs í umhverfis og auðlindafræðum frá hagfræðideild Háskóla Íslands. Verkefnið er hluti af stærra rannsóknarverkefni um hagrænt virði þjónustu vistkerfa í Heiðmörk. Að verkefninu standa Háskóli Íslands, Rannsóknastöð Skógræktar ríkisins að Mógilsá, Skógræktarfélag Íslands, Skógræktarfélag Reykjavíkur, Reykjavíkurborg, Garðabær og Orkuveita Reykjavíkur. Verkefnið var fjármagnað af Rannsóknarnámssjóði Rannís, Orkuveitu Reykjavíkur, Garðabæ og Reykjavíkurborg.

Höfundur vill koma á framfæri þökkum til allra þeirra sem komu að verkefninu að einhverju leyti með gögnum, aðstoð eða ábendingum. Sérstakar þakkir fá Brynhildur Davíðsdóttir leiðbeinandi fyrir vandaða leiðsögn og yfirlestur á öllum stigum, Daði Már Kristófersson meðleiðbeinandi fyrir aðstoð við tölfræðiúrvinnslu og Kristín Eiríksdóttir fyrir góðar ábendingar varðandi öflun og úrvinnslu rannsóknargagna. Einnig fær Guðni Guðbergsson hjá Veiðimálastofnun sérstakar þakkir fyrir mikilvægt framlag til rannsóknarinnar. Síðast, en ekki síst, fá kærar þakkir Anna Margrét Sigurðardóttir fyrir prófarkalestur og Gabriel Pic fyrir ómældan stuðning.

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1. Introduction

Managing the environment is a complicated task constantly faced by decision-makers in all the world´s communities. With increasing knowledge and public awakening concerning environmental matters, tradeoffs in land use are becoming a bigger issue. In Iceland the question whether natural environments should be protected for recreational purposes or industrially developed is a big issue and has been the subject of heated debates over recent years. One of the most apparent of such debates concerned the hydro power plant at Kárahnjúkar and the subsequent aluminum plant in Reyðarfjörður. The mindset of the Icelandic population towards the nature has been changing, not least because of the extensive discussion concerning this big project. Until today the evaluation of most of such projects has been based on an environmental impact assessment and estimation of financial profitability. But a changing mindset calls for new ways to evaluate development projects and future evaluation methods should aim to account for full social cost of proposed projects.

Over the past few decades the importance of ecosystems with regard to functions and ecosystem goods and services has been highlighted by the field of ecological economics. The earliest references regarding ecosystem functions date back to the 1960´s and early 1970´s. More recently a rapid growth has been in the publications on the benefits of natural ecosystems to human society (de Groot, Wilson, & Boumans, 2002). A certain climax was reached with the publication of the Millennium Ecosystem Assessment (MEA) published in 2005. Despite this development in both USA and widely in Europe, Iceland has not followed and is far behind in this field.

Holistically assessing the flow of goods and services from ecosystems and valuing in terms of economic benefits is a promising method, which can contribute substantially to decision making in environmental management. In 2007 an ambitious project was started through a collaborative effort between four research entities (The University of Iceland, The Icelandic Forest Research at Mógilsá, The Reykjavík Forest Association and The Icelandic Forest Association) aiming to perform the first holistic economic evaluation of ecosystem goods and services in Iceland. The main purpose of this big project was to provide a high profile environmental valuation study with up to date methods where ecosystem goods and services provided by widely used recreational area are valued. This study could then serve as a point of reference for future valuations. The subject area chosen was the nature reserve of Heiðmörk situated in the capital area of Iceland. Heiðmörk is a multi-functional natural area which simultaneously provides services such as clean water, wild-life habitat, various recreational opportunities and carbon sequestration. Thus, it was considered a good example for the first evaluation study in Iceland.

The present study is a sub-study of this Heiðmörk project where two lakes situated within the area, Lake Elliðavatn and Lake Vífilsstaðavatn are addressed specifically. The ecosystem goods and services provided by these two lakes are categorized into four categories according to the classification scheme presented by the MEA. They are then valued economically by accepted valuation methods. The ultimate aim of the study is to answer the question:

- What is the worth of the ecosystem goods and services provided by Lake Elliðavatn and Lake Vífilsstaðavatn to the surrounding society?

The thesis is divided into seven main sections. The second section is a review of literature where the foundation of this study is compiled. There, concepts, methods and issues that are relevant to the present study are introduced. In the third section the study site is presented and described, first the Heiðmörk nature reserve in general, then specifically the two subject lakes and potential services provision. All analysis and results for each services category are put forth in the fourth section. The fifth section brings together the results for each category to arrive at a total value. In the sixth section the results are discussed, weaknesses of approaches are addressed and future research suggested. The seventh section presents the final conclusion of the study.

2. Literature review

Ecosystems, their functions, services and evaluation in terms of land management have been the subject of various studies, both theoretical and empirical. Following is a review of literature on the subject. In the first section the term ecosystem is explained, what is meant by ecosystem services and some classification schemes are presented. In the second section trade-offs in ecosystem services and land management are addressed and how they essentially make the grounds for the valuation of ecosystem services. In the third section the concept of value is presented and different perspectives on that concept discussed. The fourth section is focused on the economic valuation of nature and its ecosystems, the fifth section presents different valuation methods and the sixth section presents issues related to them.

2.1 Natural ecosystems, services and classification

An ecosystem is a natural unit which consists of a living community and its non-living physical environment that interact to form a stable state system. The term is a multi-scale concept and can refer to various situations such as a rotting log, a lake and the earth (Bingham, et al., 1995). The biosphere and its natural ecosystems, through transformations of natural resources such as soil, water and living organisms, yield a flow of ecosystem goods and services, on which humanity is ultimately dependent (MEA, 2005; Daily, et al., 2000). The benefits people derive directly or indirectly from ecosystems are what is referred to as ecosystem services. These benefits are e.g.; basic life support services such as provision of clean air and water; maintenance of soil fertility; maintenance of livable climates; pollination of crops and other vegetation; control of potential pests; provision of genetic resources; production of food and fibre; and provision of cultural, spiritual and intellectual experiences (Costanza, et al., 1997; MEA, 2005). As humans depend on this flow of ecosystem goods and services provided by the biosphere and its natural ecosystems, the world´s ecosystems can in fact be seen as capital assets which yield a flow of valuable services if properly managed (Daily, et al., 2000). These capital assets are frequently referred to as natural capital. Natural capital has two major components; non-renewable stocks of natural resources such as fossil fuels and other minerals and renewable stocks embodied in ecosystems (Jansson, Hammer, Folke, & Costanza, 1994). Costanza and Daly (1992) define natural capital as “a stock that yields a flow of valuable goods or services into the future, e.g. a fish stock which provides an annual flow or yield of fish”. The maintenance of this flow is then based on the ecosystem´s structure and diversity and on its integral functioning (Costanza & Daly, 1992).

In the past, humans had plentiful of natural resources and ecosystem services to utilize at will. Manufactured and human capital, were the limiting factors of economic development while natural resources were abundant. At that time the scale of operating was too small to interfere substantially with natural processes and the free provision of goods and services. We have now reached a point in history where the natural capital has become the limiting factor of economic development while the human and manufactured capital are highly abundant (Costanza & Daly, 1992). Humans now extensively dominate the biosphere, with the result of vast transitions in the composition, structure and function of ecosystems (Vitousek, Mooney, Lubchenco, & Melillo, 1997). The operating scale has increased so that the capacity of the natural ecosystems to provide the flow of vital services and goods is being reduced substantially (Costanza & Daly, 1992). At the same time, demands for services such as food and clean water are increasing worldwide. Following a global awakening concerning these matters, a breakthrough in this field was made in the year 2000 when national governments, the private sector, nongovernmental organizations and scientists all participated in the United Nations project of establishing the Millennium Ecosystem Assessment (MEA). The MEA is an integrated assessment of the world´s ecosystems, their services and the consequences of their changes and degradations for human well-being. More than 1360 experts worldwide contributed to the work. The assessment also includes possible options for enhancing the conservation of ecosystems and their contribution to meet human needs. The MEA submits a classification scheme where all ecosystem services are categorized into four categories;

1. Provisioning services such as food and water.
2. Regulating services such as regulation of floods, drought, land degradation and disease.
3. Cultural services such as recreational, spiritual, religious and other non-material benefits.

4. Supporting services such as nutrient cycling.

The services within each category then differ, depending on the type of ecosystem in question (MEA, 2005). Other classification schemes for ecosystem services have been put forth by others, such as Goulder and Kennedy (1997) and De Groot et al (2002) and following in table 1 these three different classification schemes are compared.

Table 1. Comparison of classification schemes from the MEA (2005), Goulder and Kennedy (1997) and De Groot et al (2002), with examples of each category.

Goulder and Kennedy 1997	DrGroot et al. 2002	MEA 2005
i. Sustaining plant and animal life • Wood • Fresh water • Fuel • Food	i. Production • food • raw materials • genetic • medicinal • Ornamental	i. Provisioning • Food • Wood • Fresh water • Fuel • Medicinal • Ornaments
ii. Provision of production inputs • Soil formation • Primary production • Climate regulation • Flood prevention • Nutrient cycling	ii. Regulation • nutrient regulation • soil formation • climate regulation • disturbance prevention • water regulation • water supply • soil retention • waste treatment • Pollination	ii. Supporting (e.g.) • Nutrient cycling • Soil formation • Primary production • Water supply • Pollination
	iii. Habitat • Refugium • Nursery	iii. Regulating • Climate regulation • Flood prevention • Disease prevention • Water purification
iii. Amenity • Aesthetic • Spiritual • Recreational • Educational	iv. Information • Aesthetic • Spiritual and historic • Recreation • Science and education • Cultural and artistic	iv. Cultural • Aesthetic • Spiritual • Recreational • Educational
iv. Provision of option value		

The importance of consistent classification of ecosystem services for valuation is an issue that has been discussed in the literature (see e.g. Wallace (2007) and Fisher & Turner (2008)). Although different classification schemes may be valid, it can be helpful for credibility that classification is consistent between valuation studies. While there is not one single, accepted method of categorizing all ecosystem services, the framework provided by the MEA is widely accepted (Ozdemiroglu, Tinch, Johns, Provins, Powell, & Twigger-Ross, 2006) and commonly used at the present (Martın-Lopez, Gomez-Baggethun, Lomas, & Montes, 2009; E.S.E.E.conference, 2009). Thus the MEA framework was used as a starting point in the valuation study of the ecosystem services of Heiðmörk and in particular for the subject of the present study, the services provided by the lakes of Heiðmörk, Lake Elliðvatn and Lake Vífilsstaðavatn.

2.2 Tradeoffs in land-use and ecosystem services

Ecosystem services do not operate in isolation. Different ecosystem services in an ecosystem variously interact with one another, often in complicated and unpredictable ways. This is one of the principal challenges in environmental or ecological management (Rodriguez, et al., 2005; Heal, et al., 2001). When the environment is managed to increase the use of a certain ecosystem service, the flow of another ecosystem service may be reduced. This is called a tradeoff, as one service is traded off for another (Rodriguez, 2006). Tradeoffs in environmental management also take place when natural capital is traded off for man-made capital, e.g. buildings or golf courts. Sometimes in land management clear decisions are made to trade a certain ecosystem service to enhance another one. The results from such tradeoffs may be little but sometimes they have substantial repercussions. For example, biodiversity has commonly been traded off for monoculture in agriculture to increase the production of certain crops, presumably with high market value. However, by keeping biological diversity in agriculture the probability of the crops becoming infected by diseases can be minimized and nutrient efficiency increased, which leads to less nutrient runoff into waters (Tilman, 1999). In other cases, tradeoffs arise without the awareness of decision-makers. This may happen due to ignorance of the interactions between ecosystem services, incorrect or incomplete knowledge of such interactions or lack of markets for the ecosystem services in question (Rodriguez, 2006). For further clarification of how tradeoffs arise in land use, mangroves demonstrate a good example. There, different types of tradeoffs occur, both between ecosystem services and between natural capital and man-made capital. Mangrove ecosystems provide various valuable ecosystem services. Firstly, they are exploited for forestry products such as fuel-wood, tannins, pulp-wood and timber which is a provisioning service and obvious as such. Secondly, they provide important supporting services as they provide complex habitats for juvenile shrimp and fish. This complex habitat decreases the efficiency of predatory fish in feeding on them, thus providing an important support in local fisheries. However, this service is less obvious and often ignored by the forestry sector. Thirdly, mangrove areas are reclaimed for agriculture, aquaculture and residential development which eventually results in the loss of this resource in coastal areas (Grasso, 1998).

When it comes to land-use management, human societies generally tend to focus mainly on the provisioning services from ecosystems, followed by regulating, cultural and supporting services (Foley, et al., 2005; Rodriguez, et al., 2005). This order is mostly based on the fundamental short-term needs of humans for food, fiber, timber and habitat. The intended consequence of land use is to appropriate primary production for human consumption (Vitousek, Mooney, Lubchenco, & Melillo, 1997) but the unintended consequences, often adversely affecting other ecosystem services, may remain hidden or just behind in the order of priorities (DeFries, Foley, & Asner, 2004). Wetlands are another example as they provide water storage, maintenance of surface and groundwater flows, biochemical cycling, retention of water-suspended and dissolved materials, accumulation of peat, maintenance of characteristic biological energy flows, and maintenance of characteristic habitats (Lupi, Kaplowitz, & Hoehn, 2002).

2.3 Nature and the concept of value

When seeking ways to deal with the tradeoffs described above, ultimately we must come up with some kind of values. Things are constantly being valued and prioritized based on their values, including natural ecosystems and resources. Value, however, is a term that can represent different things. Values can be e.g. sentimental, religious, cultural or economic. Certainly they are not only represented in monetary terms. Thus, the concept of value has different meanings both to people in general and also academically, between and within disciplines (Bingham, et al., 1995). Concerning the valuation of nature, its ecosystems and resources, there are two opposing perspectives well known in the literature, the nature-centered and the anthropocentric perspective. The tension between these two concerns has been a key subject of environmental philosophy for a long time (Vilkka, 1997). The anthropocentric perspective, bases all values on benefits or satisfaction that humans derive from natural assets, thus only humans have intrinsic value while everything else has instrumental value for humans. According to some, the nature-centered perspective can be ascribed from two viewpoints, the ecocentric and the biocentric. On one hand, from an ecocentric viewpoint, ecosystem processes have intrinsic value while individual species have instrumental value. On the other hand, from a biocentric viewpoint, animal and plant species have intrinsic value while non-living nature has an instrumental value (Meffe & Carroll, 1997). Others have classified these views of environmental valuation differently, e.g. Teutsch (1985) who established a system of classification based on the anthropocentric, pathocentric, biocentric and holistic concepts of environmental ethics. However, an analysis of different interpretation and classification in environmental philosophy is not a fundamental issue here. Rather to look shortly into the key differences between the nature-centered and anthropocentric perspectives.

> Man tends to be self-centered in is his view towards nature, considering himself standing above and beyond all other living creatures. Culture seems to have abstracted humans away from nature, letting them feel such a unique and remarkable beings that their interests should have absolute priority over the interests of other creatures. This attitude makes the rights and interests of other creatures, or nature, always give way to human interests and rights of enjoyment of the values of life (Adapted from Skúlason, 2006).

This view is what Páll Skúlason (2006) and some other environmental philosophers think violates the principles of true morality. A great controversy in environmental ethics regarding attitude towards nature is whether organisms and natural entities can be considered moral objects, that is objects of direct moral responsibility (Gorke, 2003). This is one central conflict of the opposing perspectives of the anthropocentric and nature-centered views. Is nature only of instrumental value to humans or does it have an intrinsic value which human should respect morally?

Utilitarianism, a perspective within the anthropocentrism, claims that natural things have value to the extent that they confer satisfactions to humans. Economists rely on the utilitarian viewpoint and the economic approach to ecosystems is one of anthropocentric instrumentalism where ecosystems and their services are considered valuable if they satisfy humans. Many environmentalists (and environmental philosophers as demonstrated above) are against this view asserting that nature has intrinsic value. However, anthropocentric utilitarianism does not necessarily mean that ecosystems must be exploited and have no value in their natural states. Substantial sacrifices may be made to protect and maintain species and ecosystems just as long as humans take satisfaction from doing so. The term satisfaction should be interpreted broadly in this context, taking in both mundane enjoyments and lofty pursuits (Goulder & Kennedy, 1997). Taking more aspects into account surely may give better odds for the conservation and protection of species and natural ecosystems. Still, as Gorke (2003) points out, a basic structural weakness of the anthropocentric and economic approach to protection is that the burden of proof rests upon the species or the ecosystem in question. The economic approach implies a burden of proof for the species or ecosystem that they are worth protecting, that is that the services they provide give enough satisfaction for humans for them to be worth protecting. This burden of proof is problematic from a practical standpoint because such a proof is only accepted if the utility of the species or ecosystem is known at least in first approximation and it must be quantifiable. Also, when subjected to cost benefit analysis it must be shown to weigh more than potential cost of competing utility values. The problem is that complete knowledge of this is impossible. We often have to make do with limited and temporary knowledge, but when it comes to making value judgements, irreversible decisions may be made on an insufficient and constantly changing knowledge basis. Only properties of ecosystems and species that are already known can be quantified. Due to lack of knowledge, all attempts of quantification are likely to represent a rather arbitrary portion of all the potential possibilities of utilization that exist. Therefore it is important to view such attempts from the perspective of this lack of knowledge (Gorke, 2003).

Swart et al. (2001) relates the anthropocentric perspective to consequentialism where human actions are considered to be good if they lead to more positive consequences than negative. There, the benefits humans derive from nature can be various material goods, services and non-material goods such as educating information and leisure. Conserving and restoring nature can cause disadvantages such as limitations for human economic progress while development of certain ecosystems can lead to natural disasters such as flooding or diseases (Swart, van der Windt, & Keulartz, 2001). The anthropocentric, utilitarian approach allows for value to arise in number of ways, focusing not only on direct use values (Goulder & Kennedy, 1997). The approach allows for different non-market valuation methods to take into account other values such as recreational, cultural and existence values. Gorke (2003) rightfully points out that if assigning a quantitative value to various kinds of utility is possible at all, it can only occur under extreme simplification of complex phenomena. It is true that all the non-market valuation methods do involve simplifications and they do have shortcomings.

Economists generally do not subscribe to the nature-centered perspective and ultimately the anthropocentric values, which are directly based on utilitarianism, create what we call economic values (Davidsdottir, 2006). Since services and products are generally something humans value monetarily, and often pay for, the term itself "ecosystem service" points out that the ecosystems, with their structures and function are resources which provide an economic value (Limburg, O'Neil, Costanza, & Farber, 2002).

The present study aims at valuing ecosystem services in economic terms and therefore all valuation methods and economic values worked out are based on an anthropocentric perspective.

2.4 The economic valuation of ecosystem services

When it comes to allocating natural capital, the aim of decision makers must always be to achieve the best (or most efficient) allocation of resources. Essentially, options need to be evaluated in terms of economic value to the nation, community or the individual in the long run (Davidsdottir, 2006). However, many tradeoffs frequently arise representing practical dilemmas to decision makers because conventional economic frameworks, on which decisions are based, in most cases rely on the market to reveal value. However, many of the ecosystem goods and services are so called non-market goods that are not exchanged in markets and therefore excluded from formal decision making frameworks. Non-market goods and services are in most cases received free of charge and are not considered to add to welfare or utility. This may result in suboptimal allocation of natural capital and its uneconomical degradation. By attempting to capture the economic value of services provision from natural ecosystems, an important and useful contribution can be made to environmental management and decision making. Decision makers, both in public and private sectors, are increasingly realizing this fact. They want and need better information about the values of ecosystem services in weighing the advantages and disadvantages of their decisions.

It has been argued above how economic valuation of natural capital has become an urgent matter and important in order to prevent unwarranted assumptions of higher profits from economic development projects than the value of the natural capital traded off instead. As we try to economically value ecosystem services, we do not aim to put a monetary value on the total value of natural capital itself, as it is impossible. Nature itself, the stock, is invaluable. What is to be valued is the flow, the goods and services provided by the stock.

2.5 Valuation methods

How can the flow of ecosystem services be valued economically? The theory of economic valuation of ecosystem services is based on the consumer demand theory which again is rooted in the utility theory. According to the utility theory, the consumer´s main problem is how he allocates his limited income to maximize his own utility. So, he weighs the utility of consumption bundles and chooses from all the bundles he can afford, the one that maximizes his utility. This model defines the value of a good by its contribution to individual utility and is therefore fully anthropocentric. The general definition of a classic utility model, on which the valuation is based, is not described in detail here but can be found in any economic textbook. The classic model can then be extended to include ecosystem services (e.g. Haab & McConnel (2002), Hanley, Shogren and White (2007)).

The core of general financial valuation is about estimating the costs and benefits directly associated with a project to assess whether the project is profitable or not. Thus, in a general valuation process of a project, all discounted private benefits involved, e.g. sales of products are estimated versus all costs involved, e.g. investment and material costs. Risk factors related to the project, cost of capital and desired returns from investors are reflected by the chosen discount rate. Financial gain is simply the sum of discounted net profits while the project lasts:

Equation 1 $$NPV = \sum_{t-1}^{T} \frac{(B_t - C_t)}{(1+r)^t}$$

Here, *NPV* denotes net present value, B_t denotes private benefits in year t, C_t denotes private costs in year t, r denotes the discount date and T denotes the duration of the project

In a financial evaluation the only costs and benefits accounted for are the ones that affect the cash flow and the project bottom line. They are then valued by the market prices at the date they occur. Economic valuation is different as it does not only take into account everything possibly accountable in a financial valuation, but all costs and benefits which affect social welfare as a whole. In the present study, direct benefits, such as recreational fishing and electricity production, from the lakes, Elliðavatn and Vífilsstaðavatn, are evaluated by using economic valuation methods.

