Nature on Bonaire and social media behavior

Assessing the spatial distribution of tourism and recreation on Bonaire through social media

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NATURE BY NUMBERS

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Content

1. Introduction

Tourism is a very important source of income on Bonaire and forms the most important economic pillar of the island. The tourism numbers are expected to grow in the coming years. Insights into the number of visitors to specific areas on Bonaire and their impact on the different important ecosystems in terms of pollution, trampling, noise, coastal development, and disturbance in general, are, however, lacking. Without insight in the amount of tourists that visit natural areas, the impact of tourism on ecosystems on Bonaire remains unclear. This means that nature managers do not have the necessary information to steer tourism and effectively manage these ecosystems. This situation carries the risk that visitation rates will exceed the carrying capacity of ecosystems on Bonaire. Schep et al. (2013) find that the main reason to visit Bonaire is the natural environment for most tourists. This implies that if the threshold of nature's carrying capacity is breached, the island's tourism industry is likely to collapse as well. The marine and coastal ecosystems are still relatively resilient compared to other Caribbean islands, but if the ecological threshold is breached, there is a high probability that the ecosystems such as coral reefs and sea grass beds will be permanently damaged.

In this study we analyze the usage of social media data to provide insights into the behavior and characteristics of tourists on Bonaire based on data from Instagram, Panoramio and Flickr. We carried out this pilot study in Bonaire to gain an understanding of the spatial movement of tourists and the number of tourists that visit different parts of Bonaire. Analyses of social media have an enormous potential to reveal the spatial behavior of tourists and also the magnitude of the tourism activity in specific areas. For example, several studies show a striking correlation between social media activity and actual visitor numbers of national parks (Casalegno et al., 2013; Dunkel, 2015; Ruths and Pfeffer, 2014; Wood et al., 2013).

Most studies into tourists' preferences for certain ecosystems make use of stated preference methodology, such as choice experiments and questionnaires (Van Zanten et al., 2014). However, these methodologies are not based on actual behavior. Social media, on the other hand, do reveal actual preferences of a broad sample of the population. In this study we used social media data to answer the following two research questions:

1. *Which ecosystems are most popular with locals and tourists?*
2. *Which aspects of the natural environment of Bonaire are of interest to tourists?*

On the basis of the answers to these questions, the local government can get insights into the relative importance of locations for nature-based tourism on Bonaire and incorporate this knowledge in their nature policy, their economic policy related to tourism and their Spatial Development Plan. The Tourism Corporation Bonaire can use this information to more effectively target potential tourists and thus improve the design of strategic instruments, such as their Strategic Tourism Plan, which aims at developing a sustainable strong tourism industry on Bonaire. Moreover, this analysis provides insights into the main activities tourists perform, and therefore, into the potential pressures and impacts these can have on the different ecosystems of Bonaire. This, in its turn, is relevant information for STINAPA, who manages the protected areas. Such information can be used by the local government together with Tourism Corporation Bonaire and STINAPA to develop a strategic plan to sustainably develop their strongest economic pillar: tourism.

1.1. Social media and environmental studies

Social media play an increasingly important role in people's lives. In 2014, around 75% of the internet users in the U.S. was active on social network sites. Common examples are Twitter, Facebook, Instagram, Panoramio and Flickr. This increasing usage of social media, where thoughts, opinions, photos and videos are shared with either the public or friends, has caught the attention of researchers as well. The data gathered from these platforms contain a wealth of information that is otherwise only accessible through extensive surveys and experiments. Most social media platforms provide an Application Protocol Interface (API) that allows users to access and communicate with their database of publically visible posts by users. The API can also be used to download social media data for quantitative analysis. These data are not only of interest for marketing purposes, but provide large amounts of information for environmental researchers as well. In previous research, Twitter has been used for analyzing the magnitude of natural hazards, and Panoramio was successfully used as a proxy for national park visitation rates (Casalegno et al., 2013) and mapping of visual preferences across Europe (Tieskens et al., 2014). Social media is increasingly becoming a tool to assess the tourism values of nature (Wood et al., 2013). One of the key features of social media data is that these are voluntarily provided, in contrast with data from experiments, surveys or dedicated photo upload websites to gain knowledge on people's preferences. Without being asked, social media users upload content that often includes their appreciation of the (natural) environment.

In this pilot study we used social media to analyze the behavior and preferences of tourists and locals on the small Caribbean island of Bonaire. We downloaded metadata from photos uploaded on the platforms Flickr, Panoramio and Instagram to see where tourists go, what places they like and what kind of activities they engage in. In this study we focused specifically on the non-built up environment to assess which ecosystems of Bonaire are the most appreciated by visitors, but also which ecosystems face the highest threats of degradation due to human impacts caused by high visitation rates. The results of this study can of course be used to gain insights into the preferences for particular ecosystems and the activities people perform there.

In this report we will first briefly discuss the applied methodology. In the following section we describe the results and subsequently discuss the most important results.

2. Methodology

We used data from different platforms to get a broad population of social media users but also because the focus of these platforms is slightly different. Panoramio and Flickr are platforms that are mainly used by amateur photographers that use the platform to store their photos, but also to make them available to the public. Photos on these platforms often carry a geotag which reveals the exact location of the photo stored in the metadata of photos taken with cameras with a GPS signal. Although Instagram also limits its posts to photos and occasionally a video, Instagram has a different focus and use. It is often used by (a relatively younger) crowd to report activities that create a digital image of the user. Instagram photos feature the appearance of users or their friends more often than the other platforms. Although Instagram photos include geographic coordinates, the usage of the exact location in Bonaire is problematic as images are geotagged only where there is coverage by 3g or 4g networks. This limits the use of Instagram data for detailed spatial analysis on a small island with limited network coverage.

The emphasis on the environment and the exact geotags make Panoramio and Flickr very useful as a proxy for visual preferences of people. Therefore, we used data from these two platforms to

map the spatial variation of visual preferences for the environment on Bonaire. Since the geotags in Instagram are less reliable, and the main focus of this platform are activities rather than the environment, we used Instagram to assess different types of activities people do in Bonaire. Since Instagram is a tool that is used often on a daily basis it can also provide insight into the daily lives of people, including their home country or their visit purpose (e.g. a Caribbean cruise visiting many Caribbean islands, a longer stay on Bonaire, or a local resident on Bonaire).

We also considered Facebook and Twitter as potential data sources. However, at the time of writing Facebook did not provide a tool to download a sufficient amount of data based on local searches while Twitter only provided access to a very small section of its data for public use.

