Mapping the use of urban green space with regards to ecosystem resilience

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60 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Environment and Natural Resources

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Reykjavik, May 2015

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Bibliographic information:
Katrín Svana Eyþórsdóttir, 2015, *Mapping the use of urban green space with regards to ecosystem resilience*, Master's thesis, Faculty of Life and Environmental Sciences, University of Iceland, pp. 78.

Printing: Háskólaprent
Reykjavik, Iceland, May 2015

Abstract

Urban green spaces provide habitats for biological diversity and boost inhabitants' health with varied cultural services. They awaken awareness and understanding of the importance of nature conservation and ecosystem resilience, vital to adaptation strategies for climate change. The City of Reykjavík, Iceland has undertaken an adaptation project by becoming a member of the Mayors Adapt Initiative for collaboration and focus on long term context of the impact of local actions. The overall goal of the present study was to increase the understanding of cultural value of ecosystems to urban well-being, aiming to generate information to augment existing databases on urban planning and management for Reykjavík City. The study explored how the knowledge generated could expound the socio-ecological functions of urban spaces, strengthening urban resilience and help comply with the Mayors Adapt Initiative. The study used Elliðaárdalur Valley as a case study to examine cultural ecosystem services through surveys on public wintertime use, identifying indicators of use, flora, fauna, and weather. The site was divided into three survey, where 80 surveys were conducted during daylight hours in December 2014 and January 2015. Significant differences were found between types of activities in the three areas ($p < 0,05$). Most popular was walking along a circular route in the more vegetated Areas 1 and 2. Area 3 proved popular for dog-walking and the entire study site was used significantly more during weekends. These results reveal links between the site's ecological and social functions, helping to identify and raise awareness of the benefits of urban green space use during the wintertime. Additionally, the baseline information generated from the study is useful in future planning and policy decisions for incorporating urban green space into adaptation strategies, supporting both human activities and ecosystem services.

Útdráttur

Græn svæði borga eru vettvangur líffræðilegrar fjölbreytni og bæta jafnframt lýðheilsu með margvíslegum hætti. Reykjavíkurborg er þátttakandi í alþjóðlega samstarfsverkefninu Mayors Adapt þar sem horft er til langtíma áhrifa af staðbundnum ákvörðunum til aðlögunar að loftslagsbreytingum. Meginmarkmið rannsóknarinnar var að auka þekkingu á menningarlegu gildi vistkerfa fyrir lífsgæði borgarbúa og bæta við upplýsingum í núverandi gagnagrunna Reykjavíkurborgar. Rannsóknin fól í sér athugun á vetrarnotkun á rannsóknarsvæðinu í Elliðaárdal og upplýsingum safnað um gestafjölda, notkun, veðurfar flóru og fánu. Áttatíu gagnapunktum var safnað á 20 mínútna bilum á dagtíma í desember 2014 og janúar 2015 á þremur svæðum. Niðurstöður rannsóknarinnar sýna samhengi á milli samfélags- og vistfræðilegrar notkunar á svæðinu. Marktækur munur er á notkun svæðanna, þar sem ganga var vinsælasta notkunin á gönguhring á svæðum 1 og 2, og fleira fólk heimsótti svæðið um helgar. Rannsóknin leiddi í ljós tengingar milli vistfræðilegrar og samfélagslegrar virkni svæðisins og sýnir of vanmetið verðmæti í notkun grænna svæða á vetrartíma. Með rannókninni er komin grunnþekking sem getur nýst í skipulags- og stefnumótunarvinnu til að styrkja vistfræðilegt þol borgarinnar til aðlögunar að loftslagsbreytingum.

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Acknowledgements

My thanks and appreciation to my advisors, Mariana Tamayo and Hrönn Hrafnsdóttir, for their guidance, help and understanding, and all our insightful conversations.

To all my course colleagues, friends, professors and faculty at the University of Iceland, thank you for the experience.

Takk Mamma og Pabbi.

1 Literature Review

1.1 Natural Capital and Urban Areas

1.1.1 Ecosystem Services

Urban planning has long incorporated natural aspects (e.g. street vegetation and access to open spaces) as a means to sustain and increase city inhabitants' well-being, and has become an integral part of policy-making that is far-reaching (Reykjavík, 2013). Natural capital is the underlying fabric of human achievements and as such, integral to our sustainable existence. Without input from nature our expenditures in terms of social, human and financial capital do not amount to much. As Costanza et al. (2014d) state, natural capital is what encapsulates all our efforts towards increasing our well-being. Ecosystem functions (e.g., water filtration through soil, timber from forests) are the foundations of the wealth we extract from nature, and ecosystem resilience (a measure of a system's capability to absorb change (Spirn, 1984)) is thus a fundamental, if often ignored or undervalued, part of our existence (Bolund & Hunhammar, 1999; MEA, 2005).

Reykjavík City, the capital of Iceland that lies on the outskirts of the Arctic Circle in the North Atlantic fosters a variety of ecosystems. The city's urban planning policies increasingly strive to recognize and integrate its natural capital (Reykjavík, 2013). The Millennium Ecosystem Assessment's (MEA) defines ecosystem services as the benefits humans derive from ecosystems (MEA, 2005). Reykjavík's natural capital includes landscape, forests, potable water, geothermal energy, coasts, and rivers along with the ecosystem services found there. The city defines the services derived from ecosystems according to the international initiative of The Economics of Ecosystems and Biodiversity's (TEEB) definition, i.e. the range of benefits from the environment that cities depend on, and categorizes them into provisioning (e.g. energy, food, and water), supporting and regulating services (e.g. carbon sequestration, local climate and quality of air, and seed dispersal) and cultural services (e.g. recreation, aesthetic experiences, and mental inspiration) (Reykjavík, 2013; TEEB, 2011). Ecosystem services identified on the outskirts of the city include Christmas trees, berries, water filtration and recreation (Davíðsdóttir, 2010). Reykjavík's location makes it susceptible to threats regarding changes in climate, which have been found to be more immediate in the Arctic than in other regions of the globe, having ecological as well as social effects (e.g. northwards shift of species, increases in temperature and changes in shipping routes) (AMAP, 2012; *ABA*, 2013). Economic, social and cultural values of ecosystems make up the wealth of urban centers. Taking natural capital into account in Reykjavík's planning policies can prove vital in adaptation strategies for creating a sustainable future city (Shaw, Colley, & Connell, 2007).

1.1.2 Climate Change Threats

The Millennium Ecosystem Assessment report (2005) made no attempt to hide the realities of climate change. The Arctic region is more vulnerable to changes than other areas of the globe, with a warming rate twice that of the global rate, and also suffering from increased ocean acidification due to the increased solubility of CO_2 in colder water temperatures (*ABA*, 2013).

Changes in the Arctic have global implications as well. For example, with the loss of snow and ice and their reflective properties, emissions of greenhouse gases increase, sea levels rise, and changes occur in ocean and atmospheric circulation that are not limited to the Arctic region (AMAP, 2012; Overland, Wood, & Wang, 2011). Observations have shown that expansion of shrub and tree cover, as well as plant species range, are among the impacts of climate change seen in the polar regions (IPCC, 2014). But the loss of ice also opens the region to exploration and development possibilities that humans are increasingly taking advantage of with the accompanying detriment to the biodiversity, due to habitat fragmentation and destruction (*ABA*, 2013; Swiderska, 2002). Flexible methods for observing changes and responding to them, individually and collectively, requires continuous data collection on all factors (environmental, social and economic) of policy decision making. Instead of relying on historic measurements on climate, cities will have to anticipate and plan for future changes with regards to development (Shaw et al., 2007). While temperature changes in the Arctic are predicted to be higher than in other places, there has been a lack of observational data for the region (IPCC, 2014). Data gathering and accounting of cultural values of ecosystem services is a recent development in Iceland, it began as part of a multi-year, extensive economic valuation study in Heiðmörk in 2009 (Davíðsdóttir, 2010), and will hopefully continue in of the city's development of adaptation strategies.

1.1.3 Biodiversity – Ecological Conservation

Arctic species have shown remarkable resilience to changes in climate. Potential northward drift of species, which might increase the number of species found, will however not lead to a rise in global biodiversity (*ABA*, 2013). Kenter et al.'s (2014) report for the United Kingdom's (UK) National Ecosystem Assessment (NEA) highlights the importance of biodiversity to our wellbeing and financial affluence, and it uses diverse perspectives for understanding its full value. A follow-up to the UK NEA (2014) takes a realistic stance in focusing on boosting ecosystem resilience through their management, rather than enhancing biodiversity conservation. Although scientific uncertainty requires a precautionary approach to land use planning, this approach would raise awareness of the ecosystem services strategies for government institutions, private corporations and non-governmental organizations (NGOs). In particular the UK NEA report (2014) proposed non-monetary assessment methods for valuing benefits of cultural ecosystem services to wellbeing through people's interactions with natural space, where cultural values and traditions gradually build up an assortment of complicated circumstances where human's and nature's needs intersect (UK NEA, 2014). Biodiversity and its functions have traditionally been undervalued economically because of the lack of markets for them and governments' failure to account for the benefits lost when the value of land conversion is exaggerated by subsidies for development (Pearce & Moran, 1997; Strategic Analysis Centre, 2012; UK NEA, 2014).

Along with the threat to biodiversity due to climate change, increased urbanization and land use raises the need to enhance conservation efforts in urban areas (Bryant, 2006). Providing green areas for recreational use in cities can establish and support "*positive ecological values*" relative to biodiversity and ecosystem services (e.g. water filtration and carbon sequestration), which benefit all city inhabitants (Colding & Marcus, 2013). Maintaining areas for nature recreation within cities, can also be a land management and planning strategy that benefits both the users of the areas, and the ecosystems and the services present in them. Such management can be both formal by way of government policy at regional or local levels, and informal in the form of gardens or golf courses, which is are also important for maintaining biodiversity and possibly more economically feasible (Colding & Marcus, 2013; MEA, 2005). Considering the economic impacts of land-use changes on ecosystem services, may decrease the negative perception of policies favorable to the environment as hindrances to economic gains from development actions (Bateman et al., 2013).

1.1.4 Value

One way to measure the value and importance of ecosystems and their resilience is to find their monetary value through valuation methods such as contingent valuation surveys (CVS) (Forsætisráðuneytið, 2000; Jianjun, Chong, & Lun, 2013; Spash, 2000). CVS reveal stated preferences of participants and rely on participants' intuitive capability to prefer one thing to another in a given situation, i.e. to state their preference (Navrud, 2004).

Understanding the functions of ecosystem services related to biodiversity, is of utmost importance when it comes to linking natural capital with society and human well-being (Maes et al., 2012). Although the importance of biodiversity is well acknowledged, the lack of understanding and knowledge gaps can account for it being underappreciated (*ABA*, 2013; Costanza et al., 2014; Niemelä et al., 2010). The incorporation of biodiversity into land-use planning is often missing and can sometimes eclipse the urgency of conservation (Stokes, Hanson, Oaks, Straub, & Ponio, 2010). Mismanagement and obsolete policies, inadequate political will, or minimal technical capacity can stand in the way of implementing solutions (Hesselink, Goldstein, van Kempen, Garnett, & Dela, 2007).

Creating and maintaining opportunities for city dwellers to experience nature close to home is important for maintaining ecological knowledge, which again is essential for fueling informed discussion about and acceptance of new urban environmental policies (Colding & Marcus, 2013). Increased interest and awareness of the surroundings supports ecological learning and conservation of biodiversity (Colding & Marcus, 2013).

Jóhannesdóttir's (2010) estimated the annual value of cultural services (recreation and education) of Lake Elliðavatn and Lake Vífilsstaðavatn, Iceland to be ISK 28.807.540 - 37.857.166. Although assigning monetary value to ecosystem services can be limited, it can raise awareness of environmental issues in a manner that is comparable with other factors that contribute to human well-being (Costanza et al., 2014). To further understand the value of ecosystems, establish benchmark values, and gain valuable insights about the consequences of climate change, it is important to observe the behavior and interactions of people with ecosystems as it can reveal more detailed information about their preferences and impact on the ecosystems themselves (Colding & Marcus, 2013; Costanza et al., 2014; TEEB, 2011). Moreover, these same services can help limit human impact on the climate and build the buffer capacity, i.e. resilience, to climate change of our urban environments (Colding & Marcus, 2013).

1.2 Resilience

Reykjavík's participation in the Mayors Adapt Initiative, gives the city the responsibility to develop an adaptation strategy for strengthening the resilience of urban ecosystem services to meet climate change challenges (Mayors Adapt, 2014).

Resilience is at the core of adaptation strategies that are based on ecosystems and their services, and its components are the properties and characteristics of an ecosystem that dictate how fast, by what means and how far recovery can take place after a disruption (Colding & Marcus, 2013; Westman, 1985). Resilience can also be seen as how much and how often a system can be impacted by a disturbance before it can no longer sustain or create the services it originally provided (Colding & Marcus, 2013; URBES, 2013).

Ecosystems depend on their resilience to handle climate change and their services are instrumental in building the buffer capacity of our urban environments (Colding & Marcus, 2013). In order to build resilience, Colding et al. (2013) recommend protecting and providing more habitats for wild pollinators, and plan land-use that supports and even forms new ecosystem services.

Humans rely on natural capital for their wealth and well-being (Costanza et al., 2014). Given the interdependence of social and ecological systems, it is imperative that knowledge on their mechanisms and behaviors is generated in order to help build socio-ecological resilience (Berkes, Colding, & Folke, 2002). Socio-ecological systems can be overlooked in land-use management (Andersson et al., 2014). For example, Ernstson et al. (2010) discuss circumstances surrounding the impact of hurricane Katerina in New Orleans, USA in 2005, where human developments had reduced or eliminated natural levees and wetlands, making the city more vulnerable to the impact of the storm. They recommend gradually integrating the city into the existing physical landscape, promoting adaptive urbanization, where "natural" processes are restored (Ernstson et al., 2010). From a planning perspective this interplay of ecosystems and urban social structures can be looked at as an urban area's ability to cope with future changes, given that the cost of replacing ecosystem services can be very high (Colding & Marcus, 2013).

1.2.1 Human Impact - Urbanization

Urban limits are illusive and subjective constructions. A city can be defined as a hub of "*economic production and consumption*" (Pacione, 2009) where networks of social interactions and cultural enterprises come together under the rule of an administrative government. The characteristics of cities are both social (e.g., people, trade, arts) as well as ecological (e.g. topography, soils, weather), and they bring a concentration of sought after services and convenience, such as health care, employment, housing, sanitation, and sources of recreation, all of which put additional pressure on ecosystems (Ernstson et al., 2010; Niemelä et al., 2010; Pacione, 2009; United Nations, 2014).

Freedman (1989) stated that the core issue of the deterioration of our environment was overpopulation. Urban growth can be traced back to the industrial revolution, where increased production of goods lead to a surplus in a single location. This facilitated economic growth, allowing a greater number of people in urban areas, with perhaps less land use but more consumption and energy use (Pacione, 2009). Driven by societal changes, ecosystems and their services have declined since the middle of the 20^{th} century, and it is likely that increasing population growth and climate change will further increase stresses (DEFRA, 2011).

The UN World Urbanization Prospects (2014) note that the sustainable future of any urban area relies on the three aspects of economic, social and environmental development. Most of human settlement expansion is predicted in areas of limited economic and social resources (Stockholm Resilience Centre, 2014a). Any unplanned or badly managed urban sprawl can lead to a broad ecological decline whereas an integrated approach to the management of settlements brings better standards of living, with less impact on its environment (United Nations, 2014). Examining numerous biodiversity hotspots (areas of exceptional biodiversity under threat from humans), Seto, Güneralp and Hutyra (2012) predict that urban land-use will triple globally by 2030 and will be followed by a drastic loss of biodiversity, through habitat destruction and invasive species. Hence, it is imperative that local planning policies take global impacts into account. Local governments can have a wide impact when it comes to ecosystem management and conservation of biodiversity (Kohsaka, Shih, Saito, & Sadohara, 2013). Several studies of Cape Town, South Africa, also confirm that increased urbanization poses a great threat to biodiversity and is one of the primary issue that conservation faces (Cilliers & Siebert, 2012).

1.3 Urban Ecosystems

In cities where people's habits and behaviors have immediate impact, it is necessary to preserve existing urban ecosystem services to ensure future services (Colding & Marcus, 2013). Urban ecosystems differ from other ecosystems in many ways. They are often more isolated from each other, leading to longer timeframes for various ecological processes. Varying states of affluence within cities can shape the services found there, where vegetation associated with aesthetics is found in wealthier areas and sustenance related species may be found in less well-off areas (Nagendra, Sudhira, Katti, & Schewenius, 2013). The heat-island effect of cities can also extend growing seasons, fostering entirely new combination of species, while human alteration often slow down ecological succession (Colding & Marcus, 2013). Despite evidence of benefits resulting from urban ecosystems, incorporating them into city management and resilience planning has not been extensively practiced (McPhearson, Andersson, Elmqvist, & Frantzeskaki, 2014). The ecosystems can nonetheless play a crucial role in cities' transitions towards a sustainable future where urban resilience is supported via ecosystem resilience.

Cities can encourage urban ecosystems research and help build collaborations among researchers, policy-makers and private corporate owners, and facilitate the creation of interdisciplinary partnerships where dialogue on adaptation strategies can flourish (Kohsaka et al., 2013). Green spaces can play a part in climate adaptation if they are managed so the conditions for the ecosystem services they produce aid in building resilience against potential future changes. The restoration of Mayes Brook in Mayesbrook Park in East London is an example of a successful project where both the ecosystems and the community reap the benefits of restoration (e.g. hydrological functions, climate regulation, health and education) (Everard, Shuker, & Gurnell, 2011). Consciously and actively maintaining cultural ecosystem services provided by urban green areas can help maintain supportive and regulating services, such as biodiversity and pollination, and complement other strategies which focus more on technical solutions like construction and transportation (Colding & Marcus, 2013).

1.3.1 Greenways

The Master Plan for Reykjavík (2013) pushes urban densification that is partially planned alongside popular green areas such as Öskjuhlíð and the estuary of the Elliðaár River. Öskjuhlíð, on the southern coast of Reykjavík, consists of recreational areas, private and commercial enterprises and a proposed residential area (Reykjavík, 2013). It connects to Elliðaárdalur Valley via Fossvogsdalur Valley, neither of which, with the exception of Elliðaár River estuary, are under consideration for densification (Reykjavík, 2013). The proposals for the developments examine the wider environmental implications that can potentially impact the ecosystems there and the services they provide (reykjavik.is, 2014e). Whether the effects will be positive (e.g. residences closer to nature) or negative (e.g. loss of species habitat and ecosystem services) they must be taken into account in the city's development of adaptation strategies. Current zoning plans are from 1994 but present suggestions for establishing a City-Park in Elliðaárdalur include the possibility of various operations within the area (e.g., recreational and fitness facilities) (Reykjavíkurborg, 2014a).

Elliðaárdalur connects Reykjavík's encompassing *Green Scarf* with the city center and can be of great importance for the region's biodiversity as it combines, natural and cultural values (Colding & Marcus, 2013; Reykjavík, 2013). The *Green Scarf* are the communal forestry and recreational areas on the outskirts of the seven municipalities of the capital area. Elliðaárdalur can serve as a key component in spatial design of the city and play several parts in adaptation plans. For example, it can provide alternative transport routes for both humans and ecosystems, be available and open to the public, offer habitats for flora and fauna, reduce air pollution and promote seed dispersal, among other ecosystem services (Bryant, 2006; Colding & Marcus, 2013).

Although green corridors are important or necessary for conservation, there is concern that corridors can prove detrimental to biodiversity, if they facilitate undesirable and unintended effects, such as decreasing species dispersion to isolated yet suitable habitats, change the risk of predation, and limit some species' movement (Huntley, 2007). Despite this concern, there is impressive evidence of the benefits that green corridors have for cities and their inhabitants, including their capacity to enhance biodiversity and provide networks of areas for recreation that link previously isolated plots of ecosystems to the larger systems surrounding a city (Bolund & Hunhammar, 1999; Müller, Ignatieva, Nilon, Werner, & Zipperer, 2013). Creating an interconnected network from existing corridors can be considered an "*ecosystem—based policy*" (Pauchard & Barbosa, 2013, p. 599) and Reykjavík is fortunate to possess several green corridors because creating new ones in urban landscapes can be difficult (Dearborn & Kark, 2010).

1.4 Awareness and Resilience

Understanding is fostered by awareness and awareness is accomplished by increased understanding. With an increased understanding of the role that ecosystem services play, comes greater awareness of the interactions between social and ecological systems, humans and nature, and how ecosystem services are a vital component of the natural capital on which we build our well-being and wealth (Costanza et al., 2014).

Urban greenways may have a great potential for conservation of urban biodiversity (Bryant, 2006), and increased use and support of urban greenways by city inhabitants may facilitate ecological conservation. For example, as the use of green areas increases, so does the demand for such areas, and when they are maintained and kept in good condition, they support the ecology found there (Bryant, 2006). Overall, greater use of green areas can increase the awareness about their importance, leading to a better understanding, which can aid conservation efforts and management plans, strengthening the city's resilience (Costanza et al., 2014; ICLEI, 2014; Schetke, 2012; URBES, 2013).

1.5 Planning and Resilience

Spatial planning is inherently anthropocentric in nature and the approach until now has often been in the form of top-down management, where as much as possible is derived or extracted from ecosystems. Reversing this process, with a bottom-up perspective has begun to reveal previously overlooked or ignored steps and solutions that benefit ecosystems and humans (Spangenberg, von Haaren, & Settele, 2014). Describing several urban design experiments, Felson, Bradford and Terway (2013) recommend considering all possible contributors to complex projects, from researchers and workers, to managers and developers. One example from Bridgeport, CT, USA notes the communal design and construction of a public park with the additional goal of addressing flood relief in the community. As a successful project the park continues to give back to the community through education and awareness of long-term involvement of people with their local environment. Collaborating with ecologists during the earliest design stages, gave planners access to research and knowledge which enhanced the resulting urban landscape while also furthering experimental ecological research in the field (Felson et al., 2013).

Knowledge gaps and lack of information can make it difficult to value the services of ecosystems, but incorporating the interconnected features of society and nature into resilience planning strategy can help inform policy regarding economy. For example, it can generate valuable information on replacement or avoided costs due to the ecosystem services provided. Additionally, it can highlight social and cultural values people place on traditions and aesthetic. Lastly, it can benefit spatial planning actions where changes to urban landscape having a positive impact on citizen well-being can provide a measure of efficiency of actions taken (Colding & Marcus, 2013; Gómez-Baggethun & Barton, 2013; Niemelä et al., 2010).

