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Economic valuation of ecosystem services

The case of lake Elliðavatn and lake Vífilsstaðavatn

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HÁSKÓLI ÍSLANDS

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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 ultimately depends (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 include e.g.; basic life support services such as provision of clean air and water; maintenance of soil fertility; pollination of crops and other vegetation; control of potential pests; production of food and fiber; and provision of cultural experiences (Costanza et al., 1997; MEA, 2005).

Human societies mainly focus on provisioning services derived from ecosystems, followed by regulating, cultural and supporting services (Foley et al., 2005). This order is mostly based on the fundamental short-term needs of humans for food, fiber, timber and habitat. The intended consequences is therefore 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). This reveals tradeoffs that in many cases remain outside of decision-making, possibly resulting in suboptimal appropriation of ecosystem services.

Over the past few decades the importance of ecosystem services has been highlighted. The earliest references regarding ecosystem functions and services date back to the 1960´s (de Groot, Wilson, & Boumans, 2002). A certain climax was reached with the publication of the Millennium Ecosystem Assessment (MEA) in 2005. For over a decade now, assessing the flow of ecosystem goods and services and valuing them in terms of economic benefits has contributed substantially to decision-making in environmental-, land-use- and resource management. Despite this development in USA and Europe, Iceland has not followed, and is far behind in this field.

In 2008, the first Icelandic ecosystem services research project was initiated through collaborative efforts of four research entities (Brynhildur Davíðsdóttir, 2010). The project, "Estimating the value of economic services of Heiðmörk recreational area" contains six interdependent study components. This paper presents one of those components, and focuses on the economic value of the services provided by the two lakes located in the area, Lake Elliðavatn and Lake Vífilsstaðavatn. More in depth information on the analysis presented in this paper is found in Halla Margrét Jóhannesdóttir (2010).

Study site

Ellidavatn

Lake Elliðavatn is the biggest lake in the capital area, with an area of 2,02 km² (Hilmar Malmquist & Gísli Már Gíslason, 2007). The volume of the lake is around 2 Gl, with the average depth around 1m (deepest place 2,3 m). Surface influx is mainly through the river Bugða/Hólmsá and through the river Suðurá. Overall, the flow in and out of the lake is approximately 4,7 m^3/s. The water exchange rate is around five days, which is fast compared to other lakes of this size. 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 (Hilmar J. Malmquist, Finnur Ingimarsson, & Haraldur Rafn Ingvason, 2004).

Over the last century various changes have occurred in the water catchment 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 (Hilmar J. Malmquist et al., 2004).

In 1941 conventional farming ended at Ellidabær, but farming exists elsewhere in the water catchment. For example, stables are present at Heimsendi, a chicken farm at Elliðahvammur and sheepfarming at Vatnsendi and Kjóavellir (Kópavogsbær, 2000). The density of initially summerhouses and then later year round residences has increased considerably. In addition, the heavily traveled road, Suðurlandsvegur is situated in the water catchment. Water has been extracted from the Gvendarbrunnar wells since 1909 and the area is significantly forested. In April, 1964 all land owners around Lake Elliðavatn organized fishing and fish cultivation in the lake, forming the Elliðavatn Fishing Association (Guðmundur Marteinsson, 1975). Since then, this association has been in charge of all fishing in the lake and the rivers Bugða/Hólmsá and Suðurá.

Research of the ecology of the water catchment has mainly focused on salmonids, in particular salmon in the Elliðaár river. However several studies have focused 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 stickleback, salmon is not abundant and eel is rare (Hilmar J. Malmquist et al., 2004). Research 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 surely known, however a possible explanation is considered to be the increase in water temperature, particularly in the fall (Hilmar Malmquist et al., 2004; Þórólfur Antonsson & Friðþjófur Árnason, 2009)

Vífilstaðavatn

Lake Vífilsstaðavatn is situated in the north-west end of Heiðmörk and is 0,27 km^2. Adjacent to the lake are heathlands and slopes, except for the south side where there is moorland, named Dýjakrókar. Springs in the moorland supply water to the lake in little streams. On the west side of the lake, Vífilsstaðalækur falls out from the lake (Jóhann Óli Hilmarsson & Ólafur Einarsson, 2009). The lake and surrounding area is property of the municipality of Garðabær, and were officially declared a protected area in November 2007.