3. Data collection

3.1. Panoramio

Panoramio is a platform owned by Google that enables its users to upload photos to the internet and optionally display them on Google Earth. Panoramio photos are often photos of the environment, either urban or rural. The Panoramio REST API (Panoramio, 2015) provides the opportunity to download publically available photos and its metadata such as date, title and lat/long coordinates in a given geographical bounding box (per query a bounding box must be set with minimum and maximum x and y coordinates). Per query, Panoramio allows 100 photos to be retrieved. To ensure we downloaded all photos, we divided Bonaire in bounding boxes of 0.01 degree by 0.01 degree and downloaded the data separately for each bounding box. This method yielded 4,524 photos in total. The queries were automated using Python.

To avoid a bias of very enthusiastic users photographing, for instance, their favorite beach a hundred times, we filtered the data so that only one photo per user per kilometer is taken into account. The total number of Panoramio unique user per kilometer uploads was 1478 photos.

All photos downloaded from Panoramio correspond to the period between the early days of Summer 2005 and February 2016.

3.2. Flickr

Flickr is a photo sharing platform, which is similar to Panoramio, and is mainly used by amateur photographers. Flickr's database of public photos has a similar size to Panoramio's. Flickr's API works almost identically to Panoramio's (Flickr, 2016), with the difference that Flickr's geographical search parameter works to one search point with a given radius. We used a diamond grid of points each 2 kilometers to cover the entire region of Bonaire and download the data (see figure 1). Duplicates as a consequence of overlapping radius circles were removed. We applied the same method to have unique user uploads per kilometer. Flickr data were downloaded from its start in late 2004 until February 2016

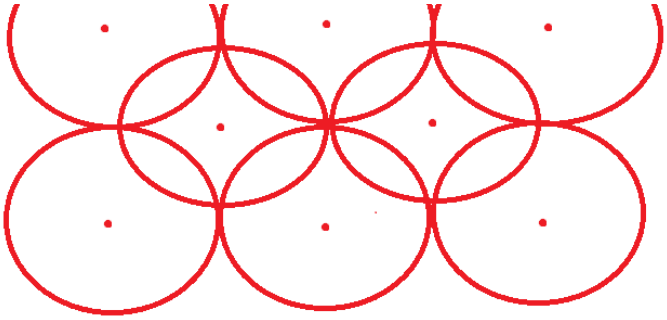

Figure 1 - Download points with 2 km radius for the Flickr API.

We combined the Flickr and Panoramio datasets and displayed the photos from the links provided by the API in Microsoft Excel to categorize the photos according to the scene it displayed. We used 6 categories:

1. Coastal: pictures of the coastline;
2. Underwater: underwater photography by divers and snorkelers (with and without marine wildlife);
3. Seascapes: scenic photos of the seascape (above water) and watersports;
4. Terrestrial landscapes: photos of terrestrial natural landscapes (excluding terrestrial wildlife);
5. Wildlife: pictures of terrestrial wildlife and birds (i.e. everything excluding marine wildlife);
6. Other: mainly indoor and urban photos.

3.3. Instagram

Instagram photos were downloaded using the same method as with Flickr. Not all Instagram posts have coordinates as geotags are an optional contribution to Instagram uploads. As we are interested in Bonaire Instagram posts only, we were confined to Instagram posts with a geotag. This method yielded 95,574 Instagram posts. We applied the same unique user per kilometer filter as in the other platforms to have 5,847 photos left. The Instagram posts were categorized using the same method and categorization.

To define the home location of Instagram users we downloaded the last 20 posts of each user and assumed the country where most posts are located is the home country of the user. In addition, we downloaded all posts by each user one week prior and one week after the first posts on Bonaire, to define what type of visitor or local the user is. Users were classified as cruise tourists if they only posted on one day in Bonaire and had at least one post in another Caribbean Island in the week prior to or after this post. If they had only one post in Bonaire and the majority of other posts were from Aruba or Curacao in the week before and after that post, we assumed a day-tripper from these islands. Other users were classified as either local or stay-over tourist based on their previously defined home location. Instagram data were downloaded for the last two years, starting in February 2014 until February 2016.

4. Results

4.1. Panoramio and Flickr

Which ecosystems are most popular with locals and tourists and for what natural aspects?

To answer this question, we investigated the spatial distribution of different photos uploaded to the photo sharing platforms Flickr and Panoramio. Figure 3a shows the general density of uploaded photos where the natural environment played a significant role. The most striking pattern, emerging from this distribution, is the high density of photos on the south western coast line. This part is the most densely populated area and contains the most tourist facilities. It is also the leeward side of the island, with a much calmer sea compared to the eastern side of the island. The southern coastline with the salt pans, however, is much less densely populated but is a clear hotspot of photos. Other hotspots can be found at the north-western North side of Klein Bonaire, at Gotomeer, Lac Bay in the east and the coastline along Washington-Slagbaai National Park.

As shown in figure 2, on more than three quarters of the photos uploaded with a geotag to Bonaire, the non-built-up environment plays a significant part. More than 600 photos (26% of the total) showed the coastline or surrounding seascape. Since modern cameras often have the ability to make photos underwater, a significant part of the photos had a diving or snorkeling theme. Other water activities such as sailing and surfing only form a small part of the data. Strikingly, one of the categories with more photos uploaded on Bonaire is the landscape category (25% of the total). A similar share of the photos was taken in either an urban environment or even indoors. This type of photos belongs to the category 'not related to nature", which is not further discussed in this report, as it is not related to Bonaire's natural environment.

In figure 3b to figure 4b, the distribution of all the specific photo categories is displayed. Coastal photos are, not so surprisingly, clustered along the coastline. Coastal photos show the same pattern previously observed in figure 3a, with most photos along the western coastline, but in this case with remarkable hotspots along the coastline in the Washington-Slagbaai National Park, the southern coast and Lac Bay. Reef photos (diving & snorkeling) (figure 3c) are more concentrated along the western coast near Kralendijk, coinciding with diving schools and diving or snorkeling spots. Seascape photos are found near Kralendijk as well (mostly sailing photos) and at a windsurfing spot at Lac Bay. The terrestrial landscape photos are more scattered across the island. They can be found mainly in National Park Washington Slagbaai, along the southern coastline and at Gotomeer. The wildlife photos are in two very distinct places: Kralendijk and Washington-Slagbaai National Park.

