Tourism Management 81 (2020) 104136

Contents lists available at ScienceDirect

Tourism Management

journal homepage: http://www.elsevier.com/locate/tourman

Social big data informs spatially explicit management options for national parks with high tourism pressures

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A R T I C L E I N F O

Keywords:
Nature-based tourism
Tourism pressure
Protected area
Social big data
Management policy

A B S T R A C T

Nature-based tourism in protected areas is an easily experienced ecosystem service that humans enjoy, but it acts as tourism pressures on ecosystem. Some park managers, however, lack an understanding of the spatial distribution and ecological impact of these pressures. We analyzed the size and spatial distribution of these pressures in Korean national parks, using visitor statistics and social big data. In addition, by overlay it with endangered species distribution data, we analyzed areas where tourism pressures and ecologically significant areas could be conflicted. The tourism pressure differed according to the individual protected areas' characteristics. Due to the unevenness of the magnitude and spatial distribution of pressures, the ecological impacts could be spatially differentiated. This study suggests that tourism pressure may be a decisive factor affecting protected areas' ecosystems with increased visitors. Using social big data, managers can establish spatially explicit management policies that consider tourism pressures on individual protected areas.

1. Introduction

Nature-Based Tourism (NBT) in protected areas is an easily experienced ecosystem services provided to mankind (Balmford et al., 2015). Protected areas are the preferred ecotourism destinations that people visit to enjoy and find inspiration from nature. The enjoyment of the nature in protected areas plays an important role in enabling visitors to recognize the value of these areas, and encourage them as potential forces for conservation (Leung, Spenceley, Hvenegaard, & Buckley, 2018). In many protected areas, NBT is an important means of securing financial resources needed to preserve ecosystems (Buckley, Castley, Pegas Fde, Mossaz, & Steven, 2012; Buckley, Morrison, & Castley, 2016).

While NBT is a beneficial factor for mankind, it could be a serious source of pressure to ecosystems in protected areas (Church, Coles, & Fish, 2017; Drius et al., 2019). Since the twentieth century, the rapid increase of visitors to these areas (Watson, Dudley, Segan, & Hockings, 2014) has affected biodiversity and ecosystem services (Buckley et al., 2016; Hausmann et al., 2018). Tourism pressure reduces the habitat of ecologically important species and leads to the depletion of natural resources (Drius et al., 2019). Over-tourism causes a loss of biodiversity in protected areas and a deterioration of the economies around them (Seraphin, Sheeran, & Pilato, 2018).

With the exception of some high-income countries, there is an increasing number of visitors to protected areas in the rest of the world (Balmford et al., 2009; Kim, Kim, Lee, Lee, & Andrada, 2019). In Northeast and Southeast Asia, the population is dense, the economy is growing rapidly, and the protected areas are small, yet the increasing trend of visitors is obvious. As of 2017, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) noticed that the combined area of land and marine protected areas totaled 11% in Northeast Asia and 5% in Southeast Asia, which is less than the average 14.6% in the Asia-Pacific region (IPBES, 2018). When compared with other regions, there is a rapid growth rate of visitors in protected areas. In China, the number of visitors to the National Forest Park annually increased by 20% between 2000 and 2009, with 2009 seeing 333 million visitors (Wang et al., 2012). The Republic of Korea (hereinafter referred to as Korea) also saw an increase in national park visitors from 27 million in 2005, to 47 million in 2017 (Korea National Park Service (KNPS, 2019d); Fig. 1c). In particular, the Korean marine and coastal national parks have exploded with more than three times the number of visitors; around 3.5 million in 2005 to around 11 million in

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https://doi.org/10.1016/j.tourman.2020.104136
Received 8 October 2019; Received in revised form 17 February 2020; Accepted 29 April 2020
Available online 14 May 2020
0261-5177/©

2018.

Therefore, there is an urgency to quantify and understand how this increasing tourism pressure will affect the environment in the protected areas (Buckley et al., 2016), and understanding how to monitor and effectively manage tourism pressures is an important issue for the sustainable management of these areas (Hausmann et al., 2019; Kim, Kim, Lee, Lee, & Andrada, 2019). For the areas that are witnessing a rapid increase in visitors such as Northeast and Southeast Asia, it is necessary to implement tourism management policies to minimize negative impacts of these pressures and maximize the positive impacts. However, some protected area managers have a lack of understanding to various human pressures, including tourism pressures (Watson et al., 2014). There are very few studies which investigate the locations that people visit within each protected area or the resources they affect and use the results in the actual management policy of protected areas.

Traditionally, the managers of protected areas have gained the information needed to manage their parks by using visitor counting data and visitor surveys (Heikinheimo et al., 2017). However, visitor-based analysis compiled at points such as ticket offices makes it difficult to understand the spatial distribution of where visitors go and what resources they affect. In addition, there are limitations in the spatially explicit understanding of how tourism pressure affects the ecosystem of protected areas, and in deriving the management policy of the pressure. In order to identify visitors' spatial visitation patterns, site-specific surveys at protected areas' entrances (Kim et al., 2019; Wood, Guerry, Silver, & Lacayo, 2013) and surveys applying Public Participation Geographic Information Systems (PPGISs) have been used (Brown & Weber, 2011, 2012; Whitehead et al., 2014). However, these surveys are expensive and can only provide limited and temporary information about the tourism pressures in protected areas (Hausmann et al., 2019; Wood et al., 2013). In Korea, park managers have been conducted to identify the distribution of visitors and to identify illegal trails in some national parks using visitor survey data (Lim, 2004), and mobile phone application data (Ko, 2019). In addition, the KNPS indexes the pressures applied to the trails by surveying the number of visitors, degradation conditions, and the degree of use of sideways in the trails of 15 mountainous type national parks, and utilize them for the trail pressure management policy (KNPS, 2015). However, these studies did not cover 1) all types of national parks, and 2) studies limited to trails did not identify the pressures of the whole national park areas. Therefore, there was a limit to establishing a strategy for spatial management of tourism pressures across the entire national park.

Social big data makes it easier to analyze and understand the spatial distribution of visitors to protected areas, and can be used for the spatiotemporal analysis of where a visitor went by using the location information included in the data as posted by a user through a mobile device (Heikinheimo et al., 2017). Therefore, good proxy data for visitor distribution can be selected in areas where the survey data are insufficient (Kim et al., 2019; Walden-Schreiner, Rossi, Barros, Pickering, & Leung, 2018). It can also be used to manage protected areas by providing information on what values and experiences visitors gain from these areas (Muñoz, Hausner, Brown, Runge, & Fauchald, 2019; Oeldorf-Hirsch & Sundar, 2016). Through spatially overlapping the analyses of visitors with biophysical information, threat identification to biodiversity conservation priorities are also available (Gosal, Newton, & Gillingham, 2018; Muñoz et al., 2019; Whitehead et al., 2014).

In previous studies, human and tourism pressures on protected areas were analyzed either on a global scale or in local cases. Jones et al. (2018) analyzed human pressures on protected areas on a global scale, and they found that 32.8% of these areas were affected by intensive human pressures. Hausmann et al. (2019) used Twitter and Flickr data to reveal that 17% of the world's Important Bird and Biodiversity Areas (IBAs) are highly threatened from visitors. Whitehead et al. (2014) used PPGISs to analyze tourism pressures and ecological impacts around Newcastle, Australia. However, on the national scale, few studies have been conducted to simultaneously identify the spatial distribution of tourism pressures within individual protected areas and analyze the ecological impacts of these pressures.

Therefore, this study aims to analyze spatially the magnitude and distribution of tourism pressures in Korean National Parks, which have a small area but is increasing in nature-based tourism. It also seeks to provide spatially explicit management options to reduce the impact of tourism pressures on ecologically important endangered wildlife habitats in national parks. For these purpose, in this paper we: (i) Identify the tourism pressures in Korean national parks using visitor statistics; (ii) analyze the spatial distribution of the tourism pressure using social big data; (iii) conduct a comparative analysis with tourism pressures and ecologically significant areas to identify which areas within the national parks are ecologically vulnerable from the tourism pressure; and (iv) propose management options of tourism pressures to sustainably maintain biodiversity and ecosystem services in protected areas based on the results.

2. Methods

2.1. Study area

Since Korea first designated the Jirisan National Park in 1967, a total of 22 areas (17 mountainous, four marine and coastal, and one historical) have been designated as national parks of May 2019, occupying 3.96% of the terrestrial land area, and 6.71% of the national land area (KNPS; 2018a; Fig. 1a; Fig. 1b), yet most of these parks are smaller than when compared to the national parks in the United States and Australia. Korean national parks are small in size (average area is 306㎢) but have a high conservation value as a habitat for endangered wildlife (173 out of 246 endangered species in Korea; KNPS, 2018a). In addition, due to the narrow land area and high population density, the number of visitors per unit area is very high and the economic value is also high. This demonstrates the special traits of Korean national parks, a protected area that collides with a high degree of conservation value and economic value worldwide.

In Korea, the five-day workweek was implemented in July 2004, leading to an increase in leisure time and an increase in the visitation to national parks. According to the KNPS statistics, in 2017, there were 47.28 million Korean national park visitors, 1.7 times that of 2005 (KNPS, 2019d). This means around 92% of Korea's population (51.17 million in 2017) visits a national park once a year.[1] This implies a stronger conflict between conservation values and economic values, and if this trend continues, it will lead to a reduction in ecological values and eventually a reduction in ecosystem services enjoyed by humans. Therefore, in order to sustainably conserve the value of Korean national parks, we need to understand the spatial distribution of the tourism pressure and how it can affect ecologically important areas (endangered species habitats).