As most of the services provided by the two lakes do not have a market price and the benefits derived from them are unknown, a simple net value can not be found. In environmental economics there are several methods used to assess the value of changes in environmental quality and the availability of ecosystem services. These methods differ both in terms of what they measure and what data is required. They can then be categorized according to whether they are based on revealed preferences or stated preferences by the consumers. Following, some of the main economic valuation methods are listed and described with special focus on the methods used in the present study.

2.5.1 Revealed preference methods

Methods using revealed preferences consider the decisions people make following a change in environmental quality. The value of ecosystem services is estimated through market goods either used in the consumption of the environmental service or directly affected by the access of an environmental service. So, in fact these methods involve a kind of detective work where clues about the values individuals place on environmental services are pieced together from the evidence that people leave behind as they respond to prices and other economic signals (Freeman, 2003). As the analyst has to infer the value on a non-market good from consumer´s behavior in the market, those methods are sometimes known as indirect methods (Hanley, Shogren, & White, 2007). Revealed preference methods mostly bring forth use values and are therefore only appropriate for certain types of cases. Following, the most commonly used revealed preference methods are listed and described.

Travel cost method

The travel cost technique was first suggested in the 1930´s by Harold Hotelling to enable the National Park system to determine admission fees for national parks. This method has constantly been applied and refined by economists over the last decades to assess the economic value of various public resources (Sohngen, Lichtkoppler, & Bielen, 2000). Travel cost models are typically used to estimate use values for recreation activities and changes in values associated with changes in environmental quality. The general model is based on consumer´s decisions to visit recreation sites that differ in travel cost and quality (Boyle, 2003). A main recognition of the model is that the cost of travelling to a site is an important component of the full cost of a visit and that, for any given site, there will usually be a wide variation in travel cost across any sample of visitors to that site (Freeman, 2003). A statistical relationship between observed visits and the cost of visiting is then used to approximate the demand curve for visits to the site. In the present study the travel cost model plays a key role in the estimation of recreational value of Lake Elliðavatn and Lake Vífilsstaðavatn. Following an example of a basic travel cost model from Freeman (2003) is presented for theoretical explanation. Assume an individual who derives utility from going to a recreational site (r). The utility of the individual depends on factors such as the quality of the site (q), the time spent on site (t_1) and the quantity of goods (X). The individual aims to maximize his utility according to:

Equation 2 $$u(X,r,q)$$

The individual has monetary constraints given by*:*

Equation 3 $$M + P_w \cdot t_w = X + c \cdot r$$

where M denotes the income of the individual, P_w denotes the wage rate, t_w denotes the hours worked, c denotes the cost of the trip and r denotes the number of trips. The individual also has time constraints given by:

Equation 4 $$t^* = t_w + (t_1+t_2)$$

where t^* denotes the total time of the individual and t_2 denotes the time spent on site. The time constraints reflect the opportunity cost time spent in the recreational activity. That is, by spending time traveling to and at the recreational site, time is taken from other activities. It is assumed that the individual can choose his working hours, thus the opportunity cost is the wage rate. The monetary cost of a trip consists of the admission fee (*f*) and the monetary cost of the travel, denoted by $p_d \cdot d$ where p_d is the cost per driven kilometer and d is the distance of the round-trip to the site. Substituting the time constraint (Equation 4) into the monetary constraint (Equation 3) gives:

Equation 5 $$M + P_w \cdot t^* = X + p_r \cdot r$$

where p_r denotes the full price of a visit which again is given by:

Equation 6 $$p_r = c + p_w \cdot (t_1+t_2) = f + p_d \cdot d + p_w \cdot (t_1+t_2)$$

The demand function of the individual for visits to the recreational site can be yielded by maximizing equation 2 from above subject to the constraints of equation 5:

Equation 7 $$r = r\,(p_r, M, q)$$

(Freeman, 2003)

A basic travel cost model can be put forth in different ways but the fundamental contents are the same. Travel cost models can be distinguished, depending on whether the aim is to estimate the demand for a single site or the demand for many sites. Single-site models are appropriate for estimating the total use or "access value" of a site. There, if the site is eliminated, the lost value is the total consumer surplus under the single-site demand function. To estimate the demand for many sites, the most widely used model is the random utility maximization (RUM) model. It takes into account the individual´s discrete choice of one recreation site over some other possible sites, on a single choice occasion in a season. The individual´s choice is assumed to reveal how he trades off one site characteristic for another. Since trip cost is always included as one of the characteristics, the model implicitly captures trade-offs between money and other characteristics (Parsons, 2003). In this study the single site model is applied to estimate the access value of the subject lakes.

The travel cost method inherently comprises certain issues which are described further in section 2.6 below. However, one of its major advantages is undoubtedly that it is based on actual behavior and thus less prone to bias than methods that are based on hypothetical situations.

Hedonic pricing method

The hedonic pricing method is based on the theory of characteristics value, first proposed by Lancaster (1966) and Rosen (1974). Hedonic pricing models are generally property value models used to infer the premium that households pay to buy a property near an environmental amenity or away from an environmental disamenity (Boyle, 2003). A typical example of such property is a real estate. The price of a real estate depends on factors like size, location, view, garden etc, in addition to other environmental factors such as noise level, air quality and proximity to green areas. The choice of a house and its associated price implies therefore an implicit valuation of the environmental amenities related to the house. The core of the hedonic pricing method is that it relies on market transactions for some distinguished goods, such as real estate, to figure out a value of underlying key characteristics, such as the environment. It is thus an indirect valuation method as the value consumers reveal for the characteristic per se is not being directly observed but it is derived from observable market transactions (Taylor, 2003). The hedonic pricing method is outside the scope of this study and is therefore not described in details here. For further clarification see e.g. Tyrvainen (1997), Haab & McConnell (2002) or Hanley, Shogren & White (2007).

Defensive behavior and damage costs

Defensive behavior is when actions are taken to reduce the impact of environmental damages. For example measures made to reduce exposure to pollution or mitigate disadvantageous effects (Dickie, 2003). Economists have acknowledged that people, or decision makers, sometimes change their behavior to decrease negative environmental impacts in order to avoid loss of welfare or to sustain existing levels of utility (Ribaudo & Shortle, 2001). Subsequently, a value placed on an environmental resource is revealed as the services preserved must be worth at least what the people paid to avoid the damage. The method of valuing defensive behavior is also referred to as environmental defensive expenditures (Escofet & Bravo-Pena, 2007), preventive expenditures (Pomeroy, 1992), averting behavior (Freeman, 2003) or averting expenditures (Ribaudo & Shortle, 2001). Such values have been used in various empirical studies as estimates of the value of the environment (Laughland, Musser, Shortle, & Musser, 1996), see e.g. Gerking and Stanley (1986) and Abdalla, Roach and Epp (1992).

Damage cost is another method in ecosystem valuation. There the focus is on real resource costs, direct or indirect, that are derived as a consequence from an environmental damage. Direct costs are the essential expenditures to compensate for the damage, e.g. illness treatments, reparations or replacements for damaged things.

Indirect costs are e.g. when opportunities for profits are lost or productivity decreases due to environmental pollution. The core of the damage cost method is that the reduction in real resource costs is used to measure the benefits of reduced pollution (Dickie, 2003).

The two methods differ mainly in two ways. One is that the defensive behavior method focuses on how people respond to environmental changes by observed behavior and the impact of the behavior on the outcomes experienced. In the damage cost method however, it is assumed that there are no behavioral responses to environmental changes or that behavioral responses are not effective. Secondly, defensive behavior is intended to estimate a somewhat theoretically consistent measure of an economic value like willingness-to-pay (WTP) but the damage cost is not (Dickie, 2003). In the present study the defensive behavior method is applied to assess the value of regulating services. Thus, the method and theory behind is explained in detail here below.

The defensive behavior method is commonly used in the context of human health, such as in the case of contaminated drinking water or air pollution. Dickie (2003) uses a model, developed by Harrington & Portney (1987) to illustrate how defensive behavior, damage cost and welfare are related. Following, the basic model is demonstrated, modified and simplified so that it is applicable to the present study.
Instead of using individual utility we use social utility. The social utility U is given by the function:

Equation 8 $U = U(X, Q)$

Where X denotes for example transportation and Q denotes the water quality of a lake. A distinguishing factor of the defensive behavior model is that bad water quality of the lake does not just happen, but is influenced by behavior, which in this case would be planning and management of the adjacent area. The quality of the lake is again a function of certain factors:

Equation 9 $Q = Q(E, Z)$

Here the E denotes the lakes exposure to pollution and Z denotes some exogenous factors that affect how susceptible and sensitive the lake and its ecosystem is to pollution. Now, exposure to pollution is affected by polluting substances released in the adjacent area and the planning and management of the area. This would be according to the function:

Equation 10 $E = E(\alpha, A)$

The ambient level of pollution is denoted by α and A denotes averting behavior. Ambient pollution increases pollution while averting behavior reduces exposure.
The aim is to define the “defensive expenditure function” (Bartik, 1988) that gives the minimum cost of maintaining desired water quality level of the lake Q° when the price of defensive behavior is p_a and ambient pollution is α:

Equation 11 $$D(p_a, Q°, \alpha, Z) = p_a \cdot A°$$

The minimum defensive expenditure is a function of price, water quality level and ambient pollution because A°, the level of averting behavior is a function of these variables (Dickie, 2003).

This method is applied in section 4.2 since the municipality of Kópavogur had a pipeline and a sedimentation pond constructed to prevent pollution from the adjacent residential area from going unimpeded into Lake Elliðavatn. Thereby, we have an estimate of certain willingness to pay to maintain desired water quality. Still, even though defensive behavior can be seen to reveal a certain willingness to pay, it shall be noted that it is not consistent with willingness to pay as obtained by valuation methods such as contingent valuation. This has been demonstrated in studies such as by Bartik (1988), where averting cost was examined as a lower bound on willingness to pay, and Laughland et al. (1996). In the latter, the relationship between willingness to pay, obtained with contingent valuation, and averting cost was studied revealing a low correlation. Nevertheless, defensive behavior does provide a value, using available data when more thorough methods are too expensive or not practicable.

Factor income

Factor income is based on enhanced income that can be attributable to the provision of ecosystem services (de Groot, Wilson, & Boumans, 2002; Freeman, 2003). If a factor q is a factor of production, then changes in q lead to changes in production or production cost which in turn affect things such as prices, the quantity of output and returns to other factor inputs. Assume a good x is produced with a production function:

Equation 12 $$x = x(k, w, \ldots, q)$$

where k and w representing production factors such as capital and labor and the marginal product of q is positive. With given factor prices (p_x, p_k) there is a cost function:

Equation 13 $$C = C(p_w, p_k, x, q)$$

As q affects the production and supply of the good x, effects of changes in q can be defined and measured through changes in market variables related to x. A change in q will cause shifts in cost curves and factor demand curves. The consequences of these shifts then depend on conditions in factor and product markets. There are two ways through which the changes in q can affect x, it can affect the prices of x to consumers or it can affect the income and profits received by owners of factor inputs used in the production of x (Freeman, 2003).

In the present study this method is applied in the attempt to capture the factor income value of Lake Elliðavatn in terms of salmon production in the Elliðaár River and the method is described in that context in section 4.4.5.

Avoided cost and replacement cost

Avoided cost is about estimating a possible cost avoided that would be incurred if a certain ecosystem service ceased to be provided. Examples are e.g. services provided by wetlands; flood control, which avoids damage costs of properties, and waste treatment, which avoids pollution and possible health costs. Replacement cost is when the cost of replacing a function of an ecological system with human-engineered systems is used as a measure of economic value. An example is natural waste treatment by marshes which can partly be replaced with costly artificial treatment systems (de Groot, Wilson, & Boumans, 2002; Freeman, 2003).

2.5.2 Stated preference methods

Stated preference methods elicit values directly through survey methods. The answers, in the form of monetary amounts, choices, ratings or other indications of preferences, are scaled according to a suitable model of preference to yield a measure of value. Stated preference methods are more prone to bias than revealed preference methods, yet they can provide an important contribution, as surveys are often the most effective way to understand people´s preferences (Brown, 2003). The revealed preference methods estimate only the use value of environmental services, and even then the methods are only applicable if that value affects behavior in a measurable and interpretable manner. For other cases and to include non-use values, stated preference methods with hypothetical markets are essential. Following, three major types of stated preference methods are introduced shortly but they are not applied in the present study.

Contingent valuation methods (CVM)

Contingent valuation methods are based on asking individuals directly for monetary values for a particular good, service or environmental change (Freeman, 2003). To implement a CVM a sample of the affected population is selected and asked questions on well specified scenarios to elicit the preferences of each respondent with respect to an environmental project. The key part of any CV study is the description of the scenario, the hypothetically planned change in environmental quality, and the question that elicits the individual respondent´s willingness to pay (WTP) or willingness to accept (WTA) for a certain change in the environment. From the results of the survey, a demand function for the environmental service in question can be obtained corresponding to consumption theory. Usually the method is used to value a single good but sometimes also for few closely related goods that have a different level of a certain key attribute. From that conclusions can be derived about the value of this certain attribute (Brown, 2003).

The main disadvantages of the CV method are related to the fact that the market is hypothetical and therefore people may not fully take their budget constraint into account or be tempted to answer strategically to influence the outcome in some manner (Mitchell & Carson, 1989). Moreover, people may not take into account all the other improvements to the environment they might want to support (Kahneman & Knetsch, 1992) or they may not understand completely what is involved in the suggested environmental change. Despite the inherent problems, the contingent valuation method is the most popular method for valuing ecosystem services as it is the only method that can be used to estimate existence value. It is widely used in the USA and Europe for various issues such as regarding water quality and wilderness protection (Lindenmayer & Burgman, 2005).

2.6 Issues in valuation

While a very important contribution to environmental management, economic valuation of ecosystem services is a complicated matter and subject to various issues. Compared to other forms of capital, most of the time there is a great lack of information and details about natural capital, ecosystems and their flow of services. Ecological functions and processes are generally inadequately understood and monitoring limited. Consequentially, the importance of ecosystem services is often only appreciated upon their loss (Daily, et al., 2000). Moreover, as ecosystems are complex and dynamic and often interact in non-linear ways, even though some knowledge exists, all predictions concerning desired levels of services flow become difficult.

One issue regarding valuing natural capital and the flow of ecosystem services concerns the question of what is to be valued and why? In the beginning of any valuation study, experts are faced with the question of what services to value, why and how. There are constraints related to money, time etc. and therefore what is to be valued must be decided carefully, also because the choice of which attributes to value is itself a valuation decision and a challenging one (Bingham, et al., 1995). Drawing boundaries is another issue but that is a critical step in any ecosystem services valuation process because at these boundaries the explicit analysis ends. Some boundaries can be fairly easy to draw, such as the boundaries of a lake or a watershed. However, other boundaries can shift greatly over space and time which causes certain problems (Limburg, O'Neil, Costanza, & Farber, 2002). Yet another issue in ecosystem services valuation regards double counting. It is important to consider how different ecosystem services interact early in the process as there can be complementarities and/or conflicts between different ecosystem services (Ozdemiroglu, Tinch, Johns, Provins, Powell, & Twigger-Ross, 2006). Such things can complicate the process of valuation and lead to double counting (Barbier, 1994; Chee, 2004) and for the credibility of valuation studies it is important that services are not double counted.

Categorizing the services that ecosystems provide can facilitate selecting what should be measured or choose from different valuation methods for different services. Different methods may be based on different categorizations. If more than one valuation method is determined to be useful in making decisions, then an understanding of the categories assumed will allow an assessment of whether certain attributes or services are being double counted (Bingham, et al., 1995).

Certain ecosystem services are almost impossible to evaluate economically even though they are essential to maintain the flow of all other ecosystem services. These are services that do not give a direct input to human welfare but are fundamental to sustain the services that do. The supporting services generally fall into this category. They have a supportive function with indirect or little understood effects on welfare. The value of these services can be very large, yet poorly appreciated by decision makers and the public, poorly estimated by scientists and not valued sufficiently by available valuation methods. However, to value such services, values may be constructed indirectly by relating the services to things that people value directly. Thereby, changes in supporting services are translated into effects on directly valued goods and services. An example is pollination, a supporting service for the production of food, e.g. almonds or tomatoes. Possibly the part of the pollinators in the food production can be isolated, thus enabling an economic valuation of their service. In practice, necessary resources such as time, data and methods may not be available for such valuation (Farber, Costanza, & Wilson, 2002; Bingham, et al., 1995). Also, in some cases it may not be pragmatic to attempt a realistic economic estimation of the value of these services as the true value can be too extensive to capture. In spite of this, the economic valuation of one supporting service is addressed in this study.

Another issue concerns ecosystem resilience. In ecosystem management a vital part is to maintain the ecosystem resilience. Resilience enables ecosystems to recover from stress or a shock and thus the flow of services is maintained. However, it is not at all clear how this emergent property of ecosystems could be economically valued (Vatn, 2000; Chee, 2004).

Regarding valuation methods, they are important in the attempt to economically value the provision of ecosystem services. Nevertheless there are drawbacks with most ways of inferring value. Market prices, for example, do not reflect the full social cost of production. Then, methods of indirect revealed preference such as travel cost, defensive behavior, damage cost and factor income do not enable one to place a value on the existence of certain assets. As a result, such approaches, and the ones based on the avoidance of cost, only provide lower bound indications of value, particularly if the service in question does not have an adequate substitute. In ecosystem valuation studies, these limitations of methods may possibly be partly overcome by applying a range of methods simultaneously. However, when that is done, one must obviously still be sure not to double count services (Daily, et al., 2000). The travel cost method has some well known issues. One of which is the estimation of opportunity cost of time but it can be difficult to put a value on the time of individuals. Another concerns substitute sites as it can be difficult to find appropriate substitute sites. Multi-destination trips can also cause a problem if people use the trip to a recreational site for other purposes as well. Then model specifications and components of travel cost can be complicated as well (Gurluk & Rehber, 2008).

3. The study site

The economic valuation of Lake Elliðavatn and Lake Vífilsstaðavatn, is a sub-study of the extensive study, the economic valuation of the nature reserve of Heiðmörk. Heiðmörk fulfills the main criteria important for a holistic environmental valuation study, making it a natural subject for the first economic valuation of ecosystem services in Iceland. Its system boundaries are clearly defined, it is a multifunctional, diverse ecosystem providing various ecosystem goods and services and the geology and ecology of the system are fairly well known. All this provides a solid foundation for the study. The area is a good example of a multifunctional ecosystem providing a range of various services. Following, the main characteristics of the study sites are described. First the overall study site of Heiðmörk in general and then the subjects of the present study, Lake Elliðavatn and Lake Vífilsstaðavatn.

3.1 Heiðmörk

Heiðmörk is an extensive nature reserve of around 3000 hectares, in the outskirt of Iceland´s capital area. The ecosystem of Heiðmörk is diverse, consisting of forests, lava-fields, open areas and two lakes. It is the biggest green recreational area in the capital area and very popular for various outdoor activities. The area surrounds the capital area and forms the outer range/background sheltering the capital settlement areas. Many walking paths and rest areas have been made in Heiðmörk, providing facilities for various activities (Skógræktarfélag Reykjavíkur, 2009). The use of Heiðmörk as a source of drinking water for the capital area started as early as 1909 at the Gvendarbrunnar Wells. The area is a key water supply area for the capital area today, supplying drinking water to more than half of the Icelandic population.

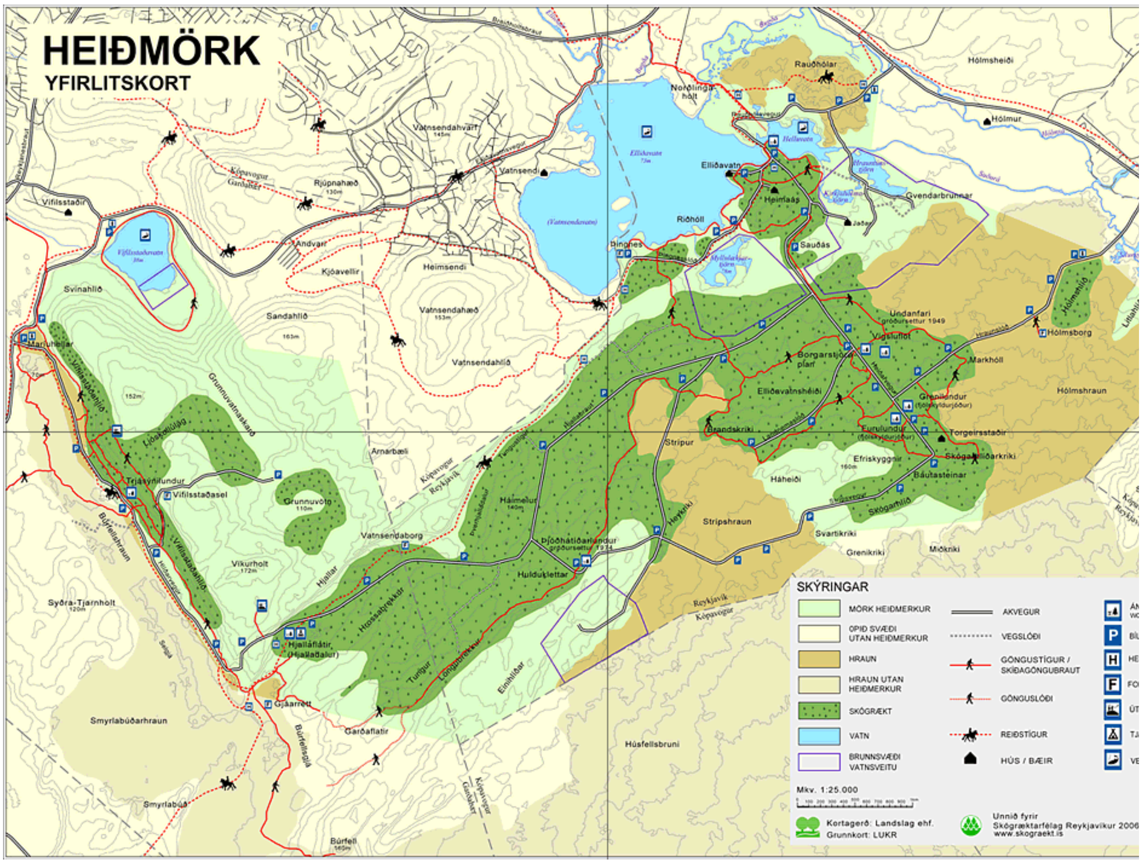

Figure 1. An overview of the nature reserve Heiðmörk. Source: Skógræktarfélag Reykjavíkur.