1.5.1 Integrating Social and Ecological Functions

Socio-ecological urban planning, where integrating the traditional urban functions, spatial elements and provision of amenities, with ecosystem services in innovative ways, helps incorporate green functions into built environments and strengthen ecosystem services. This requires an understanding of the cultural and biological values found in the landscape, what impact a plan may have on an area, and how any new developments can serve as ecological corridors between ecosystems. Providing social infrastructure, such as housing, trade and transportation routes, that urban ecosystem services can take advantage of, can help highlight how interrelated the urban social functions and ecosystems really are and how they can support each other (Colding & Marcus, 2013; Spangenberg et al., 2014).

Approaching resilience of cities from the ground up requires observing the potential effects of human action on ecosystems, assessing the impact of interactions with nature and deriving plans (Spangenberg et al., 2014). A case study from Finland (Niemelä et al., 2010) on the role of urban green areas and corridors in providing provisioning, regulating and cultural urban ecosystem services, supports using an ecosystem services approach in urban land-use planning for merging urban ecosystem and social research. The study looked at networks of spaces on both local and regional levels, and how they could contribute to ecologically sustainable land-use planning by maintaining vital urban ecosystem services (e.g., carbon sequestration, recreation, and biodiversity), and highlighted the lack of information about urban ecosystem services and the need to improve a knowledge base when planning land-use (Niemelä et al., 2010).

1.5.2 Policy and Resilience

Without proper information about the status and use of urban environments, policy decisions can have serious impact on and even lead to the loss of favorable or vital services from ecosystems. Economically, ecosystem services do not require a large actual investment for sustained provision of assets, while restoration or replacement of damaged or lost services can be very time-consuming and prohibitively expensive or even impossible (TEEB, 2011). This highlights the importance of taking into account ecosystem services in city budgets and planning in order to make more informed decisions. A greater understanding of the value of ecosystem services helps planners and administrators create sustainable cities, because maintaining well-functioning urban ecosystem services is the most fiscally feasible solution for meeting human needs (TEEB, 2011).

TEEB (2011) emphasizes that understanding how and why ecosystem services factor into decision making can open lines of communication among administrators, as different sectors agree on how to account for and incorporate ecosystem services benefits and costs into policy. This creates a desirable outcome, achieved through effective decision-making, more likely with the inclusion of realizing and anticipating the consequences of policy planning actions.

Taking ecosystem services into account does not necessarily require new procedures or management units in administration. But it does require existing entities to look for planning and procedural solutions from a new perspective, which can then be gradually introduced (TEEB, 2011).

The steps required to shift policies and securing project finances is a complex process, evidenced by experiences documented in a 2011 ecosystem valuation study in Cape Town (TEEB, 2011). The goal was to foster an understanding of the city's natural capital and motivate its protection and maintenance through business investments (de Wit et al., 2009). Planning projects were be plagued by outside issues like rivalling contractors and restrictive timeframes, and numerous political influences meant that rarely were there any explicit connections to be found between specific projects and policy budgets. The study found communication to be crucial and although different departments of the government did learn from each other's processes, and acknowledge critical issues, it was not enough to bring about the necessary changes in policy or funding (de Wit et al., 2009; TEEB, 2011).

A large part of assessing the value of ecosystem services is increasing understanding and awareness, which plays a vital role in getting the policy-making and planning to implement an ecosystem services approach (Costanza et al., 2014). Adaptation strategies need to make use of various indicators on collecting and generating consistent data for monitoring changes in ecosystems and assist in the creation of sustainable policies (MEA, 2005). The *City Biodiversity Index* and *ecoBudget* are two frameworks developed to help cities merge ecosystem services into decision making processes and budgets by monitoring various factors of natural capital (e.g. biodiversity and policy efficiency) (TEEB, 2011). While there is no single system of indicators to refer to, one thing to consider when it comes to their creation is the preferences, comprehension and interpretation of planners and decision-makers. This is especially important for bridging the gap between academia and administration/governance entities in the creation of tools and frameworks for land-use assessment (Feld et al., 2009; Schetke, 2012).

1.5.3 Indicators

Currently, there seems to be a lack of indicators to measure time and space related interactions of urban ecosystem services (e.g. flow of nutrients from one area to another over time), which can channel more information than just the quantitative metric they represent (Haase et al., 2014). Indicators can, for example, be the number of trees in a specific area that also give information on the area's carbon sequestration potential. Another example, is the number of visitors of an educational path, indicating the effectiveness of the policy that fostered the creation of the path. While indicators are excellent for gathering data and monitoring changes, of ecosystems services and their use in specific locations over a period of time, their use is not universal and some knowledge gaps do exist (Feld et al., 2009; Schetke, 2012).

Indicators used for estimating ecosystem services (e.g. annual fish harvest indicating habitat suitability for the species, kg of berries picked annually indicating changes in growing conditions) mostly focus on regulating and supporting services (Feld et al., 2009). A review of 617 studies on ecosystem services, found that cultural services were mentioned in only 6% of the studies, and most of them referred to education and recreation (41% and 31%, respectively) (Feld et al., 2009). Despite carrying appreciable economic value (Bolund & Hunhammar, 1999; Costanza et al., 2014) Feld et al.'s findings show that cultural ecosystem services, such as aesthetic values and recreation, are "*notably rarely mentioned*" (2009, p. 1868). Moreover, they suggest that a lack of study and use of indicators to find or measure the state and trends in cultural services, can have an impact on whether policies and relevant administrative actions have the intended outcome to maintain the cultural services and biodiversity (2009).

1.5.4 Scale and Networking

One way to bridge knowledge gaps is to work at a smaller scale and then move on to a larger one. In this manner, concepts, ideas, and action plans can be transferred from local observations and experiences, towards policy-making platforms. Successful adaptation strategies, formed by such platforms, that lead to increased human well-being and a more sustainable use of natural resources, can function as a measure of effective government action (World Resources Institute, 2014). The Mayors Adapt Initiative is one of many international collaborations for sharing experiences and information on adaptation process. The initiative is implemented by the European Commission's Directorate General Climate Action, within the Covenant of Mayors, as an effort for cities to reduce greenhouse gas emissions. With 77 participating members, the initiative encourages cities to collaborate through networking and open dialogue with the public and private sector on adaptation strategies to act on climate change. The initiative focuses on the long term context of the impact of local actions. The goal is to strengthen urban resilience by incorporating innovative adaptation strategies into existing plans through communication, cooperation and reporting. Reykjavík's contribution will be in the form of localized action planning to be shared with other member cities (Mayors Adapt, 2014; reykjavik.is, 2014a).

In recent years, several international projects addressing urban resilience and ecosystem services have been initiated. One of them, Resilient Cities from Local Governments for Sustainability (ICLEI), was launched in 1990 and serves to connect public and private sectors with practical expert knowledge. It provides a collaborative platform and network opportunities focusing on urban resilience using ecosystem based adaptation, and emphasizing data collection and sharing (Screiber & Kavanaugh, 2014).

Another project is the Tures partnership project on Urban Resilience and Sustainability. This five year European project began in 2012, and aims to bring together academic and local knowledge to meet the challenges urban environments face by creating visions, guidance and mechanisms for transition regarding, among other things, land-use planning. The project has been supported by the European Union's Seventh Programme for research in their goal to build resilience from the inside out (Tures, 2013).

The Urban Biodiversity and Ecosystem Services project was recently completed (2014). The project was a transatlantic consortium focused on linking expertise on the relevance of urban biodiversity and ecosystem services for well-being. A series of workshops conducted during this three year project produced two toolkits that aid in converting scientific knowledge into actionable plans. The toolkits aim to increase cross-sectorial understanding and integration of biodiversity conservation, as well as assist city planners in recognizing the relationships between urban planning, ecosystem services and well-being through multi criteria analysis. (IUCN, 2014; URBES, 2013).

All the projects described above highlight the importance of collaboration in generating tools and guidelines fostering resilience in urban areas. While international collaboration can have a positive impact on improving local biodiversity management (ICLEI, 2006), it requires constant vigilance**.** Reykjavík has been an ICLEI member since 2002 (ICLEI, 2015) and the addition of the Mayors Adapt membership, where the focus is on strengthening ecosystem resilience, may help direct attention to the topic and serve as a reminder for Reykjavík and its inhabitants**.**

1.6 Adaptation

The UK's strategy for wildlife and ecosystem services (DEFRA, 2011) highlights that any plans implemented today will have long term effect for the future of ecosystems services and the benefits we harvest from them. We have enough knowledge to do better and therefore, it is a top priority to start taking steps towards using a more integrated approach to the management of ecosystems (DEFRA, 2011).

Planning policies and conservation projects are impacted by political shifts where multiple factors influence decisions (e.g., public opinion and annual budgets) (RCEP, 2002; TEEB, 2011). The cross-cutting character of spatial planning policy is a key element in urban adaptation, because it is through planning procedures that governments and established infrastructures manage the development and use of land (Carter et al., 2014; Greiving & Fleischhauer, 2012). Flexibility is a necessary trait of all adaptation actions, and it requires an understanding of the current status of issues and processes to determine the best course of action and prevent creating situations which make future responses to changes difficult (Shaw et al., 2007). Carter et al. (2014) point out that due to the intersecting nature of adaptation agendas, administrative organizations might feel increased pressure to come up with compelling strategies, while at the same time sensing their lack of spatial planning capacity. Keeping institutional structures flexible to incorporate the maintenance, management and evolution of spatial design elements, and to respond to ever-changing circumstances, is important from a socio-ecological perspective (Colding & Marcus, 2013). New approaches challenge traditional governance frameworks, making researchers a crucial element in the adaptation process to question established procedures and to seek of collaborative solutions (Carter et al., 2014; Felson et al., 2013).

It is nearly impossible to predict accurately the effects of climate change and the impact for any specific location (*ABA*, 2013). This makes small scale, local data on the current status of ecosystem services notably more relevant when taking adaptation strategy into consideration for spatial planning (Carter et al., 2014). Collected data can help construct a database of documentation on which planning policy can be founded and referenced for creating planning directions, deciding on development locations and quotas, and for reaching conclusions in planning application disputes (Carter et al., 2014).

In order to build more adaptive capable urban environments, planners, developers, and researchers need to seek creative solutions. This includes finding solutions to maintain and grow urban green spaces, which unfortunately are often sacrificed in the name of urban development (Shaw et al., 2007). A conflicting issue is that adapting to changes in climate encourages densification of urban environments, shortening travel times, thus lowering energy use and reducing emissions, but possibly encroaching on green areas. However, interconnected open spaces in urban environments also contribute to improving air quality and biodiversity as well as the wealth and health of the people who use them (Shaw et al., 2007). Solving incompatible concerns can be furthered through expert consultation on potential results of potential scenarios (Bateman et al., 2013). Creativity requires self-awareness, and being well-adjusted and connected to reality. A creative solution is, like any solution, built on understanding the issue at hand, gathering knowledge, scrutinizing it alone and with others, and finding new un-explored connections (Csikszentmihalyi, 2013). This may require compromises and consideration of seasonal, location based variations, where incorporating open spaces into densification plans, for example, can help balance possible winter gloom that has been exacerbated by the narrower streets of a denser city (Shaw et al., 2007). This solution could prove applicable to Reykjavík, considering the city's high latitude global position, few hours of daylight in winter and the city's densification plans (Reykjavík, 2013).

1.6.1 The Role of Elliðaárdalur Valley

As Reykjavík has grown, Elliðaárdalur Valley has gradually moved from being on the outskirts of the city, to being surrounded by it. The area can have its own special role in spatial plans like reducing weather fluctuations or providing an area for recreation and a quiet space to escape from the enveloping city (Ólafsson, Gíslason, Malmquist, Gíslason, & Antonsson, 2007; Pálsson, 2004). Elliðavatn Lake shares several highly valued ecosystem services with the Elliðaár River and the Elliðaárdalur Valley, including salmon fishing, outdoor recreation, educational properties, and electricity production (Jóhannesdóttir, 2010).

The city of Reykjavík is not highly dependent on the energy harvested from Elliðaárdalur Valley. Seven geothermal boreholes are located in the lower section of the valley (only one used for hot water production), and they generate around 1,69 GL or approximately 2,4 % of the Orkuveita Reykjavíkur energy company's annual production (Ívarsson, 2014). For several years, prior to a malfunction in November 2013, the Elliðaárstöð Power Plant only produced electricity in the winter months due to what the company terms as environmental reasons and it is uncertain if the engines there will be restarted (OR, 2014). This lessens the need to manage the water resources of the valley in terms of provisional ecosystem services. The supporting and regulating services are, however, crucial to the organisms that live in and around the river (Jóhannesdóttir, 2010). The diversion of the river's course with the building of dams and landfills around the river estuary, severely impacted its ecosystems with the subsequent fluctuations in river water flow (G. M. Gíslason, Ólafsson, & Jónsson, 2007).

Today the Árbæjarstífla dam is left open during the summer for spawning salmon to reach the upper area of the river which benefits people seeking recreation by fishing. The valley's cultural service value can hardly be disputed considering people's use of it all throughout the year for recreation and relaxation (Eyþórsdóttir, 2014). Implementation of sediment or water detention ponds in several places manages polluted runoff from industrial and residential areas that surround the valley (Sævarsson, 2007). A study of one particular pond by the Úlfarsá River showed that it was successful for managing and detaining heavy metal pollution (Vollertsen, 2010). Although Reykjavík's Master Plan (2013) does not detail any new developments in Elliðaárdalur Valley, a permit for a gym in 2012 (PRESSAN, 2012) and the changing use of the old power house at Rafstöðvarvegur road in the lower section of the valley, highlight the ever-changing nature of urban spatial planning policies and management of the area.

The biodiversity in Elliðaárdalur Valley contributes to the resilience of the ecosystems found there while also enriching people‘s experience of the area (Colding & Marcus, 2013). The carbon sequestered by the vegetation and soil of any urban green space can be considerable (Snorrason, 2012), helping cities reach their goals regarding emission reductions in adaptation processes for responding to climate change (Mayors Adapt, 2014).

Finally, it is important to remember that only the Elliðaár River itself falls under a so-called neighborhood protection, under a municipal policy regarding the protection of historical artifacts, nature, landscape or vegetation due to historical, natural or cultural significance (Reykjavík, 2013). Thus, the other areas of the valley are potentially under threat of further urban development depending on the limits of the proposed City-Park (RÚV, 2013).

1.7 Generating Information

The generation of information is an essential part of developing policies for adaptation as it builds the foundation of knowledge future researchers, policy-makers and developers can access when creating the sustainable cities of the future. This section will detail two methods of generating information through quantitative and qualitative research.

1.7.1 GIS – Quantitative Data

Geographical Information Systems (GIS) can be used over any number of computer based systems that handle and process spatial information. The sometimes overwhelming influx of data, due to ever-evolving collection techniques, can be stored, sorted, analyzed and displayed with the help of GIS. GIS preserves the context and relationship between underlying geography of an area and the distribution and abundance of a species (Molles Jr, 2002). Layers of information that have been gathered can be combined to seek solutions to problems that can be modified as problems change. Besides spatial data, other types of information, like written text on the management of a site, can be associated with map features. Previously, the main hindrance limiting the use of GIS was data availability but this has changed and tools like remote sensing by means of satellite imagery, has encouraged new and diverse uses (Haines-Young, Green, & Cousins, 1993).

GIS is useful for detecting spatial and temporal patterns in landscapes and ecosystems with its hierarchical format of storage, where the data can be analyzed at small and large scales. GIS output is useful for ecological studies on modelling processes that are distributed spatially, like the effects of land-use on habitat (Stow, 1993), and can benefit planners with its detail accuracy (Kuzyk, 2012). Overlaying recently collected data onto older data in GIS can help to quantify the extent of land-use changes and rate of shifts that have e.g. fragmented or destroyed previously documented habitats (Muzein, 2006).

Biodiversity is often considered the focal point of conservation, where habitat destruction and degradation are the most serious issues (*ABA*, 2013). GIS technology provides databases of information and retains geographical context of collected data. It reveals connections and trajectories of spatial elements over time (e.g. biota, energy, nutrients, and environmental resources), and documents the response of ecosystems to climate change. GIS can, along with remote sensing and GPS technology, help in the design of better management systems for nature conservation (Bridgewater, 1993; Haase et al., 2014; Molles Jr, 2002). Some examples include optimizing irrigation through automatic tree crop management (Peeters, Ben-Gal, Hetzroni, & Zude, 2012) and the investigating impact of urbanization on wetlands (He, Tian, Shi, & Hu, 2011).

Management and Urban Land-use Planning

In terms of land-use planning, overlaying information in GIS can reveal uncharted combinations of conditions, and the system's output can be catered to fit various interest groups. Additionally, modelling of data is also useful for interpretation and prediction of future effects of policy actions and whether they can solve problems as intended (Aspinall, 1993). Chen (2009) discusses the importance to policy-making of simple yet comprehensive methods for geographically mapping the value of ecosystem services, where practical methods provide vital technological backing to conservation efforts and resource management, e.g. in cases of overexploitation. Models and computer assisted analysis can, however, be plagued with ambiguity regarding their construction and possible presumptions (Huitric et al., 2009). For GIS to be a useful and relevant tool in spatial policy plans, users of the technology, planners and policy makers need to collaborate to ensure that the best knowledge available is applied (Aspinall, 1993).

Producing study results graphically can aid in quickly reaching the intended audience, possibly aiding in decision making regarding planning policies, as well as the creation of strategic plans. Unless data are translated into an easily understood format, that enables people to visualize what they represent, their use is limited (Carter et al., 2014). For both the public and specialists, the use of graphs and maps has long been accepted as the clearest and most effective way to depict information. (Royston, 1956).

1.7.2 Mixing Qualitative and Quantitative Research

Ethnography

Collecting data on the use of an area is a form of ethnographic research where observation is a key instrument (Spradley, 1980). Considering the relatively flexible approach to conducting ethnographic research, where personal evaluation comes into account when working out results, the methods may lead to results that are too subjective. Proponents of the method do though assert that "*only ethnographic research can capture the true meaning of social processes and human activity which would remain hidden by other methods such as questionnaire surveys*" (Bloor & Wood, 2006, p. 73). Johnston's (2012) ethnographic study on an urban space in Portland, USA is an example of using a mix of methods such as video, direct examination and interviews, and analyzing the data afterwards with respects to use and changes in use of the area.

Some researches (see Bloor & Wood, 2006) suggest that qualitative research is often inappropriate for policy purposes due to its lack of generalizability, i.e. results are usually based on small sample sizes of qualitative research that are not applicable to other cases. Given the gains and trade-offs of the qualitative research, the best approach to conduct research on urban resilience planning in Reykjavík is to explore a mixture of methods (qualitative and quantitative) and evaluating every case independently.

Structured Observation

A simple observation leaves the observer unable to influence the situation being observed, and can be either structured or unstructured (Bryman, 2012). Unstructured observation requires detailed, holistic recording of behavior for extracting a sequential report of that behavior and discovering themes. Not depending on observation schedules can make the method more flexible, but it requires more data collection and relies more heavily on the researcher's interpretation (Bryman, 2012; McKechnie). Structured observation schedules rely on a clear research focus, an easy to operate recording system, and incorporation of coding behavior into categories from which various comparisons can be achieved (e.g. how different weather conditions affect the number of dog-walkers) (Bryman, 2012).

Structured observation has been criticized for imposing ideals or unrelated structure onto the conditions being observed. The use of preliminary observations is one solution to this critique (Bryman, 2012). The use of structured observations does not capture the intention of people's actions, only the displayed behavior. In addition, using a rigid schedule and being in the same places at the same time might bring notice to the observer and impact said behavior, possibly inciting negative reactions towards the researcher (Bryman, 2012). SOPARC (McKenzie, Cohen, Sehgal, Williamson, & Golinelli, 2006) is a system developed for observing communities in terms of play and recreation which prefers structured observation as a dependable tool for weighing the data collected. Structured observation is one of many systematic methods that has been developed to resolve issues of qualitative research (Bakeman, 2000). The method serves to isolate observer's bias from data collection and analysis, and produce quantitative translation of data input for models that are used in strategic planning for the city's future resilience (Bakeman, 2000).

Grounded Theory and Coding

Analyzing qualitative data with the aim of obtaining theoretical insights can be done by using grounded theory, an inductive approach to generating theory from data. This approach requires gathering more data by revisiting the field and to clarify any emerging theoretical structure which, incidentally, is ideal and essential to the ever-changing conditions cities face in any adaptation process. Using grounded theory approach to study the use of urban green areas affords both rigorous research methods, as well as allowing the research to evolve as new concepts, relationships, and contradictions reveal themselves (Charmaz, 2011).

Coding refers to assigning numbers to distinctive activities or behaviors that do not overlap in any way, so the information can be processed (Bryman, 2012). This is one of multiple processes that are helpful when using a grounded theory approach, for separating, sorting and synthesizing data to facilitate comparisons (Bloor & Wood, 2006; Charmaz, 2011). The behavior that is recorded on the use of urban green areas provides data that may at first seem fairly unstructured. However, coding the data collected enables categorization and structure building, i.e. quantifies the data (Bryman, 2012). Many type of qualitative data can be analyzed by means of coding and Irvine et al. (2013) give an example of the more traditional use, in analyzing their data collected through interviews on the effects of urban green space on human health.

Ethics

Following ethical guidelines in sociological research should not only evolve around ensuring high quality of the research being done and placate possible stakeholders, but also protect the subjects of the research (SRA, 2003). The literature agrees that the ethical principles of any social research must consider: risk of harm to participants; the potential lack of informed consent, invasion of privacy, and whether deception is involved; care is taken to respect people; ensure that non-exploitative procedures are used; and that confidentiality of data is retained throughout the research process (Bloor & Wood, 2006; Bryman, 2012; Hennink, Hutter, & Bailay, 2011).

The lack of informed consent may be the trickiest issue when it comes to observational studies (Bryman, 2012). The UK's Social Research Association (SRA, 2003) ethical guidelines state that where appropriate, consent from participants should be requested and participants in any sociological research should always be given the possibility to decline participation and/or withdraw any data. Informed consent also mainly applies to non-public areas where informing people that they are subjects of covert observation might affect their behavior and actions (Bryman, 2012).

