Mapping potential environmental impacts from tourists using data from social media: a case study in the Westfjords of Iceland.

Brack W. Hale

Department of Environmental Sciences and Studies, Franklin University Switzerland, Sorengo, Switzerland

Abstract

With tourism increasing in remote regions, it is important to be able to estimate potential environmental impacts from the tourists in order to plan and manage natural areas. This study combines measures of ecological sensitivity with data from publicly available geotagged photographs posted on the social media site Flickr to assess the vulnerability of the locations frequented by foreign tourists in the Westfjords region of Iceland between 2014 and 2016. The results suggest that tourists cluster primarily around six hotspots that represented some of the major known tourist destinations of the region. Although tourists generally frequented areas with lower ecological sensitivity and rarely went far beyond the main roads, one of the hotspots was in an area of higher ecological sensitivity. Further, tourists also appeared to have higher intensity stays when they entered areas of higher ecological sensitivity. Overall, these findings highlight the usefulness of combining data from social media in assessing potential environmental impacts of tourism. However, natural resource managers should be aware of limitations in the use of such data.

Keywords: Westfjords, GIS, tourism, social media, ecological sensitivity, Iceland

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Introduction

The number of tourists has been increasing around the globe in recent times (Brondoni 2016), and as more tourists travel, so does the potential for environmental impacts from tourism (see for example reviews by Weaver, 2006; Wong, 2004). To help manage tourists and mitigate their impacts, planners and members of the tourist industry need to have detailed information about where tourists specifically go and what kinds of environments they are accessing (Hadwen et al. 2007). This is especially true in Arctic regions where tourist numbers have rapidly increased in the last decade (Maher 2017) and where environments are particularly vulnerable to human impacts. Data from traditional sources, such as surveys, visitor logs and other visitor monitoring programs, have been and remain important sources for information on tourists and their movements (Kajala et al. 2007; Hadwen et al. 2007). However, these methods have limitations (Hadwen et al. 2007). First, they require a certain level of financial and human resources to collect and tally data. Next, the methods can be spatially limited particularly in larger landscapes where one might capture the numbers entering a specific area, but the destinations of tourists within that area might remain unknown. Finally, these methods can be temporally limited, as tourists that visit at an off-time may go unrecorded. The growth in the use of social media platforms to post geotagged photographs from individuals' travels has created a new source of data that can complement and build upon existing methods for tracking tourist flows. Further, such data can be readily combined with other types of data for more sophisticated analyses of the interaction between tourists and their destination environments. This study combines measures of ecological sensitivity with data from publicly available geotagged photographs posted on social media to assess the vulnerability of the locations frequented by foreign tourists in the Westfjords region of Iceland.

Due to notoriety gained by the eruption of Eyjafjallajökull in 2010 and recent Icelandic tourism campaigns, tourism has grown rapidly in Iceland in recent years, from just under 500,000 visitors in 2010 to almost 1.8 million in 2016 (Óladóttir 2017). Tourism to Iceland has typically focused on Iceland's nature and its wilderness (Karlsdóttir, 2013; Sæþórsdóttir and Saarinen, 2015). In a recent survey of tourists at major attractions in Iceland by Sæþórsdóttir (2015), over three-quarters of tourists stated that nature was the primary reason why they had come to Iceland. However, studies are beginning to indicate that tourism may be surpassing the ability of Iceland's natural environment to handle human impacts. Taylor (2011) found that wilderness areas in Iceland have decreased significantly since the 1930's due to energy and tourism development. Popular Icelandic hiking trails are experiencing serious degradation (Ólafsdóttir and Runnström 2013) and tourists are reporting overcrowding on trails (Sæþórsdóttir 2013; Ságoly et al. 2017). Further, tourists have been identified as the likely source of at least one non-native species in Iceland, *Digitaria ischaemum* (Wasowicz 2016). However, as Ólafsdóttir and Runnström (2013) state, more data are needed on tourism on the environmental impacts of tourism in Iceland. Social media represents a new source for data on such impacts, particularly in remote areas with limited monitoring.

The use of social media and geotagged photos

In the last decade, the use of social media and the posting of geotagged photos online to sites such as Flickr™, Instagram™, and Panoramio™ have created a new source of readily available data for tourism and environmental research. In tourism studies, researchers have used geotagged photos to estimate tourist visits to protected areas, national parks, beaches, and coral reefs, among other destinations (Wood et al. 2013; Allan et al. 2015; Levin et al. 2015; Sonter et al. 2016; Heikinheimo et al. 2017; Spalding et al. 2017). Orsi and Geneletti

(2013) used geotagged photos to identify trail use in the Dolomites in Italy. Other studies have used geotagged photos used to identify popular sites in urban areas, both among tourists and local residents (Girardin et al. 2009; Kádár and Gede 2013; Kádár 2014; Straumann et al. 2014; García-Palomares et al. 2015), as well as to identify lodging locations (Sun et al. 2013).

Several of these studies found a strong correlation between the levels of visitation estimated by photo data and data from traditional sources of visitor information such as surveys and travel logs (Wood et al. 2013; Keeler et al. 2015; Levin et al. 2015; Sonter et al. 2016). Further, studies by Wood and others (2013) and by Heikinheimo and others (2017) found that data on the origins of the photographers posting the photos generally corresponded to the information about visitors' origins from other sources. Nonetheless, some authors point out that users of specific social media platforms are often not representative of the general population. DiMinin and others (2015) state that there can be a bias towards users from developed regions. A study by Van Zanten and others (2016) found differences in users across social media platforms in Europe: Flickr was primarily used in western and central regions, while Instagram and Panoramio were more widely used in general. With respect to Flickr specifically, which this study uses, it is less commonly used than Instagram, but is more often used by photographers (hobby and professional) and features more nature photography (Di Minin et al. 2015; van Zanten et al. 2016).

The use of geotagged photos has also grown in the environmental field, sometimes in combination with touristic themes, sometimes separately. A study by Wang and others (2016) used geotagged photos together with satellite data to estimate local environmental conditions, such as vegetation and snow cover. Levin and others (2015) used geotagged photos to complement satellite data to identify human presence on the landscape, particularly with respect to protected areas. Other studies have used geotagged photos in combination with other data sources to estimate values of different aspects of the landscape, such as "cultural appreciation" (Tieskens et al. 2017), the value of tourism in coral reef areas (Spalding et al. 2017), cultural ecosystem services and environmental stressors (Allan et al. 2015), aesthetic and recreation values of landscapes (van Zanten et al. 2016), the social value of nature-oriented tourism (Sonter et al. 2016), and value of clean water for recreation (Keeler et al. 2015). Thus, geotagged photographs can provide an important complement to other digital data about the environment and the potential for human impacts.