Lake Vífilsstaðavatn is biologically rich. The benthic fauna is dense and conductivity is high, around 130μS/cm, indicating a high level of dissolved matter and good viability (Bjarni Jónsson, 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. Fish species found in the lake include the arctic char, brown trout, eels and stickleback. European eel (*A.angilla*) and a hybrid from the European and the American eel (*A. rostrata*) migrate up the Vífilsstaðalækur and can be found in the lake (Þórólfur Antonsson, Guðni Guðbergsson, Bjarni Jónsson, & Hilmar J. Malmquist, 2007). The sticklebacks in Lake Vífilsstaðavatn are unique and have been the subject of evolutionary and genetic research both in Iceland and in the United States (Bjarni Jónsson, 2004).

Analysis and Results

Both lakes provide various ecosystem services, of which a selected set is economically valued in this study. Using the MEA classification scheme, the following services were valued:

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

Each of the service categories is addressed in some aspect for Lake Elliðavatn but only cultural services for Lake Vífilsstaðavatn. The analysis is divided into four main sections according to the MEA classification categories.

Provisioning services

Provisioning services are the products people obtain from ecosystems, such as food, fresh water, and genetic resources. Lake Elliðavatn, provides two main provisioning services. First, a non-consumptive service which is the electricity production supported by the lake as a reservoir. Second, a consumptive service, fish production as three fish species are fished by recreational fishermen in the lake, two trout species and salmon. The main catch of the lake is the Brown trout and Arctic char. Salmon is mostly fished in the rivers that run to and from the lake but few can be caught in the lake in autumn as it migrates (Friðþjófur Árnason & Þórólfur Antonsson, 2005). The Arctic char is caught in Lake Vífilsstaðavatn. Although an important provisioning service, fish catch of the two lakes was excluded from the economic assessment to prevent double-counting as fishers mainly fish in the lakes for recreational purposes and therefore this service was valued through the recreational services category (see below).

The final results indicate that provisioning services from Lake Ellidavatn are worth ISK 30.665.149 (constant ISK 2009). This number comprises the worth of electricity produced from Elliðaárvirkjun in the year of 2007.

Regulating services

Regulating services are the benefits people obtain from the regulation of ecosystem processes (MEA, 2005). In inland water systems the main regulating services include climate regulation, hydrological flows, pollution control and detoxification, erosion control and natural hazards control (Aylward, Bandyopadhyay, & Belausteguigotia, 2005). Given the limittions of this study, only one regulating service was economically evaluated for Lake Elliðavatn; pollution control and detoxification. For Lake Vífilsstaðavatn services of this category were not considered extensive enough for economic evaluation.

For assessing the value of pollution control and detoxification the defensive cost method was applied. The municipality of Kópavogsbær has invested in preventing storm water pollution from the residential areas and roads to enter the lake by building a pipeline and a sedimentation pond. By investing in these operations, the municipality has revealed defensive behavior. However, it shall be noted that these operations could also be considered as replacement cost.

The investment cost for the sedimentation pond 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 providing a value of ISK 2.509.390 – 3.764.085 (Brynjólfur Björnsson, personal communication, December 18, 2009). The final results illustrate a total annual cost for both the pipeline and the pending sedimentation pond in 2009 in the range of ISK 22.082.780 – 31.345.666 (constant ISK 2009), which reveals the value of the assessed regulating servcies.