Making use of a range of methods, both qualitative and quantitative, and taking the ethical implications into consideration, can help build a framework for the city. A framework with a more holistic and publicly accepted approach, for assessing the use of urban green spaces and how they can contribute to the strengthening of the city's urban resilience.

1.8 Summary

The management of the Elliðaárdalur valley, the Elliðaár River and its catchment area have been incorporated into spatial planning and adaptation strategies, although the literature suggests more can be accomplished. Haines-Young and Potschin (2008) suggest that a sound legal structure, to direct planning and safeguard ecosystem services in the planning process, can be addressed from three different perspectives: place-based, habitat, and services approach. By incorporating site-specific criteria, defined by geographical boundaries, with the number of habitats and the ecosystem services an area provides, TEEB (2011) proposes that the aspects of scale, stakeholder priorities, biodiversity action planning, and regional and national level services, can all be taken into account when policies are established and/or changed.

The United Nations (2014) suggest that furthering urban sustainability can be accomplished through bolstering relevant institutional capacity and scope to respond to and collaborate on solutions, as well as through enhancing the application of integrated approaches. Adaptation actions should consist of observations, collection of consistent and accurate data, identification of potential problems, use of best practices and information technologies, testing solutions, determining best course of action and finally implementing a preferably scalable solution (United Nations, 2014; World Resources Institute, 2014). Generation and use of quantitative information, can help prioritize actions for adaptation regarding biodiversity conservation and aiding in its assimilation into planning (Oliver, Smithers, Bailey, Walmsley, & Watts, 2012).

Conservation and expansion of urban green areas can be an important part of adaptation strategies of cities in terms of greenhouse gas emissions if design, construction and management are taken into account (Demuzere et al., 2014; Strohbach, Arnold, & Haase, 2012). The effects of climate change are very evident in urban areas, and as part of the Mayors Adapt Initiative, the City of Reykjavík is interested in looking into protecting more green areas within the city limits (reykjavik.is, 2014a, 2014c).

Cities put a lot of stress on the environment and natural resources, yet at the same time cities are hubs of innovation where economies, technologies and social interactions are intertwined and can be used in seeking solutions and forming strategies for adaptation (Ernstson et al., 2010). Cities can serve as experimental fields, where theories and solutions can be tested and even failed experiments can contribute extensive data and experience, enhancing future ideas. Sharing the knowledge through initiatives, such as Mayors Adapt, benefits other members, which is the essence of international collaboration. One must, after all, choose wisely in the experiments implemented because ecosystems often do not adapt well to planning mistakes (Colding & Marcus, 2013).

The next chapter will describe a case study in Elliðaárdalur Valley, where the use of the area's cultural ecosystem services was surveyed with the qualitative and quantitative methods previously described. The data collected and the methods evaluated in the study will contribute to Reykjavík's strategic adaptation plans and the city's commitment both locally and internationally.

2 Mapping the Use of Urban Green Space – Elliðaárdalur Valley Case Study

2.1 Introduction

Urban resilience can be enhanced through the conservation of cities' green spaces and incorporating the socio-ecological opportunities, they provide, into future urban developments. A city becomes more resilient through the use of green spaces as awareness of their importance for well-being and biodiversity increases (Bryant, 2006; Costanza et al., 2014). Several green spaces can be found throughout the City of Reykjavík, one of which is Elliðaárdalur Valley. The valley is 270 ha and the Elliðaár River flows through it. A summer survey in 2014 indicated that Elliðaárdalur Valley has multiple uses (Eyþórsdóttir, 2014). In an effort to further understand the role of green areas in urban resilience, the upper section of Elliðaárdalur Valley was used as a case study to assess the use of urban green spaces. The main goal of the study was to evaluate wintertime use of the valley. This information is necessary for a more comprehensive view of the socio-ecological importance of green areas and their role in urban resilience. The study also aimed to provide an example of research methods applicable to other urban green areas. The information generated contributes to the design of urban adaptation strategies relative to climate change. Additionally, this case study provides a baseline to build a framework that incorporates ecological perspectives into future urban planning, helping to fulfill Reykjavík's commitments to international initiatives.

2.2 The Study Area - Elliðaárdalur Valley

Elliðaárdalur is a valley surrounding the Elliðaár River that runs from Lake Elliðavatn to the ocean, dissecting the city of Reykjavík. The whole valley is close to 6 km in length and at its widest is 1 km, covering approximately 3,5 km^2 (270 ha) (Egilsson, Skarphéðinsson, Guðjónsson, Jóhannesson, & Hilmarsson, 1999; Skógræktarfélag Reykjavíkur, 2013). The study site in the upper section of the valley is 2,7 km long and 300-500 m wide. The valley is surrounded by residential, service and industrial areas with increasing development happening around the upper or southern part, on the northern shore of Elliðavatn Lake. Three traffic bridges cross the river with one dividing the valley into a lower and upper section. Elliðaárdalur Valley is one of Reykjavík's most used recreational area and is a prominent quiet, green space for city residents to escape to (Reykjavík, 2013, p. 278).

2.2.1 History

The oldest reference about farms in the valley date from the 14th century but throughout the ages the area has been used for farming and small scale structures have been built (Pálsson, 2004). Stone and gravel were harvested from quarries, and during WWII armies of occupation built barracks in many locations around the valley (Minjasafn Reykjavíkur, N.d.; Pálsson, 2004). Even older remnants of various human activities can be found in many places including salmon farming, wool washing and execution places (Þrastardóttir et al., 2014).

In 1906 the city bought the Elliðaár River and in 1920 built the Elliðaárstöð power plant for electricity production. The course of the river has been changed several times due to the power plant construction, impacting Lake Elliðavatn. The lake was expanded as a reservoir to regulate the water flow to the power plant (Reykjavík, 2013). Urban development has been increasing gradually often accompanied with less than ideal environmental conduct, such as polluted runoff water or sewage (S. R. Gíslason, 2007; Ólafsson et al., 2007). Flooding in 1968 from a dam breach and heavy rains during the spring thaw in 1982, also significantly impacted the valley and species habitats. These events led to a sudden decrease and subsequent increase in nonbiting (*Chironomidae*) and biting midges (*Simulium vittatum*) populations (G. M. Gíslason et al., 2007; Hróðmarsson, Reynisson, & Gíslason, 2009).

A study of the micro bacterial flora in Lake Elliðavatn and the Elliðaár River showed the water quality to be poor and raised concerns (Guðmundsdóttir, 2012; Guðmundsdóttir, Klonowski, Magnússon, Reynisson, & Marteinsson, 2013). The river estuary was also used as a dumping ground for car parts in the 1970s, causing concern for the potential presence of heavy metals, oils, battery acid among others in the area known as Geirsnef (Ólafsdóttir & Steinarsdóttir, 2006). Most if not all of Elliðaárdalur has been impacted by human actions in one way or another, except perhaps a small islet in the river, Blásteinshólmi, in the upper valley, where portions of a defense flood wall constructed early in the 20th century remain (Pálsson, 2004). Around the middle of the 20th century forestry and land reclamation began in the lower valley. Areas were fenced off from sheep and trees were planted (Pálsson, 2004). Development of networks of paths and further afforestation began around 1980 and continues today (Skógræktarfélag Reykjavíkur, 2013).

A proposal to Reykjavík's City Council was presented by the mayor in September 2014 on instating Elliðaárdalur Valley as a City Park, with the highest possible zoning protection for the Elliðaár River (Eggertsson, 2014). The City Park proposal aims, through amendments to zoning plans, to protect the area's biodiversity and special attributes from any further urban development not related to recreation, and also create a collaborative forum for the area's stakeholders (Reykjavíkurborg, 2014a; RÚV, 2013). Currently he proposal has been followed up with the creation of a steering committee by the City Council, responsible for seeking planning and financing solutions for the future management of the park (Eggertsson, 2015).

2.2.2 Geology

The exposed lava in the Elliðaárdalur Valley originates from the crater Leitin, which is 15-20 km southeast of Reykjavík and erupted approximately 5200 years ago. It rests on a bedrock of dolerite formed during the interglacial periods. Sediments from the end of the last ice age can be seen around the river's estuary, where a section, called Háubakkar, is a protected natural monument (Egilsson et al., 1999; Umhverfisstofnun, 2014).

2.2.3 Flora and Fauna

The vegetation found in Elliðaárdalur Valley is a combination of native and non-native species, including planted trees, plants left over from abandoned properties, and plants from garden refuse from the surrounding area. Overall, more than 300 species of angiosperms (flowering plants) and pteridophytes (fern) have been found (Pálsson, 2004). The only area that has not been changed through afforestation is Blásteinshólmi. The valley provides ideal growing conditions for various species and its appearance has changed a lot in the latter part of the 20^{th} century, with the side-effect of reducing fluctuations in weather in the valley, particularly providing shelter from the wind (Pálsson, 2004).

European minks (*Mustela lutreola*), rats (*Rattus* spp) and semi-domesticated rabbits (*Oryctolagus cuniculus*) can be found in the valley but the majority of the fauna consists of birds (Reykjavík, 2014b). Although some species are very low in abundance, 24 species of breeding birds have been found, with greater biodiversity in the upper section of the valley. Throughout the year, local birds can be seen in the valley along with the occasional vagrant species (Egilsson et al., 1999). The river and its surroundings support a wide variety of smaller species (such as nonbiting midges (*Chironomidae*) and didymo or rock snot (*D.geminata*)), which are increasingly used for assessing ecosystem health as they provide supporting services for other species (G. M. Gíslason et al., 2007). Fish species like Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), and Arctic char (*Salvelinus alpinus*) can be found in the river and sometimes even eel (*Anguilla anguilla*) are present in Lake Elliðavatn (Antonsson & Árnason, 2010; Antonsson, Guðbergsson, Jónsson, & Malmquist, 2007). The Elliðaár River displays impressive fishing numbers compared to other salmon fishing rivers in Iceland, with over 1.100 salmon caught in 2013 (SVFR, 2014). The total number of Atlantic salmon in the river is estimated at around 2.500 individuals (Antonsson & Árnason, 2010).

2.2.4 Use

Fishing in the Elliðaár River plays a big role in the recreational salmon fishery in the South-West of Iceland and has a long tradition. The king of Denmark used to own the fishing rights in the river but the City of Reykjavík bought the river in 1906 and currently rents the rights to The Reykjavik Angling Club (Vötn og veiði, 2006). A survey conducted during the summer of 2014, revealed the numerous uses of the valley by its visitors. Physical exercise, such as walking, running, bicycling and dog-walking, was very popular, but other activities, like kayaking, theater and education, were also mentioned by participants (Eyþórsdóttir, 2014). The Horticultural Society of Iceland made a 5 year contract with the City of Reykjavík in 2009 to rent a small area along Vatnsveituvegur (Garðyrkjufélag Íslands, 2010). The paths in the valley are used by numerous pedestrians and cyclists. Several recreational facilities are located close to or in the valley itself, such as a gym, a ski-lift and a boat dock in the lower section, where kayakers have also made use of the power plant outlet. The valley's upper section includes a swimming pool, a Frisbee-golf course, stables and horse riding area (Kayakklúbburinn, 2014; PRESSAN, 2012; Reykjavík, 2014a; Reykjavíkurborg, 2012). Jóhannesdóttir (2010) highlights several that cultural ecosystem services Lake Elliðavatn provides, and values them at ISK 23.093.615-31.875.606, annually. A survey of the Elliðaárdalur Valley (Eyþórsdóttir, 2014) found the value of its cultural services to be ISK 225.006.750-317.643.225 annually.

2.3 Data Collection

This case study explored urban green space contribution to ecosystem resilience and adaptation planning, via cultural ecosystem services. The research methodology included examining existing GIS data on infrastructure and a structured observational study, focused on quantitative (visitor numbers) and qualitative variables (activities, weather conditions).

2.3.1 Existing Data

In order to determine what information was already available for the study site, the databases of Reykjavík City's GIS (LUKR), the Geography Department of the University of Iceland's and the National Land Survey of Iceland's were assessed (Landmælingar Íslands, 2014; Reykjavíkurborg, 2014c). Information on vegetation cover, hydrology, land use, infrastructure and future plans was examined and whether any data gaps existed regarding people's potential use of the study site. Moreover, Reykjavík's Environment and Planning Office was contacted regarding their survey methods on the use of the city's bicycle paths. Documentation of the cultural ecosystem services found in Elliðaárdalur is limited (IMG Gallup, 2005), and the survey conducted during the summer of 2014 contributed knowledge on the use and economic value of valley (Eyþórsdóttir).

Reykjavík City's LUKR database has data on fifteen categories that are readily available as *shape* files to use in ArcGIS (reykjavik.is, 2014b). Coastline, traffic routes, property boundaries and contour lines from LUKR were used in constructing base-maps for the study, along with hill shade layers and GPS points from the IS 50V map database (Landmælingar Íslands, 2012). Data gathered throughout the research was subsequently added as layers to the base-maps.

Aerial photographs from Landmælingar Íslands (Landmælingar Íslands, 2012) were studied and used in building preliminary maps of vegetation in the study site on top of the base-maps. The focus was on identifying the presence of vegetation with weather-tempering possibilities beneficial to recreational winter use of the area that could also contribute to the areas ecosystem resilience. These initial maps were then compared with field surveys, and revised as needed. Various tree species, including conifers (*Pinales*), aspen (*Populus trichocarpus*), willow (*Salix phylicifolia*), rowan (*Sorbus aucuparia*), and birch (*Betula* *pubescens*) trees were mapped within the study site along with hydrologic features (e.g. streams and ditches). This work produced fairly detailed maps of the distribution of trees types found at the site which, along with the observation data collected, can be added as unique layers of information to a GIS database.

2.3.2 Observations

The study site was in the upper area of the Elliðaárdalur and Víðidalur Valley, from Höfðabakki to Breiðholtsbraut. The area is diverse in terms of ecosystems as well as use, offering open upland vegetation, forested areas and the river itself, while including various recreational infrastructures (Reykjavík, 2013).

This research made use of behavioral mapping which involves the observer being physically present and documenting people's activities and interactions with the area (Nickerson, 1993). Preliminary observations over several weeks helped determine the best survey protocols in terms of which activities to document, the time of day and the frequency of observations to capture the majority of uses in the area. Those observations also revealed that in order to gain a complete overview of the study site, it was necessary to divide it into three areas.

Three locations with open views over the paths on both sides of the river - Árbæjarstífla Dam (1), a rest area by the Hlaðbær cul-de-sac (2), and a shopping complex parking lot (3) - were chosen for the study (Figure 2). Access points to the site are numerous, especially in the lower section (Areas 1 and 2). The paved paths in Area 1 are topographically relatively flat while the numerous gravel paths along the Breiðholt Hill lie in a more varied landscape. The west side of the river is more vegetated than the east side where the paved path is also closer to surrounding residential areas. Area 2 has a similar vegetative composition as Area 1 and the paved paths on both sides of the river area are relatively flat except for a slight uphill towards the southern edge of the area. Areas 1 and 2 lie between the neighborhoods of Árbær and Breiðholt and include an approx. 2,7 km long circular pathway. The upper section of the site (Area 3) is fringed by an equestrian center, a shopping area across the Breiðholtsbraut road and lies further from residential areas than the lower Areas 1 and 2. Area 3 also lies at a slightly higher elevation, is wider across and open to southerly winds coming from Lake Elliðavatn. Area 3 is less vegetated and more exposed than the lower areas, allowing for a single observation point. The section of the path in the hills of Breiðholt is more sparsely vegetated than the forested parts of Area 1 and 2 west of the Elliðaár River (Appendix A). The activities walking, dog-walking, running and bicycling were recorded. These observations spots covered the entirety of the study site. However, due to lower visibility of the paths in the more vegetated sections of the valley, special effort was made to capture activity as people entered or exited the observation areas or were temporarily obscured by vegetation or landscape. Given the valley has many access points, observation spots were chosen to maximize the visibility of area sections and access points. Furthermore, observation points were also functional for vehicle survey if needed due to inclement weather.

A structured observational schedule and reflective, research field-notes, were used during the surveys. The level of involvement chosen for this study was that of a complete observer, both to avoid influencing behavior of users of the area, as well as to capture the more random behavior of people, which might not be revealed in interviews or surveys. Surveys rely on participants' interpretation and willingness to disclose information that may not be in accordance with the image they want to portray or their perception of what kind of answers are desirable (Bloor & Wood, 2006, p. 71; Bryman, 2012).

To obtain consistent data and develop a replicable method of observation, the number of visitors and their activities were recorded on every day of the week during the daylight hours (11:00 - 15:00) for 20 minute surveys at a time. The surveys were made for four weeks from December 2014 to January 2015, with a total of 80 data-points being collected (Figure 1). Given that a single observer conducted the study (removing the need to coordinate survey interpretation), different weeks focused on different locations at different times, in an effort to make surveys at different times of day and every day of the week to cover all study areas (Bryman, 2012; McKenzie et al., 2006).

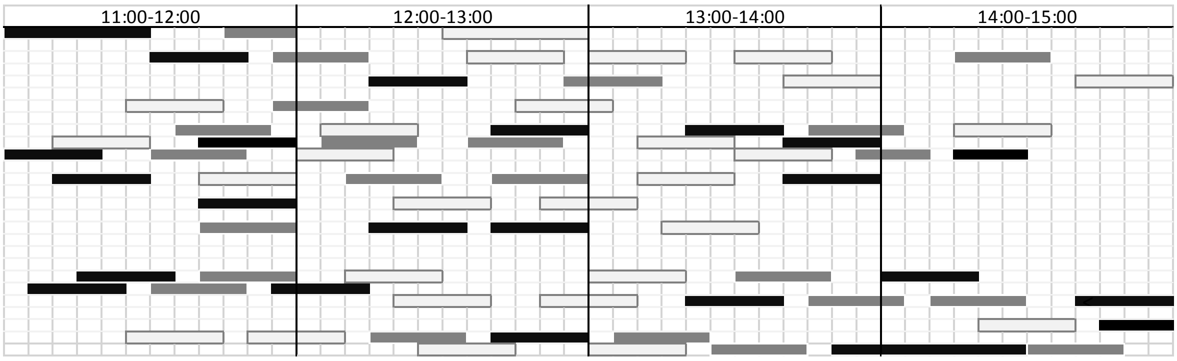

Figure 1. Part of the observation schedule for mapping the use of the upper area of the Elliðaárdalur Valley in December 2014 and January 2015. Black = Area 1, grey = Area 2, and light grey = Area 3.

Ethnographic research of any kind can present dangers for fieldworkers, for example, in terms of personal health and safety (Bloor & Wood, 2006). Although rarely mentioned or addressed as a methodological issue (Williams, Dunlap, Johnson, & Hamid, 1992) personal safety was taken into consideration when creating and executing the research plan in this study, e.g. time of day to conduct observations and the decision to rely on the use of a car rather than being out and about in the area. Practical issues such as extreme weather, road conditions and closures, and travel times also affected the research and caused deviations from the observation plan. The lack of continuous data has been identified as a weakness of structured observation schedules, as the fragmented data makes it difficult to see the bigger picture. At the risk of affecting people's behavior by becoming more of a participant in the use of the site (Bryman, 2012), time was spent on location during preliminary observations, and before, during and after scheduled observations for gaining a better overview and familiarity with its use.

Ethics

The risk of harming people physically or emotionally during the observation study was almost non-existent as visitors to the study site were not engaged in any way. The possible invasion of privacy during observations, potentially causing individuals emotional stress, was kept to a minimum by not collecting any personally identifying data or personal information (such as age, gender, income, beliefs, etc.). Finally, the issue of deception in observational research is more of a risk in so-called *field-simulations* where the researcher sets up a situation for the observed to react to (Bryman, 2012). These type of simulations were not conducted in this study. Considering the use of Elliðaárdalur as a public recreational area is hardly a controversial or a sensitive subject, and the fact that no attempt was made to determine the age, gender, or identity of observed users of the area (and thus no need to protect the identity of individuals), the ethics considered for the study focused more on avoiding favoring any personal/stakeholder preferences with regards to possible result values (Bloor & Wood, 2006).

2.4 Data Analysis

Several data analysis tools were used to assess the methodology of the study and compare the data collected. An overview of the study site, its vegetative composition, and distribution of people's activities was gained with the aid of ArcGIS.

2.4.1 Area Use and Ecosystems

Using data from preliminary observations, several experimental maps were produced for determining data input requirements and the most appropriate methods of graphical representation of spatial and location based data. GIS was used for compiling the digital data generated, and creating suitable information to add to Reykjavík's LUKR database. GIS was also used for graphically analyzing the data to reveal potential correlations between usage and ecosystems. A matrix by Burkhard et al. (2009) was used to assess the capability of different types of land cover to yield a variety of ecosystem services and benefits in the study site. The matrix indicates that forest covered areas and water courses, as can be found in Elliðaárdalur, are highly capable to provide cultural services such as recreation and aesthetic values, as well as providing intrinsic value of biodiversity. Same land cover types also ranked high on providing other ecosystem services, i.e. provisioning, supporting and regulating services (Burkhard et al., 2009). The maps produced in ArcGIS provided a good visual aid in determining which areas of the study site fit into the ecosystem services' category recommended by Burkhard et al. (2009).

2.4.2 Mapping Area Use

Observation data were imported into Microsoft Excel and added to maps produced in ArcGIS as XY data. The Lambert 1993 projection was used in creating pie charts from data gathered. Result numbers were placed on the map produced in the *Data View* option. In addition Microsoft Excel was used for creating tables and charts for mapping and modelling the area's use.

2.4.3 Data Coding

The chosen method for the research process relied on the coded structure of grounded theory. This methodology assigns numbers to various data attributes, such as the weather, species of birds, vegetation cover, and ground conditions, which can be used in data analysis. The different data attributes are discussed below.

Weather

The weather attribute encompassed temperature, wind speed, precipitation, cloud cover, and ground conditions. These attributes were documented for each observation day. Weather conditions in Reykjavík during the study deviated somewhat from historical averages. The temperature in December 2014 and January 2015 was below the 2005-2014 average (approx. -1,5°C), with more precipitation than usual, close to 40% in December and 70% in January. Wind speeds were close to average despite several storms and that there was a greater number of days where snow covered the ground (Veðurstofa Íslands, 2015a). The Icelandic Met Office website (Veðurstofa Íslands, 2015b) was consulted in determining or confirming wind speeds and precipitation for each day of observation.