Environmental sensitivity in Iceland

Certain environments are inherently more vulnerable to damage from human impacts, including those that result from tourism. Arctic regions, and the subarctic areas that are closely connected with them, are vulnerable due to very short growing seasons, frequent extreme weather conditions, and generally low levels of species diversity (Arctic Climate Impact Assessment 2004). Lying just south of the Arctic Circle, Iceland's environment reflects typical subarctic conditions, with arctic conditions in the Highlands (Arnalds 2015a). Climatic shifts since the last Ice Age have had significant impacts on the vegetation, particularly in areas vulnerable to soil erosion (Ólafsdóttir, et al. 2001). The often windy conditions and frequent heavy precipitation events contribute to soil erosion and can limit (re)vegetation (Arnalds 2015b). Typical of arctic and subarctic environments, Iceland's vegetation is fragile, with moss, heath, and wetlands considered the most fragile vegetation types (Gísladóttir and Sæþórsdóttir 2005). Further, the vegetation has already been heavily impacted by historic grazing, agricultural, and wood harvesting practices (Arnalds 2015b). Additionally, Iceland's geology provides another factor that increases the vulnerability of Icelandic ecosystems. The island is geologically young and seismically active; most of its soils are of volcanic origin and particularly susceptible to erosive forces. This is further exacerbated by frequent volcanic eruptions that can cover large areas of the landscape with ash and other volcanic debris.

Measuring the potential for environmental impact in Iceland

To assess potential environmental impacts from tourism, it is necessary to have data on the sensitivity of the regions tourists visit. Ólafsdóttir and Runnström (2009) developed a model of ecological sensitivity for Icelandic landscapes specifically to assess the impacts of tourism. Their model employed three main factors: vegetation cover, soil type, and slope of the landscape. Within a geographic information system (GIS), the authors categorized data on these three factors (low, medium, high sensitivity) and combined them to create an index of sensitivity that could be used to assess the suitability of sites for tourism. Ólafsdóttir and Runnström (2013) and Schaller (2014) both used the index to assess the potential for tourism impacts in several areas in Southern and Central Iceland to help inform tourism management in those regions.

Another method to look at potential for environmental impacts is to examine the "remoteness" of the locations visited by tourists. Boller and others (2010) discuss remoteness as an important attraction for tourists in the Swiss Alps seeking a stronger experience in and of nature. They chose to look at remote areas over wilderness, stating the former does not necessarily represent nature without human influences, although these areas are still important ones for nature conservation. Carver and other (2012) also used "remoteness" as one of their factors in developing maps of wilderness in the Scottish Highlands. The experience of remoteness and wilderness along with its seemingly unspoiled nature has been one of the main attractions of Arctic areas, including Iceland, for tourists (Sæþórsdóttir et al.

2011; Stewart et al. 2017). Ólafsdóttir and Runnström (2011) assessed wilderness areas in Iceland using distance measures of remoteness, as well as viewsheds, and found approximately a third of the country counts as "wilderness" (as defined by Iceland law). However, this wilderness is under threat both from rapidly growing tourist numbers, as well as planned energy developments (Sæþórsdóttir and Saarinen 2016).

This study integrates data from social media with data about local ecological characteristics to provide insight into the movements and possible impacts of tourists on the region of the Westfjords. Specifically, it uses publicly-available, geotagged photographs posted to the social media site Flickr to determine the locations visited by tourists in the Westfjords of Iceland. It combines these data with an ecological sensitivity index adapted for the region (*sensu* Ólafsdóttir and Runnström, 2009) and a remoteness coverage (*sensu* Ólafsdóttir and Runnström, 2011) to answer the following questions:

- What are the spatial patterns of foreign tourists in the Westfjords? Are there hotspots of tourism?
- When do tourists visit?
- How sensitive are sites frequented by foreign tourists to ecological degradation?
- How remote are the sites that tourists frequent?

Methods

Study area: the Westfjords

The Westfjords are located in the northwestern corner of Iceland between 65.4° and 66.5° latitude north and 21.2° and 24.5° longitude west (Figure 1). The region is just under 23,000 sq. km and one of the more remote areas of the country, lying about 500 km from Iceland's two largest populated areas, Reykjavik in the southwest and Akureyri in the north. The region has approximately 7400 residents (Visit Westfjords 2015), with the greatest concentration in Ísafjörður with just over 2500 inhabitants (Ísafjarðarbær 2014).

Like in the rest of Iceland, nature serves as a major tourist attraction in the Westfjords. According to the national tourism statistics, about 8% of winter and 20% of summer tourists visit the Westfjords when they come to Iceland (Óladóttir 2017). As the region's name suggests, the area abounds with impressive fjords dotted with quaint fishing towns and villages. It also contains one of the main glaciers in Iceland, Drangajökull; Iceland's second largest wilderness area, which is focused around the Hornstrandir nature reserve (Taylor 2011) and which is also the core of Iceland's population of Arctic foxes; a large waterfall, Dynjandi; and the famous bird watching cliffs of Látrabjarg. Summertime is popular with cultural tourists, visiting the sites of Icelandic sagas that took place in the region, as well as with hikers, horseback riders, anglers, and cruise ships. Ísafjörður is the third most popular destination for cruise ships in Iceland and has seen a dramatic increase in recent years, with the number almost doubling from 45 ships in 2014 to 82 ships in 2016 (Óladóttir 2017). Wintertime is popular for skiing and snowshoeing, as well as viewing the northern lights.

Geographic Information System development

The author assembled spatial data on the political and geographic boundaries, infrastructure, and environmental characteristics in the Westfjords obtained from a variety of sources (Table 1) to create a map project within a geographic information system (GIS) for this study using QGIS 2.14, an open source GIS software available at http://www.qgis.org. All data were transformed into to a common coordinate reference system (ISN 2004) appropriate for Iceland, which is based on the GRS 1980 ellipsoid (National Land Survey of Iceland 2017)

Metrics of potential environmental impacts

To measure for the potential environmental impacts from tourists within the Westfjords, this study created two different layers in the GIS project. The first followed the methodologies of Ólafsdóttir & Runnström (2009 and 2013) and Schaller (2014) to develop a layer with an ecological sensitivity index (ESI) based on vegetation type, soil, and slope (Table 2). One modification for the Westfjords region was that parcels located within the Hornstrandir Nature Reserve received an additional point to account for increased interest in protecting areas within the reserve. The second measure is an index of remoteness based on Ólafsdóttir & Runnström (2011) where remote areas are defined as areas greater than five km from regular roads or human structures (e.g. buildings, power infrastructure), or greater than three km from mountain roads (*class F*). Again, this was modified slightly for the Westfjords region, a buffer of three km was used around human structures in the Hornstrandir Nature Reserve as the area is no longer inhabited.