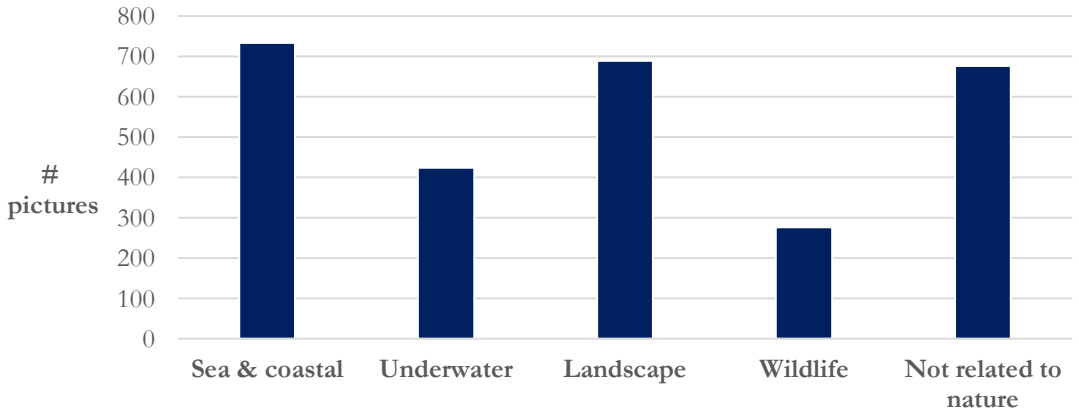

Figure 2 - photo categories Flickr and Panoramio

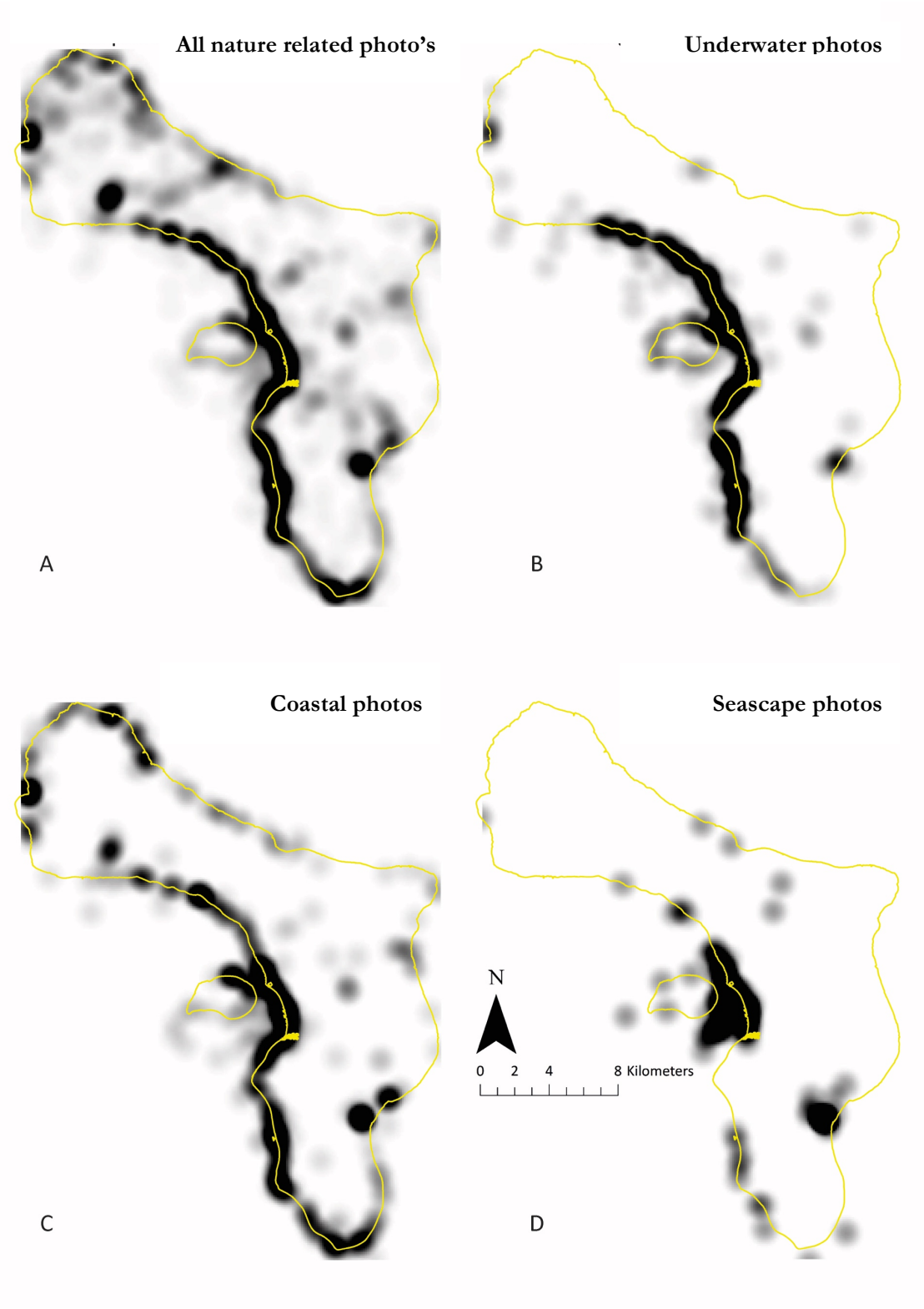

Figure 3 Photo densities Flickr Panoramio per category

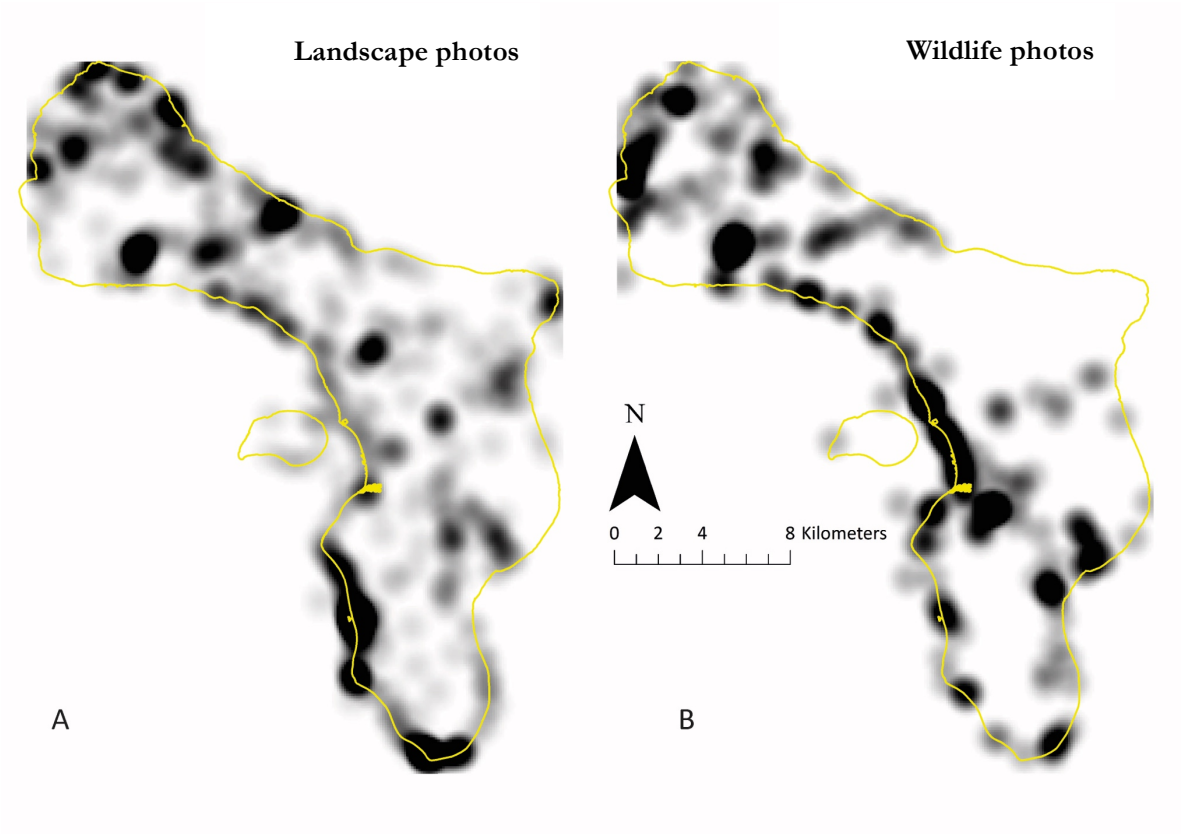

Figure 4 - Photo densities Flickr Panoramio per category

Almost 90% of all photos uploaded to Flickr and Panoramio (excluding photos not related to nature) were located in the thirteen areas listed in Figure 5. Figure 6 shows that the biggest density of photos was found along the coast of Kralendijk. The Salt Pans and Pekelmeer had slightly lower densities but still contain a relatively large number of photos per square kilometer. Obviously, most coastal and diving photos were taken in the coastal areas of these natural sites. Terrestrial landscape photos are remarkably present in the Pekelmeer, where landscape photos were mainly of the Slave Huts, the Salt Pans, and the National Park. The number of wildlife photos in the national park is also relatively high. Although the density of photos in the National park is low compared to the other nature areas, the total number of photos that are related to nature is. The reson for this is that the National Park is considerably larger than the other natural areas in this analysis.

Other areas, which are known for their natural attractions, such as Lac and Klein Bonaire have a relatively low density and a low absolute number of photos uploaded. It has to be noted, however, that within certain areas (such as Lac) visitors might still concentrate at specific locations (e.g. Sorobon within the Lac area).