The temporal change in the number of visitors from 2005 to 2017 varies depending on the type of national park (Fig. 1c). Mountainous national parks have maintained their visitor numbers since 2013, as they are close to the densely populated metropolitan areas and many people visit the mountainous parks to climb in their leisure time. The historical national parks have also received constant numbers since 2009, and visitors to marine and coastal national parks have been steadily increasing since 2005.

2.2. Methods

This study was conducted in three stages, and the data used are

[1] For reference, in the United States, the total number of visitors to the 379 parks (including national parks and other protected areas) as managed by the U. S. National Park Service (NPS) was 291.49 million in 2017. This was around 89% of the U.S. population of 327.27 million in 2017 (KNPS, 2019).

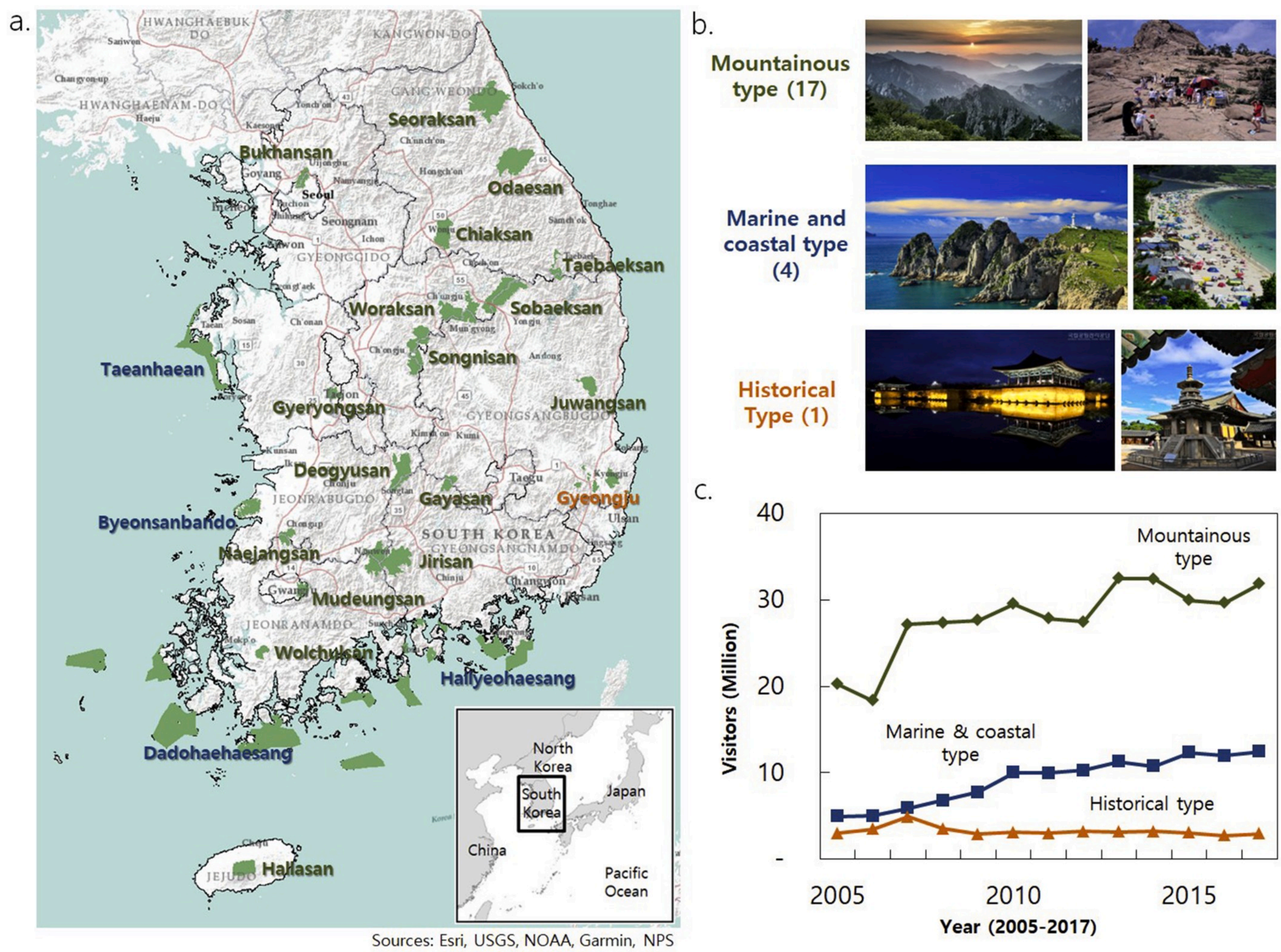

Fig. 1. National parks in Korea. (a) Location of 22 Korean national parks; (b) Representative photos of each type of national park (Source: (KNPS, 2019c)); (c) Changes in visitors to types of national parks (Source: (KNPS, 2019d)).

shown in Table 1. First, the magnitudes of the tourism pressures were analyzed by using the number of visitors to each national park. The data used were derived from the National Park Visitor Statistics (2005–2017; KNPS, 2019d). For each park, the annual mean of visitors and the annual mean of visitors per unit area (1 km^2) were analyzed between 2005 and 2017. The relationship between the area size of the national park and the number of visitors was analyzed using Pearson's correlation method.

Second, we analyzed the spatial distribution of the tourism pressures by using Flickr data. Flickr data was collected through the Integrated Valuation of Ecosystem Services and Tradeoffs recreation model (hereinafter referred to as InVEST).[2] InVEST provides Flickr data as a Photo-User-Day (PUD) basis, which means that a photographer has taken at least one photo on a specific date (Natural Capital Project, 2017). In this study, Flickr PUD between 2005 and 2017 were collected and summing for each national park jurisdiction (boundary), and mapped using a 1 × 1 km grid unit. For the validation, Flickr PUDs (total value of 2005–2017) for each national park was compared to the actual number

Table 1
Data used to analyze tourism pressure and its ecological impact on Korean national parks.

Category	Data	Value	Year	Source
Visitation	National park visitor statistics	Visitors to 22 national parks (Annually)	2005–2017	KNPS (2019d)
Social big data	Flickr	Photo-User-Day (Annually)	2005–2017	The Natural Capital Project, 2017
Endangered species emergence	Third National Park Natural Resources Survey	Discovery points of four endangered species in 21 national parks[a] (*Lutra, Martes flavigula, Prionailurus bengalensis* and *Pteromys volans aluco*)	2010–2018	KNPS, 2019

[a] Due to data limitation, Hallasan National Park was excluded from the analysis.

[2] Flickr and Instagram are mainly used as social big data to understand the spatial distribution of visitation. Flickr is popular with photographers that take good quality photos and upload them from a professional camera (Hausmann et al., 2018; Sinclair et al., 2019). Instagram is widely used to capture, post, and share memories using low quality photos in real time through mobile applications (Hausmann et al., 2018). However, Instagram's data cannot be accessed over the internet after Facebook's personal information leak in 2018. Flickr data, however, can be easily accessed using the InVEST recreation model provided by the Natural Capital Project team, and can obtain spatial information from the photos that users upload.

of visitors (total value of 2005–2017) from the visitor statistics of the KNPS. Next, we mapped the cumulative Flickr PUD values per unit area, and identified the proportion of the grids with high tourism pressures and the spatial distributions in each national park. Finally, the spatial distribution of the tourism pressure and the spatial layout of tourism support facilities (visitor information centers, restrooms, shelters, trail routes, and nature observation routes) were compared. We used the visitor support facility data of the KNPS (KNPS, 2013).

Third, to understand the impact of tourism pressure on each national parks, we conducted the overlay analysis with tourism pressures and ecologically significant areas within the parks. The proxy data used for the ecologically significant areas were the habitable areas of the four endangered species of *Lutra*, *Martes flavigula*, *Prionailurus bengalensis,* and *Pteromys volans aluco* in Korea (Jeon, Kim, Jung, Lee, & Kim, 2014; Kim, Seo, Kwon, Ryu, & Kim, 2012; Lim, Lee, Jung, & Park, 2017, Table 1; Table S1). These species have a role as high level predators in the Korean ecosystem and are likely to face local extinction due to their small populations (Crooks, 2002; Lim et al., 2017; Lyra-Jorge, Ciocheti, & Pivello, 2008). These species are also listed on the International Union for Conservation of Nature's (IUCN) red list as "vulnerable." Also they have been globally recognized for their conservation value (National Institute of Biological Resources [NIBR], 2014), and are designated as "second category" endangered species in Korea (NIBR, 2019). The analysis procedure was performed as follows. First, we have derived the discovery points of the four species using the third National Park Natural Resources Survey (2010–2018) data (KNPS, 2019), as collected from the field survey from the KNPS.[3] Second, the activity radius of each of the four species was calculated using previous studies (Choi et al., 2012a, 2012b, Eelinge, 1968, Hanski et al., 2000, Taulman and smith, 2004, Table S1), and mapping the habitable area of the species. Third, we have overlaid these species distribution maps. Fourth, we classified each maps of tourism pressures and ecologically significant areas into three classes (L: low, M: medium, and H: high). Finally, we derived the overlay map of tourism pressures and ecologically significant areas. Each grid of the result map have classified into nine classes (HH, HM, MH, HL, LH, MM, ML, LM, and LL).