Flickr data acquisition and processing

To acquire data on tourist visitation to the Westfjords, the author, using Flickr's application program interface (API), downloaded metadata from all publicly-accessible photographs geotagged within the boundaries of Westfjords posted on Flickr from January 2014 through December 2016. This timeframe represents a period of rapidly increasing tourism in Iceland and the Westfjords. Specifically, the variables of interest were latitude and longitude of the photograph, the specific time and date it was taken, the accuracy level of the photograph's geotagging, the unique photograph id, and the Flickr user's id. The download resulted in information for 10,172 unique photographs (NB: the photographs themselves were not downloaded). The author then used Flickr's API to obtain information about the user's home country, when available, from the user's profile. When this information was not provided in the user profile, other information, such as language or time zone of the profile, links to the users' external websites, and the types of locations featured in the profile, was used to determine if the user was an Icelandic resident and, when possible, the user's country of origin. Users were excluded from the database if the user was determined to be an Icelandic resident, as this study focuses on foreign tourists. Further, photographs were also excluded if they had a locational accuracy level of less than 13 (Flickr's accuracy level ranges from 1 (world) to 16 (street). A cutoff of 13 is somewhat more conservative than other studies in the literature that specify an accuracy level: for example, Straumann and others (2014) used a minimum level of 11 while Wang and others (2016) used 12. The resulting dataset, after also excluding photographs taken over open water, contained 8382 photographs.

To provide a measure for intensity of use exerted at a specific location, the unique locations (lat-long coordinates) of the photographs were coded based on the number of consecutive photographs taken by individual users at those coordinates and the time span during which the users took those photographs (Table 3). The code was assigned to the first photograph id in the sequence of photographs of each user at each set of lat-long coordinates and all remaining photos from that sequence were removed. This resulted in 3488 unique locations which were used to create a layer in the project GIS along with the attributes mentioned above.

Data analysis

To analyze the density of tourism across the landscape of the Westfjords, the unique location layer from the Flickr data was used to generate a heatmap using QGIS's heatmap function. The study used a radius of 250 m around each point (reflecting the median error distances found for Flickr nature photograph locations in Europe in Zielstra and Hochmair's (2013) study), a triweight kernel shape, and weighted each point based on location user intensity described in Table 3. The algorithm generates a heat score across the landscape that reflects the density of tourist use. The study used the Jenks Natural Breaks function within QGIS to categorize the heat scores into four categories and used the two highest classes to identify tourist hotspots for subsequent analysis.

Summary statistics were generated for the layers of tourism locations (origin of users, month of visit based on user days), the ESI, and the index of remoteness, and the tourist hotspots. To analyze across the various Flickr locations, the average values of the ESI and the heat score were calculated for a zone of 50 m surrounding each point, a modification of Hillery and others' (2001) "area of greatest likely tourist impact". The study also calculated the average distance from each location to the nearest road (locations on islands or in the Hornstrandir Nature Reserve were excluded from this analysis due to the lack of road connections to the mainland of the Westfjords). These data were then used to analyze the tourists' impacts with respect to the categories of ecological sensitivity (heat scores only), remoteness, and the identified hotspots. The study used analyses of variance (ANOVA) with Tukey post-hoc tests to analyze across ecological sensitivity categories and hotspots, and t-tests to analyze between remoteness categories. For the analysis of the heat score across the hotspots, the heat score data were transformed using the ln(x+1) transformation to account for the non-normal distribution of those data. All statistical analyses were performed in SPSS 24.0 on data exported from the GIS. The level of significance was set at 0.05.

Results

Overview of the environment of the Westfjords

Figure 2 provides an overview of ecological sensitivity of the landscape in the Westfjords as classified in this study. Approximately 25% of the landscape falls in the “high” category (i.e. ecological sensitivity index (ESI) of 6 or greater), primarily located in the west central section of the region stretching from Ísafjörður to Patreksfjörður. Another 38% of the landscape is classified as moderately sensitive and is distributed widely across the entire region. Slightly less than 37% of the area fell into the low category, which primarily represents the higher, inland areas. Figure 3 shows the areas of the Westfjords considered “remote” using the classification system in this study (approximately 27% of the total area); these areas are primarily concentrated in the highlands of the Westfjords and in Hornstrandir.

General tourism findings

This study identified 319 non-Icelandic unique users of Flickr who posted photographs geotagged within the Westfjords between January 2014 and December 2016. The users were primarily of North American or Western European origins (Table 4). Compared to national tourism statistics, there was a stronger presence of Central and Western European tourists in the Westfjords and fewer tourists from the UK and Scandinavia. The tourists primarily visit the region during the summer months, June through August (Figure 4).

Heatmap analysis and tourism hotspots

The heatmap analysis resulted in mean heat scores for the unique locations between 0 (lower use intensity) and 87 (higher use intensity). The highest category from the Jenks natural breaks analysis revealed one hotspot at Látrabjarg and the next highest category suggested five additional hotspots at Dynjandi, Ísafjörður, Skápadalur, Vigur, and Þingeyri.

Tourists and ecological sensitivity

Overlaying the Flickr tourist data with the ESI revealed that tourists most frequently visit areas of low ecological sensitivity (42.0%), followed by medium ecological sensitivity (39.6%), and high ecological sensitivity (18.4%). A chi-squared test with the general Westfjords ecological categories found a significant difference between these two distributions ($\chi^2 = 12.96$, $p = 0.002$) indicating tourists are more frequently visiting areas of lower ecological sensitivity, which is also indicated by the lower mean ESI value in the unique locations of 3.8 (SD = 1.77). An ANOVA of the heat scores across the ecological categories found significant difference in the heat scores across the ESI categories on the landscape ($F= 7.94$, $p<0.001$). The post-hoc analysis showed that mean heat scores were significantly higher ($p<0.001$) in the high sensitivity category (15.9) compared with the other two, which were not significantly different from each other (low: 12.4; medium 12.6). This suggests user intensity is higher in the highly sensitive areas.

Tourism and remoteness

Only 69 of the 3488 unique user locations were in "remote" areas (1.98%) indicating that tourists rarely access remote areas in the Westfjords. The median distance to road for user locations of 33.4 m (IQR: 8.8 – 151.6) further reflects this finding. A t-test of the ESI between the remote and non-remote location showed a significant difference ($t =-13.145$; $p<0.001$), with unique locations in remote locations generally being in much more sensitive areas (mean ESI 5.5 vs. 3.8). In contrast to the findings above, remote unique locations have a significantly ($t= 3.11$; $p=0.03$) lower user intensity (4.8) compared to non-remote locations (13.3).