In 1870 it was first suggested to make Heiðmörk a nature reserve. Still, it was not until 1936 that this idea was presented to the public, by Hákon Bjarnason the chief of forestry, as he thought the area should be an official recreational area for the general public. When the Reykjavík Forest Association was founded in 1946, the area was given to the association. It was in the spring of 1949, that the first trees were planted and in June 1950 Heiðmörk was officially opened to the public. In 1957 the Heiðmörk area was enlarged as a part of the land belonging to the Vífilsstaðir sanatorium and another piece of land from the municipality of Garðabær were merged into the area (Marteinsson, 1975). The Reykjavík Forest Association has been mainly in charge of supervision over Heiðmörk ever since but the current landowners are Reykjavík Energy, the municipality of Reykjavík and the municipality of Garðabær.

Heiðmörk is relatively densely vegetated with 89% of the area classified as vegetated land. The vegetation is very diverse but the most widely spread are planted forests (21 %), wild birch forests and shrubs (20%), mosses (17%), heath (13%), grassland (8%) and Alaska lupine (7%). 98% of the vegetation is dry land and 2% are wetlands. The areas not vegetated are mainly the lakes (8%) and some gravel areas (3%) (Egilsson & Guðjónsson, 2006).

Geologically, Heiðmörk is characterized by the wide-spread faulting and recent lava fields and its landscape is mostly influenced by these two phenomena. Doleritic basalts, probably originated from craters west of Bláfjöll in the last Interglacial period, form the bedrock. There are clear signs of glaciations in the area, particularly glacially polished rocks demonstrating striations, erratic and moraine deposits. Near Lake Elliðavatn there are remains of eskers which indicate a glacial lake larger than the present one situated there. Heiðmörk is surrounded by lava-fields, except on the north-west side. The biggest fault-line (Hjallamisgengi) runs from Vífilsstaðahlíð to Lake Elliðavatn, a distance of 5 km with a maximum vertical displacement of 65 m. The fault-line is still active and has a mean annual displacement of 2.8 mm. The fissuring of the bedrock has affected the groundwater flow substantially. All the water courses and springs in the area are situated in the north-east, at Elliðavatn, Myllulækur and Silungapollur and all these are clearly connected to the fault system (Jónsson J. , 1975).

3.2 Elliðavatn[1]

Lake Elliðavatn is the biggest lake in the capital area, with an area of 2,02 km^2 and it rises to 73m over sea level (Malmquist & Gíslason, 2007). On a big scale, it is still a relatively small and shallow lake with the average depth of around 1m (deepest place 2,3m). The volume of the lake is around 2 Gl. Surface influx is mainly through the river Bugða/Hólmsá and a little through the river Suðurá. Overall, the flow in and out of the lake is around 4,7 m^3/s. The water exchange rate has been estimated around five days, which is fast compared to other lakes of this size. However, estimations for the water replacement time should be taken with caution since the lake is divided into two or three parts in terms of depth and inflow to the water which may affect the overall water flow and replacement time. The conduction in Elliðavatn is about 80-90µS/cm which is above average and indicates good viability for organisms. Most of the dissolved matter in Lake Elliðavatn is similar to what is seen in most Icelandic lakes. An exception from this is aluminum, which is of unusually high concentration in the lake and the highest seen in Icelandic lakes. The lake can be divided into three parts,

[1] This section is largely based on the report from Malmquist, Ingimarsson & Ingvason, 2004.

Vatnsvatn, Vatnsendavatn and Engjar, Engjar being about 40% of the whole lake area (figure 2).

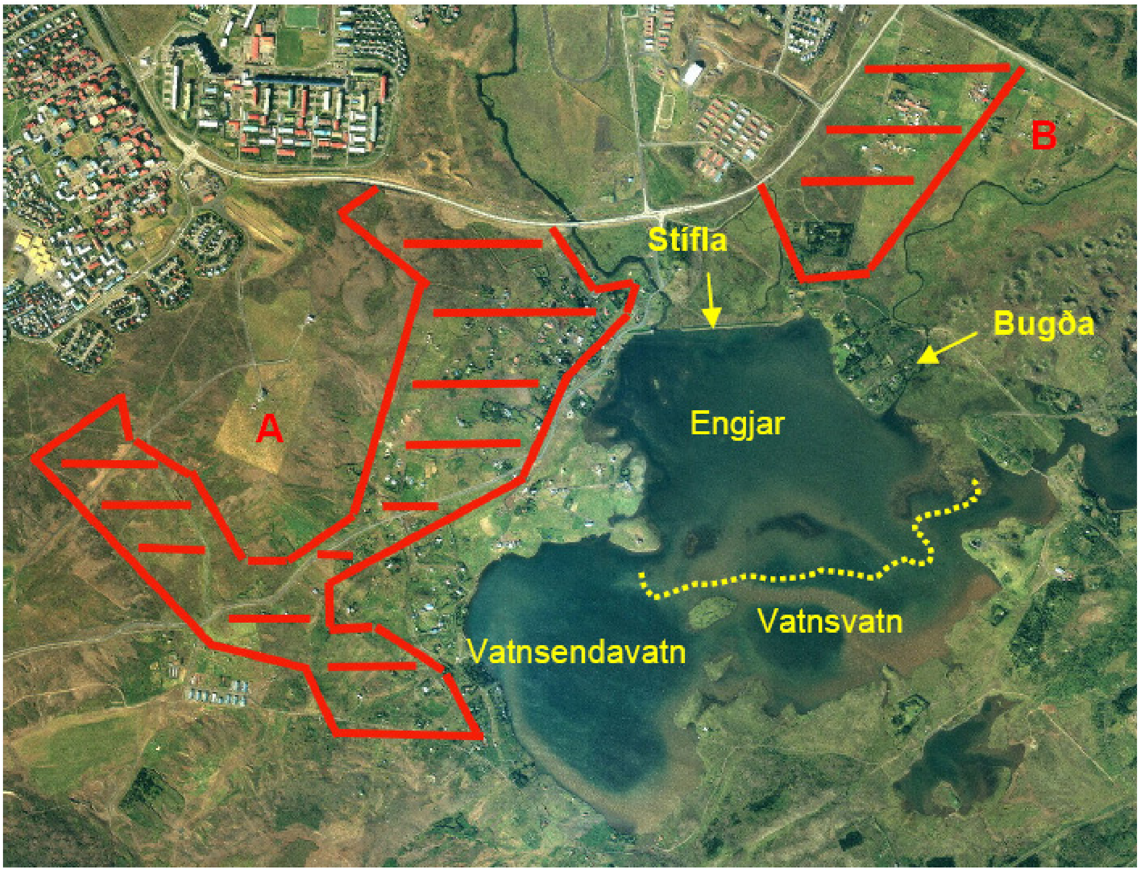

Figure 2. An aerial photo of Lake Elliðavatn from 2002. When the lake was dammed in 1924-1928 its water level elevated by 1m and the "Engjar" area was flooded. The river Bugða which used to flow outside the lake now flows into it. The yellow line demonstrates approximately the old boundaries of the lake. The red gridlines demonstrate potential residential areas that have been under construction over the recent years. These constructions are now on hold because of the economic situation in Iceland. (Photograph: Loftmyndir ehf, Source:Malmquist et al, 2004)

Over the last century various alterations have taken place on the water catchment of the lake which affected the ecosystem of the lake. The most extensive change was when the Reykjavík Power Company (Rafmagnsveita Reykjavíkur) bought the land of Lake Elliðavatn, and the lake was turned into a reservoir for hydropower generation (Skógræktarfélag Reykjavíkur, 2009). It was first dammed in 1924 and the dam was improved in 1978. The lake doubled in size as adjacent areas went under water. Early in the 20th century there was farming at the Elliðavatnsbær but in 1941 conventional farming ended there. Still there was farming elsewhere on the water catchment and in 2000 there were still horse stables at Heimsendi, chicken farm at Elliðahvammur and sheepfarming at Vatnsendi and Kjóavellir (Hjaltason, et al., 2000) (figure 3). The density of first summerhouses and then residential areas on the water catchment area has increased considerably since last century. In addition, the heavily travelled road, Suðurlandsvegur is situated on it, water has been extracted from the Gvendarbrunnar wells since 1909 and forestation has been considerable on the water catchment.

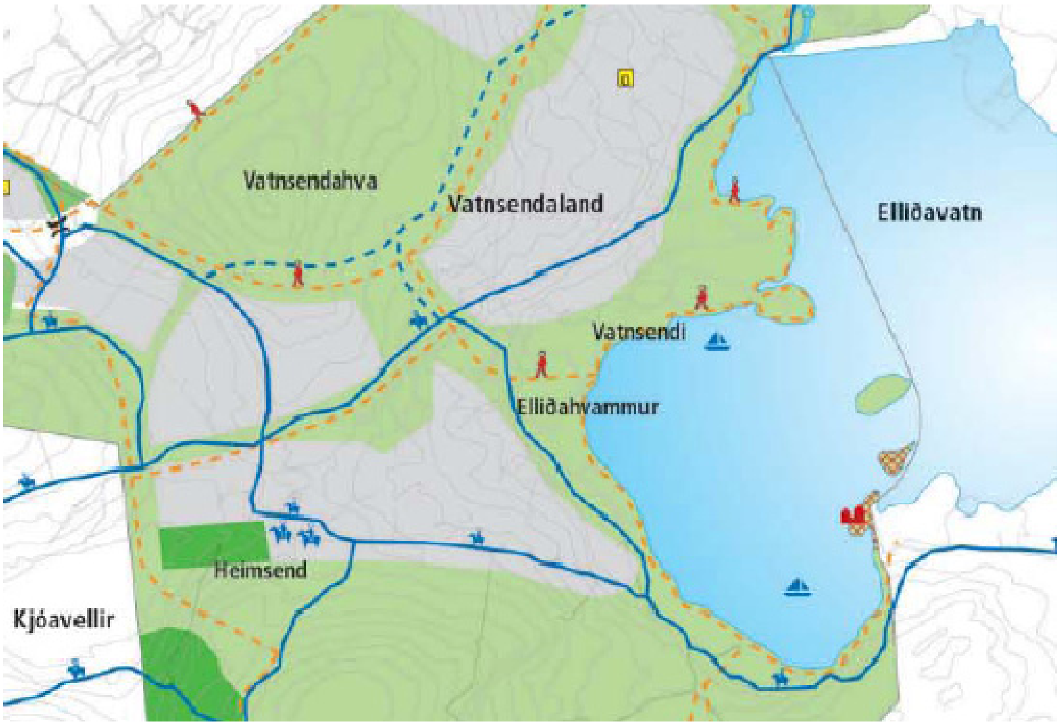

Figure 3. The landmarks Heimsendi, Elliðahvammur,Vatnsendi and Kjóavellir can be seen here. The colored area represents land owned by the municipality of Kópavogur Source: Útivistarsvæði Kópavogs (Kristjánsdóttir, et al., 1998).

It was in April, 1964 that all land owners around Lake Elliðavatn grouped together in order to organize fishing and fish cultivation in the lake, forming the Elliðavatn Fishing Association (Marteinsson, 1975). Since then, this association has been in charge of all fishing in the lake and the rivers Bugða/Hólmsá and Suðurá.

Regarding research done on the ecology on the water catchment of Lake Elliðavatn, the focus has mainly been on salmonids, in particular salmon in the Elliðaár River. However there are also several studies that have been made on the trout species in Lake Elliðavatn and adjacent rivers. Five of the seven fresh-water fish species found in Iceland; Salmon (*Salmo salar*), Brown trout (*Salmo trutta*), Arctic Char (*Salvelinus alpinus*), Stickleback (*Gasterosteus aculeatus*) and Eel (*Anguilla anguilla*) are found in the lake. The most abundant fish species are the two trout species and the stickleback. The salmon is not abundant and the eel is rare

(Malmquist, Ingimarsson, & Ingvason, 2004). Researches conducted by the Institute of Freshwater Fisheries indicate that the salmon and arctic char have been retreating in the water system over the last 15 years but the brown trout has maintained its status. The reasons for this decline in these stocks are not known for sure, but the increase in water temperature, particularly in the fall, is considered to be a possible explanation. (Malmquist, Antonsson, Ingvason, Ingimarsson, & Arnason, 2009. (In Press); Antonsson & Árnason, 2009).

3.3 Vífilsstaðavatn

Lake Vífilsstaðavatn is situated in the north-west end of Heiðmörk. It covers an area of 0,27km^2 and rises to 38m above sea level. Adjacent to the lake are heathland and slopes, except for the south side where there is moorland, named Dýjakrókar. There are springs in the moorland from which water runs to the lake in little streams. On the west side of the lake, there is a little stream, Vífilsstaðalækur, where the water runs out from the lake (Hilmarsson & Einarsson, 2009). The lake and surrounding area, which are the properties of the municipality of Garðabær, were officially declared a protected area in November 2007.

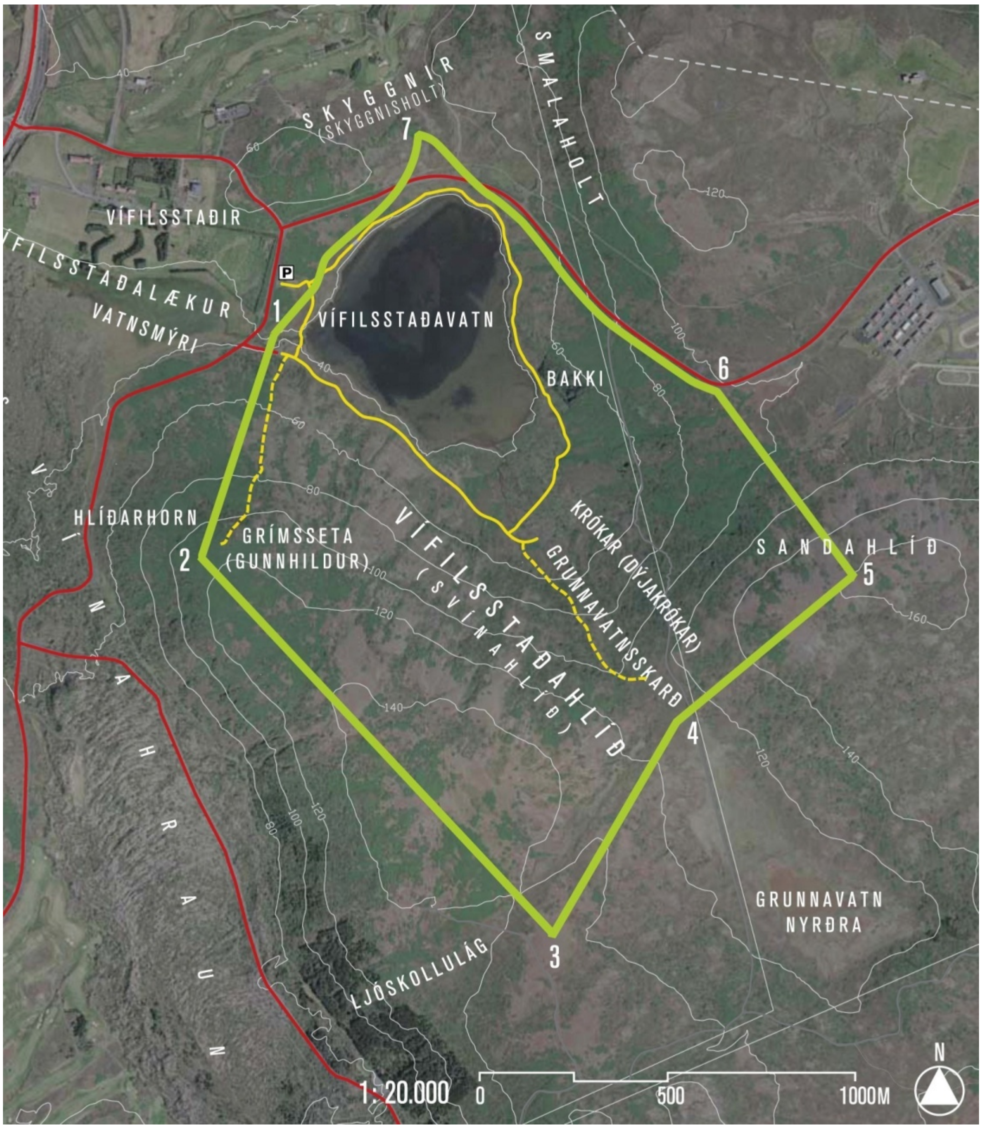

Figure 4. Vífilsstaðavatn and the protected surrounding area. Source: Data on the reservation of Lake Vífilsstaðavatn by Þráinn Hauksson.

Lake Vífilsstaðavatn is biologically very rich. The benthic fauna is dense and the conductivity is high, around 130µS/cm, so there is a high level of dissolved matters and good viability for the biosphere (Jónsson B. , 1999). The lake is also fairly undisturbed compared to other lakes in the capital area and has for example not been threatened by residential areas in the same way as Lake Elliðavatn.

The biosphere of Lake Vífilsstaðavatn has been studied to some extent. Fish species found there are the arctic char, brown trout, eals and stickleback. European eal (*A.angilla*) and a hybrid from the european and the american eal (*A. rostrata*) migrate up the Vífilsstaðalækur and can be found in the lake (Antonsson, Guðbergsson, Jónsson, & Malmquist, 2007). The sticklebacks in Lake Vífilsstaðavatn are unique for the reason that they lack womb-spikes and this is the only known such case in Iceland.

These sticklebacks have been the subject of evolutionary and genetic research both in Iceland and in the United States (Jónsson B. , 2004).

3.4 Services provision – an overview

There are various ecosystem services that Lake Elliðavatn and Lake Vífilsstaðavatn provide to the adjacent society. They are popular for recreational angling and both are encircled by nice footpaths popular for walking and jogging. They also serve as outdoor labs as schools and educational institutions use them for field work. In addition, Lake Elliðavatn provides benefits through beautiful view to the adjacent residential area and it serves as a reservoir for electricity production in Elliðaárstöð. These are the direct and obvious services that are recognized by the public. Other less obvious ecosystem services provided by the lakes are e.g. pollution control and detoxification, particularly in the case of Lake Elliðavatn due to substantial human structures in the watershed, also micro-climate regulation as water areas in cities are known to help even out temperature deviations (Bolund & Hunhammar, 1999) and sediment retention and accumulation due to aquatic vegetation, nutrient cycling, biodiversity and genetic resources.

4 Analysis and results

As described above, the subject lakes both provide various ecosystem services, some of which are economically valued in the present study, others are not. The MEA classification of ecosystem services is applied in this study and the focus is on the service categories of inland water systems. For services derived from inland water systems, the categorization is as follows:

- Provisioning services; such as food, freshwater, fiber and fuel, biochemicals, genetic material and biodiversity. In the present study the value of Lake Elliðavatn as a reservoir for electricity production is assessed.
- Regulating services; such as climate regulation, hydrological flow, pollution control and detoxification, services related to prevention of erosion and natural hazards services. In the present study the value of the potential pollution dilution and eviction capacity of Lake Elliðavatn is assessed.
- Cultural services; such as spiritual and inspirational, recreational, aesthetic and educational. In the present study the recreational and educational services provided by both lakes were assessed.
- Supporting services; such as soil formation, sediment retention and accumulation, nutrient cycling and pollination. In the present study the supporting services provided by Lake Elliðavatn for the Elliðár River were assessed.

(Aladin, et al., 2005)

Each of the service categories is addressed in some aspect for Lake Elliðavatn and Lake Vífilsstaðavatn. The analysis is divided into four main sections according to the classification categories. In each section an assessment of the ecosystem services provided and an economic evaluation are carried out. Generally, the sections consist of four parts; services definition, valuation methods, data collection and results. However, the structure varies a little, due to the inherent difference of the categories. The methods applied in the valuation process depend on the nature of the ecosystem service being valued. For the valuation of provisioning services, market data are used to derive annual revenue of electricity production from Lake Elliðavatn as a reservoir. For the regulating services provided by Lake Elliðavatn, market data are also used but the cost invested in infrastructure is converted from a single investment to an annual value. The cultural services section is divided into two sub-sections; educational services and recreational services, which are both assessed and economically valued. To value the educational services official cost data are used to value time spent on site by students in elementary and high schools. The recreational value is estimated through a single-site travel cost model. The supporting services part is different from the other parts because, as was explained in section 2.6, their benefits are generally indirect. Thus, most of the supporting services are not valued economically but are instead listed and described. However, in the last part of the supporting services section, the economic view is presented. Because Lake Elliðavatn provides essential supporting service for the Elliðaár River, an economic valuation is carried out for the factor income of the lake on the salmon yield of the river.

Overall, the study is made as a point-in-time measure of the value of goods and services provided by the lakes, in terms of annual value. The annual average consumer price index was used to convert all values to constant ISK 2009 values. For the evaluation of the provisioning services, regulating services data from 2007 are used, for the educational services data from 2008 are used and for the recreational- and supporting services data from 2009 are used.