For statistical analysis the weather conditions at the study site were categorized as (1) excellent, (2) fine or (3) poor. Excellent weather referred to no precipitation, close to average seasonal temperature (~ 1°C), and/or little or no wind (below 4 m/s). Moreover, given the time of year, days with no wind and clear skies, but temperatures well below freezing, were deemed as excellent. Fine weather represented temperatures around and below freezing (-5 to 0°C), winds between 4 and 14 m/s, and little to minimum precipitation (0.1-4 mm). Poor weather referred to heavy precipitation (more than 5 mm), extreme cold (below -6°C), and/or strong winds (over 14 m/s). Graphical representation and analysis of weather data also aided in determining if and how weather conditions influenced the use of Elliðaárdalur Valley.

Ground conditions

The ground condition of paths were recorded for all survey days and initially categorized as clear (1), icy (2) and snow covered (3) for analytical purposes. Given that the paths were snow covered for all days except one, these coded data were not used for the statistical analysis.

Fauna and Flora

Data coding was not pursued for the fauna and flora of the study site. The data collected on wildlife recorded anecdotal observation of birds seen in and around each study area during survey times. The species recorded provided descriptive insight to the study site with their presence. Vegetation data collected aimed to examine differences among study areas in terms of coverage and possible relationship with activities in the areas. The nature of people's circular use of Elliðaárdalur Valley's path networks did not suit a coding of the areas in terms of vegetation. The maps produced in ArcGIS aided in identifying differences in vegetation cover among the areas and helped identify potential relationships between area use and its vegetation cover.

2.4.4 Data Analysis

For determining what role the study site may play with regards to resilience in potential adaptation plans, analysis of data focused on the following:

- Determining daytime winter recreational use of the study site.
- Differences between Saturday-Sunday and Monday-Friday use of the study site.
- Distribution of data collected and whether it could be used in statistical analysis.
- Differences between activities within each area of the study site.
- Differences between areas in terms of activities, flora and fauna.
- Effects of weather conditions on activities in the areas.
- The potential benefits of vegetation for area activity.

The statistical program R (R Development Core Team, 2014) was used in analysis of the data. Plotting the untransformed variables indicated the data showed a left skew. Using a base-10 logarithm to transform the data improved normality (see Appendix C). The Differences between weekend and weekday use was compared with a Welsh two sample t-test. A one-way analysis of variance (ANOVA) was used to determine if significant differences were to be found among different uses and areas. The non-parametric Kruskal-Wallis test was used for comparing results from the ANOVA. Finally, the Tukey Honest Significant Difference test was used to detect where the differences in use and activities indicated by the ANOVA lay.

3 Results

3.1 Existing data

Assessment of GIS databases confirmed they focused on quantitative data such as land use, infrastructure (e.g. rest areas and garbage bins), hydrology (e.g. coastline and water courses), transportation routes (roads and paths), property boundaries and contour lines. A survey conducted in the summer of 2014 revealed various and diverse uses of Elliðaárdalur Valley (Eyþórsdóttir, 2014). Additionally a comprehensive phone survey from 2005 (IMG Gallup) on citizen use of recreational areas in and around Reykjavík showed that about 2/3 of respondents had visited Elliðaárdalur Valley in the past twelve months. The majority of visitors lived near the valley and were over the age of 45. Recent surveys on the use of Reykjavík's green areas show that just over half the respondents had visited Elliðaárdalur during the previous twelve months (Reykjavíkurborg, 2015b). The city of Reykjavík conducts counts of bicycle traffic four times a year in several spots around the city, as a part of the *Hjólað í vinnuna* survey, and one of them is in the lower section of Elliðaárdalur Valley outside of the study site. The winter count showed 77 cyclists passed through the area in December 2013 (B. Helgadóttir project manager/geographer at Reykjavík Environment and Planning Office, personal communication, November 18, 2014).

A map of the study site's vegetation was produced by adding recorded data from observational surveys onto existing data from Reykjavík's GIS and the National Land Survey of Iceland's databases and aerial photos (Landmælingar Íslands, 2012; Reykjavíkurborg, 2014c).

The map (Figure 2) produced shows the three accessible parking areas around the study site, one beside the Árbæjarstífla Dam, one by the Árbæjarlaug Pool and finally an area close to the horse facilities in Víðidalur which is not specifically designated for parking but is used as such. Numerous rest areas can be found throughout the study site and several that were not in the Reykjavík database, were added to the map. Over thirty access points marked on the map highlight the complex nature of observing the use of the study site. The vegetation mapped underscores the difference between both the west and east side of the Elliðaárdalur Valley, as well as the difference between observation areas. The west side of the valley, along the Breiðholt Hill, is more covered with trees of various types, both planted and self-sown (Pálsson, 2004). Area 1 consists of (relatively) heavily vegetated paths on the west side of the river as well as an open area on the east side and across the Árbæjarstífla Dam. Similarly, Area 2 has paths surrounded by heavy vegetation, particularly at the bottom of the Breiðholt hill on the west side, and more exposed paths on the east side. Area 3 is more exposed, lies at a slightly higher altitude, and is open to the south towards Lake Elliðavatn (reykjavik.is, 2014b). The section of the path in the hills of Breiðholt are more sparsely vegetated than other vegetated sections of the valley (Figure 2, Appendix A).

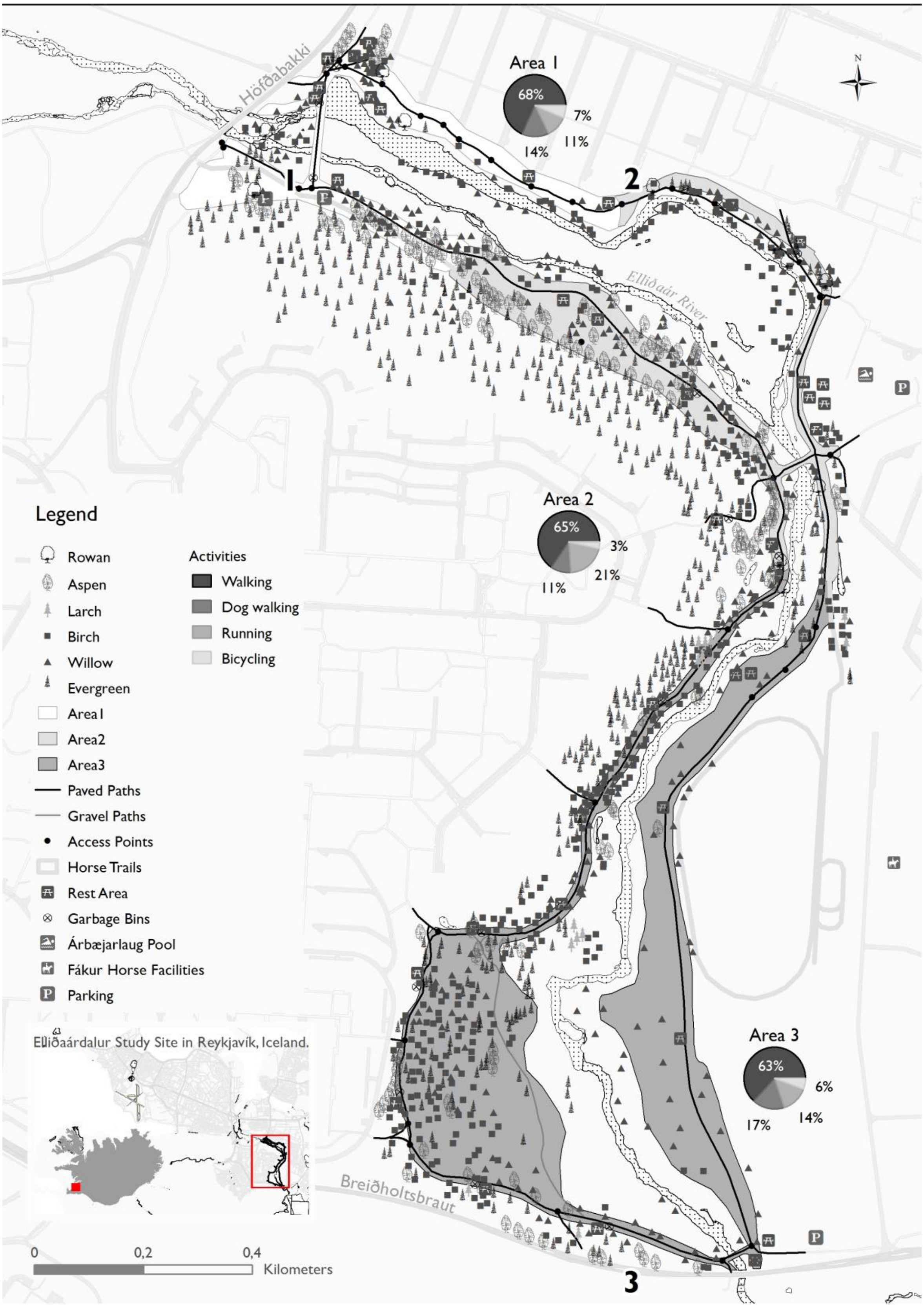

Figure 2. Elliðaárdalur study site, infrastructure, vegetation, observation areas, and distribution of activities. Observation spots marked by the numbers 1,2 and 3. Sources: Landmælingar Íslands. (2012). IS 50V, útgáfa 3.4. Reykjavíkurborg. (2014). Landupplýsinar (LUKR).

The map also clearly depicts the differences in the length of paths in the observation areas. The entire paved path around the study site is 6,7 km long. Observations showed that more people visited Areas 1 and 2 which are within a popular 2,7 km long circular route. The path around the larger Area 3 is close to 4 km in length, through a more exposed and hillier landscape (Table 1).

Table 1. Approximate area size, lengths of paths observed and elevation of observation areas at study site in Elliðaárdalur Valley. Source: Borgarvefsjá (reykjavik.is, 2014b).

	Area 1	Area 2	Area 3	Total
Area (approx.)	140.000 m^2	170.000 m^2	450.000 m^2	760.000 m^2
Paved paths	1,60 km	1,80 km	4 km	7,4 km
Gravel paths (km)	0 km	0 km	0,580 km	0,580 km
Path elevation (above sea level)	50-55 m	55-65 m	65-95 m	50-95 m

3.2 Observations - Analysis

Overall 80 surveys were conducted, each consisting of 20 minutes of observation in one of the three study areas, averaging five observations for each day of observations, where four different activities of the study site's visitors were recorded (Table 2 and Appendix B). The majority of people used Elliðaárdalur for walking, followed by dog-walking, running and bicycling. The use of Areas 1 and 2 was higher (312 and 376 people respectively) than that of Area 3 (210 people).

Table 2. Day use of Elliðaárdalur study site during observations in December 2014 and January 2015. Total number of activities during a day as well as distribution of visitors between areas is shown. Numbers in gray indicate Sundays and Saturdays.

Obs.day	Walking	Dog-walking	Running	Bicycling	Total	Area 1	Area 2	Area 3
1	15	4	1	0	**20**	13	7	0
2	24	5	17	3	**49**	10	29	10
3	100	10	18	8	**136**	51	66	19
4	21	3	15	0	**39**	0	25	14
5	22	8	5	2	**37**	12	15	10
6	26	7	4	2	**39**	14	14	11
7	54	12	25	4	**95**	30	40	25
8	38	4	3	6	**51**	21	18	12
9	6	0	1	0	**7**	3	0	4
10	23	1	1	0	**25**	9	10	6
11	13	3	10	2	**28**	14	9	5
12	36	12	5	4	**57**	29	21	7
13	48	11	10	2	**71**	31	20	20
14	35	8	7	5	**55**	18	19	18
15	85	22	18	6	**131**	34	60	37
16	46	9	2	1	**58**	23	23	12
Total	592	119	142	45	**898**	312	376	210

The mean for all surveys is 11,22 people per day using Elliðaárdalur, with a standard deviation [SD] of ± 8,82 people. On average, 7,4 people per day (SD ± 6,16) used Elliðaárdalur for walking, while 2 or less people per day used the area for dog-walking (1,49±1,58), running (1,78 ± 3,23) or bicycling (0,56 ± 0,85) (Appendix B).

Summary of activities in the study site (Table 3) confirms the high use of Elliðaárdalur for walking. The highest number seen for running (15) can be explained by a running group passing through Area 1 during one survey. The maximum number of 29 for walking, however, consisted of individuals or 2-3 persons per group. On average, the number of people dog-walking and running is similar, about 2-3 people per day. The most popular activity is walking and the least is bicycling (Table 3).

Table 3. Summary of activities of visitors to study site in Elliðaárdalur over the duration of observations in December 2014 and January 2015.

	Total	**Walking**	**Dog-walking**	**Running**	**Bicycling**
Min	1,00	0.00	0,000	0,000	0,0000
1st Qu.	5,00	3,75	0,000	0,000	0,0000
Median	8,50	5,00	1,000	0,000	0,0000
Mean	11,22	7,40	1,488	1,775	0,5625
3rd Qu.	15,25	9,00	2,000	1,250	1,0000
Max	39,00	29,00	8,000	15,000	3,0000
StDev	8,82	6,16	1,58	3,23	0,85

A boxplot of the preceding table clearly demonstrates the differences in means between activities over the whole study site during observations, as well as outlying data-points (Figure 3).

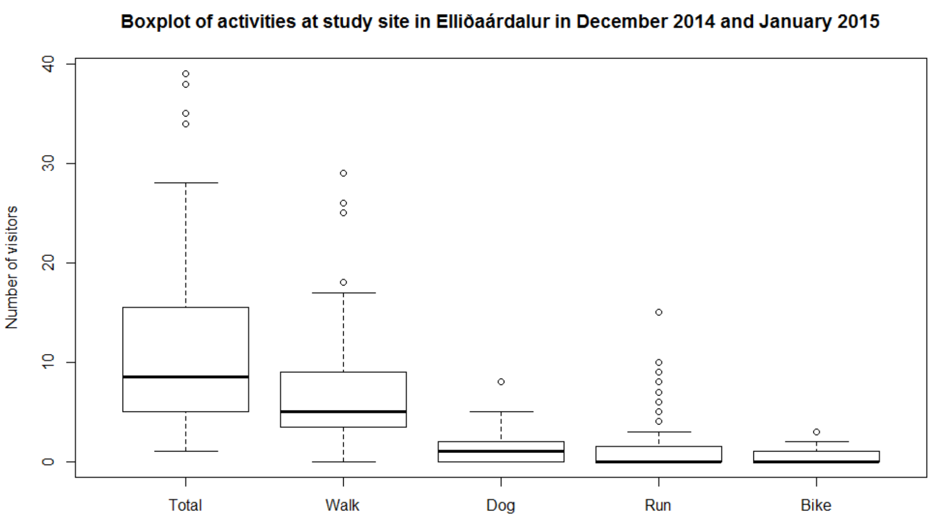

Figure 3. Boxplot of total visitor numbers and activities at study site in Elliðaárdalur during observations in December 2014 and January 2015.

Distribution of activities in each area

Results in Table 3 reveal that the majority of the activities take place around the lower section of the study site (Areas 1 and 2). Overall, walking is the most popular activity in all three areas. In Area 1 and 3 the second most common activity is dog-walking, while in Area 2 it is running (Figure 4, Appendix B).

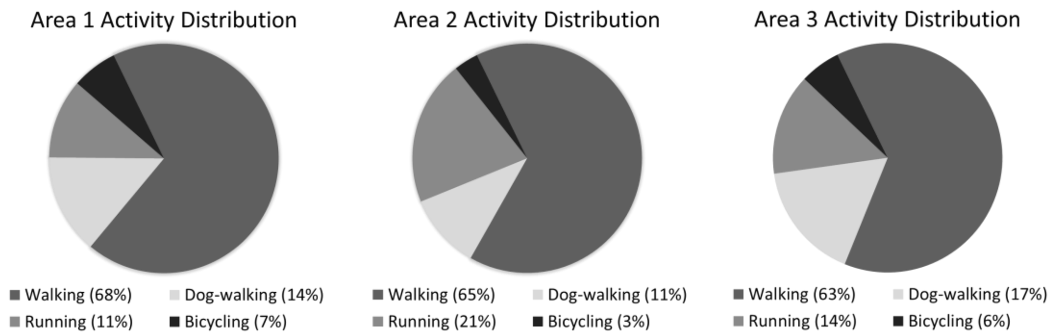

Figure 4. Graphs showing the distribution of activities (walking, dog-walking, running and bicycling) within each observation area of the study site in upper Elliðaárdalur valley.

3.2.1 Descriptive Comparison of Weekend (Saturday-Sunday) versus Weekday (Monday-Friday) Use

High use numbers were seen during the weekends relative to those seen Monday through Friday. The highest number of people observed in a weekend was 90 walking visitors in Area 2 on a Sunday. In contrast, the greatest number of people seen on a weekday was 35 walking visitors in Area 1 on a Monday (Table 4).

Table 4. Total daily use by area and activity in the Elliðaárdalur Valley study site.

	Walking				**Dog-walking**				**Running**				**Bicycling**			
	Total	**A1**	**A2**	**A3**	**Total**	**A1**	**A2**	**A3**	**Total**	**A1**	**A2**	**A3**	**Total**	**A1**	**A2**	**A3**
Sun	**185**	65	90	30	**32**	9	12	11	**36**	6	19	11	**14**	5	5	4
Sat	**89**	29	32	28	**20**	5	8	7	**32**	11	16	5	**9**	3	3	3
Mon	**74**	35	23	16	**13**	4	3	6	**5**	0	4	1	**7**	5	1	1
Tue	**34**	5	15	14	**6**	2	0	4	**25**	7	18	0	**2**	0	1	1
Wed	**57**	28	4	8	**16**	11	4	1	**7**	5	1	1	**4**	1	2	1
Thu	**70**	29	25	16	**19**	9	8	2	**15**	1	2	12	**4**	4	0	0
Fri	**73**	22	30	21	**13**	4	5	4	**22**	5	17	0	**5**	2	1	2

A closer examination of the data (Appendix B) reveals that the highest use numbers on Saturdays and Sundays were 29 and 26 walking visitors in Area 2 and 26 and 25 in Area 1, respectively for each day. Meanwhile, the highest number of visitors seen in Area 3 on Saturdays and Sundays were 11 and 15 walking visitors, respectively (Appendix B). During Monday through Friday the highest use numbers where 17 walking in Area 1, 15 running in Area 2 and 8 running in Area 3 (Appendix B).

A summary of weekend use shows that on average the study site in Elliðaárdalur is mainly used for walking (Table 5).

Table 5. Summary of weekend activities at study site in Elliðaárdalur in December 2014 and January 2015.

	Total	Walking	Dog-walking	Running	Bicycling
Min	4,00	2,00	0,000	0,000	0,0000
1st Qu.	7,50	4,75	1,00	0,000	0,0000
Median	17,00	10,50	2,00	1,00	1,00
Mean	18,05	12,30	2,35	2,35	1,05
3rd Qu.	23,50	17,25	3,00	4,25	2,00
Max	39,00	29,00	8,00	7,00	3,00

Similarly, a summary of activities during the week (Monday-Friday) indicates that the most popular use of the study site is walking (Table 6).

Table 6. Summary of Monday-Friday activities at study site in Elliðaárdalur in December 2014 and January 2015.

	Total	Walking	Dog-walking	Running	Bicycling
Min	1,00	0,000	0,000	0,000	0,000
1st Qu.	4,00	3,000	0.000	0,000	0,000
Median	8,00	5,000	1,00	0,000	0,000
Mean	8,95	5,767	1,20	1,583	0,40
3rd Qu.	11,00	8,000	2,00	1,000	1,00
Max	28,00	17,00	5,00	15,000	3,00

3.2.2 Data Distribution and Analysis of Variance in Area Use

Saturday-Saturday and Monday-Friday Use

The Shapiro-Wilk normality test for data points from Saturday-Sunday showed that total number of people seen in Elliðaárdalur (p = 0,1894) and the number of people walking (p = 0,1916) were normally distributed after a base-10 log transformation. However, the number of people dog-walking (p = 0,105), running (p = 0,0051), or bicycling (p = 0,0022) were not normally distributed. In the same manner the distribution of the total number of people in Elliðaárdalur on Monday-Friday (p = 0,4581) and people walking (p = 0,0877) was normal after a base-10 log transformation. In contrast, the number of people dog-walking ($p = 3.026 \times 10^{-6}$), running ($p = 3.717 \times 10^{-10}$) and bicycling ($p = 6.969 \times 10^{-11}$) were not normally distributed (Appendix C).

Activities Total

The log-transformed totals for each use activity were also tested for normality with the Shapiro-Wilk normality test (Table 7). Total use and walking were normally distributed. On the other hand dog-walking, running and bicycling appeared to deviate from normality.

Table 7. P-values from the Shapiro-Wilk normality test for activities on Saturday-Sunday, Monday-Friday and combined data for Saturday-Sunday and Monday-Friday.

	Sat-Sun	Mon-Fri	Sat-Sun + Mon-Fri
Total	0,1894	0,4581	0,4783
Walking	0,1916	0,0877	0,2177
Dog-walking	0,105	<0,0001	<0,0001
Running	0,0051	<0,0001	<0,0001
Bicycling	0,0022	<0,0001	<0,0001

McDonald (2014) suggests that parametric tests (such as t-test and ANOVA) are not highly susceptible to non-normality if the distributions of the datasets in question are the same. Further inspection of the data indicates that this was the case, as the deviation from normality for all datasets skewed similarly to the left. Hence, a Welch Two Sample t-test was performed to compare total use between Saturday-Sunday and Monday-Friday. Results indicate that there was significantly more visitor use on weekends than during weekdays ($p = 0.0136$) (Appendix C).

Analysis of Variance in Area Use.

Given that dog-walking, running and bicycling deviated from normality, a non-parametric Kruskal-Wallis test was carried out, in addition to a parametric ANOVA, to compare results. Both tests showed highly significant differences among activities ($p < 0.0001$) (Appendix C). Considering this finding and that parametric tests are fairly robust in terms of non-normally distributed data (McDonald, 2014), the ANOVA results (Table 8) were used for further analysis.

Table 8. Results of ANOVA test for differences among activities in Elliðaárdalur study in December 2014 and January 2015.

	Df	SumSq	MeanSq	F-value	Pr (> F)
Activity	11	23,21	2,1105	26,77	<0.0001
Residuals	308	24,28	0,0788		
16 observations deleted due to missingness					
N = 64					

To find out where the difference lay, the Tukey's Honest Significant Difference (TukeyHSD) was run. Walking was the most popular activity in Elliðaárdalur, significantly more so than all other activities ($p < 0.05$). In terms of all three study areas, running was significantly more popular than bicycling in Area 2 ($p = 0,0259$). In addition, bicycling in Area 3 was significantly greater than running in Area 2 ($p = 0,0124$) (Appendix C).