Hotspots and the environment

The six hotspots demonstrate a wide range of environmental and usage characteristics (Table 5). The largest hotspot in terms of the quantity of unique locations is Látrabjarg, which also had the highest median heat score. However, the most visited hotspot was Dynjandi with almost a quarter of the tourists making a visit there; it also had the highest ESI value (6.0), which would place it in the highest category of ecological sensitivity. None of the hotspots was located in a remote area.

The ANOVA examining the ESI values across hotspots found that the index varied significantly across hotspots and with respect to the non-hotspots ($F=103.4$, $p<0.001$). The post-hoc analysis found that all hotspots and the non-hotspots differed significantly (at p-values < 0.02) except for Látrabjarg, Vigur, and Skápadalur.

Discussion

This study sought to model potential impacts from tourists using a GIS. Being able to map out where tourists are actually going at the local level is helpful in most places, but it is even more so in an area with a very low population density and limited monitoring capabilities. As Figure 3 shows, mapping the locations of geotagged photographs can provide a precise measure of where these tourists (and by extrapolation, many tourists) are on the landscape. Further, the hotspots revealed by this analysis provide insights into areas that are receiving a larger share of tourists: in part reflecting what is already known, but also shedding some new light. Látrabjarg, Dynjandi, and Ísafjörður are certainly expected hotspots: they are advertised in the official Westfjords tourism literature and were among the five most popular Westfjords destinations in a 2015-16 survey of tourists performed in Keflavík International Airport (Óladóttir 2017). The Vigur and Þingeyri hotspots also present an interesting finding.

Although they are too mentioned in the Westfjords tourism literature, caution should be taken in interpreting the findings, particularly with respect to the latter hotspot. Both hotspots had the lowest percentage of users of the six identified hotspots, so the level of use by these individuals (i.e. the numbers of photos taken during the respective visits) at these two hotspots was much greater and thus seemingly more intense. Supplementing these findings with other data sources and on-site monitoring could help identify if these areas are indeed subject to higher tourist pressures and what to do about it. Perhaps more surprising is the Skápadalur hotspot, as it is not featured in the main tourist literature. Nonetheless, the popularity of the Skápadalur site likely relates to an old, beached whaling vessel that people generally drive past en route to Látrabjarg. Identifying places like this are important, as they represent areas that could need monitoring and the development of supporting infrastructure, such as parking areas, rest areas, etc. Thus, the use of social media data may be able to give local stakeholders an opportunity to act early and prevent damage that may otherwise occur. Another surprise may be that two of the most popular Westfjords areas mentioned in the survey at Keflavik, Hornstrandir and Holmavík/Strandir, do not stand out in the hotspot analysis in this study. This finding likely relates in part to the large spatial extent of these areas. Unlike the hotpots identified above, which are almost relatively small areas, Hornstrandir and the Strandir lack attractions that concentrate tourists in specific areas for longer periods of times. Instead, tourist visits in these areas tend to be more spread out across the landscape. Additionally, this could also reflect limited reception for cellular phone signals, particularly for smart phone cameras. In general, the findings demonstrate how this type of analysis can help both confirm and recast existing knowledge about tourism patterns; it can also identify ones that might be not stand out in traditional monitoring schemes.

Potential for environmental impacts

One of the more unique aspects of this study is the combination of the social media data from tourists with landscape measures of ecological sensitivity. This combination allows an assessment of where the tourists could have a greater impact on the environment and a means to prioritize areas for intervention, either through improved tourist infrastructure or through limits on access. Such a tool is especially important for tourism in Arctic and sub-Arctic regions, where any disturbance that damages the environment can have long lasting effects. The arctic environments do not have much time for recovery in any given year due to the short growing season; any recovery can be set back repeatedly due to frequent extreme weather events; and there is only a small pool of native species to take over from ones that might have been extirpated locally. Moreover, arctic ecosystems are already experiencing increased stress due to global climate change: temperatures have been increasing about twice as fast as they have globally, which is melting permafrost and facilitating the invasion of non-native species (Arctic Climate Impact Assessment 2004; IPCC 2014). Precipitation, particularly in the form of rain, has also been increasing while snow cover has been decreasing, altering the conditions to which many arctic species had adapted. Additionally, the stress on these environments has been aggravated by pollution, resource exploitation, and habitat destruction (ACIA 2004). Thus, any impacts from tourists in these areas will only compound impacts from other forces of environmental change.

The results from this study show that many of the ecologically sensitive landscapes in the Westfjords surround the most densely inhabited areas, where the majority of the tourist infrastructures (i.e. grocery stores, gas stations, lodging) are also located. Thus, there is potential for damage from both local residents and tourists alike. Nonetheless, the results for foreign tourists in this study suggest they tend to stick to landscapes that are less sensitive ecologically and not very remote, indicating pressure from foreign tourists may not be a concern this time. However, this likely does not represent an intentional choice by tourists to avoid more sensitive areas; a survey of tourists in southern Iceland found that most tourists were unaware of damage to the local environments that tourism is causing in that region (Sæþórsdóttir 2015). Further, many of these areas have steep slopes with minimal vegetation, so caution would be warranted if tourist activities were to start expanding from these areas, particularly in the form of hiking. Trail degradation is already a major problem on popular hiking trails in southern Iceland (Olafsdottir and Runnstrom 2013) and proper management will be needed to ensure that future trails in the Westfjords do not suffer the same fate. This study's finding that tourists entering more sensitive areas tend to have a greater intensity of use in those areas further emphasizes the need to monitor and manage the sensitive areas properly.

Combining hotspot information with the environmental data provides a new tool for managers to prioritize actions in these areas. Based on the ecological sensitivity index (ESI), the Dynjandi and Þingeyri hotspots are the most sensitive and should require the most attention in educating and managing tourists, as well as mitigating possible environmental impacts. Already, the Dynjandi area is the focus of infrastructure improvements for tourists in the Westfjords (Ólafsdóttir 2017). Further, as discussed above, the Þingeyri hotspot does not appear to have numerous visitors, but rather visitors that have a higher user intensity. Additional on-site monitoring would help determine the level of impacts the area is receiving and guide future site management.