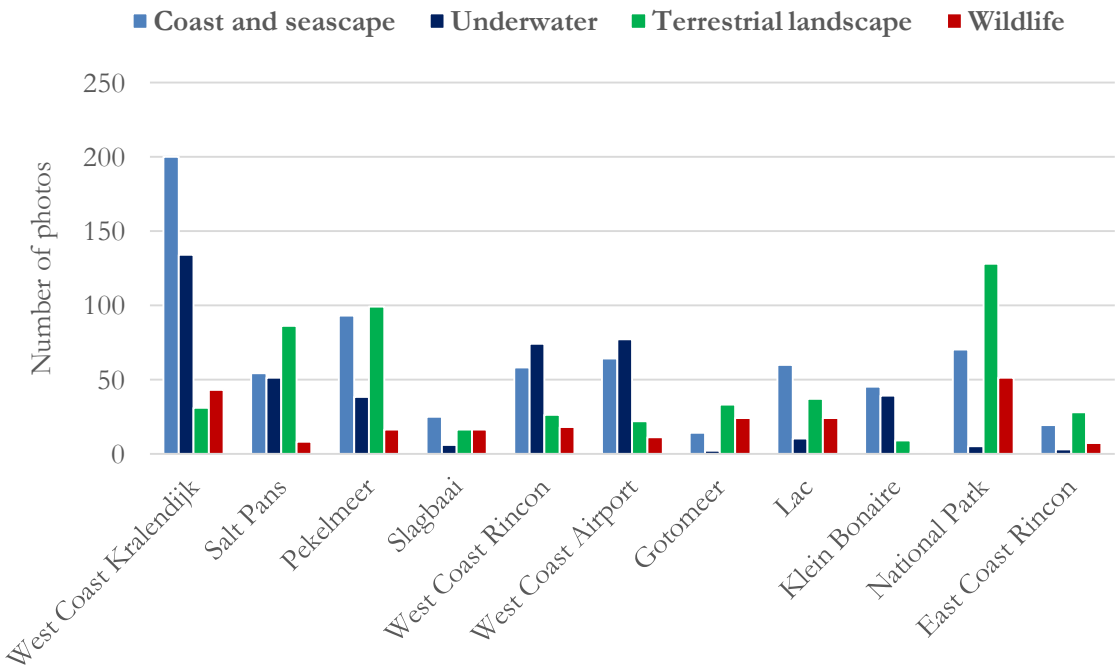

Figure 5 – Photos per category in natural area from unique users per km²

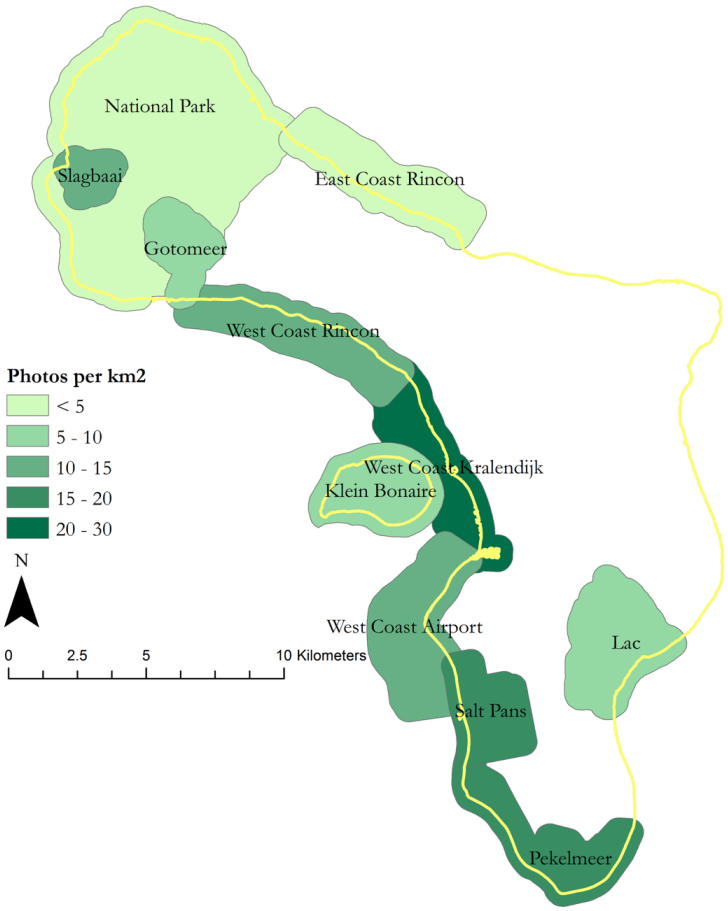

Figure 6 - Photo density in natural areas Flickr Panoramio

4.2. Instagram

We used the geotagged photos uploaded to Instagram to answer the following question: *What kind of people visit the natural environment of Bonaire?* In the analysis of Instagram photo uploads on Bonaire we were able to distinguish between cruise tourists, stay-over tourists and Bonairean locals by analyzing the Instagram patterns of users that upload photos on Bonaire. Moreover, we were able to estimate the origin of Instagram users by looking at the pattern of their Instagram posts.

Based on the procedures described in the methodology, we found the following distribution of origin (Figure 7) and type of Instagram users on Bonaire (Figure 8)

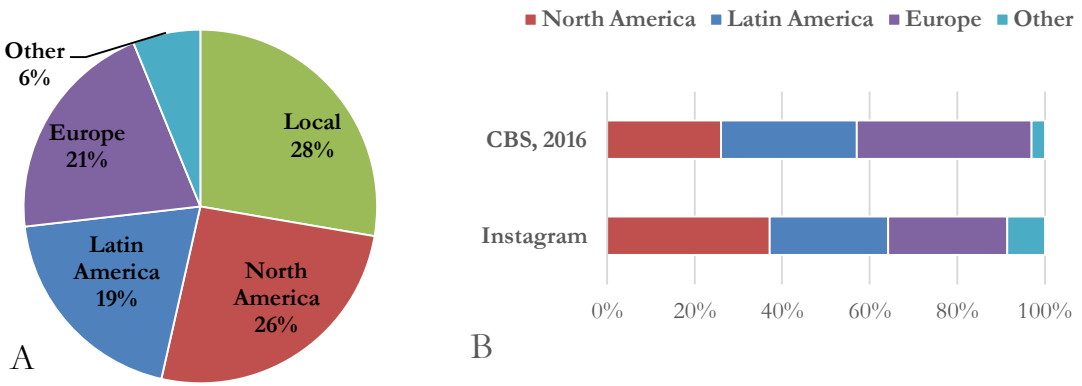

Figure 7 - A. Origin of Instagram users on Bonaire. B. Comparison of tourist origin according to the Instagram data and data from the Central Bureau of Statistics (2016)[1].

As observed in the comparison presented in Figure 7-b, the distribution of tourist origins slightly deviates from the data by the Dutch Central Bureau of Statistics (CBS). This comparison shows that our analysis results in more visitors from North America and less visitors from Europe than the estimates from the CBS. These differences canz either be accounted to the fact that the population of users of Instagram is different from the total population of tourists and