3. Results

3.1. Tourism pressures in the national parks of Korea

Between 2005 and 2017, the 22 Korean national parks saw an average of around 1,959,071 annual visitors. This figure was 2.55 times the annual mean of visitors (769,012) in the 379 protected areas of the U.S. NPS in the same period, and 96 times the median number of visitors to the 556 protected areas worldwide (Balmford et al., 2015; (NPS, 2019), Fig. 2a; Table S2). The difference in the number of visitors was very large for each national park, and the annual mean of visitors to the top six national parks was 4,273,807, which was 5.8 times the number of 737,429 belonging to the lower eight national parks. Bukhansan National Park received 7.3 million people annually, which was similar to the sum of the lower nine national parks combined (6.9 million people). The annual mean of visitors per unit area (1 km^2) in each national park was more differentiated (Fig. 2b; Table S2), with the top five national parks being higher than average (14,444 people/km^2/yr), at 42,494, which was 10.8 times the average of the 3932 people in the bottom 10 national parks. The number of annual visitors per unit area in Bukhansan National Park was 94,999, which was slightly lower than the combined average of 105,298 visitors in the lower 17 national parks. The area of the national park and the number of visitors per unit area showed a declining exponential relationship. To verify the relationship between the two variables, each variable was log transformed (log 10) and then analyzed by Pearson's correlation, indicating a strong inverse linear relationship with $r = -0.7339$ ($p < 0.001$). (Fig. 2c; Table S2). This means that the smaller the area of the national park, the higher the annual mean of visitors per unit area. The annual mean of visitors per unit area of the seven smallest national parks was 30,737, which was 6.4 times more than the 4808 of the seven large national parks.

3.2. Analysis of the tourism pressures using social big data

The tourism pressure per unit area (1 × 1 km grid) for each national park was analyzed by summing the Flickr PUDs between 2005 and 2017 and is shown in Fig. S1. The cumulative total of the PUDs for each of the 8597 grids ranged from 0 to 405, with an average of 1.055. According to the types of national parks, 17 mountainous parks averaged at 1.513 ($n = 4196$), four marine and coastal parks averaged at 0.386 ($n = 4164$), and one historical park averaged at 4.713 ($n = 237$). Bukhansan National Park ranked first with an average of 17.491 followed by Hallasan (6.3710), Gyeongju (4.7131), Seoraksan (2.2083), and Gayasan (1.3909). Grids with a cumulative sum of PUDs per grid above average (1.055) accounted for 11.6% (998) of the total 8597 grids.

To discover whether the Flickr PUDs reflected the actual number of visitors to a national park, we compared and verified it with the visitor statistics of 21 national parks (Fig. 3). Taebaeksan National Park had only one year of data in 2017 and was excluded from the validation. Pearson correlation analysis was used as a verification method, and the data were transformed by taking log values (log10) in order to make the two data's distribution normal. As a result, the Flickr PUD-based tourism pressure showed high explanatory power (Pearson's correlation coefficient 0.77, $p < 0.001$). The Hallasan and Juwangsan National Parks differed greatly from the other parks in terms of the number of visitors and the Flickr PUDs. Hallasan had a relatively high number of Flickr PUDs when compared to the number of visitors, yet Juwangsan had a relatively higher number of visitors than the Flickr PUDs.

3.3. Spatial distributions of tourism pressures

The spatial distribution of the tourism pressure for each national park, as represented by the Flickr PUDs, did not find any special pattern according to the national park types (mountainous, marine and coastal, and historical). However, it was possible to categorize the spatial distribution of the tourism pressure through the proportion of grids with a higher PUD value than the average 1.055 (Fig. S2; Fig. 4). First, the parks where more than 50% of the grids had a higher than average PUD value corresponded to the group of "Overall High" tourism pressures (Fig. S2; Fig. 4a). Classified into this category were Bukhansan (90.7%) and Hallasan National Parks (55.4%), which are mountainous parks. Second, national parks where a proportion of grids, that was higher than the average PUD, was higher than the total average of 11.6%, but less than 50%, corresponded to the group of "Partially High" parks in which the tourism pressure was only high in some regions (Fig. S2; Fig. 4b). Nine mountainous, two marine and coastal, and one historical national park (Gyeongju National Park) were classified into this group. Third, the parks where the proportion of grids, that was higher than the average PUD, was less than 11.6% of the total average, corresponded to the "Overall Low" group (Fig. S2; Fig. 4c). Six mountainous, and two marine and coastal parks were classified into this group.

Hotspots, which feature visitors concentrated in specific locations, can be classified into spatial forms of points, lines, and polygons (Fig. 4). The point type included concentrated visitations at specific points such as mountain tops, temples and historic sites, and harbors and fishing points. The line shape was found at the locations where the points of high tourism pressures were connected by a single line, and found near the main trail routes, mountain ridges, and coastlines. The polygon pattern was found at the locations where the tourism pressure was high throughout the national park, and it appeared only in Bukhansan and Hallasan National Parks. The mountainous parks were analyzed to have

[3] Hallasan National Park was excluded from the analysis due to the limitation of data acquisition.

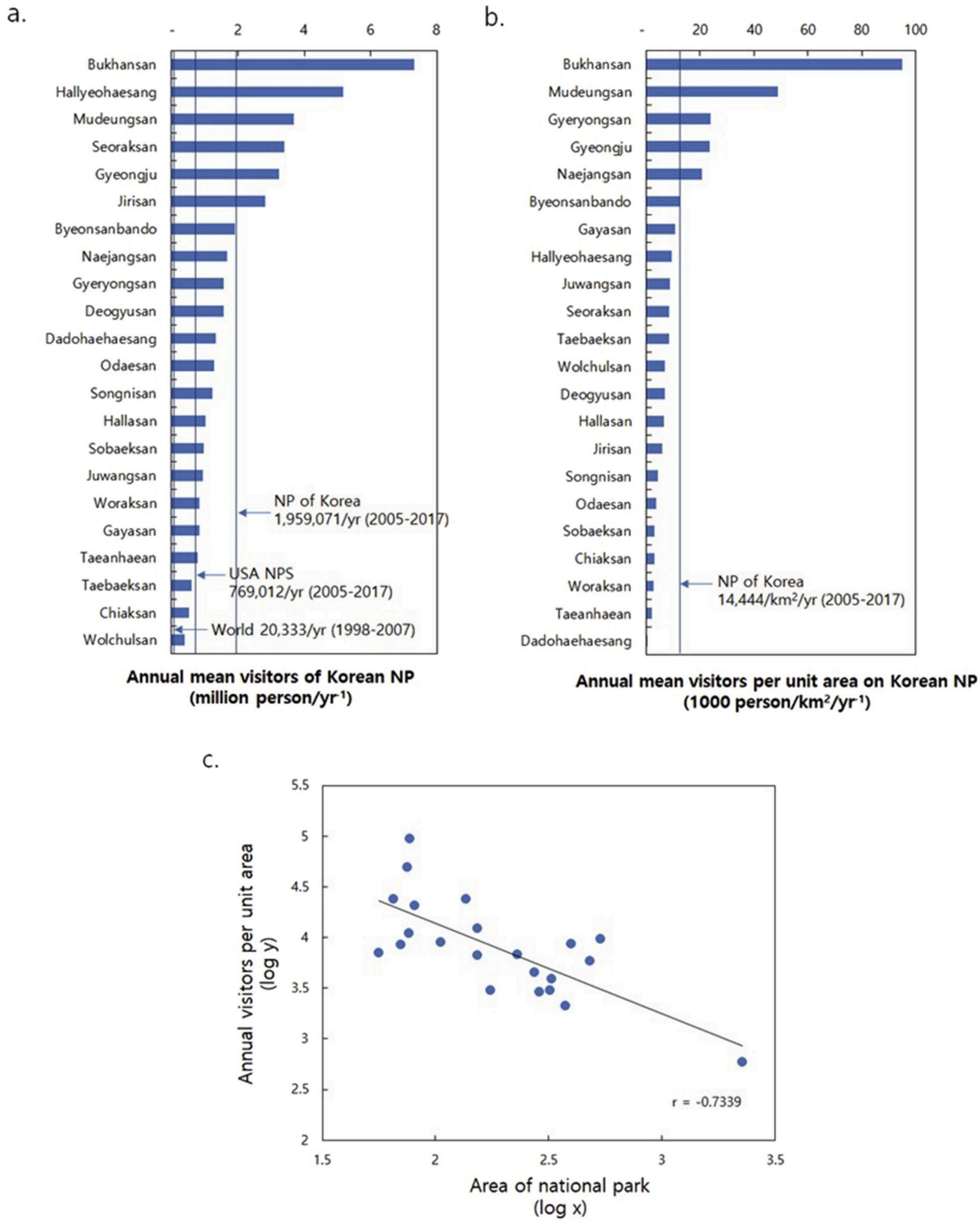

Fig. 2. Tourism pressures by the number of visitors to Korean national parks (2005–2017). (a) Annual mean of visitors of each national park (NP); (b) Annual mean of visitors per unit area of each national park (NP); (c) Pearson correlation between area of the national parks (log x) and the annual mean of visitors per unit area (log y).

had high tourism pressures near the visitation starting point, the summit of the mountain, the main ridge, the main trail route that connected to the mountain's top, and the main ridge to the starting point. Marine and coastal parks have been shown to have had high tourism pressures around the tourist attraction sites such as the harbor, beaches, parks, and cable cars. The historical Gyeongju National Park has been shown to have had high tourism pressures near the urban areas and historical sites. However, in the mountainous parks, low tourism pressures have appeared where there were no official trail routes and lacked tourist attractions such as temples and historic sites. Marine and coastal parks have had low tourism pressures in places where there are no harbors, beaches, parks, cable cars, and so on. Historical parks have had low

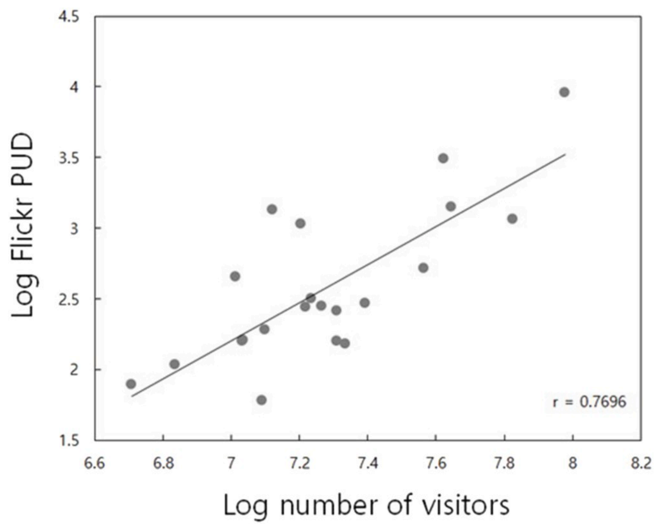

Fig. 3. Correlation between the number of national park visitors and Flickr PUD. Number of visitors [x] and Flickr PUD [y] are transformed by log10.

tourism pressures in areas with an absence of major historical sites.