An issue concerning this estimate is whether the classification is correct and if it possibly could be capturing the value of the recreational services of the lake. The ultimate reason for the defensive investment is to maintain the water quality and thereby to protect the biota, which is 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 therefore the inclusion of this value may represent double-counting.

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). Nature 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 available various opportunities for education and research and is essential as such (de Groot et al., 2002). In this study, both recreational and educational services of the two lakes were valued.

Recreational services

Lake Elliðavatn and Lake Vífilsstaðavatn provide recreational services mainly through recreational angling. In this study, a single-site travel cost method was applied to assess the values of those services. The survey performed was an on-site survey implemented during the summers of 2008 and 2009.

Lake Ellidavatn

In total 269 anglers were surveyed. Out of the total responses 164 or 61%, were usable for the analysis. Out of anglers surveyed 95% were men and 5% women with an average age 43,4 years. Most of the time or in 99% respondents came by car. In 50% of the cases observed, anglers came alone, 40% of the cases they came two together and in 10 %, three or more. Approximately 99% of respondents stated that the trip had not been a multipurpose trip. Educational level varied considerably between respondents: 21% had completed elementary school, 8% had a high-school diploma, 26% had completed an apprenticeship, 15 % had completed some undergraduate studies and 30% had graduate degrees. The average expected disposable income of respondents was 5.327.000 ISK. Approximately 67% of respondents fished on a regular day-license, 21% on a day-license paid by the municipality and 12% had summer-licences. When asked about what they do with the fish they catch, 60% answered that they keep all the catch, 34% release part of the catch and 6% release the entire catch.

Average trip value ranged from 8620 ISK to 12315 ISK with a total of 2133 annual trips in 2009. The final result revealed a total value of recreational services provided by Lake Ellidavatn in the range of ISK 19.277.000 - 27.159.000.

Lake Vifilstadavatn

In total 72 anglers in total were surveyed but only 46 or 63% of the responses were useable for the analysis. Out of anglers surveyed, 97% were men and 3% women with an average age of 41,6 years. The anglers arrived 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. 99% arrived by car and 96% stated that the trip had not been a multipurpose trip. The educational level varied where 14% had completed elementary school, 10% had a high school diploma, 37% had completed an apprenticeship, 21% an undergraduate degree and 18% had graduate degrees. The average expected disposable income of respondents was 6.531.965 ISK. When asked about the type of fishing license, 97% percent claimed to have the fishing license pass that allows access to 31 lakes around Iceland. Only two respondents claimed to have a day-license. Approximately 51% answered that they keep the catch, 36% release part of the catch and 13% release the entire catch.

Average trip value ranged from 11186 ISK to 11848 ISK with a total of 336 annual trips in 2009. Therefore, the final results indicated a value of recreational services provided by Lake Vífilsstaðavatn in the range of ISK 3.736.124 - 3.957.232 (2009 ISK).

Educational services

Natural resources provide almost unlimited opportunities for nature studies, environmental education and function as field laboratories for scientific research (de Groot, Wilson, & Boumans, 2002). 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 assessed through a questionnaire sent to all schools in the area. The time spent by students at the site was valued relative to total time spent at the school over the school year and the total cost per student. Official cost data from the annual school report (Samband íslenskra sveitafélaga, hag- og upplýsinga svið, 2008) were used in the estimation for elementary schools. Official cost data for high schools came from the ministry of educational affairs.

The results indicate a total educational value of Lake Ellidavatn to be in the range of ISK 3.816.155 - 4.716.711. In Lake Vífilsstaðvatn the results indicated a total value that ranged between ISK 1.977.801 - 2.024.328. Those results indicate the lower bound on the actual educational value of the lakes. For example the University of Iceland has used both lakes for fieldwork in biology courses. But as this usage is not registered it was impossible to estimate its value. Moreover, according to lake managers preschools use both lakes for educational purposes. Since this usage was beyond the scope of this study it is clear that the value of educational services is somewhat higher than the results indicate.