locals on Bonaire (e.g. Instagram can be more popular among tourists from North America). Another explanation is that it is difficult to exactly pinpoint someone's origin solely based on Instagram posts. However, the results in this study give a rough indication of the origin of people on Bonaire and seem to be representative of the tourist population on Bonaire.

Regarding the type of Instagram users on Bonaire, only 28% was identified as being local to Bonaire. This means that almost three quarters of Instagram users can be considered visitors. 18% was identified as a cruise tourist and 54% as a stay-over tourist (Figure 8a). A comparison if these results to data on the number of visitors in 2014 by the CBS Caribbean Netherlands, there seems to be a higher percentage of stay-over visitors in the Instagram data (Figure 8b). Stay-over tourists, however, visit Bonaire much longer than cruise tourists. The average stay-over tourist spends on average 8,2 days on the island, while cruise passengers only visit the island for a single day. This leaves much more opportunity for a stay-over tourist to upload pictures to Instagram. Taking into account the days of stay in the division of cruise and stay-over tourists indeed seems to be more in line with the division of Instagram data.

[1] http://statline.cbs.nl/Statweb/selection/?DM=SLNL&PA=83191NED&VW=T

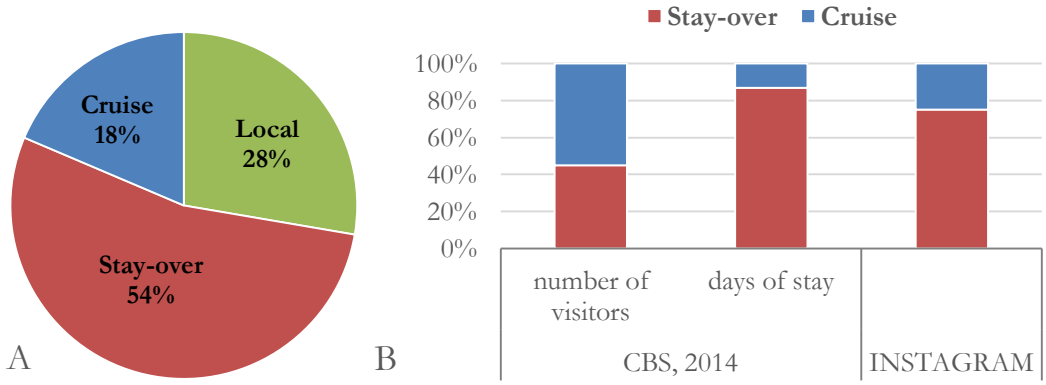

Figure 8 - A. Type of Instagram users on Bonaire; B. Division of stay-over and cruise tourists on Instagram compared to data by CBS Caribbean Netherlands from 2014.