We analyzed the relationship between the tourism pressures and the placement of tourism support facilities in six national parks (five mountainous, one marine and coastal). As a result, the distribution of pressures and the arrangement of the support facilities differed according to the characteristics of each national park. The Bukhansan and Gyeryongsan National Park are located near urban areas, and the magnitude and spatial distribution of the tourism pressures were related to the placement of the tourism support facilities. Bukhansan National Park had shown high pressures throughout the whole area, and the support facilities were densely deployed throughout (Fig. 4a). However, Gyeryongsan National Park had high pressures in some areas, and support facilities were concentrated in some areas with high pressure (Fig. 4b). At the famous tourist sites in Hallasan, Seoraksan, and Jirisan National Parks, the spatial distribution of pressure and the layout of the support facilities differed for each national park (Fig. 4a; Fig. 4b). Hallasan, like Bukhansan, had high pressures throughout the park, but relatively few support facilities. Seoraksan and Jirisan National Park had many support facilities where the pressure was high. However, there were some places where the tourism support facilities were insufficient compared to the tourism pressure. Hallyeohaesang and Dadohaehaesang National Park are marine and coastal type parks but had a lack of tourism support facilities that specialized in marine activities (Fig. 4b; Fig. 4c).

3.4. Overlaying tourism pressures and ecologically significant areas

Except for Hallasan National Park, the ecologically significant areas in 21 national parks are shown in Fig. 5. The results of nine overlapping types of tourism pressures and ecologically significant areas are shown in Fig. 6a, Fig. 6b, and Table S3. Of the total 8411 grids, 1.7% of the HH grids had both high pressures and significant areas (143 grids, Fig. 6b). There were 2039 (24.2%) grids with high amounts of any of the pressures or significant areas (HH, HM, MH, HL, LH), and grids with one middle-ranging value and one low (ML, LM) accounted for the largest percentage at 62.1% (5222). The grids with a low value of both pressure and significant areas (LL) accounted for 4.2% (355). The proportion of areas where the pressures overlapped with significant areas differed among the national parks (Fig. 6c). In eight of the 21 national parks, more than 50% of the grids had high pressures or significant area values (HH, HM, MH, HL, LH). The highest rate revealed was 90% (99/110 grids) in Gayasan, 86.7% (72/83) in Wolchulsan, and 84.3% (91/108) in Bukhansan National Park. While Bukhansan had no HH grid, the HM grid accounted for 13.9% (15/108) and the HL grid accounted for 70.4% (76/108). However, this ratio was low at 0.8% (22/2719) for Dadohaehaesang, 6.9% (35/509) for Taeanhaean, and 9.4% (68/721) for Hallyeohaesang National Park.

The number of grids where both the pressures and significant areas were high, or where one was high and the other was in the middle (HH, HM, MH) is shown in Fig. 7. Fig. 8 shows the spatial distribution of the pressures and significant area's overlapping results in Jirisan, Seoraksan, Gyeongju, and Hallyeohaesang National Parks, where the largest number of HH, HM, and MH grids occurred. Jirisan and Seoraksan National Parks (mountainous) had many HH, HM, and MH grids on their trail routes, main ridges, and mountain peaks (Fig. 8a). Gyeongju National Park (historical) had many HH, HM, and MH grids on major historical sites and hiking trails around the edge of the Gyeongju City area (Fig. 8b). Hallyeohaesang National Park (marine and coastal) had sporadically distributed HH, HM, and MH grids around some tourist hot spots (Fig. 8c).

4. Discussion

4.1. Relationship between characteristics of protected areas and tourism pressures

The findings show that highly accessible protected areas have high tourism pressures (Balmford et al., 2015; Hausmann et al., 2019). The Bukhansan National Park is located in the Seoul metropolitan area (with a population of 10 million) and is the representative case. It is the national park with the most visitors per unit area, as is recorded in the Guinness Book of Records (KNPS, 2019a). The high tourism pressures in protected areas located in many people living areas have both positive and negative attributes (Leung, Spenceley, Hvenegaard, & Buckley, 2018). On the positive side, many people can easily experience various ecosystem services from nature. With high accessibility, many tourists can easily enjoy recreational services and many local residents can maintain their health by regular hiking. On the other hand, protected areas located far from urban areas are often visited by less people, even though they have excellent natural environment. This means that the ecological welfare provided to people can be greater in the nearby located protected areas rather than the distant, and has a better natural environment. On the negative side, they are located in densely populated areas, thus their ecosystems are relatively more exposed to potential human pressures (Jones et al., 2018). Continuous tourism pressures bring about changes in ecosystem structures and functions through light pollution, noise generation, habitat fragmentation and loss, changes in species composition and movement restrictions, and reduced reproduction rates (Hall, 2010; Leung, Spenceley, Hvenegaard, & Buckley, 2018). Therefore, it is necessary to consider both sides of tourism pressures in the protected areas that are close to highly populated metropolitan areas. A tourism pressure management policy should be implemented to maximize the positive effects and reduce the negatives.

Although accessibility was relatively low, the protected areas that attracted visitors also had high tourism pressures. In Korean national parks, famous tourist destinations such as Hallyeohaesang, Seoraksan, Gyeongju, Jirisan, and Hallasan National Parks are examples. They are not surrounded by large cities and are located relatively far away from residential areas, making them less accessible. There are no charismatic megafauna such as the lions and gorillas found in Sub-Saharan Africa to cause ecotourism (Hausmann et al., 2017). There are, however, many attractive preferences that draw visitors such as magnificent and unique natural landscapes (Fyhri, Jacobsen, & Tømmervik, 2009), ruins reflecting the region's long history and culture, and unique local flora and fauna which cannot be seen elsewhere (Siikamäki, Kangas, Paasivaara, & Schroderus, 2015). Various activities such as eco-tourism, exploration of historical ruins, camping, sea bathing, and professional

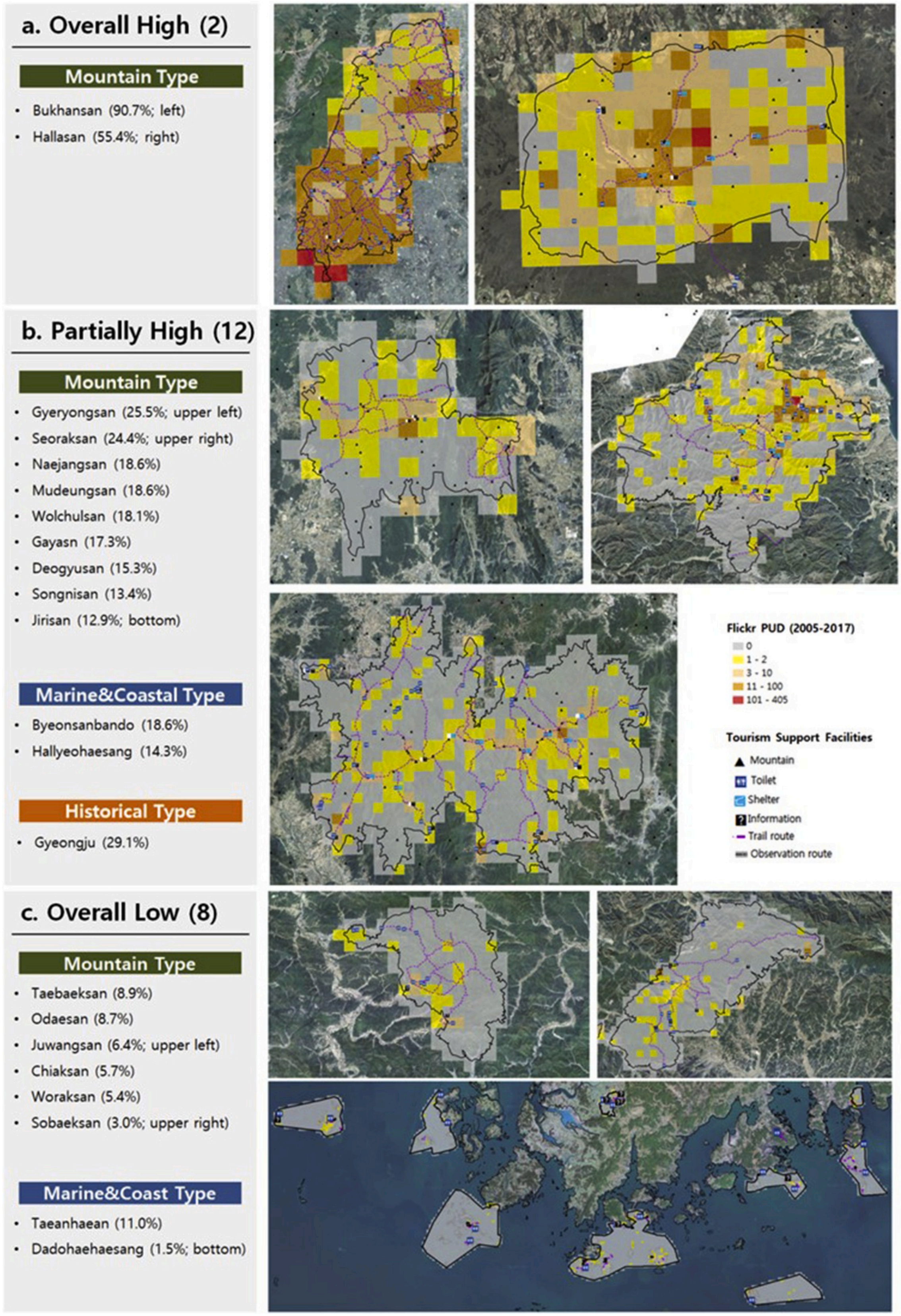

Fig. 4. The three categories for the spatial distribution of tourism pressures in national parks. (a) "Overall High" national parks where more than 50% of the grids exceed the average PUD value; (b) "Partially High" national parks where the proportion of grids above the average PUD value is 11.6% or more, but less than 50%; (c) "Overall Low" national parks where the proportion of grids above the average PUD value is less than 11.6%.