The relatively low values of the ESI for the Látrabjarg and Vigur hotspots indicate a weakness of the use of this index. The index was originally designed for examining impacts from hiking and trampling primarily and thus focuses on the potential damage to vegetation and from soil erosion. However, these two hotspots are important bird nesting areas and thus are likely much more sensitive than their ESI values suggest. Similarly, other areas in the Westfjords that are important grounds for seals and arctic foxes could also have misleadingly low ESI values. A more inclusive index that incorporates information about areas that are important animal habitats would help improve the management of environmental impacts of tourists. This would be particularly important if some form of the ESI were used to educate and direct tourists. Using the ESI to designate sensitive areas for tourists could be beneficial, but again it would be important to develop a scheme that incorporates as much ecological information as possible.

Using social media in this context

As several studies have shown previously, geotagged photographs on social media provide an important complement to existing means to track tourists' movements across the (e.g. García-Palomares et al. 2015; Heikinheimo et al. 2017; Wood et al. 2013). In a region like the Westfjords of Iceland, where landscapes are often devoid of human presence, it would be a costly endeavor to monitor visitors directly. This study has shown that geotagged photographs can give insight into who the tourists are, when they are coming, and where they are going. With respect to who the tourists are, there appears to be some demographic differences between the groups who come more frequently to the Westfjords and those that visit Iceland more generally: German, Swiss, French, and Italian tourists show a stronger preference for the Westfjords region, while British and Scandinavian tourists appear to show less. As the Westfjords are more difficult to get to, this might reflect an underlying difference in the average lengths of stays of these groups in Iceland; a visit to the Westfjords likely requires a longer stay in the country. Another possibility is that at least some of the differences may be an artifact of the methodology. Some studies have indicated that each social media platform has its own specific demographics (e.g. Di Minin et al., 2015; Gilbert et al. 2016; van Zanten et al. 2016) and the Van Zanten study in particular noted that Flickr is more commonly used among Central and Western Europeans compared to Instagram and Panoramio. However, Heikinheimo and others (2017) found that social media data did accurately reflect the origins of tourists to a national park in Finland when compared with an on-site visitor survey. Those researchers also found visitors to the park used Instagram much more often than Flickr, indicating the importance of understanding the strengths and limitations of each social media platform for tourism research. One way to deal with this issue would be to draw data from multiple platforms that represent different demographic groups, as Van Zanten and others (2016) did. Nonetheless, data from Flickr have been successfully used in multiple other studies (e.g. Allan et al. 2015; Girardin et al. 2009; Kádár 2014; Levin et al. 2015; Sonter et al. 2016; Spalding et al. 2017; Straumann et al. 2014; Sun et al. 2013; Wang et al. 2016; Wood et al. 2013) and in this study, Flickr data also appear to contribute valuable information to the understanding of tourist preferences in the Westfjords.

A comparison with the national tourism statistics also shows to some extent how tourism in the Westfjords may differ from national tourism with respect to when tourists come. Tourism in the Westfjords is much more seasonal than general tourism to Iceland, with most tourists visiting the Westfjords in the summer months. This finding in of itself is not surprising, as cruise ship tourism, a major component of tourism in the Westfjords, functions primarily as a summer phenomenon in Iceland. Additionally, the limited accessibility of the Westfjords is aggravated by storms in the winter, which often close roads and shut down airports. The results presented here (summarized by month) show a stronger seasonality than the results presented in the national tourist report. As the latter statistics are based on arrivals at the country’s main international airport in Keflavík and thus would not include cruise ship tourists whose trip may start outside of Iceland. The data from social media might thus provide a more accurate picture of how tourism plays out in the Westfjords throughout the year.

Limitations

As mentioned above, the methodology in this study has limitations, such as potentially biased demographics of Flickr users, limits to appropriate reception for geotagging, and missing ecological factors from the ESI. There are other limitations as well. For example, there is an implicit assumption that each Flickr user represents one tourist “unit”, when, in reality, one user could be traveling alone or part of a group that could range from two to an entire tour bus. This piece of information could inform and possibly alter the estimates of user intensity on the landscapes. It might be possible to derive some information regarding group size by performing a content analysis of the photographs and extracting information on the number of people portrayed in photographs. However, the appearance or absence of individuals in photographs likely varies across users and would also introduce additional uncertainties. An additional limitation is the accuracy of the locational information of the geotags. This study attempted to minimize this through the exclusion of photographs with lower accuracy tags and by using a zone around the actual location as the study object, rather than the point itself. Thus, locations should not be assumed to be exact pinpoints on the landscape, but rather zones of interest. It is also important to remember that the unique locations only represent the locations where tourists have taken photographs, not all the possible locations where tourists may have gone. The locations where photographs have not been taken could be experiencing impacts as well, but would remain ignored in this type of analysis. Visitation in some very remote regions, such as Hornstrandir, might also be underrepresented as the areas often lack appropriate coverage for some GPS devices. This is an important limitation, as it may lead to underestimates of tourism in such areas. Further, as social media photo-sharing sites often allow users to geotag photos manually, photos in these areas may have a different level of spatial accuracy then photos that were automatically tagged by the camera device in other areas. Finally, it is important to remember that both tourism trends and social media uses are dynamic. Areas or platforms that are popular today will likely change over time. Future studies following similar methodologies should be aware of these trends and adjust accordingly. Nonetheless, the use of social media to track tourism can also provide a more real-time tool to track changing trends in preferred tourist destinations. In general, an important way to deal with these limitations is to use the data in combination with other data sources (e.g. other social media platforms, visitor surveys) when possible.

Expansion of study

This study provides insights into tourism patterns and their connection to the ecological landscape. As discussed earlier, the ecological sensitivity index could be expanded to incorporate additional relevant ecological factors. Additionally, there are other aspects of tourism that future studies could take up. As mentioned in the Introduction, geotagged photographs have been used in a variety of purposes in tourism and environmental research. Data from this study and other social media platforms could be used to identify lodging areas of tourists or could be employed to assess potential social and economic impacts. A content analysis of the photographs could also highlight how tourists use (and abuse) the landscape. Such information would be useful to local stakeholders as they develop new informational materials and infrastructure for tourists. It would be particularly helpful to identify behaviors that are harmful to the environment or local culture, so that appropriate countermeasures could be taken. As Chen (2015) found that tourists in arctic areas are generally receptive to more sustainable practices, if planners can inform tourists about bad practices, improvements may be achievable.

Conclusions

This study demonstrates that data from geotagged photographs posted to social media sites can be helpful in expanding what is known about tourist patterns in remote areas. In contrast to traditional means of collecting tourist data, the data used here provide finer scale information with fewer financial costs. Further, this information, when combined with data regarding the environmental sensitivity of the landscape can help planners and other local stakeholders identify and prioritize areas for monitoring, improvement, and zoning. Researchers should recognize the limitations of these methods and when feasible, take steps to improve data quality by incorporating data from multiple social media platforms and by expanding the scope of environmental indices.