3.2.3 Weather and ground conditions

Twelve out of 16 survey days were cloudy or semi-cloudy, with four days of snowfall. The coldest survey day was -10°C and the warmest 3°C, with an average temperature of -3,5°C (SD ± 3,42). The average wind speed during the surveys was 6,4 m/s (SD ± 5,52) and on five survey days the wind speed was > 8 m/s. The highest wind speed documented during the surveys was 18-23 m/s (Appendix B).

Impact of weather conditions on area use

Comparison of use numbers with temperature, wind speed and precipitation showed that use varies with weather conditions in the Elliðaárdalur study site, yet these differences were not significant (p = 0,157) (Appendix C).

Overall the data indicate that in three out of five high wind days fewer people visited the study site. Furthermore, a higher number of visitors occurred in the more vegetated Areas 1 and 2 on most observation days with high winds. Two out of these three high wind days were also accompanied by snowfall, which may also have an impact on visitor numbers. Similarly, precipitation seems to have a greater impact on visitor numbers than temperatures as higher temperatures did not necessarily translate to greater number of visitors (Figure 5).

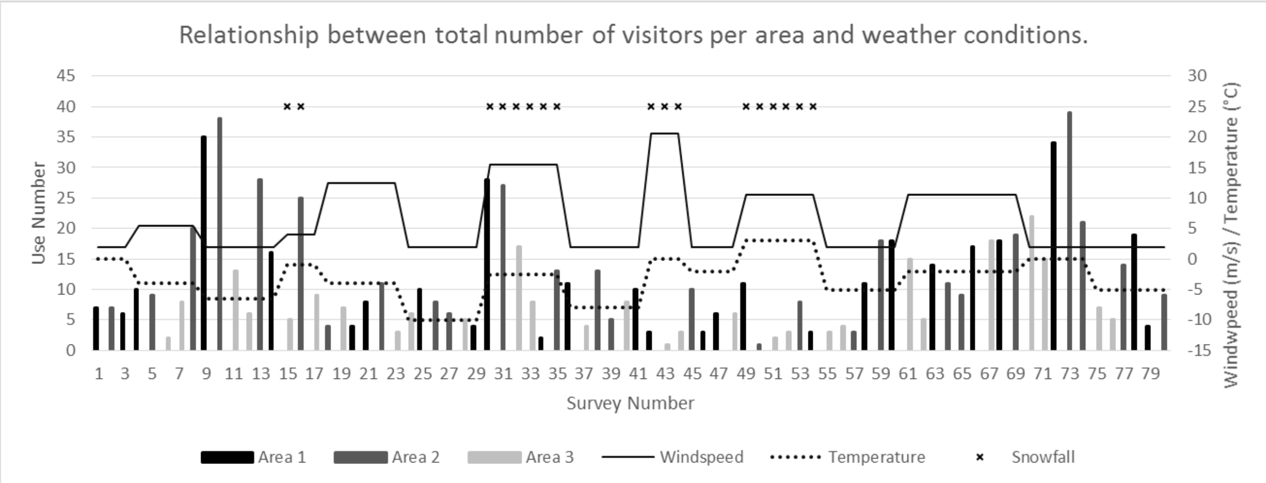

Figure 5.Number of visitors relative to average wind-speeds, temperature and snowfall in Elliðaárdalur in December 2014 and January 2015.

All surveys, besides one (27/1/2015), had similar ground conditions, snow-covered and plowed paths.

3.2.4 Flora

Maps recording the study site's vegetation, showed that Areas 1 and 2 have more vegetation cover than Area 3, with a heavy concentration of trees on the west side of the Elliðaár River (Appendix A). Evergreen (e.g. Norway spruce (*Picea abies*), mountain spruce (*Picea engelmannii*) and mountain pine (*Pinus mugo*) (Pálsson, 2004)) and aspen trees (*Populus trichocarpa*), dominate the hillside below Breiðholt, especially alongside an old road used mainly as a horse trail. Willow (*Salix phylicifolia*) and birch trees (*Betula pubescens*) are scattered around the river's banks as well as in the Blásteinshólmi islet.

3.2.5 Fauna

Several bird species were recorded during the surveys and include raven (*Corvus corax*), geese (*Anser spp*), swans (*Cygnus spp*), mallards (*Anas platyrhynchos*), passerines (*Passeriformes*), seagulls (*Laridae*) and other (Table 9) (Appendix B). Passerines included redwing (*Turdus iliacus*), starling (*Sturnus vulgaris*), and snow bunting (*Plectrophenax nivalis*). Passerines were grouped together for the purpose of this study, as were seagulls, because observing them from a distance made their species identification difficult.

Table 9. Birds observed in each area of the study site in Elliðaárdalur Valley during December 2014 and January 2015.

Species	Area 1	Area 2	Area 3	Total
Ravens	79	52	64	194
Swans	39	10	13	62
Mallards	214	4	11	226
Geese	111	34	7	152
Passerines	26	58	2	86
Seagulls	35	0	17	52
other	10	9	2	21
Total	**514**	**167**	**116**	**793**

The highest number of birds was recorded in Area 1, with mallards, geese and raven being the most frequently recorded species. The high number of mallards in Area 1 can partially be explained by people feeding them extensively near the Árbæjarstífla Dam. A detailed record of species present is found in Appendix B.

4 Discussion

Elliðaárdalur Valley fosters a wealth of cultural ecosystem services benefitting the city of Reykjavík and its inhabitants. Planning efforts that combine people's access to an urban green space and conservation of these areas' biodiversity, will in the long term be more beneficial to population centers (Bryant, 2006; DEFRA, 2011). Population centers and infrastructure are more vulnerable to impending changes in climate and need to start taking their first steps towards adaptation (Colding & Marcus, 2013). The Mayors Adapt Initiative (2014) relies on local action to contribute towards urban resilience. All planning solutions and recommendations that take ecosystem services into account, need to be tailored to each situation, as there are no 'one size fits all' solutions (TEEB, 2011). Both the northward shift of plant and animal species, and the changes in species composition and increased vegetation growth in the Arctic due to climate change, will likely affect the ecosystems found in Elliðaárdalur with unforeseen widespread impact (*ABA*, 2013). For predicting future scenarios, the impending changes require extensive documentation, i.e. continuous collection and processing of knowledge and data to understand current circumstances, *the norm*. Understanding the present to foresee the future can bolster resilience, as it can often be reached through an increased capacity to accommodate new circumstances, "*... the new normal*" (Pickett, Cadenasso, & McGrath, 2013, p. xxii). Future city development, growth and expansion may start to revolve around making the city an effectively managed unit within the landscape, where it contributes to and enhances ecosystems, instead of depleting them (Colding & Marcus, 2013).

As a relatively small city in comparison to other members, Reykjavík's participation in the Mayors Adapt Initiative can serve as an opportunity to explore innovative new methods for strengthening ecosystem resilience in the capital, benefitting other participating members. Urban planning projects, that take cultural, political, ecological and economic implications into account, can foster collaboration between the academic community, local government and the public, leading to a deeper understanding of the ecosystem functions cities rely on to prosper (Felson & Pickett, 2005). The Elliðaárdalur case study adds to a framework that explores the contribution of urban green spaces to urban resilience in strategic adaptation plans. Carter et al.'s (2014) proposal of several factors in determining adaptive capacity of urban areas, suggests that gathering and analyzing data on the use of urban green spaces, will aid in raising awareness and identifying gaps in knowledge of cultural ecosystem services. Additionally, such information can benefit the fulfillment of administrative goals for a city seeking to strengthen their ecosystem resilience with regards to climate change.

4.1 Research Methodology

The decision was made in this study to collect quantitative data (i.e. numbers) but also use methods of qualitative ethnographic research as a foundation for structuring the research plan of the study. By combining multiple methods the generalizability of the study is enhanced and allows planners and policy-makers to apply the methods to other areas (Bloor & Wood, 2006; Bryman, 2012). This combination of methods should address some of the criticism of qualitative research regarding the potential disconnect between static research results (intensive and detailed recording of data) and everyday real life (where more spontaneous aberrations occur), as it is not as reliant on tools and calculations or obsessed with accuracy and details (Bryman, 2012).

The focus of the study was not to peak behind the meaning of people's behavior but simply to determine if the area is used extensively during the wintertime, as it is in the summer months when outdoor recreation is more favorable in Iceland (Eyþórsdóttir, 2014). The methods of structured observation fit well to gather the quantitative data needed to establish the area's use. Relying partially on the methods of grounded theory worked well with the explorative nature of the study, where the research problem could be allowed to shape the methods chosen (Charmaz, 2011). Grounded theory also has the benefit of being a process oriented way to approach any ethnographic research, with less focus on the more traditional description of settings. This requires a less structured and more varied approach, leaving room for discoveries (Charmaz, 2011). Less structured preliminary observations and unscheduled visits to the study site exposes the researcher to a new understanding and experiences of how the area is used. This led to, for example, the decision to divide the site into three observation areas, to collect data during 20 minute timeslots and consideration of how accessible the area is during inclement weather. Data could also be inspected and compared from the start of the research process instead of waiting until the study period was over (Charmaz, 2011). This approach showed early in the research that visitors to the Elliðaárdalur study area used a circular route that crossed both heavily vegetated and less vegetated areas, making comparisons of visitor use and vegetation cover impractical. Establishing clear rules of use for others to follow for consistent results, can help create a methodological framework for assessing use of other urban spaces (Bryman, 2012). A cohesive base of knowledge can be built for comparison of spaces, pinpointing positive aspects and revealing weaknesses in the results of spatial planning actions, guiding assessment of effectiveness of relevant policies.

4.2 Interpreting Results

Elliðaárdalur Valley is considered by Reykjavík one of the most used green space the city has to offer (Reykjavík, 2013), warranting exploration of its use during the darkest time of year in Iceland, in December and January. The significantly higher use numbers during the weekends, were likely due to people having more time to pursue outdoor recreation activities than during the rest of the week. Given the surveys relied on daylight hours, they did not document the use of the site during traditional commuting hours to and from work and school. A study of the use of the site's paths for commuting to work has shown it is used extensively for that purpose (Reykjavíkurborg, 2012). A more extensive study would be required to analyze the differences between the site's recreational and commuting use. The overwhelming majority of visitors used the Elliðaárdalur study site for walking. The winter of 2014-2015 proved to be a fairly harsh winter, with frequent storms and higher than average number of continuous days with snow-covered ground in Reykjavík (Veðurstofa Íslands, 2015a).

The study revealed differences in use among the separate observation areas. Area 1 and Area 2 enjoy a similar composition of users, which may be explained by those areas being within the shorter circular route in the upper Elliðaárdalur Valley. This lower section of the study site is also more enclosed by the surrounding landscape, vegetation and residential areas. The closeness to residential areas and access to food provided by inhabitants, may also explain the much higher numbers of birds in Areas 1 and 2 compared to Area 3 (Appendix B). The two lower areas (Areas 1 and 2) are also more accessible, with over 20 access points from the neighborhoods surrounding them and the only designated parking area at the study site at the northern edge of Area 1. Árbæjarlaug Pool and Recreation Center is a hub of recreation, serves as a magnet for various activities, and provides parking as well. The higher number of visitors running in Area 2 can be attributed to the proximity of the Sports Center, which supports running groups with their facilities. Areas 1 and 2 consistently had higher use numbers than Area 3 for all activities, almost double except for dog-walking, which is similar in all three areas (Appendix B). Area 3 is further removed from residential areas and parking, and its more exposed nature may be more desirable for dog-walkers, as the less vegetated landscape provides a better overview and more space for visitors. Although outside the scope of this study, devoting more time and resources for extensive data collection through visitor surveys, could generate a better understanding of the socio-ecological patterns found in this study, including the effect of weather and ground conditions. The lower use of the study site during days of precipitation should be explored further as greater frequency of extreme weather due to climate change is predicted (MEA, 2005), and this may impact the recreational use of urban green spaces.

It is a limitation of the study that it only includes one season and few ecological and cultural ecosystem variables. Extending the scope of the research would be beneficial and should include a year round study of the area to delve deeper into other ecological variables. For example, further research on the interaction of visitors with ecosystems, as well as the impact of visitor use and increased urbanization on habitats, would be helpful for planning and managing urban green spaces. Furthermore, summertime research would undoubtedly produce distinct results, due to e.g. increased vegetation cover and greater number of users in the area. Additional information can be collected by the use of new technologies (e.g. flying drones to obtain snapshots of the entire area), enabling a single researcher to generate more extensive and detailed information. Use of innovative technologies would facilitate comparison of the concurrent use of different sections of an area, for achieving a deeper understanding of user interactions with the ecosystems present. Lastly, to further assess the cultural ecosystem services that an area provides, it would be useful to look at available statistics on the numbers of participants in organized, educational field-trips by schools and other associations, as well as the frequency of maintenance required for an area (e.g. repainting of benches, re-grassing of path edges, and emptying of garbage bins).

Burkhard et al.’s (2009) matrix is recommended as a tool to deliver land-use and land-management information about typical patterns of the capability of ecosystems to deliver ecosystem services, i.e. for assessing the link between land cover and benefits from ecosystem services. This matrix suggests that Elliðaárdalur Valley has good capacity for providing cultural service, especially with the presence of the Elliðaár River and tree covered areas on the west side of the river (Appendix A). During the surveys it became evident that most visitors do not prefer one side of the river to the other, but were more prone to follow the circular routes of the path network. Ideally, having more observers documenting different sections of the study site, simultaneously, would help reveal more clearly if the more heavily vegetated areas on the west side of the Elliðaár River are used more frequently than the less vegetated ones, as well as how use can be linked with wind speeds and temperature. Based on the study, the higher use of Areas 1 and 2, without considering the weather, suggests that areas with more vegetation may be favored by visitors, as the paths in these areas enjoy greater shelter from the vegetation. Alternatively, a shorter circular route and closer proximity to residential areas may also explain the higher use of these areas.

The scalable data collected in this study on vegetation can be useful in valuing and assessing the use and resilience of green spaces at other locations (Marusic & Marusic, 2012). To predict the future use of the Elliðaárdalur area, requires additional data, however, this study provides valuable baseline information. This information can be built upon, creating frameworks for planners and policy makers that are useful for future decisions regarding urban green-space management in Reykjavík. It remains to be seen if this baseline information is incorporated into the city's adaptation strategy.

4.3 Recommendations

In a growing city like Reykjavík, which has taken on international obligations of sustainable development, it is necessary to incorporate the values and benefits that urban green space provides to both the environment and society. Elliðaárdalur Valley can play an important role in Reykjavík's adaptation plans, with its provision of various ecosystem services (e.g. recreation, biodiversity, and carbon sequestration). An example of a local adaptation project is underway in the St.Kjeld neighborhood of Copenhagen, Denmark. New green areas encourage social interaction among inhabitants while contributing to flood protection for the area. Incorporating cost efficient actions (compared to construction of larger sewage systems) such as raising sidewalks and replacing concrete surfaces with vegetation and water-ways, to address issues of excess surface water and rising sea-levels, has shown that extreme preparation for climate related emergencies can also be an opportunity to develop greener cities (KLIMAKVARTER, 2015). Although the Danish example is not directly applicable to the study site in Elliðaárdalur, it does highlight the wider implications of high-level preparation to changes in climate that are met with a positive attitude from all stakeholders, as all sectors benefit from greener and more resilient urban environments. Seeking solutions to urgent issues, that satisfy the needs of both the varied sectors of society as well as those of nature, can be incorporated into the development, introduction and implementation of local adaptation plans.

TEEB's (2011) recommendations on how to incorporate the ecosystem services approach into policy and decision making include six steps, one of which is to identify the most relevant ecosystem service concerning the issue being dealt with and how it can contribute to a solution. Services that might not seem to be essential to urban services might carry potential later on. In terms of strengthening resilience, the increased recreational use of urban green spaces supports and enhances ecosystems found there, which not only facilitate human activity but also support biodiversity (Colding & Marcus, 2013), and increases awareness of the importance of environmental conservation (Costanza et al., 2014; ICLEI, 2014; Schetke, 2012; URBES, 2013). Each circumstance will dictate what resources, information, and assessment method (qualitative, quantitative or a monetary valuation) is needed to approach a solution (TEEB, 2011).

This study in Elliðaárdalur focused on the quantitative assessment of the area's use to inform and reveal spatial connections and links of the area's ecological and social system. In turn, this helps identify and raise awareness of the benefits the city derives from the area in the form of cultural services, even in the dead of winter with fairly harsh weather conditions (Table 10).

Table 10. Recommendation of indicators to collect to assess urban green space use based on the Elliðaárdalur case study.

Indicator	NOTES	Area 1	Area 2	Area 3
Use Numbers	Individual, total and area numbers, if required	312	376	210
Activities	Depends on site e.g. walking, running, bicycling, all	all	all	all
Time of day	Observation schedule	Daytime,	20 min	intervals
Fauna	Species present and their relative abundance	514	167	116
Weather	Temperature, wind-speed, precipitation,	na	na	na
Topography	Flat, hilly, combination	flat	flat	hilly
Distances	Path networks, routes, area size	1,6km	1,8km	4km
Vegetation	Forested, exposed, combination, number of species	comb.	comb.	comb.

While provisioning and supporting ecosystem services are often more easily quantified monetarily, cultural services of urban ecosystems play a vital role for city inhabitants and visitors and the ecosystems themselves (TEEB, 2011). Other steps in TEEB (2011) recommend putting the chosen methodology into action, comparing alternatives with the help of, for example, cost-benefit or multi-criteria analysis for revealing other options, and finally monitor, value and address social, economic and environmental impacts of the implemented policy or project.

Reykjavík currently uses several continually updated checklists on society, planning, transportation, ecosystems and cultural remains, energy and resources, development and construction, and natural disasters to value urban quality (Table 11).

Table 11. Reykjavík City's checklists for valuing urban quality (Reykjavík, 2013).

Checklist	Example
Society	Housing, employment, age, health and safety
Planning	Urban patterns, walking distances, climate (wind protection, shadows), vegetation cover, local spirit
Transportation	Public transportation, parking, bicycling
Ecosystems and cultural remains	Protected areas, nature and biodiversity, geology, coastline, water protection
Energy and natural resources	Energy use, water use, waste management, land-use, carbon sequestration
Buildings	Service buildings, official institutions, building materials, reusing material and buildings
Natural disasters	Floods, rising sea-levels, earthquakes

The six step approach recommended by TEEB was designed to be adaptable to unique situations and Reykjavík could incorporate this approach into future plans for not only green spaces, but the city as a whole.

In situ observations of major green spaces in the city of Granada in south-eastern Spain revealed the importance of documenting visitor behavior along with certain area features (such as existing infrastructure and vegetation cover). An increased understanding of how area features can influence most common activities in each space, can aid future action plans by highlighting what works and what is lacking, and also guarantee that planning projects meet the requirements and expectations of users (Adinolfi, Suárez-Cáceres, & Cariñanos, 2014).

Reykjavík's proposal to amend zoning plans and establish Elliðaárdalur and surrounding areas as a City Park is a step in the right direction when it comes to the protection of the area and incorporating it into strategic adaptation plans. The City Council's minutes on the proposal on the protection of recreational areas do, however, state that further definitions on what the protection means are needed and that forming a workgroup is not a sufficient solution. A steering committee created to consider the future management of Elliðaárdalur Valley (Eggertsson, 2015) will hopefully produce an efficient plan for suitable amendments to zoning plans. A strong zoning strategy that supports the conservation of green spaces and the creation of a City Park in Elliðaárdalur would only be the first step of many needed to incorporate guidance on the management of protected areas into future spatial planning, where every stakeholders' best interests (both nature and people) are kept in mind (Reykjavíkurborg, 2014a).

The city has rented out areas in the lower Elliðaárdalur Valley for horticultural use (Garðyrkjufélag Íslands, 2010). Providing more opportunities for urban farming is one planning strategy that can help strengthen Reykjavík's ecosystem services resilience in the coming years, as landscaping practices generate not only cultural services but also supporting and regulating services for urban ecosystems. However, increasing property prices in cities, with a rise in privately owned resources, can make it difficult to maintain such public areas (Lee & Webster, 2006).

Based on a study by Snorrason (2012), Reykjavík notes in its Green Steps Accounting Guidelines that 397 trees are necessary for sequestering on average one ton of carbon annually and one hectare of forested land can store 6,3 tons of carbon annually in trees and soil (Reykjavíkurborg, 2011). These can aid in determining the future use of Elliðaárdalur Valley and other green spaces within the city in terms of adaptation strategies. Although trees in Elliðaárdalur Valley are not high in numbers, they still play their part in carbon storing. The data on vegetation collected and mapped in this study can be included in adaptation plans with regards to carbon sequestration. Afforestation in the upper section of Elliðaárdalur has been debated (residents protesting diminished views) (Reykjavíkurborg, 2014d) and seeking more agreeable solutions would be preferable. Currently drained wetlands of Iceland emit a considerable amount of carbon (Alþingi, 2014). While the damage done is not completely reversible, wetlands' potential to store carbon (i.e. trapping vegetative litter for a long time, limiting its decomposition and the release of carbon dioxide into the atmosphere) can provide Reykjavík with a good adaptation and resilience strengthening opportunity alongside increased afforestation of its green spaces. Besides carbon sequestration, restoration of wetlands also provides habitat to wildlife, increasing biodiversity (Auhage, 2010). Elliðaárdalur Valley does not include extensive wetlands but several can be found in other parts of the city; close to the city center in Vatnsmýri as well as on its outskirts on the Geldinganes Peninsula, in Úlfarsárdalur Valley and in Kollafjörður Fjord (Skógræktarfélag Reykjavíkur, 2013). In December 2014 a proposal on wetland reclamation was put forward in the Environment and Planning Council and in January 2015 a memo on the state of the issue was added (Reykjavíkurborg, 2014b, 2015a). The reclamation of wetlands is, along with conservation of other green spaces, an excellent addition to ecosystem resilience strengthening for Reykjavík. Studies on the city's green space involving wetlands are essential in supporting adaptation strategies to fulfil the international obligations the city has assumed.