4.3. Comparing social media datasets

When analyzing the type of photos people uploaded from Bonaire, it is observed that a larger share of the photos on Instagram does not emphasize the natural environment compared to Flickr and Panoramio. These results suggest that Instagram is more commonly used to report activities of the user him- or herself than it is about capturing the beauty of the natural environment of Bonaire. In a vast majority of Instagram photos, the main themes were people, urban and indoor settings rather than the scenic natural environment. On the contrary, the majority of Panoramio and Flickr photos on Bonaire do not feature any human beings.

Based on these differences, Instagram was chosen as a better platform to give insights into the activities people engage in. Table 2 shows that of the photos regarding the environment, over 60% of the pictures showed the coastline and/or seascape of Bonaire. This indicates that the beaches and rocky coastlines are extremely popular among the Instagram users on Bonaire. A considerably smaller percentage of the Instagram posts is about snorkeling and diving. Terrestrial landscapes and wildlife form an even smaller share of the total uploads. The relative importance of different aspects of the natural environment does not differ much for the different types of users on Instagram. There is a substantial difference in the relative importance of natural aspects compared to Panoramio and Flickr.

Table 1 - Photo categories and type of tourist Instagram Bonaire

	Cruise	Local	Stay-over	Total Instagram	Panoramio and Flickr
Coast and seascape	37%	34%	38%	37%	28%
Underwater	6%	9%	11%	10%	17%
Landscape	8%	7%	8%	8%	20%
Wildlife	3%	2%	4%	3%	9%
Other	46%	48%	39%	42%	26%

The difference between different types of people does not show a great variation. Instagram users are mainly occupied with activities along the coast. Cruise tourists engage the least in diving or snorkeling, which are most popular among stay-over tourists. This observation is in line with findings of Schep et al. (2013), who find that diving and snorkeling are mainly done by stay-over tourists. In contrast to the findings in that study, however, underwater activities form a relatively small part of the Instagram, Panoramio and Flickr datasets: only 11% of the Instagram stay-over tourist pictures is taken underwater, while Schep et al. (2013) find that over 70% of the stay-over tourists participates in diving and/or snorkeling. Although these percentages are not entirely comparable The percentage of underwater photos uploaded to Instagram, Flickr and Panoramio, however, suggests a lower percentage of underwater activities. A possible explanation for the lower amount of underwater photos is that the characteristics of the average social-media user differ from the average visitor on Bonaire. However, this can also be caused by the fact that underwater photography is less accessible compared to landscape or wildlife photography: not every photographer is able to use his camera underwater. The difference between the Panoramio, Flickr and Instagram users also suggest that there is a difference in characteristics of the users of different social media platforms.

4.4. Estimating actual visitation rates based on Photo User Days (PUDs)

In order to estimate the actual pressure on Bonaire's ecosystems, we have to redefine the dataset somewhat. So far we have assessed unique user data per square kilometer. This means that if a user makes a picture at a given location twice, only one of these ends up in the analysis. However, to assess actual visitation rates and the pressures on an ecosystem both visits are relevant.

Wood et al. (2013) successfully estimate visitation rates of natural areas based on so-called Photo User Days (PUDs). These are defined as: one photo per user per day in a defined site. For example, if a user makes two photos in a National Park on a given day, only one PUD is counted. If the same user makes another photograph in the park the next day, two PUDs are counted. We only use the Flickr and Panoramio databases to calculate PUDs, because of the poor unreliable nature of Instagram geotags.

The following sections are based on the assumption that PUDs are a valid proxy for the number of visitors in a natural area. This implies the assumption that the share of social media users within the population of visitors is the same on each location. Although Wood et al. (2013) suggest that this is in general the case for natural areas with comparable size and visitation rates, this has never been tested on Bonaire. The following analysis should therefore be seen as an exercise to explore the use of social media to assess visitation rates on Bonaire, rather than an accurate estimate.

The only area for which actual visitation rates are available is the Washington-Slagbaai National Park, since entry tickets are required and STINAPA (NP management) keeps track of everybody going in and out of the park. Based on the relative number of PUDs, we calculated the estimated number of visitors for the other natural areas on Bonaire. Table 2 presents the outcome of the analysis.