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Table 1: Types of data and their source used in this study

Source	**Layers**
National Land Survey of Iceland (www.lmi.is)	National and Westfjords boundaries and coastal lines (IS50V) Municipalities (IS50V) Roads (IS50V) Structures (IS50V) DEM CORINE landcover
Agricultural University of Iceland (www.lbhi.is)	Soil type
Flickr (www.flickr.com/services/api/)	Geotagged photographs

Table 2: Index of ecological sensitivity components. Adapted from Ólafsdóttir and Runnström (2009).

Category (points)	**Vegetation/land cover**	**Soil type**	**Slope**	**Total**
Hornstrandir (1)	n.a.	n.a.	n.a.	
No (0)	Beach, seashore, lakes and rivers, developed areas	• Histosol	0 – 10°	0
Low sensitivity (1)	Floodplains, non-vegetated lands, wetlands	• Brown andosol-hydric andosol-histosol • Brown andosol-hydric andosol-gleyic andosol • Cambic vitrisol	10 – 20°	1-3
Medium sensitivity (2)	Agriculture, grasslands, semi-vegetated lands, forest	• Leptosol • Arenic vitrisol-leptosol	20 – 30°	4-5
High sensitivity (3)	Moss scrub	• Arenic vitrisol	30+ °	6+

Table 3: Classification of location user intensity

Location user intensity	**Description**
1	Only one photograph taken at location
2	Multiple photographs taken at same location within one hour period
3	Multiple photographs taken at same location within a period between one and two hours
4	Multiple photographs taken at same lat-long coordinates within a period longer than two hours

Table 4: Origin of tourists to the Westfjords based on Flickr data compared with national tourist statistics: 2014-2016

Country or region	**% users**	**National data[a]**
Canada & US	24%	24%
Germany & Switzerland	15%	10%
France	11%	5%
UK	9%	18%
Italy	8%	1%
Netherlands	5%	2%
Spain	3%	2%
Scandinavia	3%	12%
Other countries	22%	27%
Austria	*1%*	*Not specified in data*
Australia & New Zealand	*3%*	*Not specified in data*
Belgium	*4%*	*Not specified in data*
Eastern Europe[b] & Russia	*3%*	*Not specified in data*
Portugal	*1%*	*Not specified in data*
Remaining[c]	*3%*	
Foreign but unable to determine specific country	*6%*	

[a] Arrivals at Keflavík only, from Óladottir 2017,
[b] Estonia, Lithuania, Poland, Romania, Ukraine
[c] Argentina, Indonesia, Ireland, Japan, Mexico, Taiwan, and UAE

Table 5: Characteristics of the hotspots (ESI scores with different letters differ significantly).

Hotspot	**Number of user locations (% of total)**	**Users (%of total)**	**Median heat score**	**Mean ESI**
Látrabjarg	249 (7.1)	72 (22.6)	69	3.39[a]
Dynjandi	206 (5.9)	78 (24.5)	37	6.00[b]
Ísafjörður	65 (1.9)	14 (4.4)	35	1.00[c]
Vigur	49 (1.4)	4 (1.3)	33	2.92[a]
Skápadalur	45 (1.3)	28 (8.8)	34	3.00[a]
Þingeyri	33 (0.9)	2 (0.6)	28	5.00[d]
Non-hotspots	*2841*	*295*	*2*	*3.81*[e]