4.1 Provisioning services

4.1.1 Services definition

Provisioning services are the products people obtain from ecosystems, such as food, fuel, fiber, fresh water, and genetic resources. This services category can be divided into two parts; the consumptive and the non-consumptive services. The consumptive services are products directly consumable by people, e.g. food and fresh water. The non-consumptive services provide benefits that can be enjoyed by people but not consumed directly, e.g. fuel and genetic resources. In the case of Lake Elliðavatn, the main provisioning services are two. First there is the non-consumptive service which is the electricity production supported by the lake as a reservoir. Second, there is the consumptive service of the lake, the fish production. Three fish species are fished by recreational fishermen in the lake, the two trout species and the salmon. The main catch of the lake is the Brown trout and the Arctic char. The abundance of the Arctic char stock in Lake Elliðavatn has been retreating since the latter part of the eighties. This has come forth in the annual experimental fishing done by the Institute of Freshwater Fisheries where the share of the Arctic char in total catch per unit effort has been decreasing over the last two decades. In 2007 a little less than 10% of the total catch was Arctic char (Antonsson, Árnason, & Guðjónsson, 2008). Salmon is mostly fished in the rivers that run to and from the lake but a few can be caught in the lake in autumn as it migrates (Árnason & Antonsson, 2005).

In the case of Lake Vífilsstaðavatn, the provisioning service provided is mainly the consumptive fish production of Arctic char and Brown Trout.

4.1.2 Valuation methods

The category of provisioning services was solely addressed by valuing the non-consumptive services of Lake Elliðavatn, based on the monetary value of the electricity production. The value of these services was obtained based on the revenue of the electricity production in Elliðaárstöð in 2007. An important provisioning service, the fish production of the two lakes was not taken into account for the reason that people fish mainly in the lakes for recreational reasons, rather than directly seeking food. This came through in the pilot travel cost survey carried out at Lake Elliðavatn in summer 2008 and from the author´s personal communication with some of the recreational anglers. This was also observed in the assessment study made by Jón Kristjánsson (2003) to assess the fishing intensity of Lake Elliðavatn. Therefore, since people in general go fishing there mainly for recreational reasons, accounting for both the food value and the recreational value would be double counting. Thus the consumptive provision of fish in Lake Elliðavatn and Lake Vífilsstaðavatn, although valuable, was not accounted for. Furthermore, sufficient data of total fish-catch in both lakes are lacking. Anglers using day-licenses are required to hand in reports after their fishing days and the ones using summer-licenses should hand in a report after the fishing season. However, it is an exception when these reports are handed in, as most people do not do it. This was clear from the assessment study mentioned above (Kristjánsson, 2003), where it was stated that only 12% of sold licences in Lake Elliðavatn came back in as fishing reports. According to reports from the institute of freshwater fisheries this has not changed and therefore the catch from these lakes is an unknown figure, despite attempts to get significant registration (Antonsson & Guðbergsson, 2000).

4.1.3 Data collection

For the value of Lake Elliðavatn as a reservoir for electricity production, data on revenue from electricity produced in 2007 were obtained directly from the company Reykjavík Energy. All values were converted to ISK 2009.

4.1.4 Results

Table 2. The total value of electricity production from Elliðaárstöð in 2007 (constant ISK 2009).

Total electricity production of the year 2007 (MWh)	Total revenue (ISK)
3.256	30.665.149

4.2 Regulating services

4.2.1 Services definition

The benefits people obtain from the regulation of ecosystem processes are e.g. climate regulation, maintenance of air quality, erosion control and water purification. These kinds of benefits fall under the category of regulating services (MEA, 2005). In inland water systems the main regulating services identified by the MEA are climate regulation, hydrological flows, pollution control and detoxification, erosion control and natural hazards control (Aylward, Bandyopadhyay, & Belausteguigotia, 2005). These services are often not well recognized as their provision is not obvious. Thus, their benefits are commonly not recognized until after they have been lost (Ozdemiroglu, Tinch, Johns, Provins, Powell, & Twigger-Ross, 2006). Only one of the regulating services from the MEA categorization was considered extensive enough to be counted for in the valuation study of Lake Elliðavatn; the ability for pollution control and detoxification. For Lake Vífilsstaðavatn services of this category were not considered extensive enough for estimation and economic valuation.

Climate regulation

In terms of climate regulation, inland water systems serve two important yet contrasting roles. Firstly they regulate greenhouse gases, particularly CO_2 and secondly they buffer the impacts of local climate change. Also, these ecosystems both store and release carbon as they sequester carbon in sediments and transport carbon to the sea (Aladin, et al., 2005). There is substantial evidence which indicates the majority of the world´s lakes as being net sources of CO_2 to the atmosphere (Kling, Kipphut, & Miller, 1992; Algesten, Sobek, Bergström, Aagren, Tranvik, & Jansson, 2003). A study by Algesten et al. (2003) on the role of lakes in organic carbon cycling in the boreal zone, demonstrated that on average emissions from lakes were eight times higher than the sediment burial of carbon. The study was performed for all lakes and rivers in 21 water catchments covering an area of 316 100 km^2 in the boreal zone of Scandinavia. In that context, the role of climate regulation of Lake Elliðavatn and Lake Vífilsstaðavatn is quite uncertain, could even be a cost rather than a benefit. However, further data were not available on this subject, thus this service was not accounted for.

Pollution control and detoxification

Regarding pollution control and detoxification, it is known that natural systems are able to store and recycle certain amounts of organic and inorganic human waste through dilution, assimilation and chemical re-composition (de Groot, Wilson, & Boumans, 2002). That ability then depends on the properties of both the waste and the ecosystem itself. There are mainly two types of ecosystem processes that enable the reduction of concentration or impact of waste in an environment over time. There are a) processes that act to change waste into less toxic forms and b) processes that move and transport wastes (Hinga, Batchelor, Ahmed, & Osibanjo, 2005). The reduction of waste concentration in water is a result of two processes: dispersion (dilution by mixing into larger volumes of water) and advection (water moving downstream). Both these processes reduce the concentration of the waste at its point of entry in the ecosystem (Hinga, Batchelor, Ahmed, & Osibanjo, 2005). It has been stated that, due to rapid water exchange, Lake Elliðavatn is tolerant when it comes to pollution

(Þórðarson, 2003). Thus, dispersion and advection is a service readily provided by Lake Elliðavatn as the lake takes in pollution from the surrounding area and should, due to relatively rapid water exchange, dilute it and bring to the sea fairly quickly. However, as the lake is divided into two or even three parts in terms of depth, shape and locations of in- and out-flux, the water exchange rate is unlikely to be the same for all parts of the lake (Malmquist, Ingimarsson, & Ingvason, 2004).

In addition to the provision of dispersion and advection services in Lake Elliðavatn, both Lake Elliðavatn and Lake Vífilsstaðavatn comprise a relative abundance of aquatic plants. Such plants, aquatic macrophytes, probably play a role in the waste regulating processes of the lakes. Henrik W. de Nie (1987) stated that the presence of aquatic macrophytes can strongly affect the physical environment in the water. It is widely acknowledged that vegetation in some inland water systems is able to remove high levels of nutrients, especially phosphorus and nitrogen. Furthermore, there are many wetland plants that can play a critical role of removing different chemical pollutants derived from some industrial activities (Aladin, et al., 2005). Also, plant roots and underground stems help to prevent resuspension of sediments from the lake bottom (Environmental, 2008).

In the first part of the 20th century there used to be farming at Lake Elliðavatn. The density of summerhouses and later residential areas in the water catchment area has been increasing exponentially over the last century and until today. In addition, the heavily travelled road Suðurlandsvegur is in the water catchment area (Malmquist, Ingimarsson, & Ingvason, 2004). Urban areas are a big source of easily degradable organic matter, which in high concentration can deplete the oxygen content in water due to microbial activity. Storm water in urban areas can also transport pollutants including salt, fine sediments, petrochemicals and various other toxic compounds including pesticides used in private gardens (Friberg, 2007). Considering these facts, it is reasonable to conclude that Lake Elliðavatn, with its regulating processes, has provided considerable benefits to the local society through regulating services.

4.2.2 Valuation methods

For the regulating services the defensive behavior method was applied. The municipality of Kópavogsbær, which represents most of the residential areas adjacent to the lake, has already gone into some operations and more are foreseen, to prevent storm water pollution from the residential areas and roads to enter the lake. By spending money on these operations, the municipality has revealed a defensive behavior as described in section 2.5. However, it shall be noted that these operations can also be considered a replacement cost. The constructions replace a regulating service provided by the lake, thus the value of the regulating service could in fact be assessed by either of these methods, defensive behavior or replacement cost. This is merely a matter of definition and the results would be the same. In the present study it was determined to go by the defensive behavior approach.

As has already been described, the water exchange of the lake is rapid and the pollution from adjacent areas could readily be received by the lake, diluted and removed from the area to the sea. However, with increasing population pressure, that is, if the lake would take in all the pollution unimpeded, it would put the whole ecosystem of the lake at risk. Consequentially, all the cultural services provided by the lake would be risked as well. This can be seen as a tradeoff between the provisioning of two possible ecosystem services. In fact the stand has already been taken. Authorities and the municipalities have gone into operations to prevent polluting Lake Elliðavatn thereby, revealing a willingness to pay to preserve the lake´s ecosystem which again provides other important services. The estimated cost of all the operations to prevent pollution reaching the lake, both the already done and those expected, was used as a measure to estimate the value of the regulating services of the lake.

4.2.3 Data collection

The municipality of Kópavogur represents most of the residential areas in the water catchment area of the lake. The operations made to prevent pollution from these areas to enter the lake were twofold;

1. The building of a big pipeline which lies beneath the residential area, along the shore of Lake Elliðavatn (figure 5).
2. A sedimentation pond, on the other side of the river Dimma, where the water exits the lake. That sedimentation pond is then supposed to receive the surface water from the pipeline for dilution (figure 6)

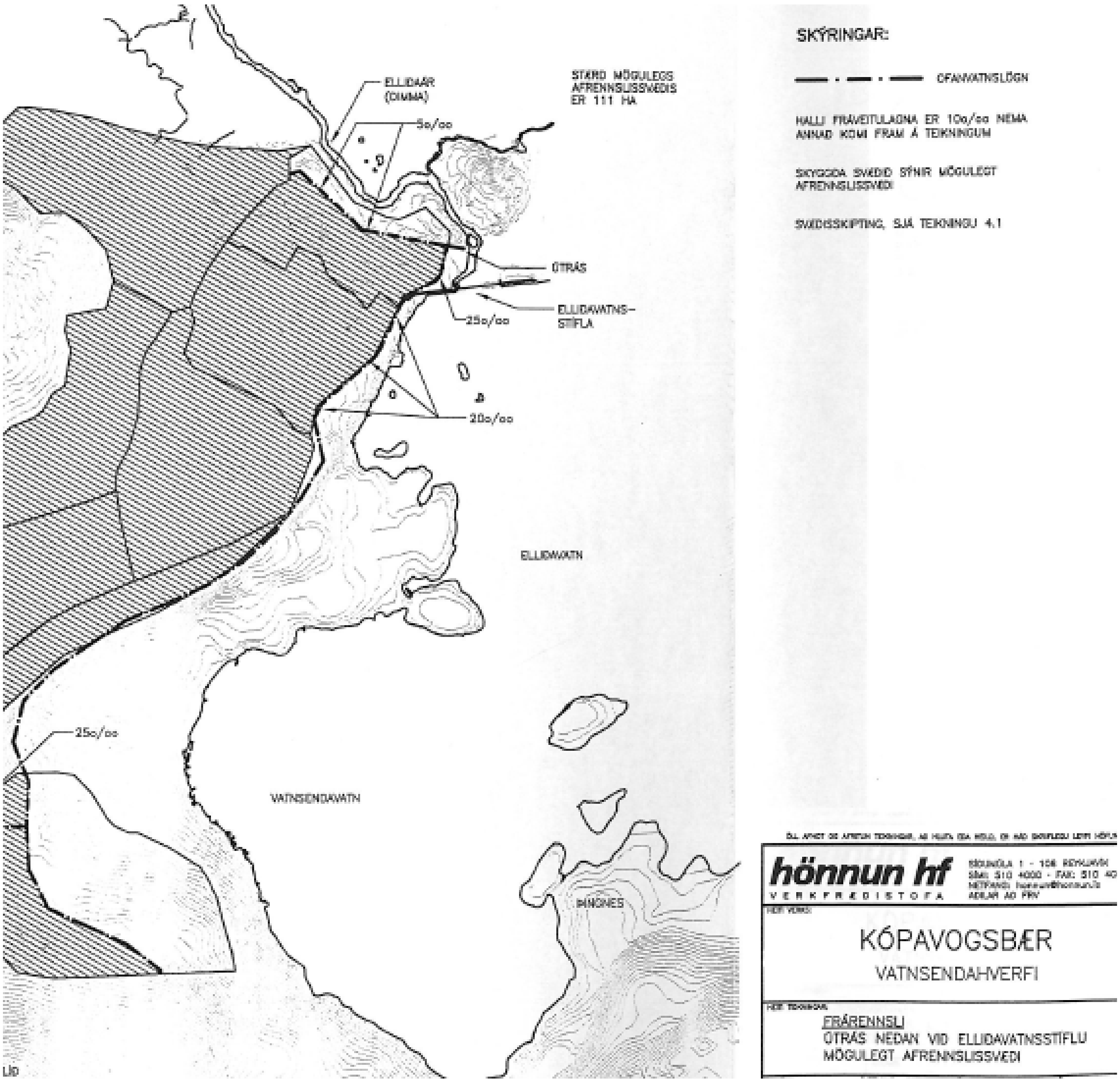

Figure 5. The pipeline constructed to receive stormwater from the adjacent residential area. The broken line represents the pipeline and the colored area represents residential area. Source: Mannvit.

The pipeline has already been constructed but the sedimentation pond has yet to be made. So far, the surface water from the pipeline still enters the lake untreated at the outflow where Dimma begins and is washed away with the rivers. The estimated costs of the pipeline, the pending sedimentation pond and annual running costs were obtained from the engineering firm, Mannvit which was responsible for the operations on behalf of the municipality of Kópavogur. Since the pipeline was constructed over a long period, accurate numbers were not available (Brynjólfur Björnsson, personal communication, December 18, 2009) and therefore the values are a rough estimate in ISK 2009. The values were converted from 2007 values to constant 2009 values.

Figure 6. The site intended for the pending sedimentation pond which will receive the stormwater from the pipeline for treatment before letting it into the Elliðaár River.
Source:Mannvit

4.2.4 Results

To arrive at an annual cost the investment cost was converted to uniform series amount for the lifetime of the constructions by using equation 14.

Equation 14 $$U = P\cdot \left[\frac{i}{(1-(1+i)^{-n})}\right]$$

(Rubin & Davidson, 2001)

Here U denotes the annual cost, P denotes the present value of investment cost, i denotes the discount rate and n denotes the lifetime of the construction. The discount rate applied was 5%.

For the pipeline the estimated investment cost is ISK 188.204.238 – 250.938.984. The estimated annual running cost is 0,5% of the investment cost as the pipeline may get clogged, solids may accrue in it which need to be cleaned and spare parts may need to be renewed. The annual running cost is then ISK 941.021 – 1.254.695 (Brynjólfur Björnsson, personal communication, December 18, 2009). The results for the pipeline are presented in table 3 below.

Table 3. The total defensive cost of the pipeline (constant ISK 2009).

	Upper bound	Lower bound
Total investment cost	250.938.984	188.204.238
Annual investment cost	12.973.333	9.729.999,7
Running cost	1.254.695	941.021
Total cost	14.228.028	10.671.021

For the sedimentation pond the estimated investment cost is ISK 125.469.492 - 188.204.238. The estimated annual running cost is 2% of investment cost for things such as mechanical equipment and water exchange. The annual running cost is then ISK 2.509.390 – 3.764.085 (Brynjólfur Björnsson, personal communication, December 18, 2009). The results for the sedimentation pond are presented in table 4 here below.

Table 4. The total defensive cost of sedimentation pond (constant ISK 2009).

	Upper bound	Lower bound
Total investment cost	188.204.238	125.469.492
Annual investment cost	13.353.553	8.902.368,8
Running cost	3.764.085	2.509.390
Total cost	17.117.638	11.411.759

The total annual cost for both the pipeline and the pending sedimentation pond in 2009 are in the range of **ISK 22.082.780 – 31.345.666**.

4.3 Cultural services

According to the MEA, cultural ecosystem services are defined as “the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences” (MEA, 2005). Natural ecosystems provide people with numerous possibilities of spiritual enrichment, mental development and leisure. In his book, Winifred Gallagher (1993) points out that as the longest period of human evolution happened within the context of undomesticated habitat, human sense for learning and well-being is robustly linked to the experience of natural landscapes and species diversity (Gallagher, 1993). Furthermore, it is evident in art, religion and traditions of diverse cultures how deeply people appreciate natural ecosystems. Other activities such as gardening, pet-keeping, nature photography and film-making, bird-feeding and watching, hiking, camping, mountaineering, river-rafting, boating, fishing and hunting all testify on the importance of man´s relationship with nature. Nature, with its ecosystems and species, is for many a unique source of astonishment and inspiration, peace and beauty, fulfillment and rejuvenation. (Daily, et al., 1997). In this sense, nature is a source of inspiration for different disciplines and makes various opportunities for education and research available and is essential as such (de Groot, Wilson, & Boumans, 2002). The benefits derived from cultural ecosystem services are various and although they may be less tangible than material services, they are nonetheless highly valued by people in all societies (Hefny, Pereira, & Palm, 2005). Since their benefits are mostly based on personal experiences e.g. spiritual, inspirational and aesthetic, they are not easily valuable in an economic sense. Information about such services and valuation methods are therefore not easily accessible and were not addressed particularly in this study. Yet, the economic value of these services should partly come through the overall existence and recreational value of the ecosystem of Heiðmörk which is currently being estimated. In this study, however, both recreational and educational services of the two lakes were valued. Following is a more detailed definition of these services and a description of the methodology applied.

4.3.1 Recreational services

4.3.1.1 Services definition

Lake Elliðavatn and Lake Vífilsstaðavatn provide recreational services mainly through recreational angling. In this study, and discussed below, a single-site travel cost method was applied to assess the values of those services. Access to such natural ecosystems or relatively unspoiled nature for recreation is an important factor in the lives of many people. In today´s society a great focus is put on materialism. The consequence is speed and stress and the majority of people´s time is occupied by work, both at the workplace and at home. Having a natural place, where people can come for relaxation, refreshment and recreation, in the vicinity of cities and urban areas is therefore very valuable to many people. Aesthetic qualities and miscellaneous landscapes, such as those surrounding Lake Elliðavatn and Lake Vífilsstaðavatn, provide various possibilities of other recreational activities than fishing, such as walking and picknicking. The benefits people obtain from recreation in a natural environment contribute to their health and well-being as there is a correlation between green areas, good air quality and human health (McMichael, Scholes, Hefny, Pereira, & Palm, 2005). In addition to the personal benefits of users, the conservation of natural ecosystems for recreational purposes inevitably has some economic benefits for the society, e.g. through better health of people which consequently are a better work force and through generated income. However, estimating the social economic benefits of recreation and natural ecosystem through the health and performance of employees would require an extensive research which is beyond the scope of this study.

4.3.1.2 Valuation methods

At Lake Elliðavatn fishing licenses are sold to recreational anglers. In the fishing season of 2009, anglers had the option to buy a day license for 1200 ISK or a summer license for 13500 ISK which allows unlimited access to the lake for the whole season. For the elderly, disabled people and children of the municipalities of Reykjavík and Kópavogur the municipalities pay for the access. These groups must report to the fishing guards where they register but do not pay themselves. At the end of the season the municipalities pay for the fishing license cost of these groups with a 10% quantity discount. This subsidization by the municipalities affects the demand curve of those who enjoy the subsidized access fees. If the same people would have to pay access fee they would maybe come less frequently. When accounting for this group the access fee is simply excluded, then the amount paid by the municipalities is not added to the total access value of the lake as it should come in through the modified demand curve of the subsidized group.

Accounting for discounts such as for the summer license holders is difficult and usually ignored in travel cost studies (Parsons, 2003). Due to this system the cost paid by summer license holders can not be included in the actual travel cost study. Yet they pay an amount for the use of the lake and it was not considered to be justifiable to leave it unaccounted for. Thus, the total cost paid by summer license holders was added to the access value of Lake Elliðavatn found with the travel cost method, thereby arriving at a total value of the recreational services of Lake Elliðavatn.

The travel cost model

The fundamentals of the travel cost method were described in chapter 2.5.1. It is a revealed preference method based on observed behavior and therefore estimates only use values. Travel cost models can be separated in terms of single-site or multiple site models, depending on the aim of the study in question. As the aim here was to estimate the total use, or "access value" of the lakes, a single-site model was applied to each lake separately. A single-site model reveals a downward sloping demand function where number of trips to the site equal the "quantity demanded" and the price is the trip cost of reaching the site. Variation in price is generated by observing people that live at different distances from the site with low price for people living close to it but high for those living far away. The demand function slopes downward if trips decline with distance to the site (Parsons, 2003). The travel cost model has two basic approaches depending on the definition of the dependent variable. These are the "individual" and "zonal" models. In its original form the travel cost model was a zonal model where concentrated circles are formed around the destination site and a given zone implied a given distance, hence a given travel cost. In the zonal approach the dependent variable is the number of visits made from a particular zone during a certain period. It is based on means within each zone assuming that behavior, income and other factors within the zone are identical (Haab & McConnel, 2002). This imposes a problem and the zonal model has actually fallen out of favor because the individual characteristics which affect the demand curve are lost by using zonal means. However the zonal model can provide a useful approximation when data are limited (Parsons, 2003). The individual approach uses individual data. It requires a visiting number of one or more per visitor during a season/year. If everybody visits the site only once, it creates a problem which is commonly solved by using zonal method (Gurluk & Rehber, 2008). Provided with sufficient data the individual model was applied in the present study.