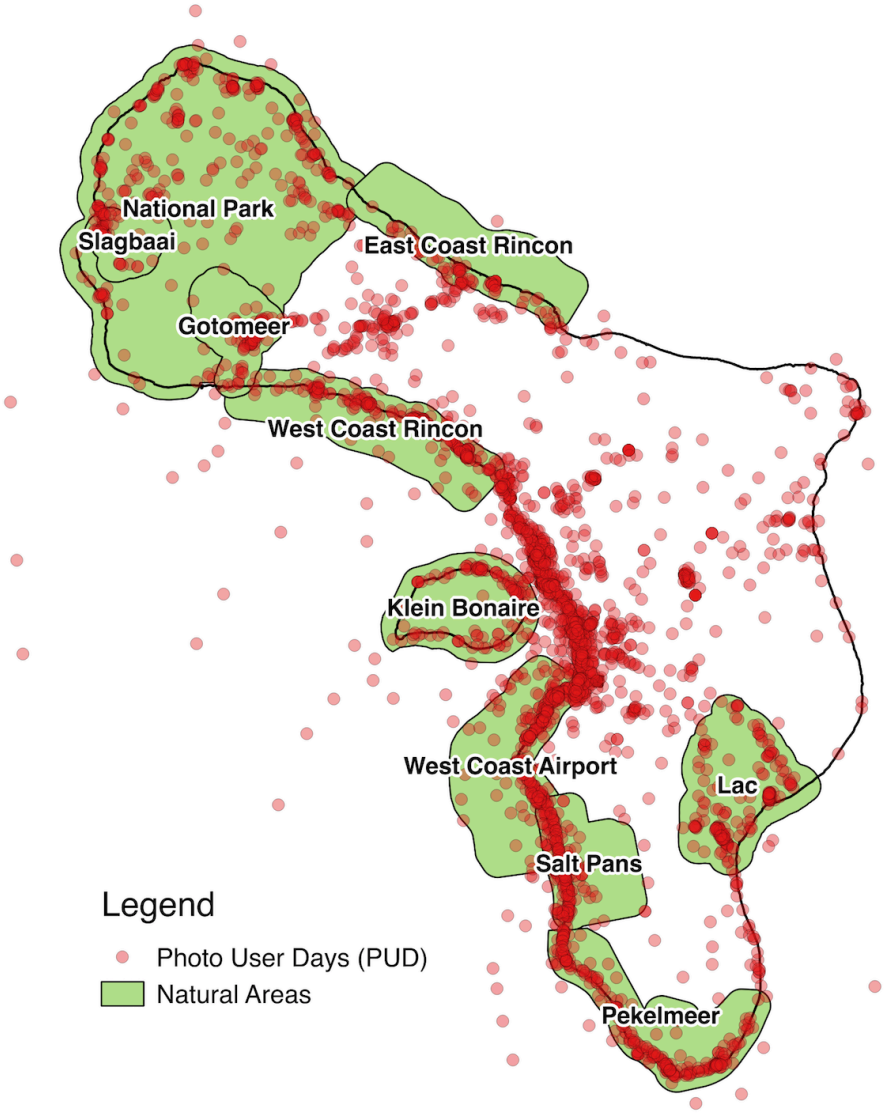

Figure 9 – The distribution of Photo User Days (PUDs) on Bonaire

Table 2 – From Photo User Days (PUD) based on Flickr & Panoramio to the density of annual visitors

	Area (Ha)	PUDs	Index	Estimated daily visitors	Estimated annual Visitors	Yearly visitors / Ha
Salt pans	1,046	275	0.965	100	36,496	34.9
West-coast airport	1,679	357	1.253	130	47,378	28.2
Pekelmeer	1,507	303	1.063	110	40,212	26.7
West-coast Rincon	1,627	252	0.884	92	33,443	20.6
Lac	1,569	197	0.691	72	26,144	16.7
Gotomeer	766	92	0.323	33	12,210	15.9
Klein Bonaire	1,279	111	0.389	40	14,731	11.5
East-coast Rincon	1,579	77	0.270	28	10,219	6.5
Washington-Slagbaai NP	*5,945*	*285*	*1.000*	*104*	*37,823*	*6.4*

The most visited area seems to be the coastline near the airport. This area (including Donkey and Te Amo beaches) is indeed a very popular area to which many locals and tourists go for recreation. As this area does not have as many unique users (Figure 5), it is likely that a relatively high share of the visitors visit the location more than once.

The salt pans at Cargill (near the Cargill plant) are estimated to have the highest visitation rates per hectare. This is the result of high visitation rates and a relatively small area. Washington-Slagbaai NP, on the other hand, has a higher number of visitors, but a very low density due to the fact that the total area is larger.

Again it is important to stress that some locations within the natural areas have a disproportionately high number of visits in comparison with other sites. This is especially the case for Slagbaai in the National Park Area, Sorobon and Lac Cai areas in Lac, the north side of Klein Bonaire and the road through Gotomeer. As expected, most of the photos on the west-coast are taken close to the coastal road. Estimates for exclusively the Sorobon area indicate over 100 visitors per hectare per year. This is almost 6 times higher than in the rest of Lac, indicating a much higher local impact. However, due to the specific characteristics of these particular locations (e.g. the presence of restaurants, bars and a hotel in Sorobon) it is difficult to compare these numbers to the visitation rates of an entire natural area.

Visitation rates are an important indicator to monitor the pressure on ecosystems due to human activity. If these visitation rates can be linked to estimates for natural resources use per visitor, such as water use or physical damage to coral reefs, the information can be used for sustainable management of the natural areas on Bonaire.

4.5. Annual fluctuation of visitors

Another important factor that determines the impact of tourism on ecosystems is the annual fluctuation of visitors. A higher concentration in a given period implies that the impact on natural areas will be relatively high in particular parts of the year. Figure 10 presents the monthly distribution of PUDs as the percentage of the total annual visitors. As presented in the figure, 12% of the total annual PUDs are in January, the busiest month. The average of monthly PUDs is 8.3%, which means that January is roughly 1.5 times busier than the average month. The quietest month is October, with only 6% of the annual PUDs. This implies that January is about twice as busy as October. The high season ranges from December to April.

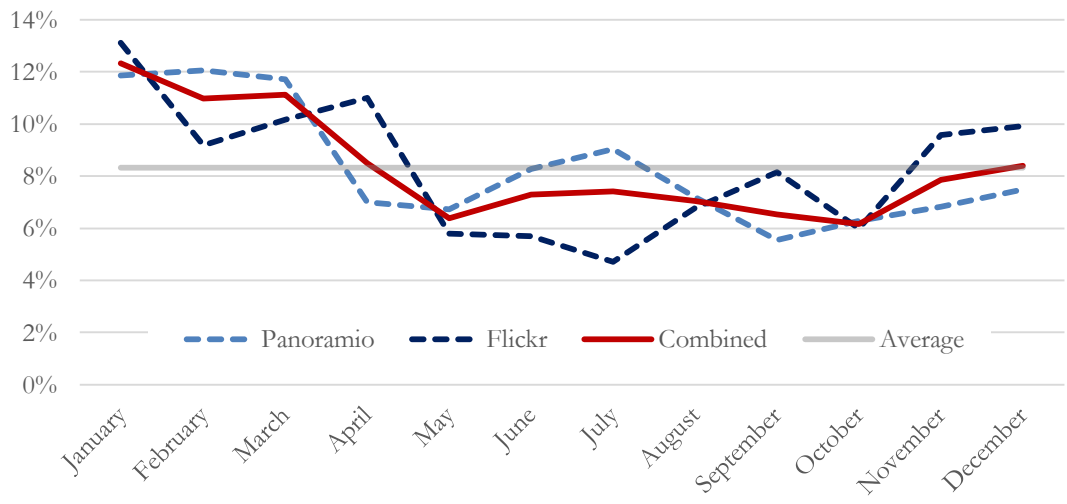

Figure 10 – Monthly distribution of PUDs on Bonaire in percentage of the annual total. The average percentage of PUDs is 8,3%.

5. Discussion

5.1. Conclusion

By far the largest share of photos on social media are taken along the western side of the island, which is accessible through paved roads and has a much calmer sea compared to the Eastern "wild" side of the island. An earlier study by Schep et al. (2013) confirms that the primary focus of most tourists on Bonaire is on marine based activities such as diving, snorkeling and surfing.