Supporting services

Supporting 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 et al., 2006). According to the MEA (2005) support services of inland waters include sediment retention and accumulation, nutrient cycling services such as storage, recycling, processing and acquisition of nutrients and pollination services such as support for pollinators (MEA, 2005). Although Lake Ellidavatn and Vifilstadavatn provide multiple support services, in this study only the supporting services Lake Elliðavatn provides to the salmon-river, Elliðaár was evaluated. Other services were described but not valued (Halla M. Jóhannesdóttir, 2010).

When rivers are compared in terms of salmon production, rivers originating in lakes or overgrown watersheds generate more of salmon, proportionally to watershed size (Hákon Aðalsteinsson & Gísli Már Gíslason, 1998; Gísli Már Gíslason, Jón S. Ólafsson, & Hákon Aðalsteinsson, 1998). Such rivers carry a lot of organic drifting particles, which affect the composition of the benthic invertebrate community. In rivers that originate in lakes, benthic communities are generally characterized by the filter feeding blackfly larvae, which is an important food source for salmon. Lakes 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 to other stream areas. This is considered to be due to the high density of blackfly larvae (Vigfús Jóhannsson, 1988; Einarsson, Mills, & Jóhannsson, 1990). In the Elliðaár River watershed, 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. Those measurements have demonstrated larger growth below the lake and higher density of all fry and parr year classes (Þórólfur Antonsson & Friðþjófur Árnason, 2009).

Net factor income was applied to value the benefits of nutrient cycling and provision of nursery habitat by Lake Elliðavatn for Elliðaár. 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 against the presence of a lake and four other independent factors. Data were available for the period from 1974 to 2008 (Guðni Guðbergsson, 2009). The results indicate that 65% of the river yield per wetted area can be explained by the presence of a lake (see Halla M. Jóhannesdóttir, 2010).

According to Brynjar Örn Ólafsson (2009) the average annual number of sold salmon fishing licenses over the period 2005-2008 equaled 30.831. The annual average price of salmon fishing license during this period was ISK 30.049 at constant ISK 2009. In the Elliðaár River 380 "rod-days" (days of angling with one rod) are sold. Assuming that price of angling licenses are dependent on yield, gives the total value of supporting services provided to Ellidaár river equal to ISK 7.422.103 (constant ISK 2009) for the year 2009.

Summary

Tables 1 and 2 summarize the results for each lake.

Table 1. Total value of the ecosystem services of Lake Elliðavatn on an annual basis (constant ISK 2009)

Service type		Economic value	
		Lower bound	Upper bound
Provisioning services			30.665.000
Regulating services		22.083.000	31.346.000
Cultural services	Recreational services	19.277.000	27.159.000
Cultural services	Educational services	3.816.000	4.717.000
Supporting services			7.422.000
Total		83.264.000	101.309.000

Table 2. Total value of the ecosystem services of Lake Vífilsstaðavatn on an annual basis (constant ISK 2009)

Service type		Economic value	
		Lower bound	Upper bound
Cultural services	Recreational services	3.736.000	3.958.000
Cultural services	Educational services	1.978.000	2.024.000
Total		5.714.000	5.982.000

Conclusion

The final results of this study illustrate that the overall value of ecosystem services provided by Lake Elliðavatn in 2009 is in the range of ISK 83.264.000 - 101.309.000 (constant ISK 2009). For Lake Vífilsstaðavatn this value is in the range of ISK 5.714.000 - 5.982.000 (constant ISK 2009). This study is based on many assumptions and rough calculations. Yet the final result can serve as an indicator of the potential value of good and services provided by these ecosystems. Evaluating ecosystem goods and services can never fall solely in the domain of the economist and monetary valuation is not the only appropriate metric of importance (Limburg & Folke, 1999). However by properly identifying and valuing ecosystem services we at a minimum can get a ballpark value of their economic importance which can serve as first baby steps towards properly incorporating ecosystem servcies into economic decision-making.

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