The model applied is a demand model for trips to the lake in question by individuals during the fishing season. The total cost is the sum of all costs involved in the individual´s trip to the site, including travel expenses and total opportunity cost of time. A negative relationship between the number of trips and the trip cost is expected as in any demand function. But other factors than trip costs that can affect the demand for recreation trips, such as income, age, etc. are also included. The model then looks like this:

Equation 15 $r = f(tc, y, z)$

where r is number of trips, tc is trip cost, y is income and z is a vector of demographic variables believed to influence the number of trips. Substitute sites are something that can also be incorporated into such a model. If an individual lives near another recreation site the number of trips to the site of interest are likely to decline as the individual substitutes trips away from it to the other site instead (Parsons, 2003). However, in the present study the scope of the study was limited to the subject lakes, not accounting for substitute lakes. A linear version of the model is:

Equation 16 $r = \alpha + \beta_{tc}tc + \beta_y y + \beta_z z$

where the α is the constant and the β_i´s are the coefficients to be estimated.

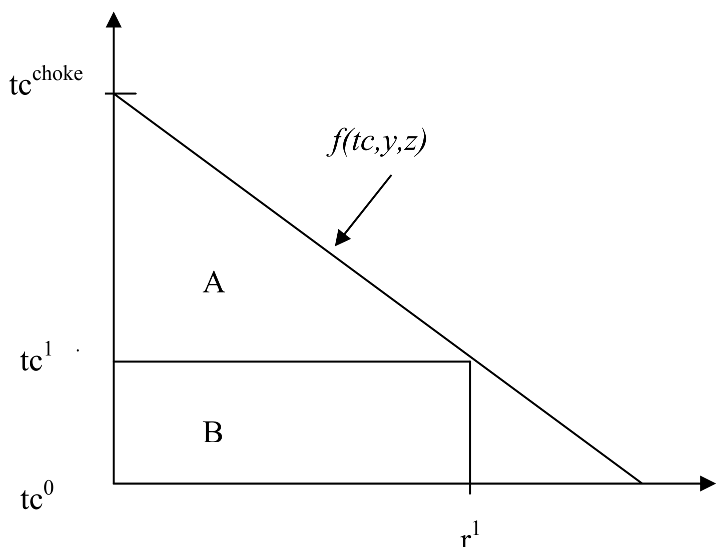

Figure 7. Access value in a Linear Single-site Model

In figure 7 here above the area under the demand curve *f(tc,y,z)* represents the value of access to the site. When an individual faces a trip cost of tc^1 he or she takes r^1 trips to the site. The choke price tc^{choke} is when the price is too high so that the number of trips falls to zero. The area marked by A represents the individual´s consumer surplus for the trips to the site during the season. Area B represents the total trip cost. Mathematically the access value of the site (A+B) can be calculated by:

Equation 17 $$\int_{tc^0}^{tcchoke} f(tc, y, z)dtc$$

The basic count data travel cost model is estimated by a Poisson regression. The number of trips taken by a person to a site in a given season is assumed to be generated by a Poisson process. The Poisson distribution approaches the normal distribution as its parameter increases. The most popular specification also lets the Poisson parameter equal the conditional mean of the dependent variable. Therefore the benefits of using a Poisson or Poisson based estimator are likely to be greatest when the mean of the dependent variable is not large (Creel & Loomis, 1990). The probability of observing an individual taking *r* trips in a season is:

Equation 18 $$\Pr(r) = \frac{exp\,(-\lambda)\cdot\lambda^r}{r!}$$

where the parameter λ represents the expected number of trips and is assumed to be a function of the variables specified in the recreational demand model. It is both the mean and variance of *r*. To prevent negative probabilities λ usually takes a log-linear form:

Equation 19 $$\ln(\lambda) = \beta_{tc}tc_r + \beta_y y + \beta_z z$$

which is the Poisson form of the recreation demand specified above. In the Poisson model the, access value *S*, or aggregated per-trip value, for each person has an explicit form:

Equation 20 $$S_n = \frac{\lambda_n}{-\beta_{tc}}$$

where *n* denotes the individual. Thus to arrive at an average per-trip-per-person value *t,* the per-person seasonal value is divided by number of trips:

Equation 21 $$t = \frac{\frac{\lambda_n}{-\beta_{tc}}}{\lambda_n} = \frac{1}{-\beta_{tc}}$$

(Parsons, 2003)

4.3.1.3 Data collection and model

Sampling strategy

The sites valued are Lake Elliðavatn and Lake Vífilsstaðavatn in terms of recreational fishing. The season for Lake Elliðavatn is approximately 18 weeks, from 1st of May to 15th of September. For Lake Vífilsstaðavatn the season is approximately 22 weeks, from 1st of April to 15th of September.

The sampling strategy applied was on-site sampling where anglers were asked to fill out a written survey. The sampling began in June 2008 and at that time the season in both of the lakes had already long begun. According to the staff at the sites both lakes are most visited during the first two months of the season. That is possibly related to the fact that these are among the first sites to open for fishing in spring and they are in the vicinity of the capital area. Salmon fisheries in rivers commonly begin the 15th of June each year and many of the anglers go elsewhere at that time. Thus the summer of 2008 was used as a pilot survey to develop the sampling strategy. The pilot sampling at Lake Elliðavatn began the 24th of June 2008. The fish guards and license sellers were asked to hand the surveys out to all anglers and ask them to bring them back at the end of the fishing day. The response rate was low, 27 went out and 3 came back. The next step was to give out envelopes and stamps and ask people to mail the surveys even though the response rate for mail surveys is known to be lower than for other modes of administration. (Champ, 2003). The return rate was still very low so a decision was made to have the anglers filling out the surveys on site, before they went fishing. This meant that people had to estimate themselves the time spent on site possibly causing a certain bias. However this gave a much better success with 38 surveys given out and answered so it was determined to be necessary to use this method for the final survey to get a sufficient sample. The final survey was then executed during the fishing season of 2009.

On-site sampling has certain advantages and disadvantages which should be noted. A good advantage is that the target population is hit directly and every individual interviewed has visited the site. However, when the sampling is on-site the people who don´t visit the site are excluded. This means that there are no observations taking zero trips which affect the accuracy of the "choke price" for the demand function (Parsons, 2003). This is a selection bias which must be corrected for in the assessment. Since the surveys only intercepted individuals at the lakes, the entire population was not sampled and thus the data was truncated in the statistical analysis to correct for this bias. Individuals truncated from the sample include those who either did not visit the subject lake during the season of 2008 or individuals who never visit the lake (Sohngen, Lichtkoppler, & Bielen, 2000). Another issue concerns a bias of more frequent users. When a person visits ten times more often than someone else, that person is ten times more likely to be sampled than someone visiting the site only once. This is called endogenous stratification and can introduce a bias into the estimation of demand coefficients that may need to be corrected for (Parsons, 2003). However, in the present study such an error was not anticipated because each angler was only surveyed once.

In the sampling process for Lake Elliðavatn an interviewer was placed on-site for the whole month of May to survey the recreational fishers. Children under 18 were excluded from the survey as they generally do not incur cost directly. By fully sampling the month of May, the majority of all users were surveyed as the attendance is by far the highest in May. For example, most of the summer license holders buy their licenses during that month. Each angler was only surveyed once. As the fishing season goes by, paying anglers reduce their attendance but non-paying anglers become more frequent. The proportion of licenses paid by the municipalities increased from 21% in the first two months to 54% at the end of the season on 15th of September. In June the overall attendance starts decreasing. But for further sampling an interviewer was situated on-site at ten random shifts. Also, the fishing guards occasionally had people fill out surveys. The total sample of filled out surveys was 269.

At Lake Vífilsstaðavatn there is a different system for angling licenses. There, recreational anglers can either buy day licenses at the GKG golf club near the lake or buy a certain fishing license pass that allows access to 31 lakes around Iceland (isl. veiðikortið). People using this license are yet required to report at the golf club and register. In the fishing season of 2008 when the sampling strategy was being developed it became clear that almost nobody buys day licenses and almost none of the license keepers register at the golf club. As supervision of fishing in the lake is little people do not feel obliged to register or buy licenses. This made the sampling a bit more complicated as it was not possible to have people filling out surveys before they went fishing. This was tried but not a single survey was filled out in 2008. The season starts 1st of April and it was decided to carry out the final survey in April,

2009. An interviewer was placed on-site during 8 random shifts in April at Lake Vífilsstaðavatn to survey people. 72 surveys were filled out in 8 days. To monitor further the usage of the lake, 15 random times during the season were observed and the anglers fishing each time counted. The total sample of filled out surveys was 72.

Survey design

The survey was roughly divided into four parts. The first part on the first page was solely introductory material where the study was introduced, its purposes, the parties concerned and noted that the survey was anonymous. The second part consisted of trip count questions regarding the frequency of angler´s visits to the subject lake. Parsons (2003) pointed out that asking people about the number of trips made last season can lead to a bias caused by a recall error as people may not remember accurately how many trips they took a year ago. However, by using this method, it still gave an idea of the number of trips per person which then could be compared to total visits to the lake throughout the whole season. The third part of the survey concerned the trip of the day, that is, time spent on site, mode of transport, equipment cost, the type of license and the purpose of the trip. In similar studies, people are sometimes asked about the last trip to get for example the correct time spent on-site (Parsons, 2003). Since some of the people were coming for the first time and many were coming for the first time that season, it was decided to ask people instead about the trip of the day even though time spent on-site had to be estimated and catch numbers were excluded. The data from this part are used to construct the trip cost and possibly also create other explanatory variables in the demand model. A question on multi-purpose trips was in this section where people had the opportunity to weigh proportionally the importance of the fishing trip if it was not the only purpose. The fourth and last part of the survey was on the "demand shifters" or demographic/household characteristic variables such as number of people in household, income, name of street (to measure distance), age, gender, marital status, participation in labor market and level of education. A copy of the final survey can be found in annex 1.

Measure of trip cost

After assembling and organizing the data, the trip cost to the site was estimated. As not everybody pays access fees, the access fee was only taken into the individual total travel cost for those who paid it, for the rest it was zero. The majority of trips to both of the lakes were made by car. The travel cost was measured by assessing the average cost of operating a vehicle per kilometer in urban areas from a report made by the engineering firm Verkís (2009). According to this report the cost per driven kilometer in an average private vehicle is 24,7 ISK. These costs include fuel, upkeep and depreciation. The distance driven was found by using the mapping site on the webpage; www.ja.is. Measuring points were made from the streets of respondent´s residence to the lakes. Departing points were taken from the end of the street in question or, if it was open in both ends, from the middle of the street. At Lake Elliðavatn the destination point was the parking space were licenses are sold but at Lake Vífilsstaðavatn the destination point was between the two main parking spaces at the lake. The mapping site then measures the shortest driving distance between these points. For the roundtrip the distance was multiplied by two. The cost per kilometer was then multiplied with roundtrip distance to arrive at trip cost.

Equipment cost is sometimes accounted for in travel cost models. However, it is difficult to estimate and is generally a negligible portion of the trip cost when the full equipment cost is divided with its lifetime (Parsons, 2003). Fishing gear may have a very long lifetime and it is highly unlikely that it is used only for Lake Elliðavatn or Lake Vífilsstaðavatn. Thus, equipment cost was not accounted for when estimating the individual travel cost in the present study.

Estimating the time cost of the trip probably is the biggest issue in travel cost modeling. The time lost while travelling to and from the site and time spent on the site represent time that would otherwise have been devoted to other activities. Thus, the visitor to a site does not only sacrifice cash costs in travelling to the site but also the opportunity cost of using the time in an alternative manner. The value of this time is called the opportunity cost of time and is recognized by economists as an important determinant of the demand for the recreational site. There are different approaches available for time valuation. Wage-based applications are well known where it is common to use some fraction of the imputed wage, anywhere from one-third of the wage to full wage as the value of time (Bockstael, Strand, & Hanemann, 1987; Parsons, 2003; Amoako-Tuffour & Martinez-Espineira, 2008). The key question is which proportion of the wage rate should be used as a proxy for the opportunity cost of time. One third, or 33%, is a commonly chosen fraction which represents the lower bound and thereby it is attempted to prevent overestimation of time costs (Amoako-Tuffour & Martinez-Espineira, 2008; Hellerstein & Mendelsohn, 1993; Englin &

Cameron, 1996; Coupal, Bastian, May, & Taylor, 2001; Bin, Landry, Ellis, & Vogelsong, 2005; Hagerty & Moeltner, 2005; Gurluk & Rehber, 2008). The same fraction was applied in time cost estimation for the model of this study. To estimate the time cost people were given five classes of annual disposable income to choose from. The average expected annual disposable income for each group was then calculated in terms of a gamma distribution. For the hourly wage the total expected household income was divided by 1760 hours, a number of annual working hours accounting for all holidays and sickness days (Sveinbjörn Sveinbjörnsson, certified public accountant, personal communication, November 10, 2009). This may introduce an error into the estimate as some individuals work more and some work less in any given year and some households have more than one wage earner. But by using the estimate of one third fraction of hourly wage rate the effects of this bias may be reduced (Sohngen, Lichtkoppler, & Bielen, 2000). Thus, to arrive at the total time cost of the trip 0.33 was multiplied with hourly wage, number of adults in the car and total time spent for both driving and recreation.

Model estimation

The number of trips taken in the last season was modeled as the dependent variable of the regression. In their responses to the question on the number of visits during last season people would commonly give a range of visits such as “10-15 times”. Therefore, an analysis was done separately for the upper and lower limit of visits, represented by TRIPH (upper limit) and TRIPL (lower limit). To the question of intended time spent fishing it was also common to have answers given in ranges such as “2-4 hours”. Thus, when calculating the time cost, there were also upper and lower limits. The total trip cost, including both cost of driving and time cost, was represented by MAXCOS (the upper limit) and MINCOS (the lower limit). In the regression the two lower limits and the two upper limits were regressed together in separate regressions to arrive at an interval of a lower bound and an upper bound recreational value. The sign on the trip-cost variable was expected to be negative, according to travel cost theory, as number of trips should decrease when travel cost increases. Five other independent variables were selected for model specification: CATCH which denotes the number of fish caught in the last season. It was expected to have a positive impact on number of trips as anglers who fish more are likely to take more frequent trips. However this can be a bi-causal variable as it is also likely that the anglers who come more often, fish more. The variable FELSM denotes the average number of times fished elsewhere. It was expected to have a negative impact on the number of trips because it was considered likely that as anglers go more often to other fishing sites they take less frequent trips to the lake in question. The socio-economic variables included were: EINC which denotes the expected household disposable income. It was expected to have a negative impact on the number of trips due to the characteristics of the lakes; they are both in close vicinity to the outer districts of the capital area. Furthermore, in the case of Lake Elliðavatn the elderly, disabled and children from the adjacent municipalities can fish there for free. EMPL denotes the level of employment. It was expected to have a negative impact on the number of trips because as people are less occupied by work and have more free time they are likely to take more frequent trips to the lake. EDU denotes the highest educational level completed. It was expected to have a negative impact on the number of trips according to what was found in Shresta et al. (2002), as the higher level of education was completed, anglers would take less frequent trips to the site. An overview of all the model variables is presented in table 5. The general equation with all the explanatory variables applied and their expected signs would then be:

Equation 22 $TRIP = \alpha - \beta_i COS + \beta_{ii} CATCH - \beta_{iii} FELSM - \beta_{iv} EMPL - \beta_v EDU$

Table 5. Definition of the variables used in the model

TRIPH	Maximum trips taken to the lake during last season (2008).
TRIPL	Minimum trips taken to the lake during last season (2008).
MAXCOS	Maximum trip cost, including driving cost and time cost.
MINCOS	Minimum trip cost, including driving cost and time cost.
EINC	Expected mean income of household according to gamma distribution.
CATCH	Average number of fish caught in the lake during last season (2008)
FELSM	Average number of times fished elsewhere during last season (2008)
EMPL	Level of employment, ranging from 1:Full time job, 2:Part time job, 3:Unemployed, 4:Out of labor market (the elderly, disabled etc.)
EDU	Level of education, ranging from 1:Elementary school, 2:High school diploma, 3:Apprenticeship, 4:University undergraduate, 5:University graduate

4.3.1.4 Results – Lake Elliðavatn

Descriptive statistics

Out of anglers surveyed, 95% were men and 5% women. The average age of respondents was 43,4 years. Most of the time, or in 50% of the cases observed, anglers came alone. In 40% of the cases they came two together and in 10 %, three or more. Children were only present in 22% of the total cases, which indicates that fishing in Lake Elliðavatn is not primarily a family sport. Regarding multipurpose trips, 99% of respondents stated that the trip had not been a multipurpose trip, thus the surveys with multipurpose trips were excluded from the model. The educational level varied considerably between respondents. 21% had completed elementary school, 8% had completed a highschool diploma, 26% had completed an apprenticeship, 15 % had completed some undergraduate studies from university and 30% had completed graduate studies from university. The average expected disposable income of respondents was 5.327.153 ISK. 67% of respondents fished on a regular day-license, 21% on a day-license paid by the municipality and 12% had summer-licenses. When asked about what they do with the fish they catch, 60% answered that they keep all the catch, 34% release a part of the catch and 6% release all the catch. One question in the survey dealt with environmental quality where anglers were asked about the effect of increasing proximity of residential areas to Lake Elliðavatn. 47% answered that increasing proximity of residential areas would not affect their fishing frequency. 39% answered that it was rather or very likely that their visits would dwindle. 14% answered rather or very likely that they would increase their visits. 99% of anglers came to Lake Elliðavatn by car.

Economic value

The recreational fishing trip demand models were estimated using truncated Poisson model in the econometric software LIMDEP. The values for overdispersion in the Poisson model were 2,725 and 3,084 which is under the critical value of 3,84 thus it was not necessary to use a less restrictive model such as the Negative binomial (Greene, 2007)

The preliminary results from the first run of the model gave a significant constant at the 5% level for both upper and lower limit. The sign on travel cost, MAXCOS and MINCOS was negative, as expected, and significant in both cases which is consistent with Creel and Loomis (1990), Sohngen et al. (2000) and Shresta et al. (2002). This is the main result of the recreation demand model, that anglers take fewer trips as travel cost increases. The coefficient on income, EINC, was positive and significant in both cases, indicating that anglers with higher income take more frequent trips to the lake. The coefficient on CATCH was positive and significant as expected for both upper and lower limit. This may indicate that anglers able to harvest more fish take more frequent trips, although as already pointed out it may be the other way around. The coefficient on FELSM, the frequency of anglers fishing elsewhere during the last season was negative as expected. However it was only significant for the lower limit, not the upper limit. The coefficient on EMPL was positive as expected and significant. This indicates that anglers who have less than a full time job take more frequent trips to Lake Elliðavatn than the ones with a full time job. This is not in accordance to the income variable as it must be considered likely that people with full time jobs have higher income than others. However, the employment coefficient was of low significance thus it is possible that the employment and income are too collinear for the independent estimation of the effect of employment. The sign on EDU was positive and significant for both upper and lower limit. This indicates that anglers with higher education are likely to take more frequent trips to the lake. This is not as was expected and seen in Shresta et al (2002) but goes along with the income variable as it would be expected that income is likely to increase with higher education. In total 269 anglers were surveyed. Out of the total responses 164 or 61%, were usable for this travel cost demand estimation. Incomplete essential information or zero trips during last season were the main reasons for the exclusion of part of the observations.

The model was run again to get the final equation for recreational demand where insignificant FELSM variable was eliminated. The results are presented in tables 6 and 7 below.

Table 6. The results from the final model estimation of the upper bound of travel cost valuation in Lake Elliðavatn.

```
+--------------------------------------------+
| Poisson Regression                         |
| Maximum Likelihood Estimates               |
| Dependent variable                TRIPH    |
| Weighting variable                 None    |
| Number of observations              164    |
| Iterations completed                  7    |
| Log likelihood function       -1120.186    |
| Number of parameters                  6    |
| Info. Criterion: AIC =         13.73397    |
```

```
|   Finite Sample: AIC =         13.73724      |
| Info. Criterion: BIC =         13.84738      |
| Info. Criterion:HQIC =         13.78001      |
| Restricted log likelihood     -1262.094      |
| McFadden Pseudo R-squared      .1124388      |
| Chi squared                    283.8167      |
| Degrees of freedom                    5      |
| Prob[ChiSqd > value] =         .0000000      |
+----------------------------------------------+
+----------------------------------------------+
| Poisson Regression                           |
| LEFT  Truncated data, at Y =  0.             |
| Chi- squared =  2850.41677  RsqP=   .0682    |
| G  - squared =  1667.17540  RsqD=   .1410    |
| Overdispersion tests: g=mu(i)  :  2.752      |
| Overdispersion tests: g=mu(i)^2:  2.109      |
+----------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.45983738	.04683339	52.523	.0000	
MAXCOS	-.811849D-04	.831598D-05	-9.763	.0000	5232.74681
EINC	.331458D-07	.960561D-08	3.451	.0006	.513581D+07
CATCH	.00208976	.00021708	9.627	.0000	-4.18292683
EMPL	.00250721	.00119831	2.092	.0364	-4.35975610
EDU	.00102706	.00033159	3.097	.0020	-8.90853659

Table 7. The results from the final model estimation of the lower bound of travel cost valuation in Lake Elliðavatn.