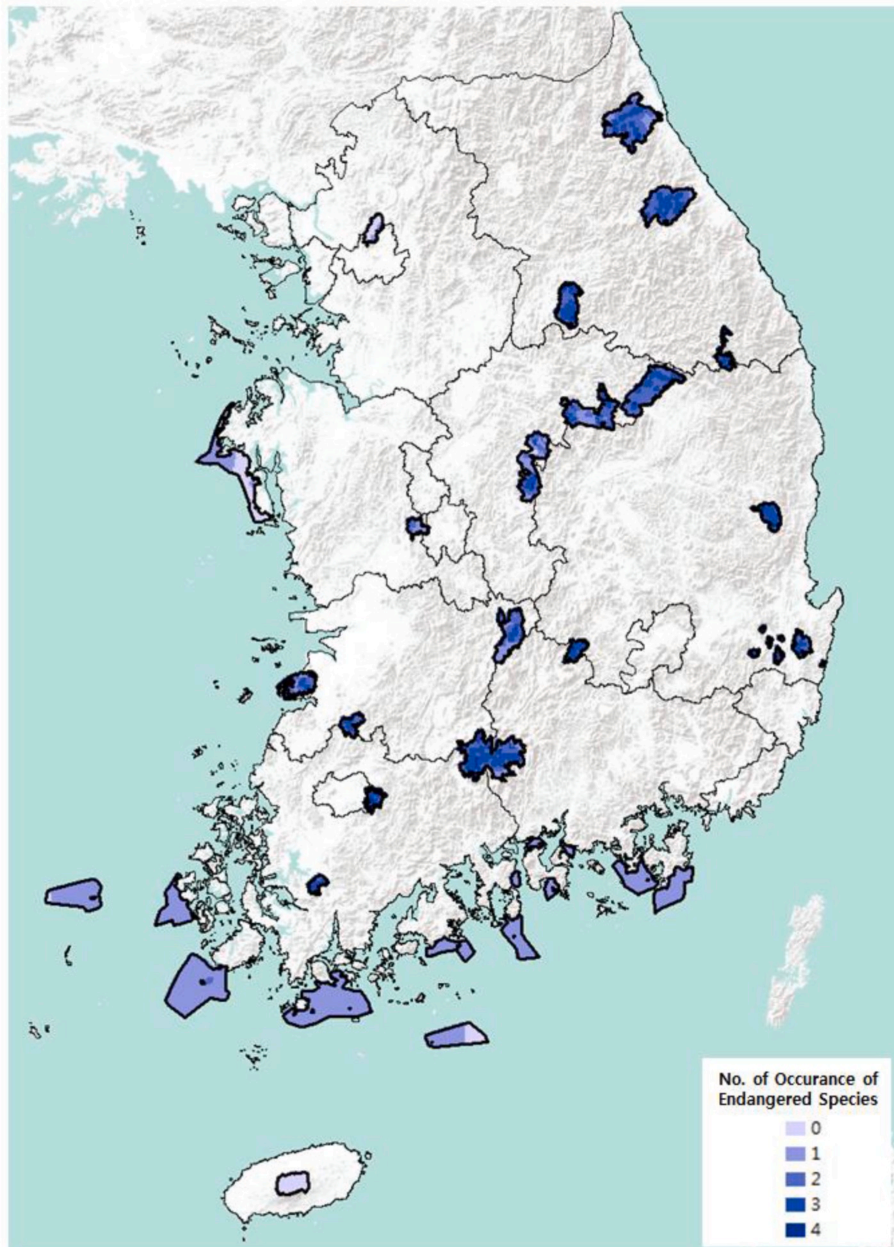

Fig. 5. Ecologically significant areas in 21 national parks: Number of species that could be habitable.

climbing are carried out.

There are also temporal (seasonal) differences in tourism pressures depending on the unique nature of each protected area and the purpose of the visit. For instance, the climbing and sightseeing at the mountainous parks means that tourism pressures are high in spring and autumn, whereas tourism pressures are high in summer for the marine and coastal parks. In this study, visitor statistics and flicker PUD also showed differences in seasonal distribution of tourism pressures. The Seoraksan and Naejangsan National Parks, famous for their autumn leaf color, were highly tourism pressures around the mountain peaks and valleys in autumn, while the Taeanhaean National Park showed high tourism pressures near beaches and coastal trails in summer (Fig. S3). Therefore, it is necessary to implement a customized tourism pressure management policy that considers the spatial characteristics of individual protected areas, the main types of visits, and the time (seasonal) differences. For example, in Seorak and Naejangsan National Parks, the place where tourists visit in autumn should be considered as a priority area for tourism pressure management. Taeanhaean National Park needs a policy to reduce the tourism pressure in coastal areas where visitors are concentrated in summer, especially beaches and coastal trails. Tourism pressures can be reduced by pre-visiting reservation or temporarily controlling access to trails, especially in hot spots where tourist concentration is high.

4.2. Using a Flickr as a tourism pressure analysis data

The results of this study show that the Flickr data can be used as a evidence for the magnitude and spatial distribution of tourism pressures in protected areas with active nature-based tourism. In this study, the difference of the tourism pressure by national park was shown similar to the visitor statistics, and the spatial distribution was well represented. This may be due to the characteristics of the Flickr data. Flickr started its service in 2004 and has over 100 million users. It is also a popular platform for people who love taking and sharing pictures (Hausmann

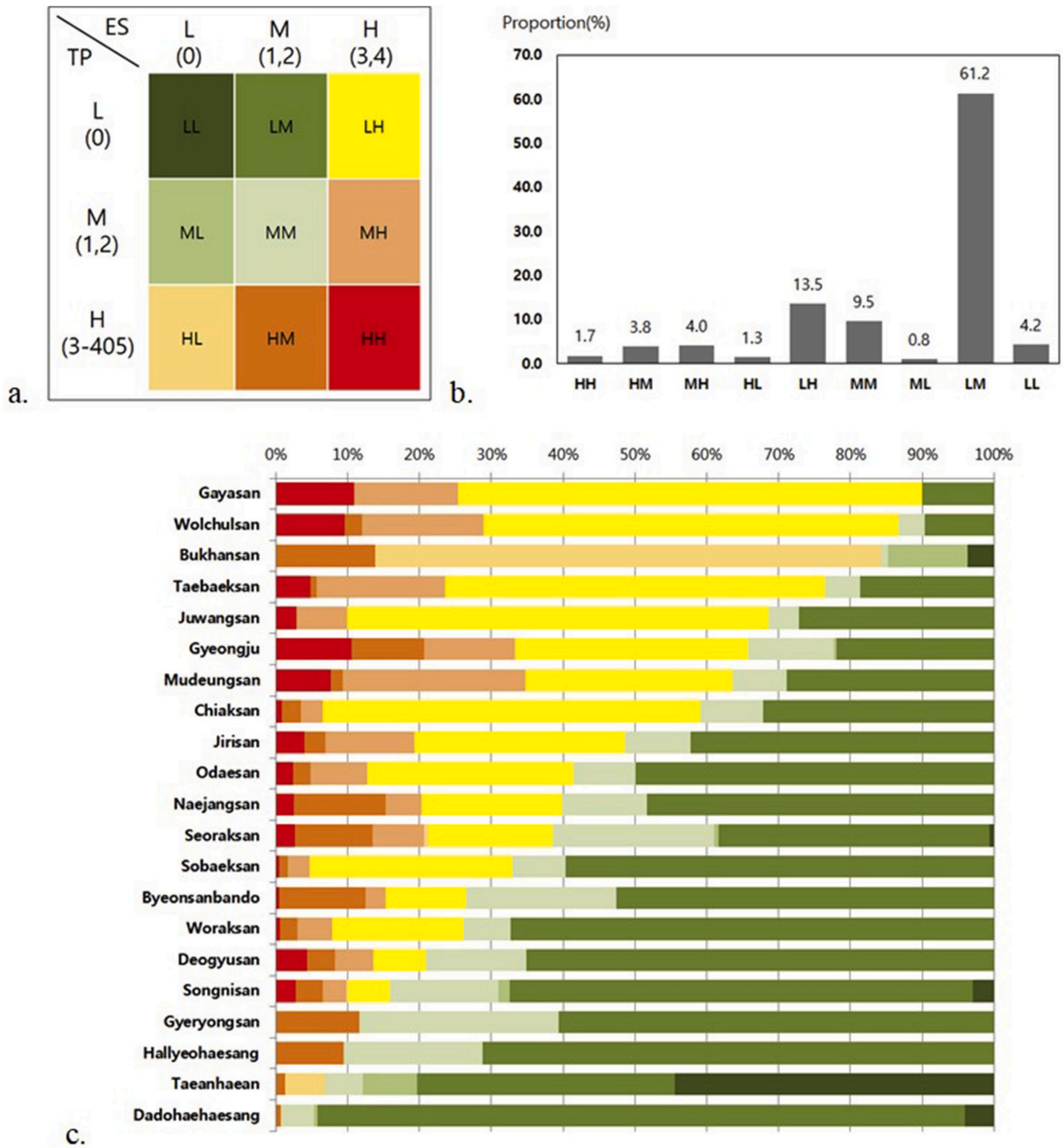

Fig. 6. The grid ratio of 21 national parks by nine overlapping types of tourism pressures (TP) and ecologically significant areas (ES). (a) Nine categories according to the degree of TP and ES (L: low, M: middle, H: high); (b) The proportion of grids by nine types in 21 national parks; (c) The ratio of grids by nine types in each of the 21 national parks.