More remarkable is that a very high percentage of photos contained a terrestrial landscape rather than a coastal landscape. Especially in the National Park tourists appreciate the terrestrial landscape of Bonaire. Another hotspot of terrestrial photos was found on the Salt Pans. Despite the relatively small area of 7.4 square kilometers, more than 5% of all Panoramio and Flickr photos were taken at the site of the salt extraction. This result suggests that the site is an important attraction for tourists. The Salt Pans areas are more popular among tourists than for instance the mangroves at Lac or the western coastline in general. It also appeared from the data that the open nature plains and the Kunukus are less popular among the people of Bonaire and its visitors. One can only very rarely find a photo of a Kunuku area on Flickr or Panoramio.

Some specific locations within a natural area, such as Sorobon within Lac, have disproportionately high visitation rates in comparison to the rest of the area. This can be explained, however, by the presence of facilities such as restaurants and hotels or a specific attraction.

The results offer a valuable input to support a sustainable tourism development in Bonaire and have great potential to guide the management of human impacts on the natural environment of the island. Perhaps the most important potential use of social media data is the monitoring of human impact on the natural environment. Tourism has an impact on the ecosystems in terms of pollution, trampling, noise, coastal development, and disturbance in general. The marine and coastal ecosystems are resilient, but if the ecological threshold is breached, there is a high probability that the ecosystems such as coral reefs and sea grass beds are damaged beyond repair. Without proper mitigation through planned management and growth, unregulated growth of tourism will have adverse effects and essentially break down the ecosystem services on which the industry itself is based. In order to control tourism growth, monitoring of both human impact and the state of ecosystems is paramount.

This is useful information for the Government of Bonaire and the Tourism Corporation Bonaire, who are working on a Tourism Development Plan to support sustainable development of the tourism sector. Information regarding the visitation rates of tourists to ecosystems is crucial information for STINAPA (responsible for management of natural areas) to keep track of human impact to ecosystems. WWF NL can use these results to support the process towards sustainable tourism development on Bonaire, but also in a wider geographical setting. Analysis of social media data can be done on a larger scale with relatively small effort. This means that similar analysis can be conducted on other islands by using similar methods and scripts that have been developed for this research. Where other research methods (such as surveys) require an extensive data collection process to investigate tourist behavior, social media data are free of charge (at least for the platforms used in this study at the time of writing).

5.2. Limitations and further research

Although the data collected and the results presented in this report are very promising regarding the use of social media data for the evaluation of ecosystems, we have dealt with some limitations

during the analysis. The results presented in this report provide a general overview of what can be done with the collected data, but there is still room for further applications.

Additional analyses could yield valuable information about specific activities on Bonaire. The data can be filtered on for instance the photos in such a way that a specific analysis can be made of diving tourism on Bonaire, or bird spotting. Moreover, the fact that the data also include timestamps of photos, the consequences of certain events can be analyzed such as the effect of certain policy measures or natural hazards on the visitation rates of different ecosystems. For example, the recently opened touristic route on the eastern side of the island could lead to a higher level of visitors to the Washikemba area and, thereby, a more even spread of tourism over the island's natural areas.

Although social media are widespread and the dataset contains several thousands of uploads on the small island of Bonaire, there is limited knowledge about age, gender, occupation and other characteristics of the actual people that upload the data. There might be biases in people that use social media and their preferences that are not captured in this type of study. With the use of a list of criteria, however, we were able to establish basic distinctions between types of tourists that help deal with this limitation. These distinctions can be further explored to increase robustness and identify additional characteristics of users.

The Instagram application relies on the availability of mobile data network. Instagram posts are less useful for geo-locating tourist hotspots as some popular ecosystems (such as the Washington Slagbaai National Park) are not covered by a 3g or 4g network. For this reason, we used only Panoramio and Flickr uploads in the analysis of spatial density of photos, while Instagram was used mainly to analyze the main tourist activities.

The Photo User Days (PUDs) are potentially an interesting proxy for actual visitor numbers, and thereby to quantify human impact. Although scientific evidence to support the usefulness of PUDs as a valid indicator is thin, we acknowledge the use of PUDs as a general reference for the estimation of visitation rates. For further research, it would be of added value to investigate the accuracy of PUDs as a proxyon Bonaire in more detail. This could potentially be done by estimating the number of visitors to the different natural locations using other types of estimation methods.

Another important next step would be to link the density of visitors and PUDs to the carrying capacity of ecosystems of Bonaire and the ecological impact of tourists. Monitoring human activity and the state of ecosystems over a longer period of time, would provide insight in the effects of human activity and contributes to the understanding of Bonaire's carrying capacity. Without research on the carrying capacity, it remains unclear whether current visitation rates form a threat to the natural environment. In addition, the photos uploaded to social media can potentially be used to track the state of the natural environment on Bonaire, as natural aspects is clearly visible.

In summary, the study provides a promising starting point to further explore the use of social media data for environmental management on Bonaire. While previous research on tourism in Bonaire relied on labor intensive surveys, social media provide a wealth of valuable information on tourist behavior. This study has provided valuable insights for sustainable tourism management and the data gathered offer plenty of opportunities for further research.

6. References

Casalegno, S., Inger, R., Desilvey, C., Gaston, K. J., 2013, Spatial covariance between aesthetic value & other ecosystem services, *PLoS One* **8**(6)**:**e68437.

Dunkel, A., 2015, Visualizing the perceived environment using crowdsourced photo geodata, *Landscape and Urban Planning.*

Flickr, 2016, https://www.flickr.com/services/api/.

Panoramio, 2015, Panoramio API.

Ruths, D., Pfeffer, J., 2014, Social media for large studies of behavior, *Science* **346**(6213)**:**1063-1064.

Schep, S., Van Beukering, P., Brander, L., Wolfs, E., 2013, The Tourism value of Nature on Boanire, Institute for Environemntal Studies.

Tieskens, K., Schulp, C. J. E., Verburg, P. H., Kuemmerle, T., 2014, Typology of cultural landscapes, Available at: http://www.hercules-landscapes.eu/tartalom/HERCULESWP4 D4 1 VUA.pdf.

Van Zanten, B. T., Verburg, P. H., Koetse, M. J., van Beukering, P. J., 2014, Preferences for European agrarian landscapes: A meta-analysis of case studies, *Landscape and Urban Planning* **132:**89-101.

Wood, S. A., Guerry, A. D., Silver, J. M., Lacayo, M., 2013, Using social media to quantify nature-based tourism and recreation, *Scientific Reports* **3:**2976.