```
+----------------------------------------------+
| Poisson Regression                           |
| Maximum Likelihood Estimates                 |
| Dependent variable                 TRIPL     |
| Weighting variable                  None     |
| Number of observations               164     |
| Iterations completed                   7     |
| Log likelihood function       -1291.548      |
| Number of parameters                   6     |
| Info. Criterion: AIC =         15.82375      |
|   Finite Sample: AIC =         15.82701      |
| Info. Criterion: BIC =         15.93716      |
| Info. Criterion:HQIC =         15.86979      |
| Restricted log likelihood     -1520.257      |
| McFadden Pseudo R-squared      .1504415      |
| Chi squared                    457.4195      |
| Degrees of freedom                    5      |
| Prob[ChiSqd > value] =         .0000000      |
+----------------------------------------------+
+----------------------------------------------+
| Poisson Regression                           |
| LEFT  Truncated data, at Y =  0.             |
| Chi- squared =  3419.56730  RsqP=   .1453    |
| G  - squared =  1999.76983  RsqD=   .1829    |
| Overdispersion tests: g=mu(i)  :  3.131      |
| Overdispersion tests: g=mu(i)^2:  2.386      |
+----------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.58327370	.04373585	59.065	.0000	
MINCOS	-.00011632	.860099D-05	-13.524	.0000	4640.08701
EINC	.499097D-07	.883548D-08	5.649	.0000	.513581D+07
CATCH	.00226416	.00019751	11.463	.0000	-4.18292683
EMPL	.00271774	.00123640	2.198	.0279	-4.35975610
EDU	.00108817	.00031127	3.496	.0005	-8.90853659

From the results here above, the equations for upper and lower limits of recreation demand are derived:

Equation 23

$TRIPH = 2,46 - 0,811 \cdot 10^{-4} MAXCOS + 0,33 \cdot 10^{-7} EINC + 0,0021 CATCH + 0,0025 EMPL + 0,0010 EDU$

Equation 24

$TRIPL = 2,58 - 0,00012 MINCOS + 0,5 \cdot 10^{-7} EINC + 0,0022 CATCH + 0,0027 EMPL + 0,0011 EDU$

To estimate the average per-trip-per-person surplus value of Lake Elliðavatn, equation 21 from before is applied:

Equation 21 $$t = \frac{\frac{\lambda_n}{-\beta_{tc}}}{\lambda_n} = \frac{1}{-\beta_{tc}}$$

(Parsons, 2003)

The average per-trip value is then multiplied with the number of trips taken to the site during the season of 2008, a total of 2.133 trips, to arrive at an aggregate value for the Lake Elliðavatn (tables 8 and 9).

Table 8. The upper bound of per-trip value for Lake Elliðavatn in the season of 2009 (ISK 2009).

Average per trip value	$t = \frac{1}{-(-0,0000812)} = 12.315$
Aggregated value	12.315 · 2.133 = 26.267.895

Table 9. The lower bound of per-trip values for Lake Elliðavatn in the season of 2009 (ISK 2009).

Average per trip value	$t = \frac{1}{-(-0,000116)} = 8.620$
Aggregated value	8.620 ·2.133 = 18.386.460

66 summer-licenses were sold at the price of ISK 13500 which gives a total value of

66·13.500 = 891.000

The total access value 2008 then becomes;

lower limit: 18.386.460 + 891.000 = ISK 19.277.460

upper limit: 26.267.895 + 891.000 = ISK 27.158.895

As a result, based on the single site individual travel cost method applied here and the assumptions involved the total recreational access value of Lake Elliðavatn for the season of 2009 is in the range of **ISK 19.277.460 – 27.158.895**.

4.3.1.5 Results – Lake Vífilsstaðavatn

Descriptive Statistics

Out of anglers surveyed, 97% were men and 3% women. The average age was 41,6 years. The anglers came alone in 66% of the cases, in 21% of the cases they came two together and in 9% of the cases they came three or more. Children were present in 20% of the cases. Regarding multipurpose trips, 96 % of respondents stated that the trip had not been a multipurpose trip, thus the surveys with multipurpose trips were excluded from the model. The educational level varied considerably, 14% had completed elementary school, 10% had completed a high school diploma, 37% had completed an apprenticeship, 21% had completed undergraduate studies from university and 18% had completed graduate studies from university. The average expected disposable income of respondents was 6.531.965 ISK. When asked about the type of fishing license anglers had, 97% percent claimed to have the fishing license pass that allows access to 31 lakes around Iceland. Only two people claimed to have a day-license. Regarding what anglers do with their catch, 51% answered that they keep all the catch, 36% release a part of the catch and 13% release all the catch.

Economic value

The model for Lake Vífilsstaðavatn was estimated the exact same way as for Lake Elliðavatn. The values for overdispersion in the Poisson model were 2,35 and 2,68. At Lake Vífilsstaðavatn 72 anglers in total were surveyed and only 46 or 63% of the responses were useable for the travel cost demand estimation. This is indeed a very small sample and therefore the calculations are less reliable than for Lake Elliðavatn. However the results in terms of travel cost are quite similar to those of Lake Elliðavatn.

The preliminary results from the first run of the model gave both constants for upper and lower limit significant at the 5% level. The sign on travel cost, MAXCOSV and MINCOSV were negative as expected and significant in both cases. The coefficients for the rest of the independent variables were not significant which is not of much surprise concerning the size of the sample. The model was run again to get the final equation for recreational demand where all the insignificant variables were eliminated. The results are presented in table 10 and 11 here below.

Table 10. The results from the final model estimation of the upper bound of travel cost valuation in Lake Vífilsstaðavatn

```
+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Dependent variable               TRIPHV     |
| Weighting variable                 None     |
| Number of observations               46     |
| Iterations completed                  6     |
| Log likelihood function       -298.1618     |
| Number of parameters                  2     |
| Info. Criterion: AIC =         13.05051     |
|   Finite Sample: AIC =         13.05658     |
| Info. Criterion: BIC =         13.13002     |
| Info. Criterion:HQIC =         13.08030     |
| Restricted log likelihood     -312.3744     |
| McFadden Pseudo R-squared      .0454986     |
| Chi squared                    28.42520     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .0000000     |
+---------------------------------------------+
+---------------------------------------------+
| Poisson Regression                          |
| LEFT  Truncated data, at Y =  0.            |
| Chi- squared =   585.61475  RsqP=   .1130   |
| G  - squared =   428.69164  RsqD=   .0616   |
| Overdispersion tests: g=mu(i)  :  2.097     |
| Overdispersion tests: g=mu(i)^2:  2.238     |
+---------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 Constant|    2.58850475       .07649296    33.840   .0000
 MAXCOSV |   -.894155D-04    .191331D-04    -4.673   .0000   3997.83637
```