et al., 2018; Sinclair, Ghermandi, Moses, & Joseph, 2019; Tenkanen et al., 2017). This suggests that Flickr data is more advantageous in analyzing nature-based tourism than other social media platforms, given that people refer to experiences that others have posted on SNS with photos when planning their trip (Parra-López, Bulchand-Gidumal, Gutiérrez-Taño, & Díaz-Armas, 2011). Because of these advantages, Flickr is widely used in researches analyzing spatial distribution and preference factors of visitors around the world, and reported to be highly reliable. Wood et al. (2013) found that the estimated visitation rate from Flickr in 836 resorts worldwide fits well with visitor statistics. Sessions, Wood, Rabotyagov, and Fisher (2016) found that Flickr can significantly predict seasonal difference of visitation rates in 38 national parks in the western United States. Kim et al. (2019) and Fisher, Wood, Roh, and Kim (2019) found that Flickr reflects the actual visitation rate in Asian Heritage Parks in Thailand and Jeju Island in Korea, respectively.

By analyzing the ecosystem survey data created through field surveys and the visitor distribution data based on social big data, like Flickr, protected area managers can spatially understand the ecological impact of the tourism pressure (Walden-Schreiner et al., 2018; Whitehead et al., 2014). Understanding the relationship between tourism pressures and environmental and ecological factors is critical to mitigating the impact on protected areas (Walden-Schreiner et al., 2018). This study shows the possibility of Flickr using with the various ecosystem survey data accumulated over the decades by protected area management agencies to analyze the direct and indirect effects of nature-based tourism on endangered habitats and ecosystem services at individual national park level.

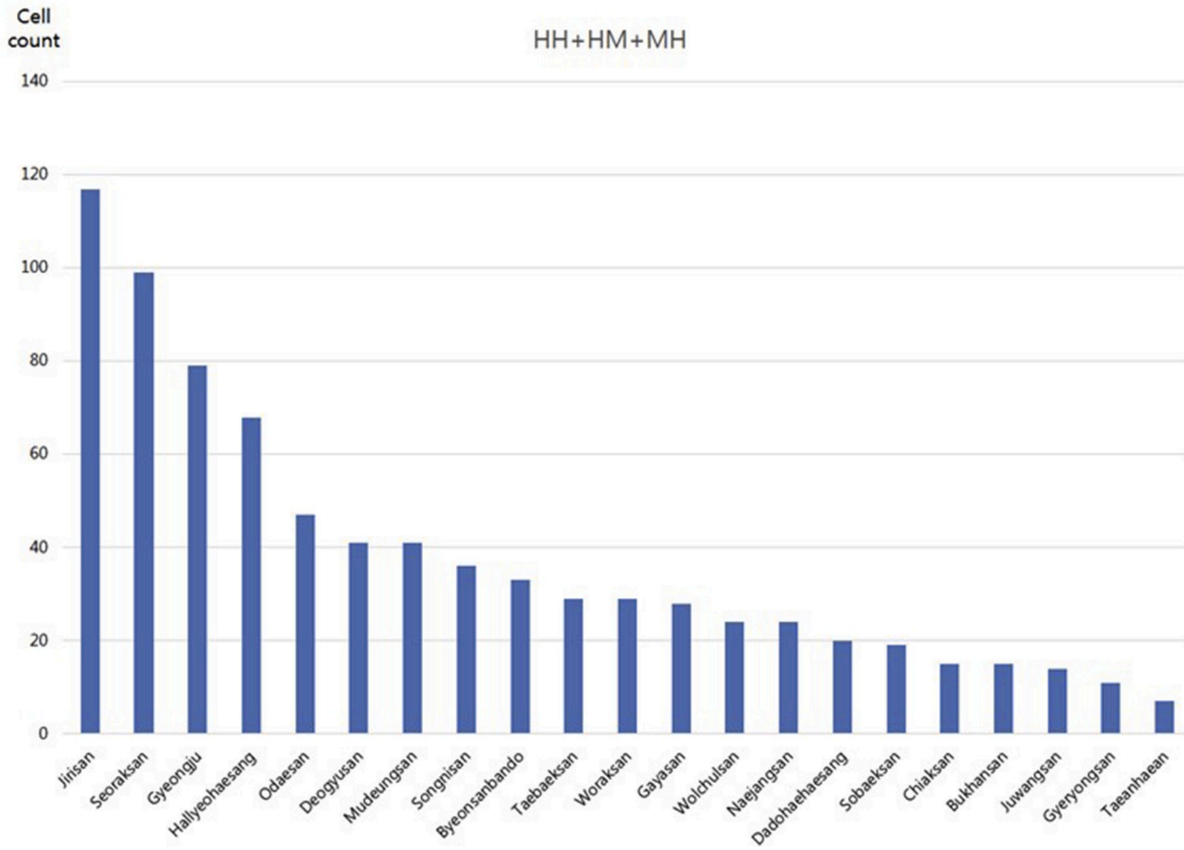

Fig. 7. Display of HH, MM, MH grids. Grids which relate to high tourism pressures and ecologically significant areas (HH), and grids which relate to one high area, and one medium or high area (HM, MH).

4.3. Ecological impacts of tourism pressures to protected areas

This study shows that the size of the tourism pressures varies between protected areas, suggesting that the impact on ecosystems may vary between protected areas. This means that tourism pressures can play a decisive role among the pressure factors affecting the protected area's ecosystems. The United Nations Environment Program (UNEP) has revealed direct pressures affecting ecosystems worldwide, including climate change, land-use change and habitat stress, unsustainable use and over-exploitation, and pollution and invasive alien species (UN Environment, 2019). Climate change is a common pressure factor that affects not only protected areas, but also natural ecosystems (Intergovernmental Panel on Climate Change [IPCC], 2014; UN Environment, 2019). Changes in land use brings about habitat conversion and degradation, which has a large impact on regional biodiversity and ecosystem services (Newbold et al., 2015). However, in protected areas, the regulation of the actions that cause these changes is made so that the ecological impact is smaller than that in the unprotected areas. The tourism pressure, however, varies greatly depending on the location, the size of demand, and the attractiveness of the protected area. While tourism pressures may be negligible in some protected areas, it can pose as a significant threat to the ecosystem in others. This implies that it is necessary to consider the tourism pressure first when implementing pressure factor management policies for the conservation of ecosystems in protected areas.

This study demonstrates that the protected areas that are smaller in size but have higher tourism pressures may experience an increased impact upon their ecosystems. This supports previous findings that smaller protected areas are more vulnerable to human pressure (Jones et al., 2018). Since the Bukhansan National Park has an excessive number of visitors per unit area (mean annual number of visitors is 91,111), it can be said that the entire park area is exposed to high-density tourism pressures (Fig. S2; Fig. 4a). Periodic visits to certain courses, especially for health care purposes, can lead to over-tourism that exceeds the capacity of the local ecosystems. The concentration of visitors to a relatively narrow area has a greater environmental impact on ecosystems and their functions (Drius et al., 2019). For example, this study found that the *Martes flavigula,* has a relatively wide range of behaviors (15 km) but was not found in Bukhansan National Park, and only *Prionailurus bengalensis* was found, which has a narrow radius of action (1.5 km), meaning that the habitat degradation of wildlife has already proceeded. Therefore, a management strategy must be urgently prepared to reduce the ecological impact of the national parks that have a small area, high tourism pressures, and high ecological importance. Permanent closure of trail routes, temporary entry restrictions, and enabling special protection regions using the IUCNs category *Ia*, "Strict Nature Reserve" are necessary. In the Philippines, Boracay Island (with an area of 10.32 km^2) was closed to tourists for six months in 2018 in order to limit tourism pressures, despite many concerns of regional economic losses.