Spirn (Spirn, 1984) suggests that despite all talk of incorporating nature into cities in an attempt to adapt to changing climate, the fact remains that cities are a part of nature and not the other way around. Reykjavík is exploring potential membership to the Urban Biosphere Initiative (URBIS, 2015) by ICLEI (Local Governments for Sustainability) which is a relatively new development that recognizes cities for what they are; an intricately interwoven parts of nature, open systems of energy, material, information and waste. This interpretation of cities can inform their design and maintenance, where knowledge of the interplay between and within ecosystems, of which humans and their settlements are a part, is essential for future planning (Spirn, 1984). The city is dependent on its deeper structures (e.g. geography) for design and growth, structures that have been around much longer and will endure long after humans leave (Spirn, 1984). A city's resilience can be strengthened by incorporating these features and characteristics into its spatial and temporal plans. Green spaces contribute to a city's resilience with the ecosystem services they provide, for example, by improving air and water quality, fostering biodiversity and providing valuable recreational and aesthetic potential to the city's inhabitants.

5 Conclusions

Incorporating ecological perspectives into established social infrastructure enhances the socio-ecological resilience of cities where the pressures on the environment are concentrated. Green spaces can provide not only habitats and venues for biological diversity but also boost city inhabitants' health with their varied cultural services. Use of green areas awakens awareness and understanding among citizens on the importance of nature conservation and resilience of ecosystems. Urban ecosystem resilience is vital to adaptation strategies to climate change, and which the City of Reykjavík, Iceland has undertaken by its membership in the Mayors Adapt Initiative. The initiative encourages cities to collaborate to act on climate change with a focus on the long term context of the impact of local actions. To help achieve the initiative's goals, this study looked at cultural value of ecosystems to urban well-being. Overall, the study generated valuable information to contribute to existing databases on urban planning and management. In addition, the study has provided a way of assessing urban green space, highlighting its contribution to strengthening of ecosystem resilience, and thus benefitting adaptation strategies. The knowledge generated is useful for increasing awareness of socio-ecological functions of urban areas, and can be incorporated into policy actions to strengthen urban resilience and comply with the Mayors Adapt Initiative.

A detailed exploration of urban planning and design relative to climate change is imperative to generate knowledge for use in urban design (Carter et al., 2014). There is, however, a risk that some adaptation actions may impact biodiversity more than climate change will, e.g. planting exotic species for carbon sequestration that ultimately displace native plants (Colding & Marcus, 2013). Solutions to integrate urban social functions with ecosystem services and vice versa can lie in expanding current, essential urban design elements to include the services that ecosystems provide (Colding & Marcus, 2013).

The methods used for the Elliðaárdalur case study included indicators of the site's use, documentation of weather conditions and analysis of the composition of visitors' activities in conjunction with the presence of weather tempering vegetation. The flexible qualitative approach (e.g. determining what constitutes weather tempering vegetation) to the study makes it adaptable to other urban green spaces, while the structured quantitative methods used for collecting data allow modelling of future use and impact of planning changes. GIS has proven to be a valuable tool for analyzing both spatial and temporal landscapes, as well as aid in management and planning of urban land use (Huitric et al., 2009; Stockholm Resilience Centre, 2014b). Once a GIS layer has been created it can provide a wealth of new information and allow data analysis at different scales, which can help establish connections between ecosystem services and well-being (Haase et al., 2014; Kuzyk, 2012). Public input on area use and values, that may be overlooked by specialists, can be incorporated to reveal overlapping interests of society and nature conservation (The Trust For Public Land, 2015). Furthermore, the data gathered can be used to derive new indicators for planning purposes (Schetke, 2012)

Resilience is important for ecological as well as social systems and finding ways to integrate the two will increase our capacity to address climate change. The value of cultural service of urban green spaces, evident by their use, play a big role in both fostering understanding of nature and in ensuring ecosystems we rely on continue to thrive (Costanza et al., 2014; ICLEI, 2014; Schetke, 2012; URBES, 2013). Effective urban planning increasingly acknowledges that an ecosystem services perspective can help create sustainable cities. Taking a city’s ecological footprint into account can steer city planners towards urban densification thus improving public transport and reducing emissions (Reykjavík, 2013), while providing more urban green space for recreation (TEEB, 2011). By mapping ecosystems and use of areas planners can more easily identify green spaces and incorporate an ecosystem approach into land-use management (TEEB, 2011). Making data on ecosystems readily available to planners may encourage and facilitate communication between different city departments. Good communication and relationships between collaborating parties (public, private and political) are one of the requirements needed to support design projects and have a successful ecosystem approach to urban planning (TEEB, 2011).

Despite proposed plans of development in the Elliðaárdalur Valley, serious consideration needs to be given to the area’s contribution of ecosystem services to Reykjavík. For example, the area yields provisioning services (e.g. energy and hot water), supporting and regulating services (e.g. carbon sequestration and seed dispersal), and cultural (e.g. recreation and inspiration) (Reykjavík, 2013). It is clear from this case study that upper Elliðaárdalur is extensively used by people even during the winter months. Elliðaárdalur Valley is not the only urban green space in Reykjavík. Other areas such as Öskjuhlíð, Vatnsmýri and the Green Scarf that encircles the city and neighboring municipalities, provide similar cultural services that are worth examining further. In conclusion, urban green spaces contribute to urban resilience by providing various ecosystem services, fostering awareness on the importance of conservation, and enhancing biodiversity.

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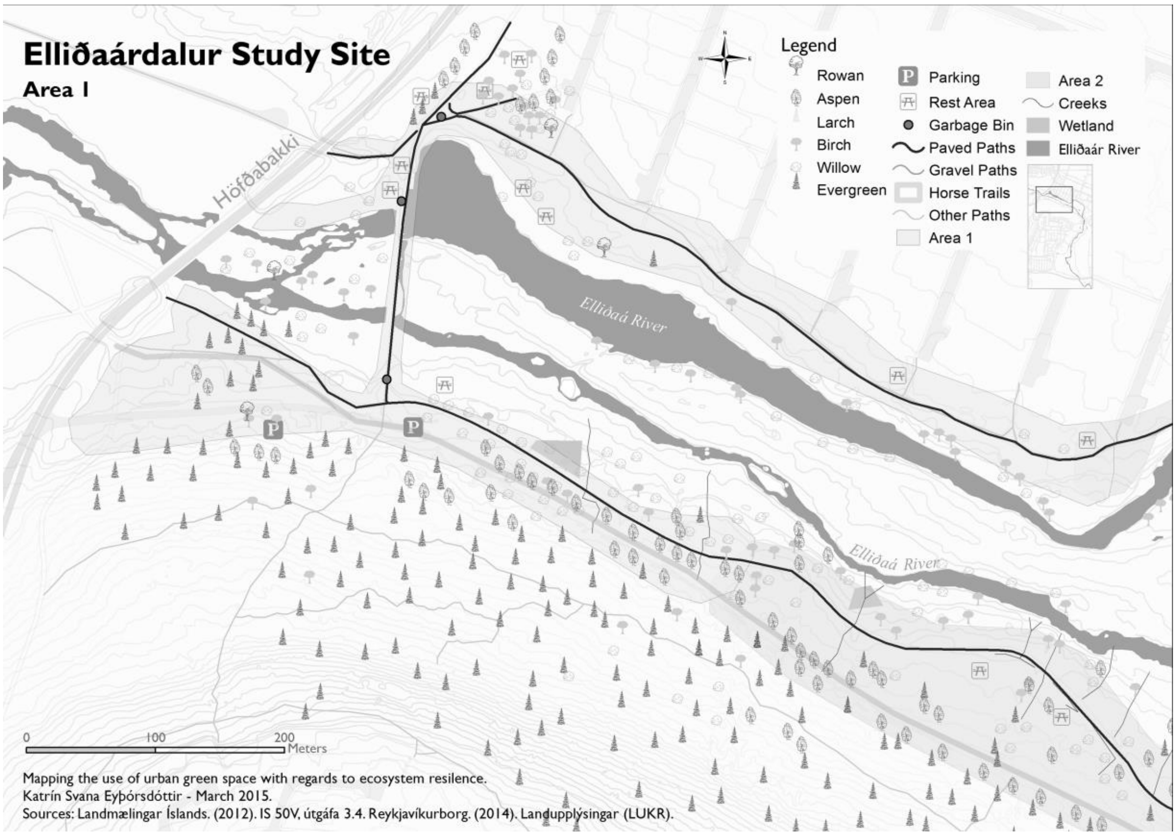
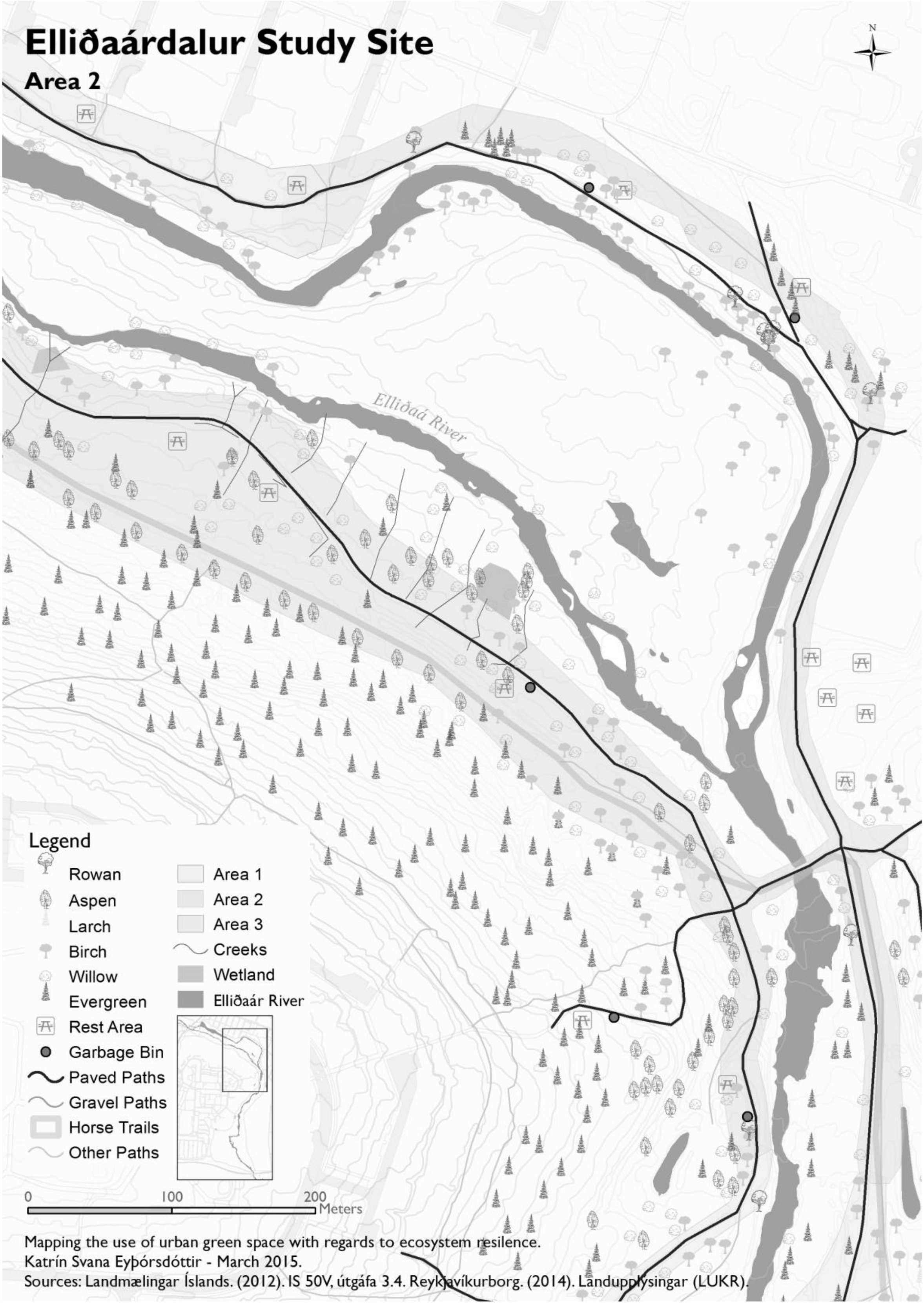
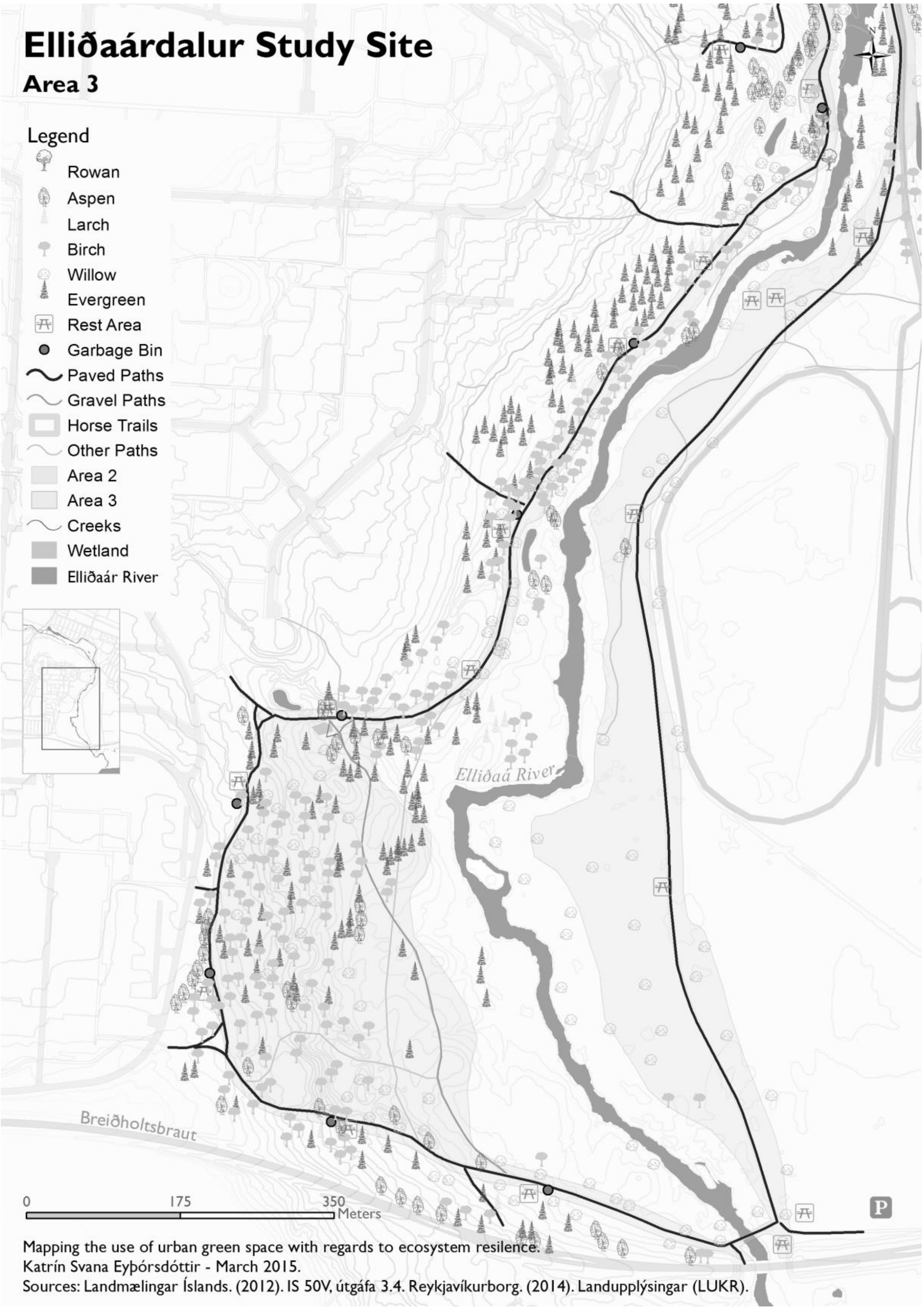
Appendix A


Elliðaárdalur Study Site
Area 1
Legend
Rowan
Aspen
Larch
Birch
Willow
Evergreen
Parking
Rest Area
Garbage Bin
Paved Paths
Gravel Paths
Horse Trails
Other Paths
Area 1
Area 2
Creeks
Wetland
Elliðaár River
Höfðabakki
Elliðaá River
Elliðaá River
0
100
200
Meters
Mapping the use of urban green space with regards to ecosystem resilience.
Katrín Svana Eyþórsdóttir - March 2015.
Sources: Landmælingar Íslands. (2012). IS 50V, útgáfa 3.4. Reykjavíkurborg. (2014). Landupplýsingar (LUKR).


Elliðaárdalur Study Site
Area 2
N
Elliðaá River
Legend
Rowan
Aspen
Larch
Birch
Willow
Evergreen
Rest Area
Garbage Bin
Paved Paths
Gravel Paths
Horse Trails
Other Paths
Area 1
Area 2
Area 3
Creeks
Wetland
Elliðaár River
0
100
200
Meters
Mapping the use of urban green space with regards to ecosystem resilence.
Katrín Svana Eyþórsdóttir - March 2015.
Sources: Landmælingar Íslands. (2012). IS 50V, útgáfa 3.4. Reykjavíkurborg. (2014). Landupplýsingar (LUKR).


Elliðaárdalur Study Site
Area 3
Legend
Rowan
Aspen
Larch
Birch
Willow
Evergreen
Rest Area
Garbage Bin
Paved Paths
Gravel Paths
Horse Trails
Other Paths
Area 2
Area 3
Creeks
Wetland
Elliðaár River
Elliðaá River
Breiðholtsbraut
0
175
350
Meters
Mapping the use of urban green space with regards to ecosystem resilience.
Katrín Svana Eyþórsdóttir - March 2015.
Sources: Landmælingar Íslands. (2012). IS 50V, útgáfa 3.4. Reykjavíkurborg. (2014). Landupplýsingar (LUKR).

Appendix B – Survey data

Table 12. All data-points collected during observations in Elliðaárdalur study in December 2014 and January 2015, seperated by activites and total visitors to areas (A1 = Area 1, etc.).

OB. NR.	DATE	TIME	WALK	DOG-W.	RUN	BIKE	A1 TOTAL	A2 TOTAL	A3 TOTAL
1	3/12/14	11:45-12:00	5	2	0	0	7		
2	3/12/14	11:45-12:00	5	1	1	0		7	
3	3/12/14	12:30-13:00	5	1	0	0	6		
4	5/12/14	11:30-11:50	5	3	1	1	10		
5	5/12/14	11:55-12:15	8	0	1	0		9	
6	5/12/14	12:35-12:55	2	0	0	0			2
7	5/12/14	13:00-13:20	5	1	0	2			8
8	5/12/14	13:30-13:50	4	1	15	0		20	
9	5/12/14	14:15-14:30	26	1	5	3	35		
10	7/12/14	12:15-12:35	29	5	4	0		38	
11	7/12/14	12:55-13:15	11	1	1	0			13
12	7/12/14	13:40-14:00	2	0	2	2			6
13	7/12/14	14:40-15:00	18	3	6	1		28	
14	7/12/14	15:05-15:25	14	0	0	2	16		
15	7/12/14	15:30-15:45	5	0	0	0			5
16	9/12/14	11:25-11:45	10	0	15	0		25	
17	9/12/14	11:55-12:15	6	3	0	0			9
18	9/12/14	12:45-13:05	2	1	1	0		4	
19	11/12/14	11:35-11:55	3	0	4	0			7
20	11/12/14	12:05-12:25	2	2	0	0	4		
21	11/12/14	12:40-13:00	4	2	0	2	8		
22	11/12/14	13:20-13:40	9	2	0	0		11	
23	11/12/14	13:45-14:05	2	1	0	0			3
24	11/12/14	14:15-14:35	4	2	0	0			6
25	12/12/14	11:40-12:00	4	1	4	1	10		
26	12/12/14	12:05-12:25	5	3	0	0		8	
27	12/12/14	12:35-12:55	4	1	0	1		6	
28	12/12/14	13:10-13:30	5	0	0	0			5
29	12/12/14	13:40-14:00	4	0	0	0	4		
30	13/12/14	11:00-11:20	15	2	9	2	28		
31	13/12/14	11:30-11:50	16	1	10	0		27	
32	13/12/14	12:00-12:20	9	2	5	1			17
33	13/12/14	13:30-13:50	4	3	0	1			8
34	13/12/14	13:55-14:10	1	0	1	0	2		
35	13/12/14	14:15-14:30	9	4	0	0		13	
36	15/12/14	11:10-11:30	8	1	0	2	11		
37	15/12/14	11:40-12:00	4	0	0	0			4
38	15/12/14	12:10-12:30	10	1	2	0		13	
39	15/12/14	12:40-13:00	4	0	1	0		5	
40	15/12/14	13:10-13:30	5	2	0	1			8
41	15/12/14	13:40-14:00	7	0	0	3	10		
42	17/12/14	11:40-12:00	3	0	0	0	3		
43	17/12/14	12:20-12:40	1	0	0	0			1

Table 12 cont.

OB. NR.	Date	Time	Walk	Dog-W.	Run	Bike	A1 Total	A2 Total	A3 Total
44	17/12/14	12:50-13:10	2	0	1	0			3
45	19/12/14	11:40-12:00	9	0	1	0		10	
46	19/12/14	12:15-12:35	3	0	0	0	3		
47	19/12/14	12:40-13:00	6	0	0	0	6		
48	19/12/14	13:15-13:35	5	1	0	0			6
49	27/1/15	11:15-11:35	4	0	7	0	11		
50	27/1/15	11:40-12:00	0	0	0	1		1	
51	27/1/15	12:10-12:30	0	1	0	1			2
52	27/1/15	13:00-13:20	3	0	0	0			3
53	27/1/15	13:30-13:50	5	0	3	0		8	
54	27/1/15	14:00-14:20	1	2	0	0	3		
55	28/1/14	09:45-10:05	2	0	0	1			3
56	28/1/14	10:15-10:35	3	1	0	0			4
57	28/1/14	10:45-11:05	2	0	0	1		3	
58	28/1/14	11:05-11:25	6	5	0	0	11		
59	28/1/14	11:20-11:40	14	3	0	1		18	
60	28/1/14	11:55-12:15	9	3	5	1	18		
61	29/1/15	12:20-12:40	7	0	8	0			15
62	29/1/15	12:50-13:10	4	1	0	0			5
63	29/1/15	13:15-13:35	9	3	1	1	14		
64	29/1/15	13:45-14:05	7	4	0	0		11	
65	29/1/15	14:10-14:30	7	1	1	0		9	
66	29/1/15	14:40-15:00	14	2	0	1	17		
67	31/1/15	14:20-14:40	15	2	0	1			18
68	31/1/15	14:45-15:05	13	3	1	1	18		
69	31/1/15	15:05-15:25	7	3	6	3		19	
70	1/2/15	11:25-11:45	10	5	7	0			22
71	1/2/15	11:50-12:10	7	5	1	2			15
72	1/2/15	12:15-12:35	25	8	1	0	34		
73	1/2/15	12:40-13:00	26	3	7	3		39	
74	1/2/15	13:05-13:25	17	1	2	1		21	
75	2/2/15	12:25-12:45	4	2	1	0			7
76	2/2/15	13:00-13:20	3	2	0	0			5
77	2/2/15	13:25-13:45	12	2	0	0		14	
78	2/2/15	13:50-14:10	17	2	0	0	19		
79	2/2/15	14:10-14:30	3	1	0	0	4		
80	2/2/15	14:30-14:50	7	0	1	1		9	
		Total	592	119	142	45	312	376	210
		Mean	7.4	1.4875	1.775	0.5625	12	14.46154	7.5
		Stdev	6.16	1.58	3.23	0.85	9.16	10.15	5.43

Table 13. All data-points collected during observations in Elliðaárdalur study in December 2014 and January 2015, seperated by activites in each area (A1 = Area 1, A2 = Area 2, A3 = Area 3, W = walking, D = dog-walking, R = running, B = bicycling).