Table 11. The results from the final model estimation of the lower bound of travel cost valuation in Lake Vífilsstaðavatn

```
+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Dependent variable               TRIPLV     |
| Weighting variable                 None     |
| Number of observations               46     |
| Iterations completed                  6     |
| Log likelihood function       -237.8752     |
| Number of parameters                  2     |
| Info. Criterion: AIC =         10.42935     |
|   Finite Sample: AIC =         10.43542     |
| Info. Criterion: BIC =         10.50886     |
| Info. Criterion:HQIC =         10.45914     |
| Restricted log likelihood     -247.7805     |
| McFadden Pseudo R-squared      .0399762     |
| Chi squared                    19.81066     |
| Degrees of freedom                    1     |
| Prob[ChiSqd > value] =         .8549752E-05 |
```

```
+--------------------------------------------+
+--------------------------------------------+
| Poisson Regression                         |
| LEFT  Truncated data, at Y =  0.           |
| Chi- squared =   387.92704  RsqP=   .1031  |
| G  - squared =   311.92243  RsqD=   .0589  |
| Overdispersion tests: g=mu(i)  :  2.716    |
| Overdispersion tests: g=mu(i)^2:  2.883    |
+--------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.40107617	.08259153	29.072	.0000	
MINCOSV	-.844088D-04	.217951D-04	-3.873	.0001	3735.09080

From the results here above, the equations for upper and lower limits of recreation demand are derived:

Equation 25 $TRIPHV = 2{,}58 - 0{,}894 \cdot 10^{-4} MAXCOSV$

Equation 26 $TRIPLV = 2{,}4 - 0{,}844 \cdot 10^{-4} MINCOSV$

The access value of Lake Vífilsstaðavatn is estimated in the same way as for Lake Elliðavatn. The same equation is used to find an average per-trip-per-person value which is then multiplied with the total visits to the lake over the season. Since the total number of visits is not registered for Lake Vífilsstaðavatn, like it is for Lake Elliðavatn, the total number of visits had to be approximated from observed data. As already described an interviewer was situated at Lake Vífilsstaðavatn on 8 random shifts during the month of April where 72 anglers were surveyed, which provides an observation of 72 visits. . Then, for the rest of the season, 15 random checks were made where the number of anglers was counted at each time. To approximate a number of visits, the average visits observed per week-day were multiplied with 18 weeks, the angling season in Lake Vífilsstaðavatn excluding the month of April when visits were observed. These approximations are presented in table 12.

Table 12. Calculated average visits, from 15 random observations, in Lake Vífilsstaðavatn from 1st of May to 15th of September 2009.

Week day	Average visits	Average visits/week day
Friday	1.7	30
Saturday	2.5	45
Sunday	1	18
Monday	1	18
Tuesday	1	18
Wednesday	2.5	45
Thursday	5	90
Total visits		**264**

Total approximated visits to Lake Vífilsstaðavatn during the season of 2009:

264 + 72 = 336

The results for estimated consumer surplus, access value, of Lake Vífilsstaðavatn are represented in tables 13 and 14.

Table 13. The upper bound of per-trip value for Lake Vífilsstaðavatn in the season of 2009 (ISK 2009).

Average per trip value	$t = \frac{1}{-(-0{,}0000894)} = 11.186$
Aggregated value	11.186 · 336 = 3.758.496

Table 14. The lower bound of per-trip value for Lake Vífilsstaðavatn in the season of 2009 (ISK 2009).

Average per trip value	$t = \frac{1}{-(-0{,}0000844)} = 11.848$
Aggregated value	11.848 · 336 = 3.980.928

It is interesting to see that according to the model, the upper bound of the trip value gets a lower value than the lower bound. As mentioned in the model estimation section, the maximum number of trips was regressed against the maximum travel cost and the minimum number of trips was regressed against the minimum travel cost. The regression was run this way in the attempt to capture the complete upper and lower bound of potential recreational value. The reason for the observed result can be explained by the fact that it is expected that those that visit the lake more frequently have most likely lower overall travel cost, according to travel cost theory. Therefore the demand curves for the upper and lower bound as assessed in this analysis cross. In the case of Lake Elliðavatn, the demand curves also cross as the constant for the upper bound was lower than the constant for the lower bound.

Based on the single site individual travel cost method applied here, the assumptions involved and the reservation of a very small sample the total recreational access value of Lake Vífilsstaðavatn for the season of 2009 is on the range of **ISK 3.758.496 – 3.980.928**.

4.3.2 Educational services

Natural resources such as ecosystems are fundamental for progress in knowledge in the fields of biology and nature studies. They provide almost unlimited opportunities for nature studies, environmental education and function as field laboratories for scientific research (de Groot, Wilson, & Boumans, 2002). Opportunities for on-site, scientific assignments and projects are important as a part of natural sciences education at all levels. It is particularly important for children to let them come into contact with nature and draw a link between what takes place inside the classroom and nature itself. Nature, the health of its ecosystems and provision of ecosystem services, is after all the fundamental precondition for the functioning of human societies. In our modern society we have removed ourselves from nature and therefore do not experience directly the consequences of many of our actions. The natural environment is most of the time not involved in our every day life. For that reason it is even more important to introduce the natural environment to children through their education and teach them about nature, its ecosystems and their functions and importance for society. But it is not only important for children to be able to work in the natural environment, it is also important for higher education. Natural sciences departments in universities, e.g. biology, benefit from having access to natural ecosystems in their vicinity. As field trips are an essential part of their educational programs it can save a considerable amount of money to be able to practice field work in the surroundings of the universities. Both of the subject lakes, Lake Elliðavatn and Lake Vífilsstaðavatn play a role for education at different levels in the education system, and that role was used to obtain an economic value of the educational ecosystem services of the lakes.

4.3.2.1 Valuation methods

To estimate the value of the educational services of the two lakes, the use of the lakes for education by schools in the capital area was observed. The time spent by students at the site was valued relative to total time spent at the school over the school-year and to the total cost per student. Official cost data from the annual school report (Skólaskýrsla, 2008) were used in the estimation for elementary schools. Official cost data for high schools came from the ministry of educational affairs. All numbers were obtained at price levels of 2007 but in the final results, they were converted to price levels of 2009, using the annual average consumer price index.

4.3.2.2 Data collection

To obtain data about the usage of the lake in educational purposes, all elementary schools in the three municipalities adjacent to Heiðmörk were contacted, that is Reykjavík, Kópavogur and Garðabær. First, an attempt was made to reach the principals by phone and then by e-mail. Surveys were then sent by e-mails to the schools and out of 60 primary-schools that received a survey, 43 answered. Out of 43, 8 had used either of the two lakes during the school year 2007-2008. The schools in Reykjavík (3) made use of Lake Elliðavatn while the schools in Garðabær (4) and Kópavogur (1) made use of Lake Vífilsstaðavatn. Surveys were also sent to the high-schools (isl. framhaldsskólar) in the capital area. Out of the seven asked, 1 had used the lake, 5 had not used the lake and 1 did not answer. The department of biology at the University of Iceland has used both of these lakes for fieldwork. However the magnitude of this usage is not registered and thus unknown. Therefore it was not possible to account for this value in this estimation even though there certainly is one.

4.3.2.3 Results

The annual cost per student in elementary schools varies between municipalities. In the municipality of Reykjavík it was 990.000 ISK in 2007. For the other municipalities in the capital area it was 938.000 ISK in 2007. The amount of lessons per day varies between classes as younger children have fewer lessons per day than older children. The range is from 6 lessons/day for the youngest to 7,4 lessons/day for the oldest. The number of schooldays is however the same for all children, 180 per year. When responding to the survey, Vatnsendaskóli gave a range of students in class, 18-27 students per class. This is not an exact number of students which again makes the cost estimation less accurate. Another issue concerns the school Barnaskóli Hjallastefnunnar as answers about number of trips were unclear. This school uses the Lake Vífilsstaðavatn on a regular basis as all students go at least once a week to the lake and then there are 2 to 4 organized trips. In the assessment only the organized trips were accounted for, minimum 2 and maximum 4 full day trips per year. Thus, upper and bounds of total cost of time for the students of these two schools are given. While the elementary schools usually took half day or full day trips to the lakes, the one high school that used the lake only used it for one lesson over the school year. To estimate the time cost per student in elementary schools the value of each lesson was calculated by dividing the annual cost per students with annual amount of lessons. Thereby the value per lesson is found and that then multiplied with the time spent on site and number of students.

For the high school the annual cost per student was 750.000 ISK in 2007. This cost was divided by average annual amount of school-units completed (isl. þreyttar einingar) which are 35, thereby finding the value per unit. The amount of lessons behind each completed unit is 72 lessons per year. Thus the value per lesson calculated, 298 ISK/lesson. Finally to find the value of time spent on site the value of lesson was multiplied with the number of lessons and number of students. The results are presented in the tables 15 and 16 below.

Table 15. Results for educational use of Lake Vífilsstaðavatn by elementary and high schools in the capital area the school year 2007-2008 (constant ISK 2009).

School	Lake	Number of classes	Number of students		Value of time on site (constant ISK 2009)	
			Upper bound	Lower bound	Upper bound	Lower bound
Barnaskóli Hjallastefnu	Vífilsstaðavatn	4	175	175	93.054	46.527
Salaskóli	Vífilsstaðavatn	6	211	211	573.190	573.190
Sjálandsskóli	Vífilsstaðavatn	1	40	40	232.635	232.635
Hofsstaðaskóli	Vífilsstaðavatn	2	115	115	505.981	505.981
Flataskóli	Vífilsstaðavatn	1	52	52	604.851	604.851
Fjölbr.Garðabæ	Vífilsstaðavatn	2	44	44	14.614	14.614
Total value of time on site in Lake Vífilsstaðavatn					**2.024.328**	**1.977.801**

Table 16. Results for educational use of Lake Elliðavatn by elementary schools in the capital area the school year 2007-2008 (constant ISK 2009)

School	Lake	Number of classes	Number of students		Value of time on site (constant ISK 2009)	
			Upper bound	Lower bound	Upper bound	Lower bound
Ísaksskóli	Elliðavatn	5	237	237	1.048.924	1.048.924
Norðlingaskóli	Elliðavatn	7	170	170	966.115	966.115
Vatnsendaskóli	Elliðavatn	9	243	162	2.701.671	1.801.115
Total value of time on site at Lake Elliðavatn					**4.716.711**	**3.816.155**

4.4 Supporting Services

Supporting services, sometimes called life-support services are services that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating and cultural services in that their impacts on people are indirect (Ozdemiroglu, Tinch, Johns, Provins, Powell, & Twigger-Ross, 2006). This goes along with the ideology of Fisher and Turner (2008) which conceptualized that benefits from ecosystem services are derived through intermediate or final ecosystem services. In their response letter to Wallace (2007) they give an illustrative example of relationships between some intermediate services, final services and benefits. There, services such as nutrient cycling, pollination and soil formation, which according to the MEA are categorized as supporting services fall into the category of intermediate services. According to the MEA, soil formation service of inland water systems is sediment retention and accumulation of organic matter. The nutrient cycling service includes the storage, recycling, processing and acquisition of nutrients and the pollination service includes support for pollinators (MEA, 2005).

The following sections list and describe the main supporting services provided by Lake Elliðavatn, and Lake Vífilsstaðavatn in terms of the MEA categorization. The ecosystem service of habitat function brought forth in deGroot et al. (2002) is also mentioned shortly, although it is not categorized specifically in the MEA. In addition to the description of various supporting services provided by the lake ecosystems, an attempt was made to estimate the economic value of the supporting service Lake Elliðavatn provides to the popular salmon-river, Elliðaár River. Services definition, data collection process and results are presented below in section 4.4.5 of economic view.

4.4.1 Sediment retention and accumulation

Lake Elliðavatn can be divided into three parts, Vatnsvatn, Vatnsendavatn and Engjar. Engjar, representing about 40% of the lake area, is the part which was flooded when the lake was turned into a reservoir for hydropower generation in 1924. The lake bed in Engjar is different from the other two parts, with less organic sediments and smaller aquatic vegetation. In Vatnsvatn and Vatnsendavatn the lake beds are mostly made of thick permeable organic sediments with batches of tall aquatic plants (macrophytes), namely *Myriophyllum alterniflorum* and *Potamogeton* spp (Malmquist, Ingimarsson, & Ingvason, 2004). Lake Vífilsstaðavatn is also densely covered (over 75%) with tall aquatic plants, mainly *Myriophylllum alterniflorum* (Malmquist & Gíslason, 2007). In such benthic ecosystems, ecosystem services such as sediment retention and accumulation take place as the aquatic macrophytes affect water movements by reducing water turbulence and thus increasing sedimentation of particulate mineral and organic matter (de Nie, 1987). Macrophytes play a big role when it comes to long-term sediment accumulation and retention. An example of that was revealed dramatically in Lake Constance, a big lake in South-Germany when an increase in algal turbidity caused the disappearance of macrophyte beds which then led to the loss of extensive amount of sediments, deposited over centuries (Rooney, Kalff, & Habel, 2003). Although these lakes are not of the same caliber, it still demonstrates the importance macrophytic vegetation can have for the sediment retention and accumulation, and thus the health of the lake ecosystem. Diatoms are another important factor in sediment retention and accumulation.

In Lake Elliðavatn they sequester around 255 tons of SiO_2 according to a research done in 1997-1998. This corresponds to an annual 402 tons of sediment production and biosynthesis of 35g/m^2 of carbon (Gíslason S. R., 2007).

4.4.2 Nutrient cycling

Although its presence may not always be noted by man, nutrient cycling is a very important ecosystem service, one of the fundamental factors enabling life on earth. The constant cycling of certain basic chemical elements is essential to sustain ecosystems, their processes and functions and thus life. These chemical elements are about 30-40 of the 90 chemical elements occurring in nature, and out of the nutrients the most important ones are nitrogen (N), sulfur (S) and phosphorus (P) (de Groot, Wilson, & Boumans, 2002).

Benthic ecosystems of rivers, lakes and wetlands are widely considered to be of significant importance in terms of their role in maintaining biodiversity and storing and cycling materials, nutrients and energy (Covich, et al., 2004). Particulate minerals and organic matter, including the main nutrients, accrue in the sediments in lakes, consequently the distribution, transport and destinations of the sediments can greatly affect the nutrient cycling in lakes (Rooney, Kalff, & Habel, 2003). The input from surrounding terrestrial areas, its vegetation, and the overlying water affect the sediment composition of sediments in shallow lakes (Covich, et al., 2004). In most lakes, there is a net deposit of phosphorus in the sediments. Therefore, the phosphorus metabolism of lakes can be highly dependent on the sediments, which then serve both as a sink and a source of phosphorus (Boström, Andersen, Fleischer, & Jansson, 1988). In the parts of Elliðavatn, Vatnsvatn and Vatnsendavatn, where in most places the sediment layer is about 1m, the aquatic vegetation, namely the macrophytes, is tall and dense and the benthic fauna is dense and diverse, particularly in terms of benthic crustaceans (Malmquist, Ingimarsson, & Ingvason, 2004).

The macrophytes play a big role in the nutrient cycling of the lake. They sequester nutrients from the lake, during periods of active growth, but they also serve as a source of nutrition in different ways for various organisms (de Nie, 1987; Linhart, 1999). They generally become covered with a layer of periphyton, a collection of organisms such as attached algae, bacteria and microinvertebrates together with detritus and plant secretions (Jones, Moss, Eaton, & Young, 2000). The epiphytic algae use the macrophytes as a habitat and they also benefit from inorganic nutrients and dissolved organic compounds released by the macrophytes, particularly if the lake is oligotrophic (Allen, 1971; Bronmark & Vermaat, 1998). The epiphytic algae are grazed by various herbivorous invertebrates such as small crustaceans and snails (Bronmark & Vermaat, 1998). Thus the macrophytes sustain various organisms, herbivores, detritovores, epiphyte grazers or other animals feeding on fine particulate organic matter which becomes trapped on the plant surfaces. They also provide nutrition for the benthic organisms down in the sediment when nutrients are released due to damage, autolysis or microbial breakdown on living parts of the plants (de Nie, 1987). The invertebrates, living both in the sediments and on plant surfaces, such as the crustaceans, water snails and chironomid larvae are an important food source for many fish species. In Lake Elliðavatn the Stickleback and the Arctic char feed mainly on such invertebrates. The Stickleback feeds mostly on crustaceans such as Cladocera and Ostracoda and small chironomids in the earlier life stage. After reaching a size of 20-30mm they start eating Copepoda such as *Cyclops* spp. and bigger chironomid larvae (Snorrason, Kristjánsson, Ólafsdóttir, Malmquist, & Skúlason, 2002). The diet of the Arctic char in Elliðavatn, changes seasonally but according to the research of Björnsson (2001), where the trophic ecology of Arctic char and the Brown trout in Lake Elliðavatn were studied, the annual diet of the Arctic char consisted of chironomid larvae, cladocerans, bivalves, water snails, chironomid pupae and char eggs. The diet of the Brown trout however primarily consisted of sticklebacks but also salmonids and water snails. The trophic ecology of Arctic char and Brown trout in Lake Vífilsstaðavatn is slightly different. There the food selection between the species is more overlapping and it is noteworthy that the Brown trout does not feed much on sticklebacks (Jónsson B. , 1999).

The food chain in the lakes recycles nutrients, each link is important and the equilibrium is sensitive. For example, excessive growth of epiphytic algae can be harmful to macrophytes because it prevents the macrophyte from getting sufficient amount of light and inorganic carbon, thus hindering the macrophytes photosynthesis (de Nie, 1987). Therefore, the role of the epiphyte grazers for example is very important, as they both contribute to the maintenance of the macrophytes and are an important food source for the fish. The same goes for each link of the food chain, the epiphytic algae are an important food source for the epiphyte grazers, which are a food source for the fish, which is a food source for birds and humans and an important part of people´s attraction for recreational and educational activities.

The nutrient cycling service of the lake is however not only a local function within the lakes as it provides services to other ecosystems, for example through migration of birds and fish and through the rivers/streams that run down from the lakes. In the case of Elliðaár River which runs down from Lake Elliðavatn, its biosphere profits considerably from the organic production that takes place in the lake. The reflux from Elliðavatn contains organic drifting particles that benefit the benthic fauna of the Elliðaár River. There the black fly larvae have an important role as they filter these particles from the stream and subsequently become one of the most important food source for salmon. The salmon migrates up the Elliðaár River and spawns in the rivers. Approximately half of its nurturing areas are below Lake Elliðavatn, other nurturing areas are in the rivers that flow into the lake, Hólmsá and Suðurá. The benefit of the organic production of Lake Elliðavatn leads to faster growth of the salmon below the lake compared to the salmon in the rivers above the lake where there is both less organic production and lower temperature (Árnason & Antonsson, 2005). The nurturing areas below the lake are therefore very important for the propagation of salmon in Elliðaár River (Antonsson & Guðjónsson, 1998). In section 4.4.5 below, the economic value of supporting services is based on these benefits provided to the Elliðaár River by Lake Elliðavatn.

Salmon is an anadromous fish species which means that it migrates between sea and freshwaters. Consequently, they transport nutrients and energy between lake and marine ecosystems through reproductive products, excretion and death (Polis, Anderson, & Holt, 1997). After hatching, the salmon grows up on the nurturing areas in the rivers around the lake until they reach smolting maturity that is the stage of development when it assumes the silvery color of the adult and is ready to migrate to the ocean. The smolting age in Elliðaár ranges from 1 to 5 years, but the smolting of salmon is dependent on size, not age (Antonsson, Heiðarsson, & Snorrason, 2007) and due to the organic production of Lake Elliðavatn the salmon below the lake reach smolting maturity one year, on average, before the salmon above the lake (Antonsson & Guðjónsson, 1998). After staying in the ocean, feeding and growing, the salmon returns back to the rivers for spawning.

The migration of birds has an identical role in nutrient cycling as the salmon has, through the distribution of nutrients between ecosystems (de Groot, Wilson, &

Boumans, 2002). At Lake Elliðavatn and its watershed there are at least thirteen water-bird species that spend some part of the year there, plus other species that have been seen a few times. In addition there are also other bird species than water birds (isl. mófuglar and máffuglar) which also benefit from the lake and its adjacent rivers and ponds (Hilmarsson, 2006). At Lake Vífilsstaðavatn eleven water-bird species come regularly to the watershed, plus the less frequent ones. Fourteen other species (isl. mófuglar, máffuglar) are also frequent visitors to the watershed (Hilmarsson & Einarsson, 2006). Migrating birds that feed for example from fish and invertebrates in lakes transport considerable amounts of nutrients with their droppings, their fecal excretions, between ecosystems. In a corresponding manner, birds that feed on land bring nutrients to the water (Polis, Anderson, & Holt, 1997). Thus it is clear that the nutrient cycling services of both Lake Elliðavatn and Lake Vífilsstaðavatn are not only local but there are interactions with other ecosystems which is an important factor as well.

4.4.3 Support for pollinators

The service value of this category is probably insignificant. Larvae from both midges and Caddis flies are a part of the benthic fauna of Lake Elliðavatn and most likely Lake Vífilsstaðavatn as well. Adult caddis flies feed on flower nectar and can thereby carry pollen between flowers. Midges also sometimes alight on flowers, probably for flower nectar. However they only live for a few days and do not feed substantially in their adult stage (Gíslason G. M., personal communication, March 31, 2009). Although these flies may carry pollen between plants it is unlikely that any plant species rely on them for reproduction. The extent of the service of support for pollinators in both lakes is therefore considered to be negligible.

4.4.4 Habitat function

The MEA does not categorize specifically the provision of habitat as an ecosystem service provided or derived from inland water systems as it may overlap with other functional groups. However, deGroot et al. (2002) emphasize the importance of habitat functions and how maintaining healthy habitats is directly or indirectly essential for the provision of all ecosystem goods and services. In their article they divide the habitat functions in two parts, first the refugium function which includes sustaining biological and genetic diversity, and second the nursery function which concerns the provision of breeding and nursery areas to species. The MEA (2005) places the "refugium function" into the category of provisioning services. However, the habitat functions provided will be described in this section, in a similar sense as in deGroot et al (2002).

The lake bottom is a heterogeneous ecosystem where various physical, chemical and biological processes take place and generate possibilities for different niches. Deposit particles, organic, inorganic and of different sizes, settle in various compositions and are affected by different rates and direction of flows. Plant roots grow and die, subsequently taking in and leaving behind sediment substances. Benthic organisms modify sediments through burrowing, digestion and fecal production (Covich, Palmer, & Crowl, 1999). The benthic ecosystem inhabits various kinds of organisms; microbes, algae, invertebrates and macrophytes. Their habitats are generated through these processes, and these processes are brought forth through interactions between the organisms and the organic and inorganic substances in the water. The importance of these organisms, in terms of food chains and nutrient cycling, has already been described in section 4.4.2. However, the benthic ecosystem, particularly when well vegetated, provides a heterogeneous habitat which plays a fundamental role for microinvertebrates, fish species and their interactions in a lake ecosystem. The macrophytes provide a structurally complex, functional habitat both in a nutritional and spatial sense as invertebrates use it as a substrate, shelter and a feeding habitat and young/small fish use it as a shelter and a feeding habitat (Linhart, 1999; de Nie, 1987). Evidence has shown that if habitats are moderately complex, they contribute to a more stable predator-prey relationship between the macroinvertebrates and the fish and the young/small fish and adult fish by supplying young fish food and a hideaway (Savino & Stein, 1982; Diehl, 1992). Benthic invertebrates commonly serve a major role as a main food source for many fish species. Lake Elliðavatn and Lake Vífilsstaðavatn are no exceptions and as was brought forth above they are an important nutrition for the Arctic char and the Stickleback in Lake Elliðavatn and also the Brown trout in Lake Vífilsstaðavatn. The magnitude and diversity of microinvertebrate communities is related to the extent of aquatic vegetation, density, size and shape. Abundance and species richness of benthic invertebrates in densely vegetated aquatic habitats is generally higher than in less vegetated habitats (de Nie, 1987; Diehl, 1992). This can be seen in Lake Elliðavatn where the benthic ecosystem varies between lake parts. The results from a comprehensive research done by Smári Haraldsson (2004) on the benthic fauna of Lake Elliðavatn in 1975-76, revealed a great difference in microinvertebrate biomass between lake parts. In Vatnsendavatn and Vatnsvatn, where the bottom is characterized by sediment and macrophytes, the average annual biomass of all microinvertebrates was 12,3g/m^2. In Engjar, where the bottom is mainly dense turf and rocks, the annual biomass of all microinvertebrates was 5,7 g/m^2. In addition a clear difference was seen in species composition and diversity between the sediment and the turf bottom, with more diversity on the sediment bottom (Haraldsson, 2004). Thus, the benthic ecosystem of Lake Elliðavatn, its vegetation and sediments, provides important habitat services that sustain biological diversity and are fundamental for a balanced relationship between different links of the food chain. The littoral zone in the lake also provides important habitat services, especially for species that inhabit on stones and rocks such as caddis flies larvae (Trichoptera) and water snails (Lymnaea) (Haraldsson, 2004). The water snails are a food source for fish species and the caddis flies are a link to the terrestrial system.

The habitat provision of the lakes is not only for species that live within the lakes but also for species that live around them, such as birds, where the lake plays a fundamental role in their processes of feeding and breeding. According to the conservation plan for birds at Lake Elliðavatn (2006), thirteen water-bird species come regularly to the watershed for feeding, eleven out of these thirteen also breed in the surrounding of the lake. Some of the species stay during the winter but others migrate. Four of these species are listed on watch lists, three as vulnerable (VU) and one at low risk (LR). Twelve other species than water-birds are also regular guests or breeders and benefit from Lake Elliðavatn through feeding and breeding (Hilmarsson, 2006). At Lake Vífilsstaðavatn eleven water-bird species come regularly to the watershed, six of them come each year and three of them breed there each year. Fourteen other species are frequent visitors on the watershed and eight breed annually in the lake´s surrounding (Hilmarsson & Einarsson, 2006).

From this discussion it is clear that the ecosystems of Lake Elliðavatn and Lake Vífilsstaðavatn provide important ecosystem services in terms of habitat provision.

4.4.5 Economic view – Lake Elliðavatn

4.4.5.1 Services definition

The Elliðaár River is a popular salmon river in the heart of Reykjavík city with one of the longest angling histories in Iceland. The angling season is from 21st of June until 1st of September and are 4-6 fishing rods allowed at a time. The average catch for the period of 1974-2003 was 1200 salmons (Guðbergsson, 2009). In this section we attempt to capture an economic value of the nutrient cycling service and provision of nursery habitat already described in section 4.4.2 provided by Lake Elliðavatn for the Elliðaár River.

When rivers are compared in terms of salmon production, rivers originated in lakes or overgrown watersheds generate a lot more of salmon, proportionally to watershed size, compared to rivers originated in poorly vegetated watersheds. The former carry a lot of organic drifting particles which affect the composition of the benthic invertebrate community. In rivers that originate in lakes, the benthic communities are generally characterized by the filter feeding black fly larvae, an important food source for salmon. Further down the rivers, the concentration of organic particles decreases and the benthic community changes where the chironomid larvae, which feed of epiphytic algae become predominant. Between rivers in well vegetated watersheds the rivers that are also lake-fed generally have higher salmon catches than rivers that are not (Aðalsteinsson & Gíslason, 1998; Gíslason, Ólafsson, & Aðalsteinsson, 1998). Lakes also seem to have positive effects on fry and parr production and it has been demonstrated that lake outlets in Iceland are generally very productive compared with other stream areas. This is considered to be due to the high density of blackfly larvae (Jóhannsson, 1988; Einarsson, Mills, & Jóhannsson, 1990). On the watershed of the Laxá í Kjós River the Bugða River has very high densities of fry and parr just below the lake outfall. Bugða is originated in Lake Meðalfellsvatn and joins the Laxá í Kjós River before it enters the sea (figure 8). In the report from Sigurður Már Einarsson (2001) the Bugða River had the most fry and parr density per unit of the watershed.

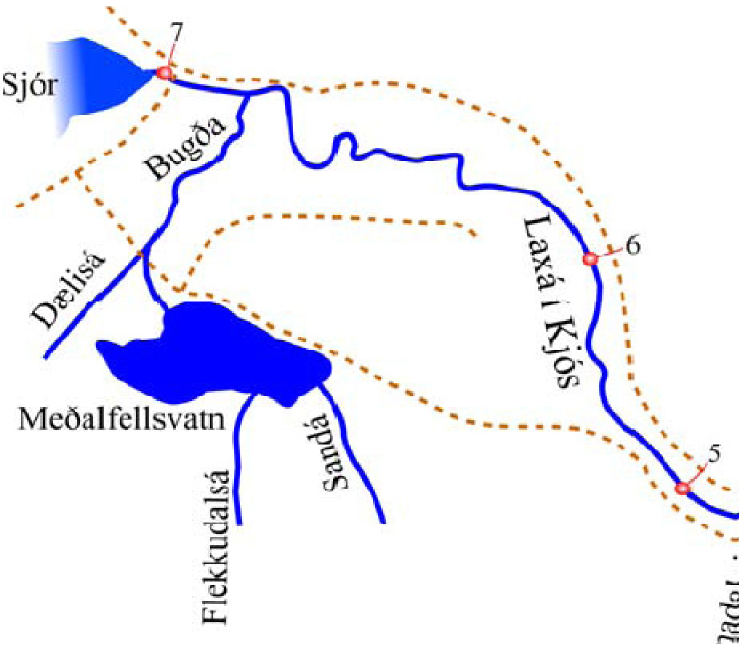

Figure 8. Part of the watershed of Laxá í Kjós. It is demonstrated how the Bugða River runs down from Lake Meðalfellsvatn joining first the Dælisá River and then the Laxá í Kjós River before enterind the sea. (The numbers denote electro fishing stations which are not directly related to the present study.) Source: (Antonsson Þ. , 2009).

In the Elliðaár River watershed, where fry and parr densities have been measured separately for the Hólmsá River and Suðurá River on one hand and for the Elliðaár River below Lake Elliðavatn on the other hand (figure 9). Those measurements have demonstrated that growth is more below the lake and there is also higher density of all fry and parr year classes (Antonsson & Árnason, 2009)

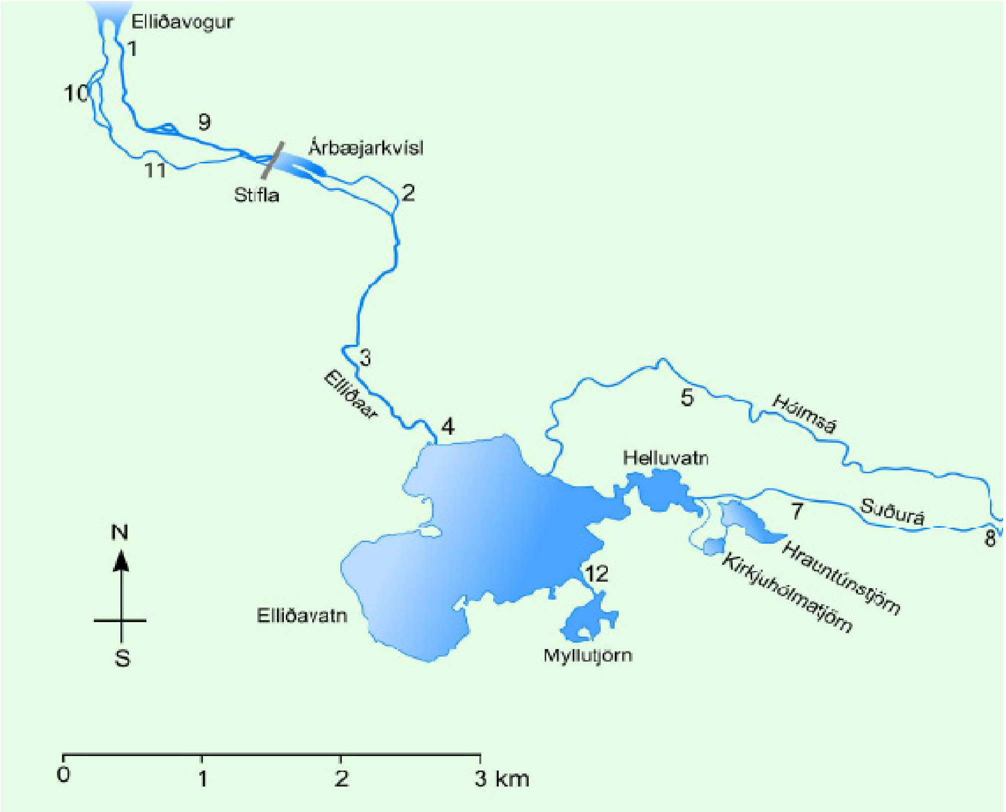

Figure 9. The river system of the Elliðaár watershed. (The numbers denote electro fishing stations which are not directly related to the present study.) Source: Antonsson & Árnason, 2009.

4.4.5.2 Valuation methods

The factor income method described in section 2.5 was applied here to value the benefits of nutrient cycling and provision of nursery habitat by Lake Elliðavatn for the Elliðaár River. Thus the salmon fishing licenses in Elliðaár River denote the production good x as described in section 2.5 and the production factor of interest, q, is Lake Elliðavatn. Its quality and production of organic material affect the salmon yield of the Elliðaár River and thus the demand for salmon fishing licenses since prices and angling licenses in salmon rivers are generally dependent on the yield from the rivers (Agnarsson & Helgadóttir, 2004). Other possible production factors included were rods, production units, river type and time. To capture the extent of the service provided by lakes as a production factor, a comparison study was made between fifteen rivers, ten with lakes and five without lakes. A multiple regression was run with salmon yield per wetted area as the dependent variable and the presence of lake and four other possible production factors as independent variables. The model and its variables are described in further details below.

4.4.5.3 Data collection and model

The fifteen rivers used for the comparison were the following; Elliðaár, Úlfarsá (Korpa), Laxá í Kjós, Laxá í Leirársveit, Langá, Straumfjarðará, Krossá á Skarðsströnd, Víðidalsá, Vatnsdalsá, Laxá á Ásum, Laxá í Aðaldal, Hafralónsá, Selá í Vopnafirði, Vesturdalsá and Hofsá. These rivers were chosen because they have had relatively consistent research done on them and thus comparable data were available. Data on yield were available for the period from 1974 to 2008 at the Institute of Freshwater Fisheries (Guðbergsson, 2009). Data on the other variables were provided by Guðni Guðbergsson at the Institute of freshwater Fisheries through personal communication.

The task of the valuation process is twofold, first to estimate the extent of the service traceable to the lake and then assign an economic value to this service. To specify the model, the dependent variable used was YWA, salmon yield (number of fish) per wetted area (m^2). As mentioned above, five independent explanation variables were included. The first one, LAKE denotes whether the river originates in a lake or not. This was the main variable of interest as the goal was to see whether the presence of a lake had significant effect on salmon yield per wetted area. The other explanation variables were included as they may also affect salmon yield per wetted area. The variable RODS denotes the number of rods allowed for angling in the river per day. Significant effects were not expected as it has been demonstrated that correlation is between catch and the total number of salmons that come up rivers so that there is always a similar proportion caught independent of how many rods are used (Guðbergsson & Antonsson, 2008). However the variable was included for comparison purposes. PU denotes production units, an indicator of quality of salmon habitats in rivers. Production units are measurements of the salmon production potential of Icelandic rivers based on substrate quality on riverbeds. These units are based on production area and the coarseness of the bottom substrate (Antonsson, Einarsson, & Guðjónsson, 2001). The production units were expected to have negative impacts because they are calculated by:

Equation 27 $$PU = QV * A$$

where QV denotes the quality value of substrate and A denotes the substrate unit (m^2). Thus, when the QV*A increases the area (of the production unit) becomes larger and the yield per wetted area, Y/WA, thus decreases. RTYPE2 denotes the type of the river. The nature of the different river types is different which may affect the salmon yield of the river. Most of the rivers are run-off rivers, twelve out of fifteen, and to include a river type variable a dummy variable was used on whether the river is a run-off river or not. TIME denotes the years, from 1974-2008. Thereby a distinction is made between the years as weather condition etc. can vary between years which may also affect the yield. There are various other factors that may affect the salmon yield of rivers, such as size and vegetation of the watershed, resistance, flux, parr release etc. However, as consistent data were not available on all possible explanation factors for the fifteen rivers the scope was drawn at the five variables already described.

4.4.5.4 Results

A multiple regression was conducted with panel analysis in the LIMDEP economic software and a random effects model applied. Panel analysis was applied to allow for variation in constants as well as slope. Each panel group represents one river and within each group there are 35 observations, one per year from 1974 to 2008. Fixed effects model could not have been applied due to lack of variety within groups for all the variables except the yield. This is normal because the presence of lake, production unites, river type etc are always the same for the same river. The model used for the regression was:

Equation 28 $YWA = \alpha + \beta_i LAKE + \beta_{ii} RODS - \beta_{iii} PU + \beta_{iv} TIME + \beta_v RTYPE2$

The results are presented in table 17 on a natural logarithm form. Since the LAKE and RTYPE2 variables are 0 or 1 variables it was not necessary to transform them to natural logarithm.

Table 17. Results from the panel data analysis, random effects model.