This study reveals that the uneven distribution of tourism pressure between individual protected areas can lead to spatial differences in the impact on ecosystems. As shown in Fig. 4a, protected areas with high levels of tourism pressures will have a high ecological impact all around. In protected areas with partially high levels of tourism pressures as shown in Fig. 4b, the ecological impact will be concentrated around the hotspots where visitors are condensed. Where the tourism pressure is low and dispersed as shown in Fig. 4c, the ecological impact will be small. In addition, within the individual protected areas, differences in the spatial distribution of the tourism pressures lead to differences in the overlap between the tourism pressures and the ecologically important areas. In particular, different endangered species have different habitat conditions and different breeding seasons, so it is necessary to analyze

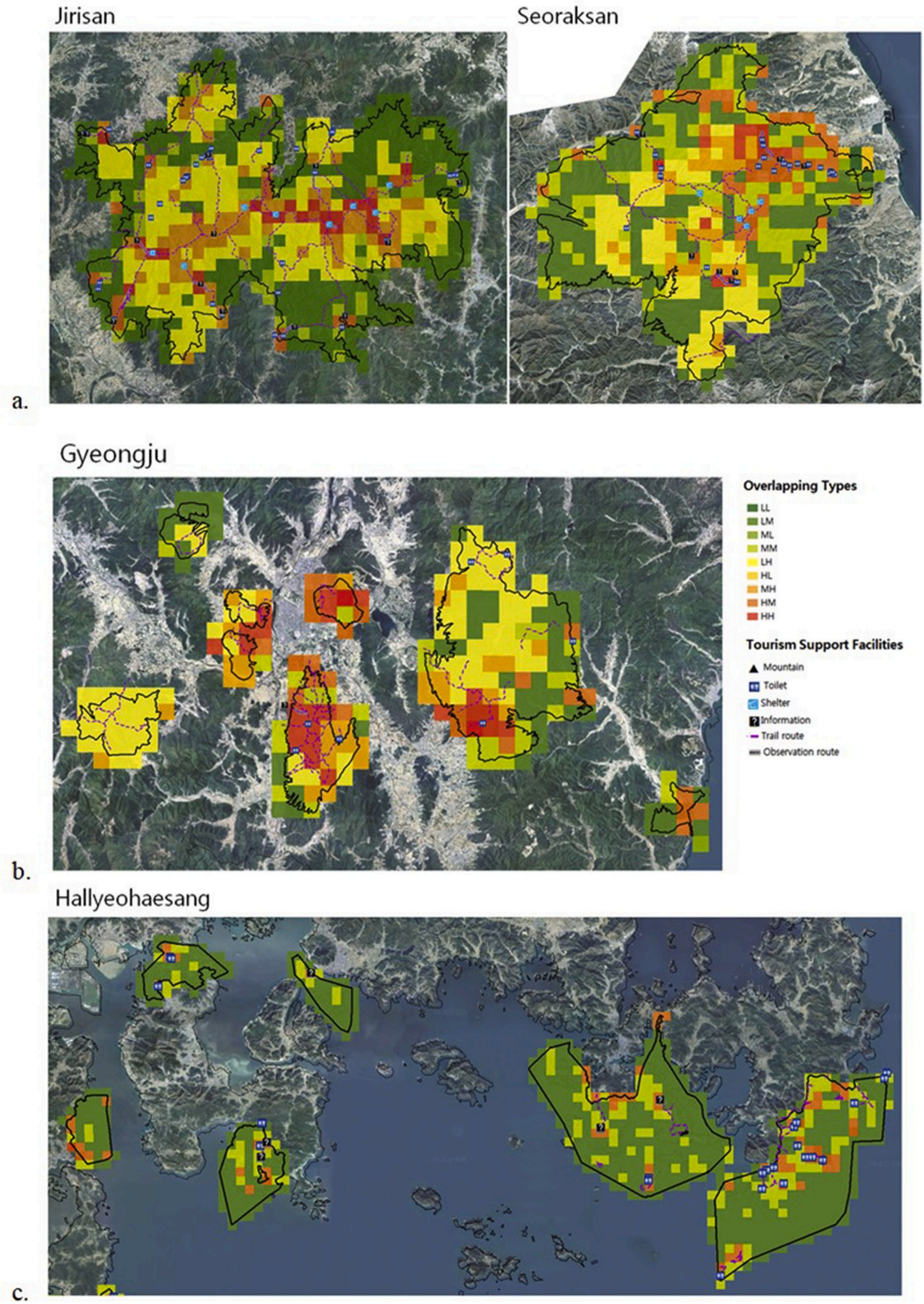

Fig. 8. Spatial distributions of the overlap of tourism pressures and ecologically significant areas. (a) Jirisan National Park and Seoraksan National Park (mountainous); (b) Gyeongju National Park (historical); (c) Hallyeohaesang National Park (marine and coastal).

the impact of tourism pressures on each season and on individual species. For example, as shown in Fig. 9, we identified areas where tourism pressures and habitats overlap in the breeding season of each species in Seoraksan National Park. This allows protected area managers to create spatially explicit tourism pressure management policies to protect endangered species in individual protected areas.

In addition, in the protected areas with high demands, when considering that the spatial distribution of the tourism pressure is related to the placement of tourism support facilities (Norman & Pickering, 2017), the ecological impact of tourism pressures may be high around the areas where tourism support facilities are located (Fig. 8). The construction of these facilities causes light pollution, noise, transport of vehicles, earthwork, waste, introduction of weeds, and pathogens. In addition, large-scale tourism support facilities have resulted in habitat fragmentation, collisions with wildlife and transportation vehicles, and the spread of invasive alien species (Leung, Spenceley, Hvenegaard, & Buckley, 2018). Therefore, it is necessary to manage the ecological impact of the tourism pressures of individual protected areas by considering the size and the spatial distribution of the pressures, and the layout of the facilities. Park managers need to monitor the various tourism support facilities in the park and analyze it with tourism pressure distribution data. This can provide management options, such as temporarily or permanently closing trails in areas where visitor pressure is high.

In this study, marine and coastal national parks had fewer regions overlapping both tourism pressures and ecologically significant areas than other in the national parks. This is due to the lack of data representing the ecological importance of marine ecosystems (KNPS, 2018b), and it does not mean that the ecological importance of marine ecosystems is inferior to that on land. This is similar in the marine protected areas of East Asia, where the pressure for visitation is increasing. Recent studies have shown that East Asian marine ecosystems are subject to relatively higher human pressure than other parts of the world (Halpern et al., 2008). In addition, human pressure is expected to increase significantly due to the economic and population growth, expansion of marine activities, and increase in marine ecotourism. This will not only change the ecosystem structure and function of East Asian marine protected areas, but also reduce marine ecosystem services such as the reduction of fish productions, which is the livelihood of many people in East Asia. Therefore, the tourism pressure applied to marine protected areas should be spatially monitored to find the locations where conservation is urgently needed. Detailed marine ecosystem habitat maps should be established to identify the vulnerable areas induced by the direct impacts of tourism pressures. In addition, it is necessary to introduce tourism support facilities that are specialized for marine protected areas so that tourism pressures can be properly managed, and

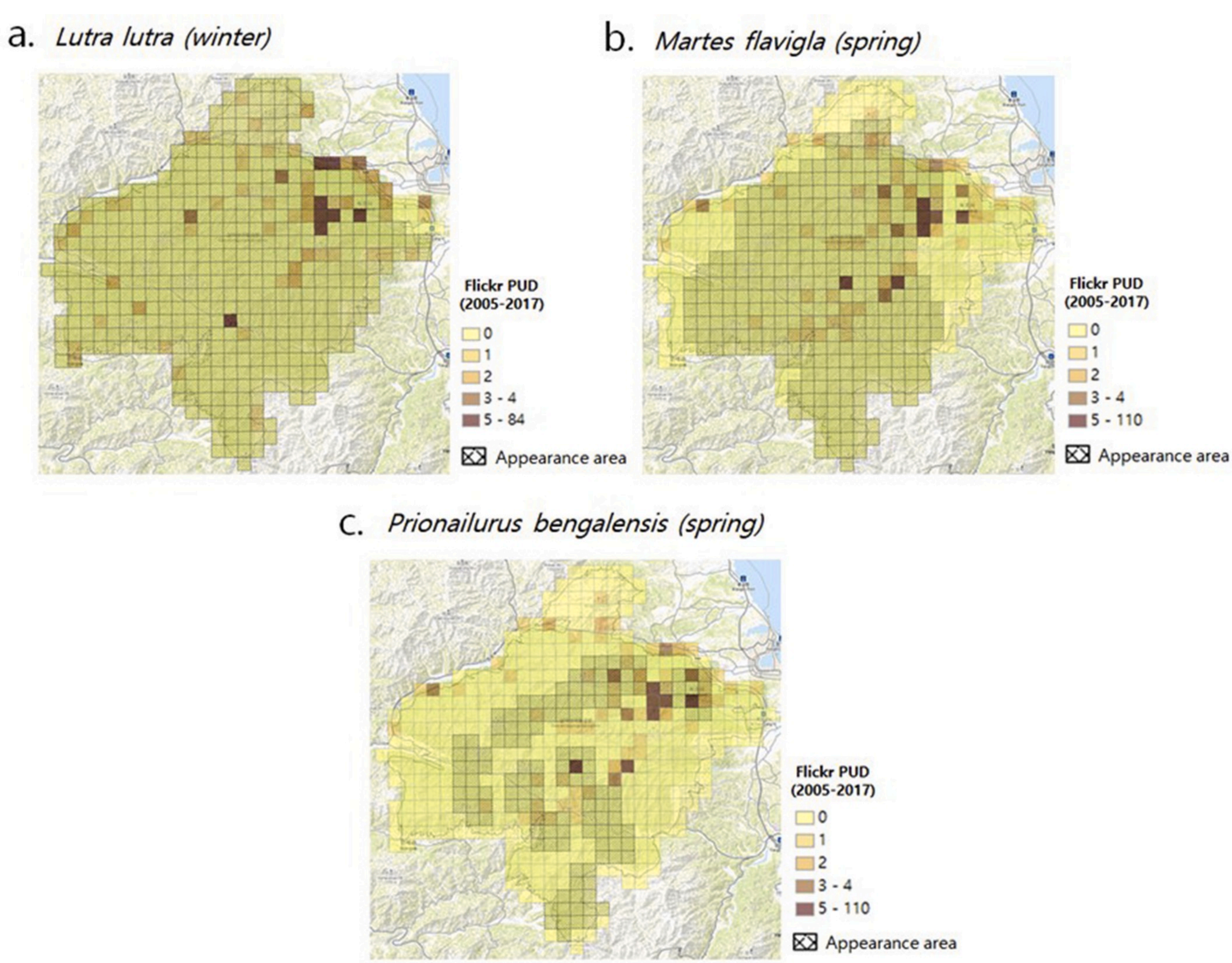

Fig. 9. Overlapping area of seasonal tourism pressures and endangered wildlife habitat in the Seoraksan National Park. (a) Seasonal tourism pressures and habitats of *Lutra lutra* (12~2 month); (b) Seasonal tourism pressures and habitats of *Martes flavigla* (3~5 month); (c) Seasonal tourism pressures and habitats of *Prionailurus bengalensis* (3~5 month).

the ecological impact can be reduced.