OB.NR.	DATE	TIME	W-A1	W-A2	W-A3	D-A1	D-A2	D-A3	R-A1	R-A2	R-A3	B-A1	B-A2	B-A3
1	3/12/14	11:45-12:00	5			2			0			0		
2	3/12/14	11:45-12:00		5			1			1			0	
3	3/12/14	12:30-13:00	5			1			0			0		
4	5/12/14	11:30-11:50	5			3			1			1		
5	5/12/14	11:55-12:15		8			0			1			0	
6	5/12/14	12:35-12:55			2			0			0			0
7	5/12/14	13:00-13:20			5			1			0			2
8	5/12/14	13:30-13:50		4			1			15			0	
9	5/12/14	14:15-14:30	26			1			5			3		
10	7/12/14	12:15-12:35		29			5			4			0	
11	7/12/14	12:55-13:15			11			1			1			0
12	7/12/14	13:40-14:00			2			0			2			2
13	7/12/14	14:40-15:00		18			3			6			1	
14	7/12/14	15:05-15:25	14			0			0			2		
15	7/12/14	15:30-15:45			5			0			0			0
16	9/12/14	11:25-11:45		10			0			15			0	
17	9/12/14	11:55-12:15			6			3			0			0
18	9/12/14	12:45-13:05		2			1			1			0	
19	11/12/14	11:35-11:55			3			0			4			0
20	11/12/14	12:05-12:25	2			2			0			0		
21	11/12/14	12:40-13:00	4			2			0			2		
22	11/12/14	13:20-13:40		9			2			0			0	
23	11/12/14	13:45-14:05			2			1			0			0
24	11/12/14	14:15-14:35			4			2			0			0
25	12/12/14	11:40-12:00	4			1			4			1		
26	12/12/14	12:05-12:25		5			3			0			0	
27	12/12/14	12:35-12:55		4			1			0			1	
28	12/12/14	13:10-13:30			5			0			0			0
29	12/12/14	13:40-14:00	4			0			0			0		
30	13/12/14	11:00-11:20	15			2			9			2		
31	13/12/14	11:30-11:50		16			1			10			0	
32	13/12/14	12:00-12:20			9			2			5			1
33	13/12/14	13:30-13:50			4			3			0			1
34	13/12/14	13:55-14:10	1			0			1			0		
35	13/12/14	14:15-14:30		9			4			0			0	
36	15/12/14	11:10-11:30	8			1			0			2		
37	15/12/14	11:40-12:00			4			0			0			0
38	15/12/14	12:10-12:30		10			1			2			0	
39	15/12/14	12:40-13:00		4			0			1			0	
40	15/12/14	13:10-13:30			5			2			0			1
41	15/12/14	13:40-14:00	7			0			0			3		
42	17/12/14	11:40-12:00	3			0			0			0		
43	17/12/14	12:20-12:40			1			0			0			0
44	17/12/14	12:50-13:10			2			0			1			0
45	19/12/14	11:40-12:00		9			0			1			0	
46	19/12/14	12:15-12:35	3			0			0			0		
47	19/12/14	12:40-13:00	6			0			0			0		

Table 13 cont.

OB.NR.	Date	Time	W-A1	W-A2	W-A3	D-A1	D-A2	D-A3	R-A1	R-A2	R-A3	B-A1	B-A2	B-A3
48	19/12/14	13:15-13:35			5			1			0			0
49	27/1/15	11:15-11:35	4			0			7			0		
50	27/1/15	11:40-12:00		0			0			0			1	
51	27/1/15	12:10-12:30			0			1			0			1
52	27/1/15	13:00-13:20			3			0			0			0
53	27/1/15	13:30-13:50		5			0			3			0	
54	27/1/15	14:00-14:20	1			2			0			0		
55	28/1/14	09:45-10:05			2			0			0			1
56	28/1/14	10:15-10:35			3			1			0			0
57	28/1/14	10:45-11:05		2			0			0			1	
58	28/1/14	11:05-11:25	6			5			0			0		
59	28/1/14	11:20-11:40		14			3			0			1	
60	28/1/14	11:55-12:15	9			3			5			1		
61	29/1/15	12:20-12:40			7			0			8			0
62	29/1/15	12:50-13:10			4			1			0			0
63	29/1/15	13:15-13:35	9			3			1			1		
64	29/1/15	13:45-14:05		7			4			0			0	
65	29/1/15	14:10-14:30		7			1			1			0	
66	29/1/15	14:40-15:00	14			2			0			1		
67	31/1/15	14:20-14:40			15			2			0			1
68	31/1/15	14:45-15:05	13			3			1			1		
69	31/1/15	15:05-15:25		7			3			6			3	
70	1/2/15	11:25-11:45			10			5			7			0
71	1/2/15	11:50-12:10			7			5			1			2
72	1/2/15	12:15-12:35	25			8			1			0		
73	1/2/15	12:40-13:00		26			3			7			3	
74	1/2/15	13:05-13:25		17			1			2			1	
75	2/2/15	12:25-12:45			4			2			1			0
76	2/2/15	13:00-13:20			3			2			0			0
77	2/2/15	13:25-13:45		12			2			0			0	
78	2/2/15	13:50-14:10	17			2			0			0		
79	2/2/15	14:10-14:30	3			1			0			0		
80	2/2/15	14:30-14:50		7			0			1			1	
		Total	213	246	133	44	40	35	35	77	30	20	13	12
		Mean	8.19	9.46	4.75	1.69	1.54	1.25	1.35	2.96	1.07	0.77	0.50	0.43
		Stdev	6.78	7.02	3.28	1.83	1.50	1.43	2.48	4.40	2.19	0.99	0.86	0.69

Distribution of area activities

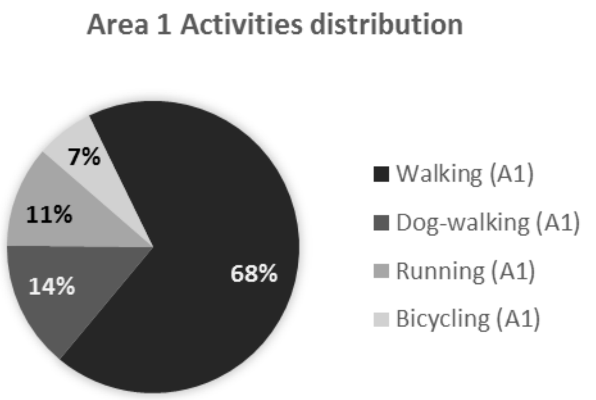


Figure 6. Distribution of activities in Area 1 during observations in Elliðaárdalur in December 2014 and January 2015

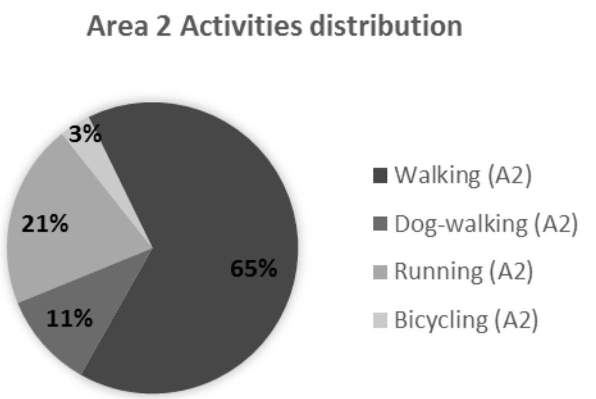


Figure 7. Distribution of activities in Area 2 during observations in Elliðaárdalur in December 2014 and January 2015.

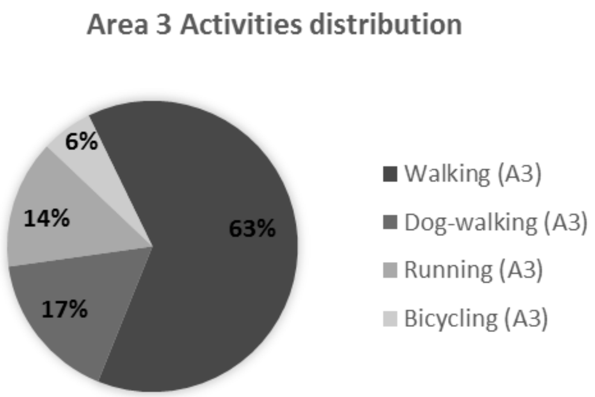


Figure 8. Distribution of activities in Area 3 during observations in Elliðaárdalur in December 2014 and January 2015.

Distribution of activities between areas on Saturday-Sunday and Monday-Friday

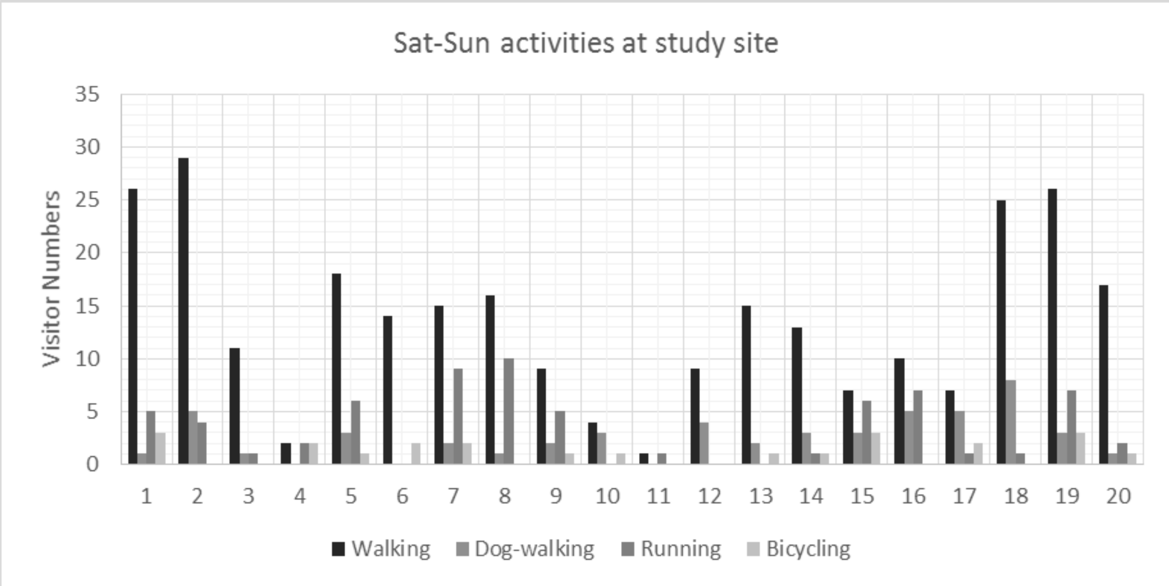


Figure 9. Distribution of activities on Saturday-Sunday during observations in Elliðaárdalur in December 2014 and January 2015.

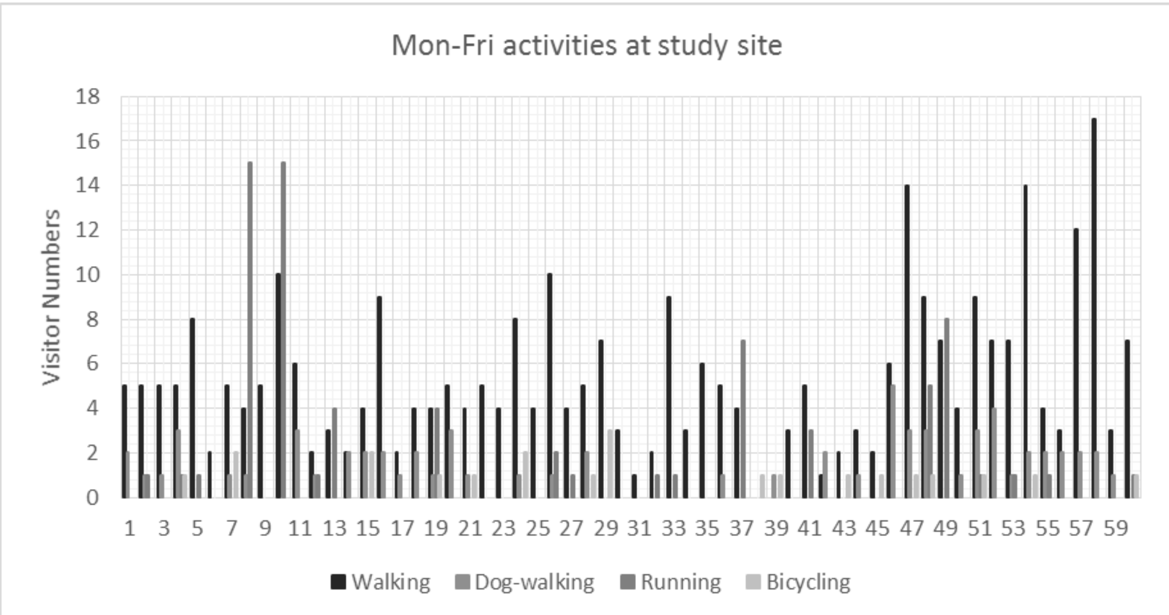


Figure 10. Distribution of activities on Monday-Friday during observations in Elliðaárdalur in December 2014 and January 2015

Weather conditions

Table 14. Weather conditions during observation days in the Elliðaárdalur study in December 2014 and January 2015.

DAY	DATE	TEMP. (°C)	AVE. (°C)	WIND (M/S)	AVE. (M/S)	CLOUD COVER	PRECIPITATION	GROUND COND.
1	3/12/14	0	0	0-4	2	cloudy		snow
2	5/12/14	-4	-4	3-8	5.5	cloudy		snow
3	7/12/14	-5-8	-6.5	0-4	2	clear		snow
4	9/12/14	-1	-1	3-5	4	cloudy	snowing	snow
5	11/12/14	-3-5	-4	10-15	12.5	semi-cloudy		snow
6	12/12/14	-10	-10	0-4	2	high clouds		snow
7	13/12/14	-5-0	-2.5	13-18	15.5	cloudy	heavy sn.fall	snow
8	15/12/14	-8	-8	0-4	2	cloudy		snow
9	17/12/14	0	0	18-23	20.5	cloudy	Flurries -> heavy sn.fall	snow
10	19/12/14	-2	-2	0-4	2	semi-cloudy		snow
11	27/1/15	3	3	8-13	10.5	cloudy	snowing	clear -> snow
12	28/1/15	-5	-5	0-4	2	clear		snow
13	29/1/15	-2	-2	8-13	10.5	semi-cloudy		snow
14	31/1/15	-2	-2	8-13	10.5	semi-cloudy		snow
15	1/2/15	0	0	0-4	2	cloudy		snow
16	2/2/15	-5	-5	0-4	2	clear		snow

Bird species and numbers

Table 15. Bird species recorded during weeks of observations in the Elliðaárdalur study in December 2014 and January 2015 (A1 = Area 1, A2 = Area 2, A3 = Area 3).

SPECIES	WEEK 1			WEEK 2			WEEK 3			WEEK 4			WEEK 5			TOTAL IN AREAS			TOTAL
	A1	**A2**	**A3**	**A1**	**A2**	**A3**	**A1**	**A2**	**A3**	**A1**	**A2**	**A3**	**A1**	**A2**	**A3**	**A1**	**A2**	**A3**	
RAVENS	2	1	1	34	27	19	13	6	16	26	15	18	4	3	7	79	52	64	**194**
SWANS	5	4	0	0	0	1	0	0	0	28	6	0	6	0	12	39	10	13	**62**
MALLARDS	0	0	0	4	0	6	0	2	0	130	2	5	80	0	0	214	4	11	**229**
GEESE	0	0	0	10	4	6	55	0	1	30	21	0	16	9	0	111	34	7	**152**
PASSERINES	0	0	0	12	41	2	8	2	0	6	15	0	0	0	0	26	58	2	**86**
SEAGULLS	0	0	0	20	0	1	0	0	16	15	0	0	0	0	0	35	0	17	**52**
OTHER	0	0	0	0	0	1	0	0	0	8	4	1	2	5	0	10	9	2	**21**

Appendix C - Statistics

The Shapiro-Wilk normality test for data-points from Sat-Sun observations:

Total numbers Sat-Sun:

```
> shapiro.test(SatSunLog$Total)
        Shapiro-Wilk normality test
data:  SatSunLog$Total
W = 0.9346, p-value = 0.1894
```

Walking Sat-Sun:

```
> shapiro.test(SatSunLog$Walk)
        Shapiro-Wilk normality test
data:  SatSunLog$Walk
W = 0.9349, p-value = 0.1916
```

Dog-walking Sat-Sun

```
> shapiro.test(SatSunLog$Dog)
        Shapiro-Wilk normality test
data:  SatSunLog$Dog
W = 0.9213, p-value = 0.105
```

Running Sat-Sun:

```
> shapiro.test(SatSunLog$Run)
        Shapiro-Wilk normality test
data:  SatSunLog$Run
W = 0.8491, p-value = 0.005146
```

Bicycling Sat-Sun:

```
> shapiro.test(SatSunLog$Bike)
        Shapiro-Wilk normality test
data:  SatSunLog$Bike
W = 0.8268, p-value = 0.002228
```

Shapiro-Wilk normality test for data-points from Mon-Fri observations:

Total numbers Mon-Fri:

```
> shapiro.test(MonFriLog$Total)

        Shapiro-Wilk normality test
data:  MonFriLog$Total
```

```
W = 0.9807, p-value = 0.4581
```

Walking Mon-Fri:

```
> shapiro.test(MonFriLog$Walk)
        Shapiro-Wilk normality test
data:  MonFriLog$Walk
W = 0.9655, p-value = 0.08767
```

Dog-walking Mon-Fri:

```
> shapiro.test(MonFriLog$Dog)
        Shapiro-Wilk normality test
data:  MonFriLog$Dog
W = 0.8499, p-value = 3.026e-06
```

Running Mon-Fri:

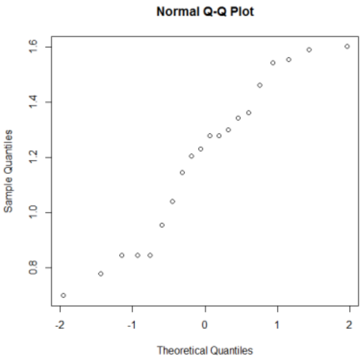
```
> shapiro.test(MonFriLog$Run)
        Shapiro-Wilk normality test
data:  MonFriLog$Run
W = 0.68, p-value = 3.717e-10
```

Bicycling Mon-Fri:

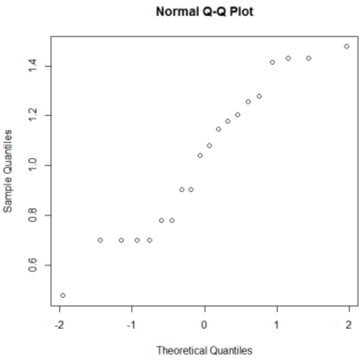
```
> shapiro.test(MonFriLog$Bike)
        Shapiro-Wilk normality test
data:  MonFriLog$Bike
W = 0.6389, p-value = 6.969e-11
```

Qqnorm plots for activities on Sat-Sun

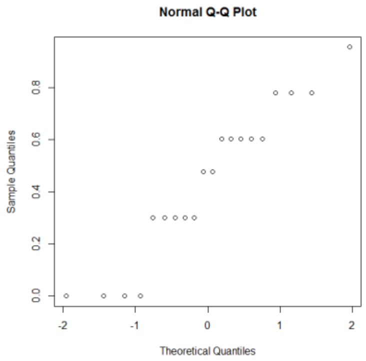
Total numbers Sat-Sun:



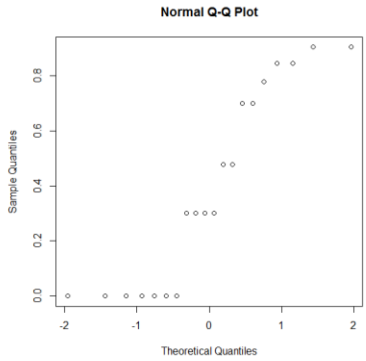
Walking Sat-Sun:



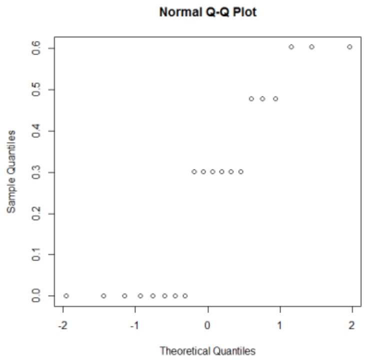
Dog-walking Sat-Sun:



Running Sat-Sun:

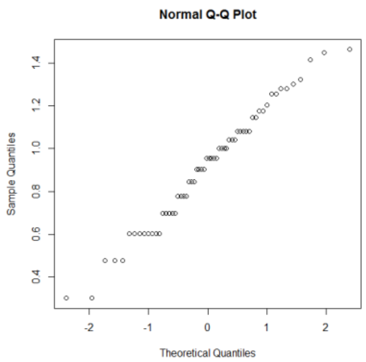


Bicycling Sat-Sun:

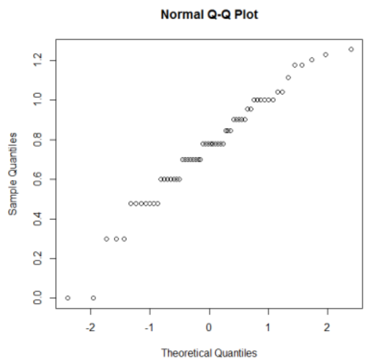


Qqnorm plots for Mon-Fri

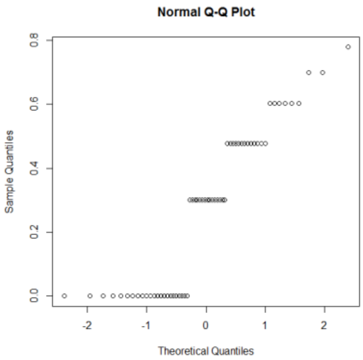
Total numbers Mon-Fri:



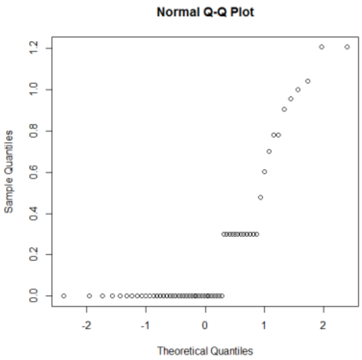
Walking Mon-Fri:



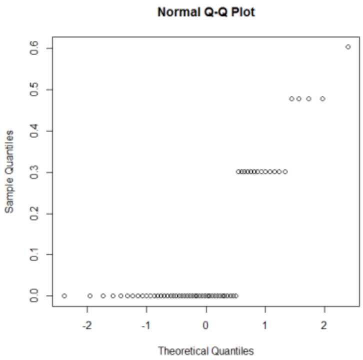
Dog-walking Mon-Fri:



Running Mon-Fri:



Bicycling Mon-Fri:



Shapiro-Wilk normality test results for activities combined

Total

```
> shapiro.test(normAct$Total)
        Shapiro-Wilk normality test
data:  normAct$Tlog
W = 0.9851, p-value = 0.4783
```

Walking

```
> shapiro.test(normAct$Walk)
        Shapiro-Wilk normality test
data:  normAct$Wlog
W = 0.9792, p-value = 0.2177
```

Dog-walking

```
> shapiro.test(normAct$Dog)
        Shapiro-Wilk normality test
data:  normAct$Dlog
W = 0.8802, p-value = 1.95e-06
```

Running

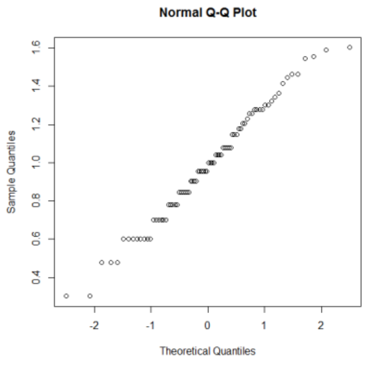
```
> shapiro.test(normAct$Run)
        Shapiro-Wilk normality test
data:  normAct$Rlog
W = 0.7497, p-value = 2.315e-10
```

Bicycling

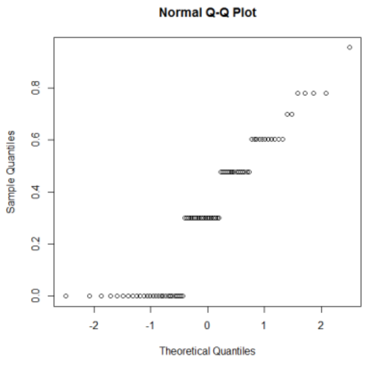
```
> shapiro.test(normAct$Bike)
        Shapiro-Wilk normality test
data:  normAct$Blog
W = 0.7045, p-value = 2.127e-11
```

Qqnorm plots for activities combined

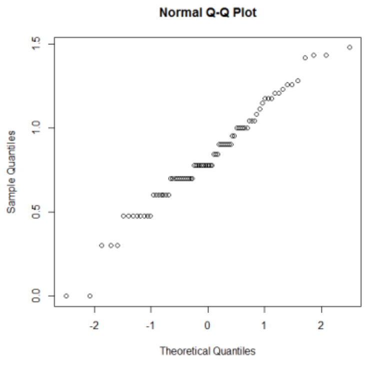
Total numbers



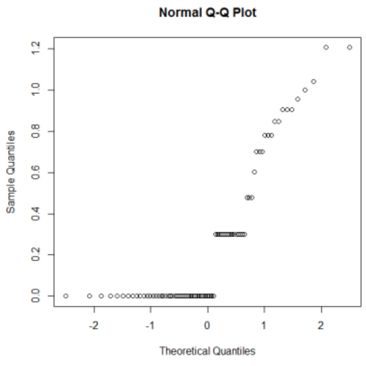
Dog-walking



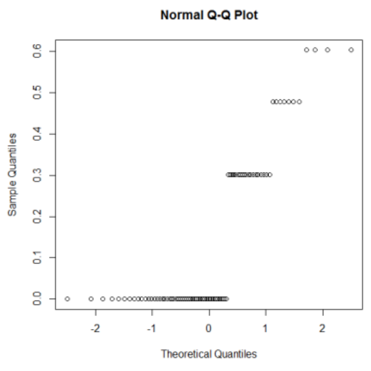
Walking



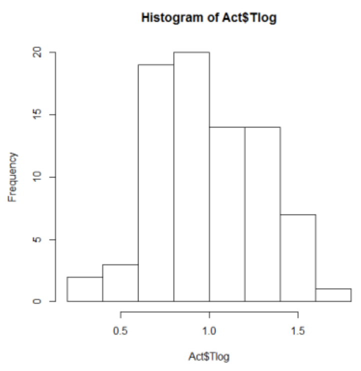
Running

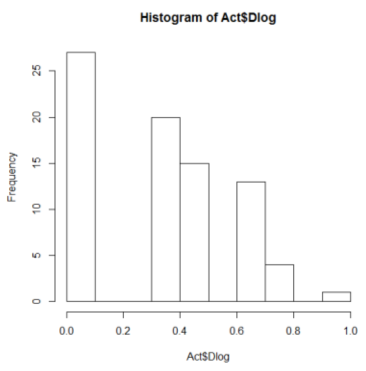


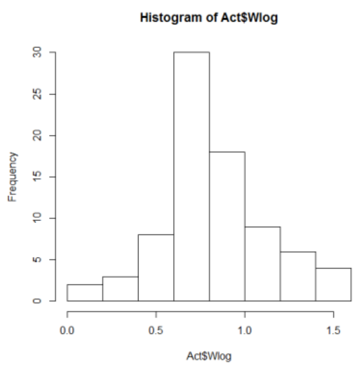
Bicycling

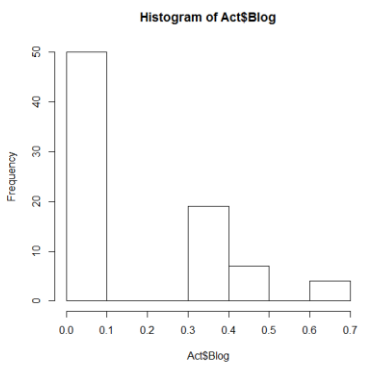


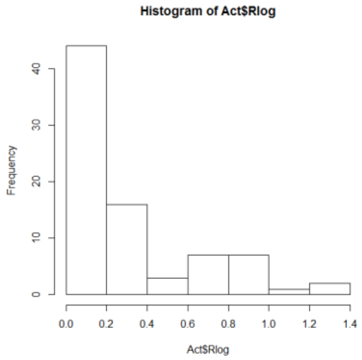
Histograms for activities combined











Welsh two sample t-test results of comparing total use numbers for weekends and weekdays.

Welch Two Sample t-test

data: ssmf$SatSun and ssmf$MonFri
t = 2.6493, df = 25.796, p-value = 0.01358
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
0.06090901 0.48335233
sample estimates:
mean of x mean of y
1.1584862 0.8863555

Kruskal Willis non-parametric test results, examining distribution of data for dog-walking, running and bicycling

```
    Kruskal-Wallis rank sum test

data:  data by act
Kruskal-Wallis chi-squared = 146.2843, df = 11, p-value < 2.2e-16
```

One-way ANOVA and Tukey's Honest Significant Difference test results of comparing activity between areas

ANOVA test for comparing activities in areas:

```
>test<-read.table("C:\\Users\\rhubarb\\Documents\\Spring 
2015\\Observations\\Trying 
Stuff\\Anova\\textfiles\\natest01.txt",head=TRUE,sep="\t")

> sttest<-stack(test)
> names(sttest)<-c("data","AA")

> av5<-aov(data~AA,data=sttest)
> summary(av5)

             Df Sum Sq Mean Sq F value Pr(>F)
```

```
AA           11  23.21  2.1105   26.77 <2e-16 ***
Residuals   308  24.28  0.0788
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
16 observations deleted due to missingness
```

A Tukey multiple comparison of means was performed to examine where the differences lie:

```
> tk<-TukeyHSD(av5)
> tk
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = data ~ AA, data = sttest)
```

Significant differences in activities among the areas are shown in bold:

$AA

	diff	lwr	upr	p adj
A1Dlog-A1Blog	0.15641721	-0.10005728	0.41289171	0.6873226
A1Rlog-A1Blog	0.02864337	-0.22783113	0.28511786	0.9999999
A1Wlog-A1Blog	**0.67109534**	**0.41462084**	**0.92756983**	**0.0000000**
A2Blog-A1Blog	-0.06182519	-0.31829969	0.19464930	0.9997239
A2Dlog-A1Blog	0.13961880	-0.11685570	0.39609329	0.8208716
A2Rlog-A1Blog	0.21102370	-0.04545079	0.46749819	0.2264581
A2Wlog-A1Blog	**0.73381553**	**0.47734104**	**0.99029002**	**0.0000000**
A3Blog-A1Blog	-0.07355748	-0.32541043	0.17829548	0.9983252
A3Dlog-A1Blog	0.08690025	-0.16495271	0.33875320	0.9927884
A3Rlog-A1Blog	-0.01005207	-0.26190503	0.24180088	1.0000000
A3Wlog-A1Blog	**0.50568933**	**0.25383638**	**0.75754229**	**0.0000000**
A1Rlog-A1Dlog	-0.12777385	-0.38424834	0.12870065	0.8925385
A1Wlog-A1Dlog	**0.51467812**	**0.25820363**	**0.77115262**	**0.0000000**
A2Blog-A1Dlog	-0.21824241	-0.47471690	0.03823209	0.1841617
A2Dlog-A1Dlog	-0.01679842	-0.27327291	0.23967608	1.0000000
A2Rlog-A1Dlog	0.05460649	-0.20186800	0.31108098	0.9999184
A2Wlog-A1Dlog	**0.57739832**	**0.32092382**	**0.83387281**	**0.0000000**
A3Blog-A1Dlog	-0.22997469	-0.48182764	0.02187827	0.1114033
A3Dlog-A1Dlog	-0.06951696	-0.32136992	0.18233599	0.9990031
A3Rlog-A1Dlog	-0.16646929	-0.41832224	0.08538367	0.5676970
A3Wlog-A1Dlog	**0.34927212**	**0.09741917**	**0.60112508**	**0.0004385**
A1Wlog-A1Rlog	**0.64245197**	**0.38597748**	**0.89892646**	**0.0000000**
A2Blog-A1Rlog	-0.09046856	-0.34694305	0.16600593	0.9913306
A2Dlog-A1Rlog	0.11097543	-0.14549906	0.36744992	0.9578448
A2Rlog-A1Rlog	0.18238034	-0.07409416	0.43885483	0.4492090
A2Wlog-A1Rlog	**0.70517216**	**0.44869767**	**0.96164666**	**0.0000000**
A3Blog-A1Rlog	-0.10220084	-0.35405379	0.14965211	0.9736737
A3Dlog-A1Rlog	0.05825688	-0.19359607	0.31010983	0.9998151
A3Rlog-A1Rlog	-0.03869544	-0.29054839	0.21315751	0.9999971
A3Wlog-A1Rlog	**0.47704597**	**0.22519302**	**0.72889892**	**0.0000001**
A2Blog-A1Wlog	**-0.73292053**	**-0.98939502**	**-0.47644604**	**0.0000000**
A2Dlog-A1Wlog	**-0.53147654**	**-0.78795103**	**-0.27500205**	**0.0000000**
A2Rlog-A1Wlog	**-0.46007164**	**-0.71654613**	**-0.20359714**	**0.0000006**
A2Wlog-A1Wlog	0.06272019	-0.19375430	0.31919469	0.9996829
A3Blog-A1Wlog	**-0.74465281**	**-0.99650576**	**-0.49279986**	**0.0000000**
A3Dlog-A1Wlog	**-0.58419509**	**-0.83604804**	**-0.33234214**	**0.0000000**
A3Rlog-A1Wlog	**-0.68114741**	**-0.93300036**	**-0.42929446**	**0.0000000**
A3Wlog-A1Wlog	-0.16540600	-0.41725895	0.08644695	0.5777797
A2Dlog-A2Blog	0.20144399	-0.05503050	0.45791848	0.2918218
A2Rlog-A2Blog	**0.27284889**	**0.01637440**	**0.52932339**	**0.0259215**
A2Wlog-A2Blog	**0.79564072**	**0.53916623**	**1.05211522**	**0.0000000**
A3Blog-A2Blog	-0.01173228	-0.26358523	0.24012067	1.0000000

A3Dlog-A2Blog	0.14872544	-0.10312751	0.40057839	0.7299186
A3Rlog-A2Blog	0.05177312	-0.20007983	0.30362607	0.9999425
A3Wlog-A2Blog	**0.56751453**	**0.31566158**	**0.81936748**	**0.0000000**
A2Rlog-A2Dlog	0.07140490	-0.18506959	0.32787940	0.9989203
A2Wlog-A2Dlog	**0.59419673**	**0.33772224**	**0.85067123**	**0.0000000**
A3Blog-A2Dlog	-0.21317627	-0.46502922	0.03867668	0.1905207
A3Dlog-A2Dlog	-0.05271855	-0.30457150	0.19913440	0.9999311
A3Rlog-A2Dlog	-0.14967087	-0.40152382	0.10218208	0.7218257
A3Wlog-A2Dlog	**0.36607054**	**0.11421759**	**0.61792349**	**0.0001646**
A2Wlog-A2Rlog	**0.52279183**	**0.26631734**	**0.77926632**	**0.0000000**
A3Blog-A2Rlog	**-0.28458118**	**-0.53643413**	**-0.03272822**	**0.0124103**
A3Dlog-A2Rlog	-0.12412345	-0.37597641	0.12772950	0.8994568
A3Rlog-A2Rlog	-0.22107577	-0.47292873	0.03077718	0.1493502
A3Wlog-A2Rlog	**0.29466563**	**0.04281268**	**0.54651859**	**0.0077376**
A3Blog-A2Wlog	**-0.80737301**	**-1.05922596**	**-0.55552005**	**0.0000000**
A3Dlog-A2Wlog	**-0.64691528**	**-0.89876823**	**-0.39506233**	**0.0000000**
A3Rlog-A2Wlog	**-0.74386760**	**-0.99572056**	**-0.49201465**	**0.0000000**
A3Wlog-A2Wlog	-0.22812619	-0.47997915	0.02372676	0.1185883
A3Dlog-A3Blog	0.16045772	-0.08668728	0.40760273	0.5956800
A3Rlog-A3Blog	0.06350540	-0.18363960	0.31065041	0.9994909
A3Wlog-A3Blog	**0.57924681**	**0.33210180**	**0.82639182**	**0.0000000**
A3Rlog-A3Dlog	-0.09695232	-0.34409733	0.15019268	0.9796686
A3Wlog-A3Dlog	**0.41878909**	**0.17164408**	**0.66593409**	**0.0000034**
A3Wlog-A3Rlog	**0.51574141**	**0.26859640**	**0.76288641**	**0.0000000**

Summary of results with p-value < 0.05 :

$activity

	diff	lwr	upr	p adj
A1Wlog-A1Dlog	0.51467812	0.25820363	0.77115262	0.0000000
A1Wlog-A1Rlog	0.64245197	0.38597748	0.89892646	0.0000000
A1Wlog-A1Blog	0.67109534	0.41462084	0.92756983	0.0000000
A2Wlog-A1Blog	0.73381553	0.47734104	0.99029002	0.0000000
A2Wlog-A1Dlog	0.57739832	0.32092382	0.83387281	0.0000000
A2Wlog-A1Rlog	0.70517216	0.44869767	0.96164666	0.0000000
A2Wlog-A2Blog	0.79564072	0.53916623	1.05211522	0.0000000
A2Wlog-A2Dlog	0.59419673	0.33772224	0.85067123	0.0000000
A2Wlog-A2Rlog	0.52279183	0.26631734	0.77926632	0.0000000
A2Blog-A1Wlog	-0.73292053	-0.98939502	-0.47644604	0.0000000
A2Dlog-A1Wlog	-0.53147654	-0.78795103	-0.27500205	0.0000000
A2Rlog-A1Wlog	-0.46007164	-0.71654613	-0.20359714	0.0000006
A2Rlog-A2Blog	0.27284889	0.01637440	0.52932339	0.0259215
A3Wlog-A1Blog	0.50568933	0.25383638	0.75754229	0.0000000
A3Wlog-A1Dlog	0.34927212	0.09741917	0.60112508	0.0004385
A3Wlog-A1Rlog	0.47704597	0.22519302	0.72889892	0.0000001
A3Wlog-A2Blog	0.56751453	0.31566158	0.81936748	0.0000000
A3Wlog-A2Dlog	0.36607054	0.11421759	0.61792349	0.0001646
A3Wlog-A2Rlog	0.29466563	0.04281268	0.54651859	0.0077376
A3Wlog-A3Blog	0.57924681	0.33210180	0.82639182	0.0000000
A3Wlog-A3Dlog	0.41878909	0.17164408	0.66593409	0.0000034
A3Wlog-A3Rlog	0.51574141	0.26859640	0.76288641	0.0000000
A3Blog-A1Wlog	-0.74465281	-0.99650576	-0.49279986	0.0000000
A3Dlog-A1Wlog	-0.58419509	-0.83604804	-0.33234214	0.0000000
A3Rlog-A1Wlog	-0.68114741	-0.93300036	-0.42929446	0.0000000
A3Blog-A2Rlog	-0.28458118	-0.53643413	-0.03272822	0.0124103
A3Blog-A2Wlog	-0.80737301	-1.05922596	-0.55552005	0.0000000
A3Dlog-A2Wlog	-0.64691528	-0.89876823	-0.39506233	0.0000000
A3Rlog-A2Wlog	-0.74386760	-0.99572056	-0.49201465	0.0000000

```
plot(tk)
```

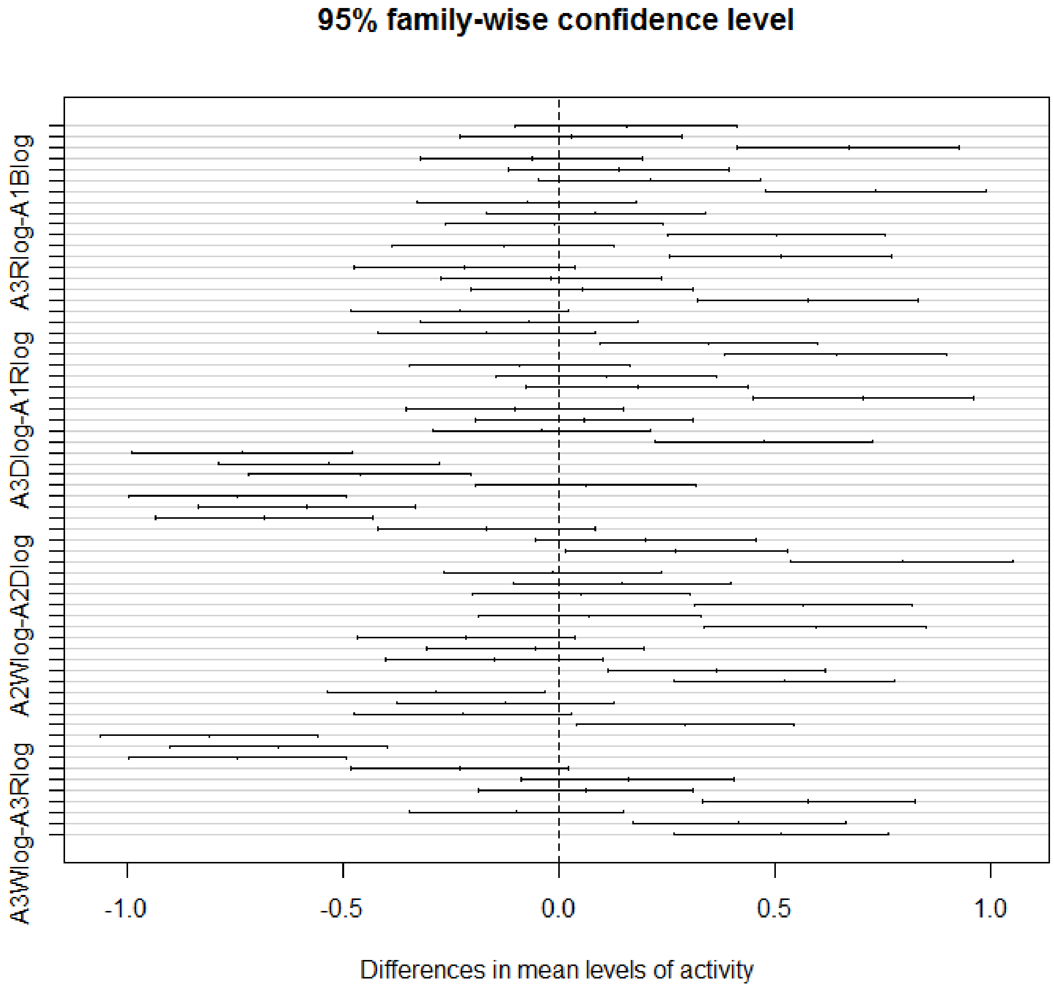


Figure 11. Boxplot of results from TukeyHSD test on the differences between activities in areas during observations in Elliðaárdalur in December 2014 and January 2015.

ANOVA for weather conditions

```
> summary(av8)
> summary(av9)
              Df  Sum Sq  Mean Sq  F value  Pr(>F)
Coded          1   0.190  0.18967    2.047   0.157
Residuals     78   7.228  0.09267
```