Figure captions

Fig. 1 Overview of the Westfjords

Fig. 2 Ecological sensitivity in the Westfjords

Fig. 3 Overview of Flickr unique locations and remote areas in the Westfjords

Fig. 4 Monthly distribution of user visits

Figure 1

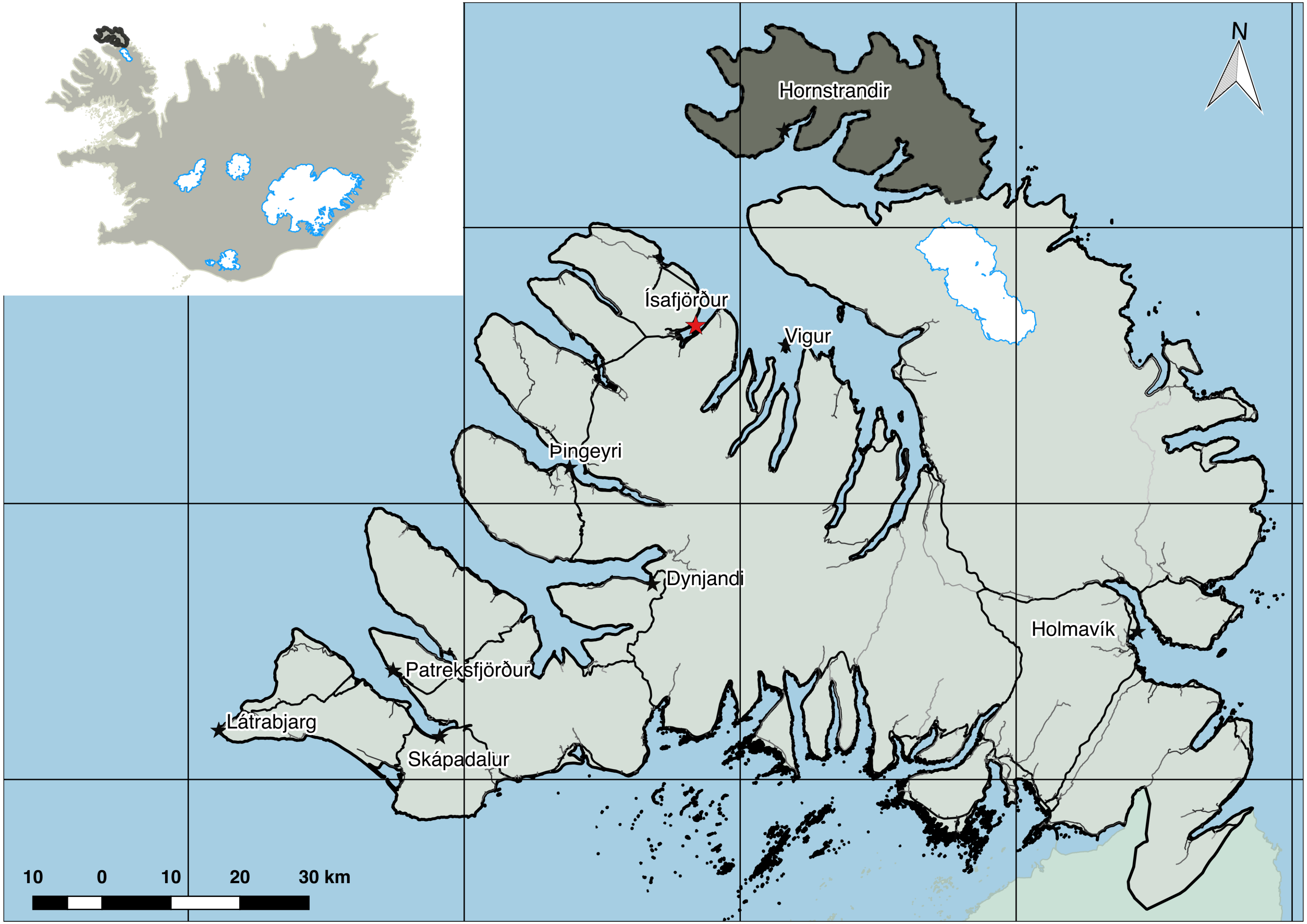
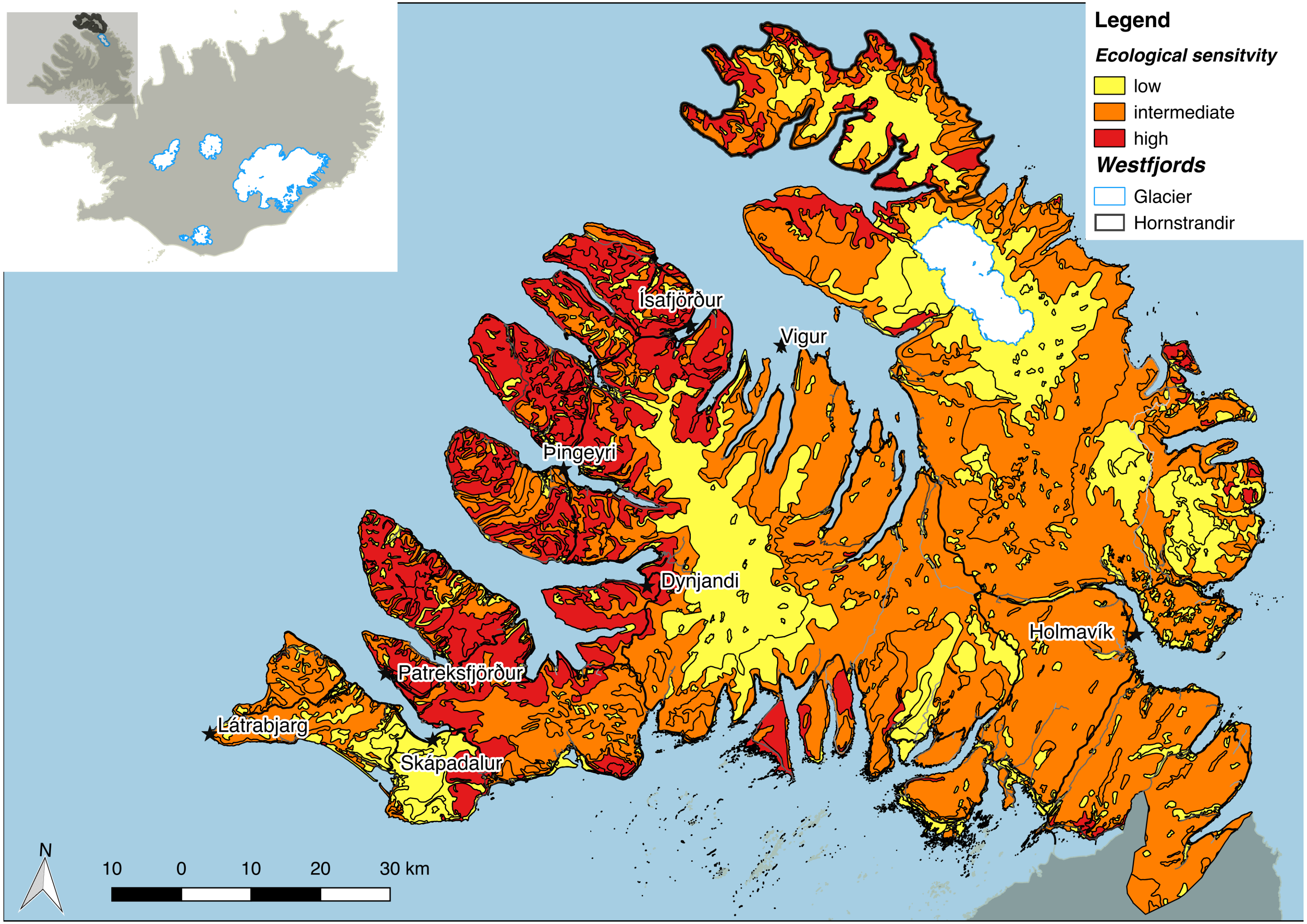

N
Hornstrandir
Ísafjörður
Vigur
Þingeyri
Dynjandi
Holmavík
Patreksfjörður
Látrabjarg
Skápadalur
10 0 10 20 30 km

Figure 2



Legend
Ecological sensitvity
low
intermediate
high
Westfjords
Glacier
Hornstrandir
Ísafjörður
Vigur
Þingeyri
Dynjandi
Holmavík
Patreksfjörður
Látrabjarg
Skápadalur
N
10 0 10 20 30 km