4.4. Future policies to manage tourism pressures

All protected areas have conflicting obligations to both preserve nature and delight visitors (Brown & Weber, 2011). Globally, national park management agencies earn 84% of their funding through ecotourism, and in developing countries, the economic returns from protected areas are of national importance (Balmford et al., 2009; Watson et al., 2014). However, human activity affects regional biodiversity and changes ecosystem functions (Newbold et al., 2015) which ultimately results in reduced ecosystem services and reduced social benefits to mankind (Millenium Ecosystem Assessment, 2005). Before it is too late, it is urgent to establish and implement a strategy to manage the tourism pressure to protected areas at an appropriate level.

In protected areas with high tourism pressures, like the small national park of Korea, urgent action must be taken to reduce the tourism pressure. Individual protected area managers need a policy to actively disperse visitors from areas with high pressures and induce them to areas with fewer visitors. For example, as shown in Fig. 10, the tourism pressure management area can be selected using the overlapping analysis of the tourism pressure and ecologically significant areas. Visitors can actively participate in conservation activities in protected areas through Flickr-based tourism pressure distribution information. People are generally aware of the need to preserve ecosystems in protected areas, but they lack information about when and where they visit have

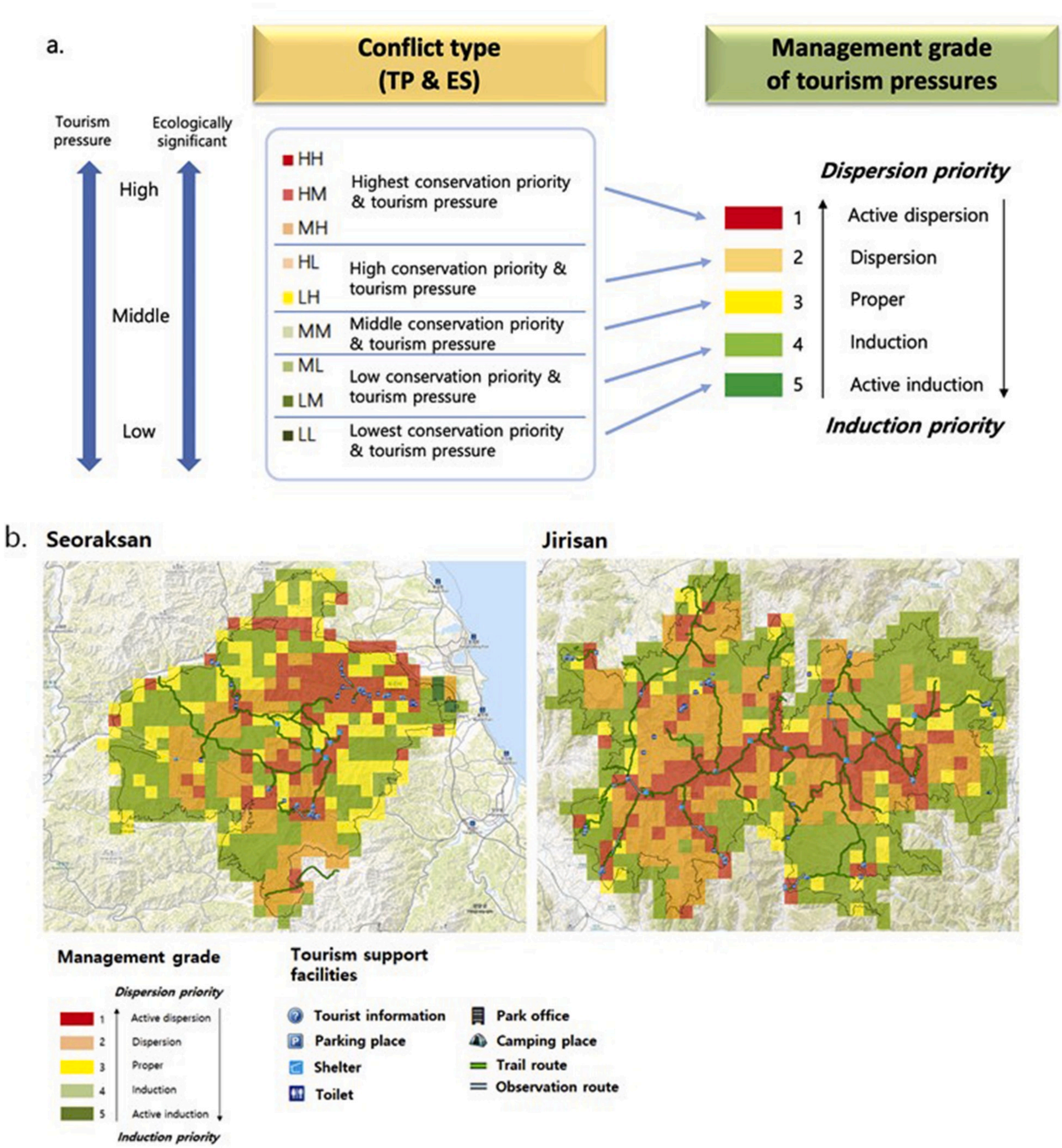

Fig. 10. Tourism pressure management areas of Seoraksan and Jirisan National Park. (a) Grade of tourism pressure management area and its classification methods; (b) Tourism pressure management areas of Seoraksan and Jirisan National Park.

less impact on the ecosystem. Therefore, as shown in the results of this study, a map of tourism pressure distribution and habitat information of endangered species should be provided to help visitors adjust the timing and destination of visitations to protected areas.

Based on the results of this study, we propose the following management directions to reduce tourism pressures and ecological impacts in protected areas. First, maximize the positive impacts of tourism pressures and minimize the negative impacts, especially in protected areas with high tourism demand. Second, in order to reduce the tourism pressures in small protected areas where over-tourism occurs, tourism support facilities should be reduced or relocated, and all tourism should be temporarily halted when necessary. Third, management strategies for tourism pressure hotspots should be established and implemented, considering the characteristics (location, type, spatial distribution of tourism pressures) of individual protected areas. Fourth, basic survey data necessary for the conservation of marine ecosystems should be established, and tourism support facilities that are specialized for marine protected areas should be introduced. Fifth, tourism pressure should be periodically monitored spatiotemporally by using social big data and visitor statistics. Sixth, the hot spots of tourism pressures should be analyzed, and ecologically vulnerable areas should be identified to prepare ways to reduce the ecological impacts to protected areas.

5. Conclusion

This research is of great importance in two aspects academically. First, we found out Flickr, a social big data sharing user's photograph, can be used as quantitative evidence for understanding the size and spatial distribution of nature-based tourism in Korean national parks. Second, we spatially overlapped the social big data representing the spatial distribution of visitors and the endangered wildlife distribution data representing ecologically significant areas. This allowed us to quantitatively and spatially analyze the impact of tourism pressures in protected areas through the nature-based tourism. In terms of policy implementation, this study shows spatially conflicting areas with tourism pressures and ecologically important areas. This helped the protected area manager establish a spatially explicit tourism pressure management option. Due to the limited availability of social big data, only Flickr was used to identify tourism pressures in Korean national parks. However, this study provides good implications for the management of the high tourism pressures in protected areas like Korean national parks, and has important values in terms of ecosystem services. In particular, spatially explicit management options could be made using the hotspot maps of tourism pressures.

However, there are some research gaps that remain within the field, and we suggest the following as potential topics for future studies. It is necessary to evaluate the impact of tourism pressures on the protected areas in socio-economic terms using various big data such as credit cards and mobile phones. These studies can help to attract human attention, which is essential for the management of ecosystems in protected areas, and can help maximize the positive impact of tourism pressures. Research is needed to develop a model that predicts future tourism pressures in protected areas using visit demand statistics and various big data.

Declaration of competing interest

The authors declare no conflict of interest.

CRediT authorship contribution statement

Joungyoon Chun: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing - original draft, Writing - review & editing. **Choong-Ki Kim:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing - review & editing. **Gang Sun Kim:** Data curation, Formal analysis, Methodology, Software, Validation, Visualization. **JuYoung Jeong:** Investigation, Resources, Writing - review & editing. **Woo-Kyun Lee:** Methodology, Writing - review & editing.

Acknowledgements

This research was supported by the project titled 'Marine Oil Spill Risk Assessment and Development of Response Support System through Big Data Analysis,' of the Korea Institute of Marine Science & Technology promotion, funded by the Korea Coast Guard, grant number 20190439.

This research was also supported by the project titled 'Marine ecosystem-based analysis and decision-making support system development for marine spatial planning,' of the Korea Institute of Marine Science & Technology promotion, funded by the Ministry of Oceans and Fisheries , grant number20170325.

This research was conducted by the Korea Environment Institute and supported by the Korea National Park Service.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tourman.2020.104136.

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