```
+--------------------------------------------------+
| Random Effects Model: v(i,t) = e(i,t) + u(i)     |
| Estimates:  Var[e]              =   .324529D+00  |
|             Var[u]              =   .300879D+00  |
|             Corr[v(i,t),v(i,s)] =   .481093      |
| Lagrange Multiplier Test vs. Model (3) = 1920.66 |
| ( 1 df, prob value =  .000000)                   |
| (High values of LM favor FEM/REM over CR model.) |
| Baltagi-Li form of LM Statistic =       1920.66  |
|             Sum of Squares          .104190D+08  |
|             R-squared              -.165592D+05  |
+--------------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
LAKE	1.05244989	.34464913	3.054	.0023	.64285714
LRODS	.01241446	.35560353	.035	.9722	1.74662116
LPU	-.54001622	.29818825	-1.811	.0701	9.50310132
LTIME	-.10470869	.03025199	-3.461	.0005	2.63246216
RTYPE2	.11510457	.51803050	.222	.8242	.78571429
Constant	-2.26064828	2.17878711	-1.038	.2995	

According to the results from the random effects model, two out of the six explanatory variables are significant at the 5% level, the LAKE and LTIME. The sign on LAKE is positive with a coefficient of 1,052. This suggests that 65% of the river yield per wetted area can be explained by the presence of a lake[2]. The significance of LTIME indicates that external factors which vary between years, such as weather, significantly affect the salmon yield per wetted area. The sign on LRODS was positive, but insignificant. The sign on LPU was negative but insignificant. The RTYPE2 variable on river type was highly insignificant but that may also be due to the size and characteristic of the sample where out of fifteen rivers twelve were of the same type.

To derive an economic value, the aim was to apply the proportion of salmon yield attributable to the lake, according to our model, to the income of sold fishing license in the Elliðaár River. However there is one issue of concern. The Elliðaár River is not comparable to other salmon rivers in license-prices because the fishing licenses are in fact subsidized and the demand by far exceeds the supply. Reykjavík Energy is in charge of operating the river and the angling club of Reykjavík is in charge of daily management, partly by volunteers from the association. The cost of managing the river is much higher than the income, thus a calculated average price of

[2] The difference in yield per wetted area between rivers who have a lake (YWA^L) and rivers who do not have a lake (YWA^0) is given by the ratio $\frac{YWA^L}{YWA^0} = e^{\beta}$ where β denotes the coefficient on the lake variable Thus, $\frac{YWA^0}{YWA^L} = e^{-\beta} \rightarrow 1-\frac{YWA^0}{YWA^L} = 1-e^{-\beta} \rightarrow 1-e^{-1{,}052} = 0{,}651$

the salmon hardly represents a real market price (Haraldur Eiríksson, personal communication, December 5, 2009). Because of this special status of the Elliðaár River, a possible economic value of the river is generated by using the average price of fishing licenses, during the period of 2005-2008, from 38 angling zones in Iceland all operated by the same fishing association, the Angling Club of Reykjavík. Thereby all heteroskedasticity due to different markup on license prices is prevented. The numbers are based on a M.Sc. thesis in economics on the economic value of Icelandic angling zones by Brynjar Örn Ólafsson (2009). All prices from the paper were converted from the price levels of 2006 to price levels of 2009 by using annual average consumer price index. According to Ólafsson (2009) the annual sold salmon fishing licenses over the period 2005-2008 were 30.831. The annual average price of salmon fishing license during this period is ISK 30.049 at constant ISK 2009. In the Elliðaár River 380 "rod-days" (days of angling with one rod) are sold.[3] According to the assumptions made and the model results above, the monetary value of angling in Elliðaár River which can be attributed to Lake Elliðavatn comes down to **ISK 7.422.103**[4] (constant ISK 2009) for the year 2009.

[3] Licenses are sold both for half and whole days. Two half days count as one whole "rod-day".

[4] 380 * 30.049 = 11.418.620 → 0,65* 11.418.620 = 7.422.103

5. Summation

In tables 18 and 19 all results have been gathered for each lake and the total value for ecosystem goods and services provided by the lakes presented on an annual basis.

Table 18. Total value of the ecosystem services of Lake Elliðavatn (constant ISK 2009).

Provisioning services			30.665.149
Regulating services		Upper bound	31.345.666
		Lower bound	22.082.780
Cultural services	Recreational services	Upper bound	27.158.895
		Lower bound	19.277.460
Cultural services	Educational services	Upper bound	4.716.711
		Lower bound	3.816.155
Supporting services			7.422.103
Total		Upper bound	**101.308.524**
		Lower bound	**83.263.647**

Table 19. Total value of the ecosystem services of Lake Vífilsstaðavatn (constant ISK 2009).

Cultural services	Recreational services	Upper bound	3.957.232
		Lower bound	3.736.124
Cultural services	Educational services	Upper bound	2.024.328
		Lower bound	1.977.801
Total		Upper bound	**5.981.560**
		Lower bound	**5.713.925**

6. Discussion

Ecosystem services have been defined as the "instrumental values of ecosystems, as means to end of human well-being" (Costanza, 2008). Throughout history it has been the rule rather than an exception to implicitly assess the value of nature in collective decision making, treating the provision of ecosystem services as free (Daily, et al., 2000). If humans ultimately aim to achieve sustainability, a fundamental prerequisite is to view the economy in its proper perspective, as a subsystem of the larger ecological system (Costanza & Daly, 1992). Evaluating ecosystem services in the disciplinary field of ecological economics provides an important contribution to decision making when it comes to the protection or development of natural ecosystems.

On the grounds of international development in the field of ecological economics and transforming views towards nature and natural ecosystems in Iceland, the aim of the present preliminary study was to give a demonstration of an economic valuation of ecosystem services in Iceland. In accordance with the MEA framework, different valuation methods were applied for different services, in an attempt to capture a potential economic value of the ecosystem goods and services provided by Lake Elliðavatn and Lake Vífilsstaðavatn. Although the methods are debatable, and each of them has some defects, when applied simultaneously they address the subject in more depth than any method previously used in Iceland. The results should provide a new perspective and will hopefully serve as a reference for further such studies in the near future.

Following is a discussion of the results in each category, some future studies possibilities mentioned. Finally, in section 7, an overall conclusion from the study is made.

Provisioning services

The final result from the valuation of the provisioning services category of Lake Elliðavatn was ISK 30.665.149 (constant ISK 2009). This number comprises the worth of electricity produced from Elliðaárvirkjun in the year of 2007. The other provisioning service considered extensive enough for possible economic valuation would be the fish production. In Lake Vífilsstaðavatn that would be the sole provisioning service accountable as the lake does not provide any other provisions directly benefitting the human society. However, to prevent double counting, as the fish production is the main attraction for the recreational anglers, this service was not valued separately but through the recreational services category. Double counting benefits in environmental valuation studies can lead to overestimation of the benefits value and undermine the credibility of the study. The methodology applied in this category is fairly simple as it is based on compiling available market data on the electricity production from Elliðaárstöð. However it must be noted that market price only provides an indicator of the minimum value of the service. To obtain a true value the demand curve and consumer surplus of electricity would have to be estimated. This was however beyond the scope of the present study.

Other potential issues regarding this category concern whether important services are being left out of the valuation for some reason. For example services such as gene pool or biodiversity service but these are categorized as provisioning services in inland water systems according to the MEA (Aladin, et al., 2005). In section 2.3 the anthropocentric perspective is described and the origin of economic value which is based on an instrumental perspective. This means that the value of biodiversity must be derived from an interaction between it and human subjects. Moreover, biodiversity can be classified in terms of genetic diversity, species diversity, ecosystem diversity and functional diversity. Different values of biodiversity can also be identified and characterized in different categories (Nunes & van den Bergh, 2001). Thus, valuing the economic value of biodiversity is both a very controversial and complicated matter. In both of the subject lakes various species of flora and fauna exist but at present they do not have a role as a provisioning service because they do not give benefit directly to the human society. Such a role may yet to be discovered or it may be non-existent. Therefore, the importance and potential services of gene pool and biodiversity shall not be ignored although it was not addressed here.

Regulating services

The result from the valuation of regulating services provided by Lake Elliðavatn was in the range of ISK 22.082.780 - 31.345.666 (constant ISK 2009) in 2009. Evidently this is not the true cost since construction has not been completed, but this is the intended defensive expenditures. An issue concerning this part is the driver behind these constructions and then there is a question of whether the categorization is correct. The ultimate reason for these constructions is to maintain the water quality and thereby to protect the biota, the fish and the pristine water which are also a great attraction for outdoor recreation. Thus there is a question of whether the constructions could possibly illustrate the value put on recreational use and the inclusion of this value may represent a possible issue of double counting. However, the lake can and has served to dilute and evict pollution. If there would not be a lake, this service would possibly have to be replaced by a sedimentation pond in any case. These constructions have been made in order to provide this service instead of the lake. When a certain service is replaced so it can be maintained, without risking another ecosystem and its goods and services, it must reveal a value of that service. This is also why these constructions can be a replacement cost, as well as a defensive behavior, since a service is being replaced. Therefore, it was considered completely justifiable to use this categorization and method for valuating this service. Yet the possible tradeoff is acknowledged and the double counting issue considered.

Cultural services – Recreational services

The final result for the valuation of recreational services provided by Lake Elliðavatn in the year 2009 was in the range of ISK 19.277.460- 27.158.895. In the case of Lake Vífilsstaðavatn this value was in the range of ISK 3.736.124 - 3.957.232. These results are based on certain assumptions, such as the opportunity cost of time, mentioned in section 2.6. Some of the assumptions may be seen questionable. For example in the assessment of opportunity cost of time, the individual time value is based on a wage rate. This poses a question about fairness and equity. Is it justifiable that the leisure time of a bank director with a high salary is valued much more than the leisure time of a general worker? Shaw (1992) stressed that the value and cost of time are different concepts, and that someone with a low wage can value time very highly. This is a valid perspective and should not be ignored. Valuing people´s time will always be difficult and debatable but using the wage rate is a valid approximation.

Another factor that can affect the results is that substitution sites were excluded. In the survey anglers were asked about the frequency of visits to other angling sites, i.e. lakes in the vicinity of the capital area. In the end however, these questions were commonly left out by respondents of the survey, time was limited for estimating the price of substitution sites and there was a question of whether the selected substitute sites were the appropriate ones. Thus, they were left beyond the scope of this study.

In the case of Lake Vífilsstaðavatn, the upper bound of the per-trip value came out with a lower total value than the lower bound[5]. This is most likely due to that more frequent visits are expected if the cost is lower as was mentioned in section 4.3.1.4. However, the travel cost results are less reliable than in Lake Elliðavatn. This is due to the very small sample of only 46 usable surveys where only the travel cost variable reached significance in the model. While in Lake Elliðavatn 164 surveys were usable. The total visits to Lake Vífilsstaðavatn are also very roughly estimated as it is very time consuming to attempt to get a better idea of the overall usage. This is not very accurate compared to Lake Elliðavatn where all anglers are registered each time, except the summer license holders, thus the number of total visits is relatively accurate.

Cultural services – Educational services

The final result for the valuation of educational services provided by the lakes in the school year 2007-2008 was in the range of ISK 3.816.155 - 4.716.711 in Lake Elliðavatn. In Lake Vífilsstaðvatn it was in the range of ISK 1.977.801 - 2.024.328. The total usage of both lakes for educational services seen here is an absolute minimum. For example it is certain that the University of Iceland has used both lakes for field work in biology courses. But as this use is not registered it is impossible to estimate in a fairly reliable manner. Moreover, according to the lake managers, kindergartens and various courses use both of the lakes for educational purposes. Thus, although this usage was beyond the scope of this study it is clear that the value of educational services may be somewhat higher.

Supporting services

This category is the one most difficult to value in economic terms. Yet the ecosystem services within this category are possibly the most important ones to sustain all other goods and service provision. However, through factor income method it was attempted here to assess a potential economic value of a supporting ecosystem service provided by Lake Elliðavatn to the Elliðaár River. The result was ISK 7.422.103 based on the assumption of an average price of rod days from 38 angling sites. This result is a very rough estimate and as the demand curve for angling licenses in the

[5] The upper bound included more visits and longer while the lower bound included fewer visits and shorter.

Elliðaár River is unknown, the real value stays unknown. Furhermore, it must be noted that the explanatory variables used in the multiple correlation are possibly not the variables that mostly affect salmon production in rivers. As mentioned in section 4.4.5.3 variables were left out, due to a lack of available data, which can also affect salmon production per wetted area, such as vegetation on watershed. The result here was that 65% of salmon production per wetted area can be attributable to the presence of a lake. Although this is what the statistical analysis demonstrates, due to the fact that other potential key variables were left out, the value might be overestimated. When compared to the recreational value of Lake Elliðavatn it is interesting to see that the estimated total income of angling license in Elliðaár River (~ISK 11,5 million) is only in the range of half to one third of the value of the lake (~ ISK 19 – 27 million). Certainly the study only includes the price of angling licenses in the river, excluding travel and opportunity cost of time. Yet, this value is strikingly low.

It shall also be noted that applying the proportion of salmon yield attributed to the lake to the estimated income of license is questionable. As the demand curve for angling license is unknown, it is also unknown whether a relationship between salmon yield and price of angling license exists. However as the prices of angling licenses in salmon rivers are generally dependent on the yield from the rivers (Agnarsson & Helgadóttir, 2004) an assumption can be made of an existing relationship.

Further research

There are few things concerning the present study that suggest further research in terms of economic valuation. A hedonic pricing study for the residential area surrounding Lake Elliðavatn is one of them. As mentioned in section 2.5 the price of a real estate depends on various factors and the adjacent environment is one of them. The proximity to Lake Elliðavatn which offers both a nice view and various recreational opportunities is undoubtedly a factor that can increase the value of a real estate. It could provide an additional value to the services from Lake Elliðavatn. Also, to repeat the travel cost study including substitute sites could affect the outcome of services value for both the subject lakes. Thus these are two potential subjects for further research on the value of Lake Elliðavatn.

An interesting topic for other valuation studies is the comparison of the recreational value of angling in Lake Elliðavatn vs. angling in the Elliðaár River. The results from this study indicate that the recreational value of the lake is higher than the one of the river. In this context, a travel cost study on the Elliðaár River provides a significant subject for further research. Thereby the demand curve and consumer surplus of angling in Elliðaár River could be estimated and compared to this study.

More in depth assessment on the relationships between lakes and rivers is also an interesting research topic. The result of 65% of the Elliðaár River salmon yield per wetted area attributed to Lake Elliðavatn is fairly high. The question is whether some important factors that affect salmon yield were left out, or if lakes in general really have such vast impacts on salmon yield in rivers. This is a potential research material, which could serve an important role for further evaluation studies in Iceland. In general, regarding future economic valuations of other sites in Iceland, it is important to keep doing basic ecological research and identify linkages in ecosystem dynamics. That facilitates further ecosystem valuation research and enables different perspectives when it comes to environmental development management.

7. Conclusion

The economic valuation of the ecosystem goods and services provided by Lake Elliðavatn and Lake Vífilsstaðavatn provides the first sub-results from the project; The economic valuation of ecosystem services, the case of Heiðmörk, Iceland. This is the first valuation study of ecosystem services executed in Iceland and will hopefully serve as a reference for further such studies in Iceland.

The final results from the present study are that the overall value of ecosystem services provided by Lake Elliðavatn in 2009 is in the range of ISK 83.263.647 - 101.308.524 (constant ISK 2009). For Lake Vífilsstaðavatn this value is in the range of ISK 5.713.925 - 5.981.560 (constant ISK 2009). Overall the study is based on many assumptions and rough estimations of numbers. Yet the final result can serve as an indicator of a potential value of the goods and services provided by these ecosystems. Evaluating ecosystem goods and services can never fall solely in the domain of the economist and money is not the only appropriate metric (Limburg & Folke, 1999). Some important ecosystem services will never be valued in economic terms. However, by applying various valuation methods at the same time and trying to understand the ecosystem functions we can get some idea of the economic value, such as has been done here.

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Annex 1

Hagrænt mat á fjölþættri þjónustu vistkerfa
~ Virði Heiðmerkur ~

Kæri þátttakandi,

Um þessar mundir stendur yfir heildstætt verðmætamat á náttúru- og útivistarsvæði Heiðmerkur. Heildstætt verðmætamat er grundvallarforsenda þess að hægt sé að nýta og vernda svæðið og náttúru þess af skynsemi og fyrirhyggju. Slíkt verðmætamat er ekki hægt að framkvæma nema með þátttöku þeirra sem nota Heiðmörk. Könnun þessi er einn liður í verðmætamatinu og verður hún notuð til þess að meta verðmæti frístundaveiða í Elliðavatni. Að framkvæmd verðmætamatsins standa Háskóli Íslands, Rannsóknarstöð Skógræktar ríkisins að Mógilsá, Skógræktarfélag Íslands, Skógræktarfélag Reykjavíkur, Reykjavíkurborg, Garðabær og Orkuveita Reykjavíkur. Dr. Brynhildur Davíðsdóttir er ábyrgðamaður rannsóknarinnar fyrir hönd Háskóla Íslands.

Allar persónuupplýsingar sem upp eru gefnar í könnun þessari verða órekjanlegar til einstakra þátttakenda. Mjög mikilvægt er að **öllum** spurningum sé svarað eftir bestu getu.

- Kærar þakkir fyrir þátttökuna

1. Ritaðu dagsetningu veiðidags.

2a. Veiðitímabilið í Elliðavatni er frá 1 maí til 15 september, ár hvert. Hversu oft að meðaltali á viku veiðir þú í Elliðavatni yfir veiðitímabilið.

- ☐ **1 sinni**
- ☐ **2-3 sinnum**
- ☐ **4-5 sinnum**
- ☐ **6-7 sinnum**
- ☐ **Annað, þá hvað** ______________________________

2b. Hversu oft á síðasta veiðitímabili, árið 2008, veiddir þú í Elliðavatni?

____

2c. Hversu marga fiska veiddir þú á síðasta veiðitímabili í Elliðavatni?

____

2d. Hversu oft á veiðitímabilinu árið 2007, veiddir þú í Elliðavatni?

____

2e. Hversu marga fiska veiddir þú á veiðitímabili ársins 2007 í Elliðavatni?

____

3. Hvað gerir þú vanalega við aflann sem þú veiðir?

☐ **Hirði hann**

☐ **Sleppi hluta hans**

☐ **Sleppi öllum**

4. Af hverju veiðir þú í Elliðavatni? Vinsamlegast raðið eftirfarandi ástæðum í röð frá 1 upp í 5 eftir mikilvægi þeirra þar sem mikilvægasta ástæðan fær númerið 1 o.s.frv.

☐ **Nálægð við höfuðborgarsvæði**

☐ **Verð veiðileyfa**

☐ **Njóta náttúru**

☐ **Veiðivon**

☐ **Annað, þá hvað ____**

5. Á undanförnum árum hefur byggð verið að færast nær Elliðavatni. Hvaða áhrif telur þú að það hafi á veiðivenjur þínar í Elliðavatni?

☐ **Mjög líklegt er að ég muni auka komur mínar**

☐ **Frekar líklegt er að ég muni auka komur mínar**

☐ **Engin áhrif tíðni ferða**

☐ **Frekar líklegt er að ég muni minnka komur mínar**

☐ **Mjög líklegt er að ég muni minnka komur mínar**

6. Hversu oft á síðasta veiðitímabili, árið 2008, veiddir þú annarstaðar en í Elliðavatni?

____

7. Hversu oft á síðasta veiðitímabili veiddir þú í eftirfarandi vötnum:

Hafravatn ______

Reynisvatn ______

Vífilsstaðavatn ______

Hvaleyrarvatn ______

8. Hversu löngum tíma býst þú við að eyða við vatnið í dag?

____

9. Hvert er áætlað verðmæti (í krónum) þess búnaðar sem þú notar við veiðar að Elliðavatni?

____

10. Hvers konar veiðileyfi veiðir þú á?

☐ **Dagsleyfi, greitt af sveitarfélagi**

☐ **Dagsleyfi**

—

☐ **Sumarleyfi**

11. Með hvaða hætti komst þú að Elliðavatni í dag?

☐ **Á einkabifreið**

☐ **Gangandi**

☐ **Annað** ____

12. Ef þú ferðaðist með einkabifreið merktu þá annað hvort í reitinn „Fólksbifreið“, eða „Jeppi“ eftir því sem við á.

☐ **Fólksbifreið**

☐ **Jeppi**

13. Ef þú ferðaðist með einkabifreið, hversu margir voru í bifreiðinni?

____

Hversu margir voru undir 18 ára?

____

14. Var koma þín að Elliðavatni eini tilgangur ferðar þinnar?

☐ **Já**

☐ **Nei**

Ef þú hefur merkt í „Nei“ reitinn, að hversu stórum hluta var koma þín í Heiðmörk í dag, ástæða ferðarinnar?

____

15. Við hvaða götu býrð þú og hvert er póstnúmerið? Alls ekki skrifa húsnúmer!

____

16. Merktu við kyn þitt.

☐ **KK**

☐ **KVK**

17. Hvaða ár fæddist þú?

____

18. Hver er hjúskaparstaða þín?

☐ **Í hjónabandi**

☐ **Í sambúð**

☐ **Einhleyp/einhleypur**

☐ **Ekkja/ekkill**

19. Hversu margir búa á heimili þínu?

____

Hversu margir eru undir 18 ára?

___

20.Hvert er hæsta menntunarstig sem þú hefur lokið?

☐ **Grunnskólapróf**

☐ **Stúdentspróf**

☐ **Iðnnám**

☐ **Grunnám á háskólastigi**

☐ **Framhaldsnám á háskólastigi**

21.Hver er atvinnuþátttaka þín?

☐ **Í fullu starfi**

☐ **Í hluta starfi**

☐ **Atvinnulaus**

☐ **Utan vinnumarkaðar** (t.d. heimavinnandi húsmæður, eldri borgarar, öryrkjar og námsmenn)

22. Hverjar eru ráðstöfunartekjur heimilisins á ársgrundvelli? Ráðstöfunartekjur eru allar tekjur heimilisins eftir skatta. Merktu í þann reit sem endurspeglar svar þitt sem best.

☐ **0 – 2.500.000,- kr.**

☐ **2.500.001 – 5.000.000,- kr.**

☐ **5.000.001 - 7.500.000,- kr.**

☐ **7.500.001 - 10.000.000,- kr.**

☐ **10.000.001,- kr eða hærri**

Kærar þakkir fyrir þáttökuna