Figure 3

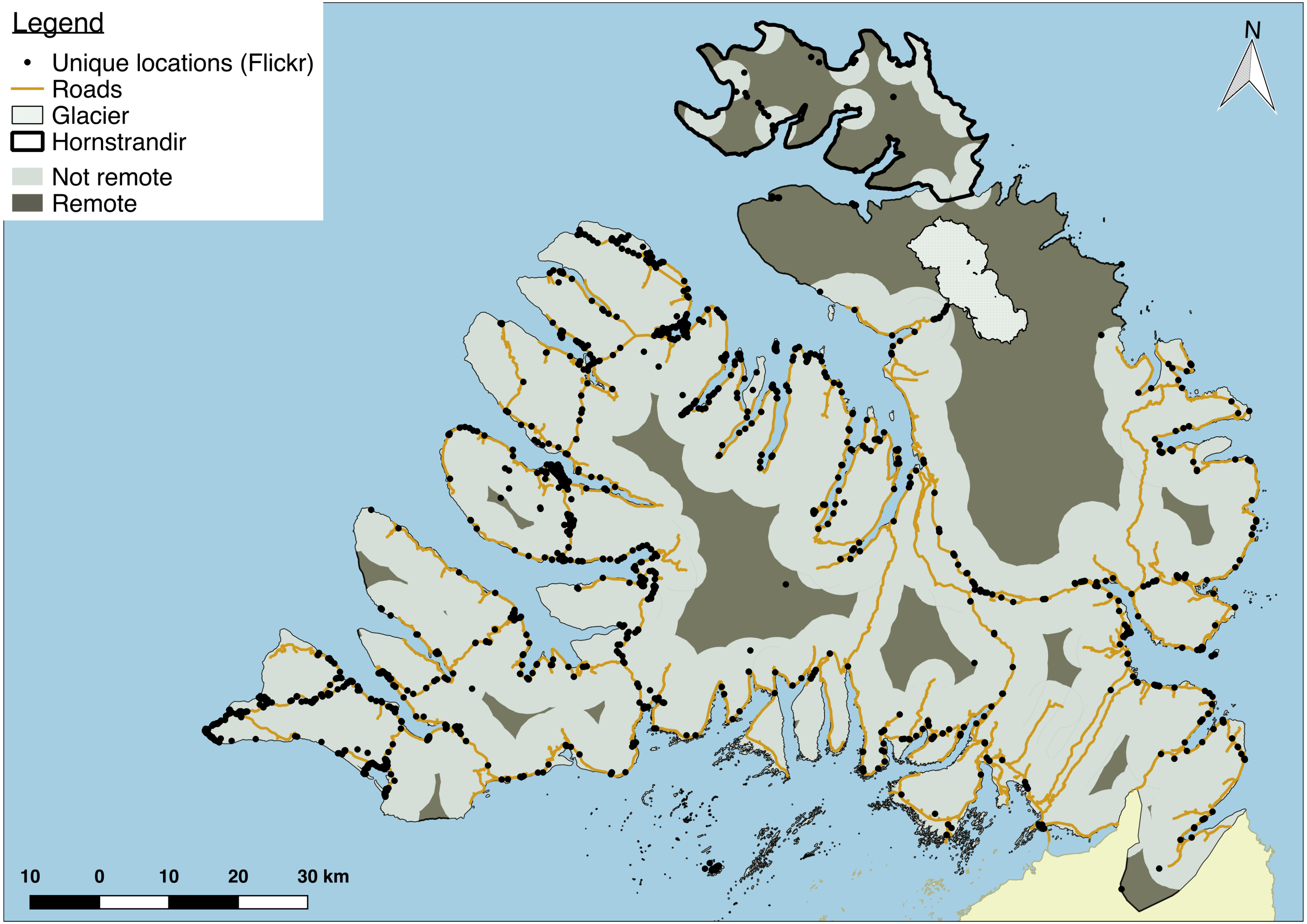
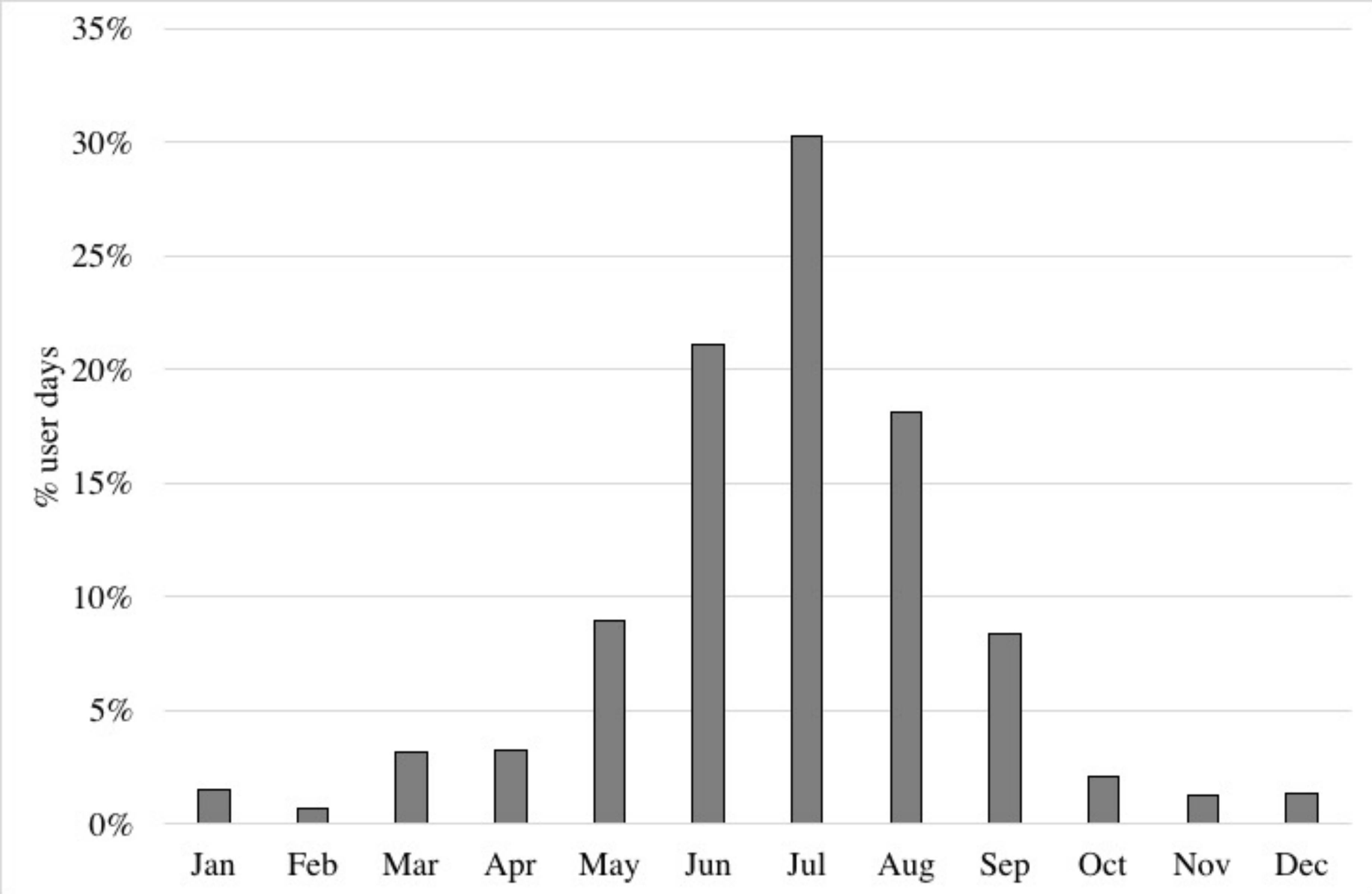

Legend
Unique locations (Flickr)
Roads
Glacier
Hornstrandir
Not remote
Remote
N
10
0
10
20
30 km

Figure 4


35%
30%
25%
20%
15%
10%
5%
0%
% user days
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec