Journal of Great Lakes Research xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Determining preferences for ecosystem benefits in Great Lakes Areas of Concern from photographs posted to social media

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ARTICLE INFO

Article history:
Received 21 June 2017
Accepted 12 December 2017
Available online xxxx

Communicated by Marc Gaden

Keywords:
Great Lakes Areas of Concern
Social media
Photo sharing
Ecosystem services and benefits
Decision making
Restoration

ABSTRACT

Relative valuation of potentially affected ecosystem benefits can increase the legitimacy and social acceptance of ecosystem restoration projects. As an alternative or supplement to traditional methods of deriving beneficiary preference, we downloaded from social media and classified ≈21,000 photographs taken in two Great Lakes Areas of Concern (AOC), the St. Louis River and the Milwaukee Estuary.

Our motivating presumption was that the act of taking a photograph constitutes some measure of the photographer's individual preference for, or choice of, the depicted subject matter among myriad possible subject matter. Overall, 17% of photos downloaded from the photo-sharing sites Flickr, Instagram, and Panoramio depicted an ecosystem benefit of the AOC. Percent of photographs depicting a benefit and the photographs' subject matter varied between AOCs and among photo-sharing sites. Photos shared on Instagram were less user-gender biased than other photo-sharing sites and depicted active recreation (e.g., trail use) more frequently than passive recreation (e.g., landscape viewing). Local users shared more photos depicting a benefit than non-local users. The spatial distribution of photograph locations varied between photos depicting and not depicting a benefit, and identified areas within AOCs from which few photographs were shared. As a source of beneficiary preference information, we think Instagram has some advantages over the other photo-sharing sites. When combined with other information, spatially-explicit relative valuation derived from aggregate social preference can be translated into information and knowledge useful for Great Lakes restoration decision making.

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Introduction

The assessment of ecosystems services (key terms are defined in Table 1) and associated ecosystem benefits has been recognized as useful for prioritizing, designing, and comparing habitat conservation and restoration projects (reviewed by Boulton et al., 2016). Angradi et al. (2016) showed how habitat restoration scenarios for Great Lakes Areas of Concern (AOCs) could be compared based on trade-offs resulting from marginal change in the area of habitats supporting different ecosystem services. They felt that the reliability, credibility, and social acceptance of these analyses would be increased if marginal changes in the area of habitats associated with restoration could be weighted using relative valuation elicited directly from beneficiaries, an idea with strong support in the literature (e.g., Daily et al., 2009; Lin et al., 2017; Rodrigues et al., 2017, and papers cited therein). The traditional method for obtaining stated preference information from beneficiaries is via surveys, interviews, and focus groups which are time consuming and expensive (Richards and Friess, 2015; Tenerelli et al., 2016). As a possible alternative or supplement to stated preference methods we explored using sets of geotagged (attributed with geospatial metadata) photos posted to social media.

Photographs may reflect the aesthetic values, interests, sentimental attachments, and emotional state of the photographer at a particular time and place (Garrod, 2007; Guerrero et al., 2016; Stedman et al., 2004). Although we cannot know the photographer's exact motivation behind each photograph, we reasoned that the act of taking a photograph reflects the photographer's individual preference for, or choice of, the depicted subject matter among all the other possible subject matter. In aggregate for a spatially explicit set of photographs, these preferences may serve as a relative rank or weight coefficient for ecosystem services and benefits associated with a habitat restoration (Satz et al., 2013).

This approach of using the content of photographs posted to social media to quantify or map ecosystem benefits or preferences is supported by some recent studies (Hausmann et al., 2017; Heikinheimo et al., 2017; Richards and Friess, 2015; Richards and Tunçer, 2017; Tenerelli et al., 2016; Wood et al., 2013; Yoshimura and Hiura, 2017),

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https://doi.org/10.1016/j.jglr.2017.12.007
0380-1330/Published by Elsevier B.V. on behalf of International Association for Great Lakes Research.

Table 1
Explanation of key concepts used in this paper.

Beneficiary: a member of a class comprised of individuals who benefit similarly from ecosystems via active or passive consumption, use, or appreciation (after Harwell et al., 2017).
Cultural ecosystem services: the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, or sensory experiences (after MEA, 2005; see also Chan et al., 2012; Dickinson and Hobbs, 2017).
Ecosystem or ecological benefit: the contribution to human ***well-being*** that results from the consumption, use, or appreciation of a final ecosystem good or service (after Harwell et al., 2017). Benefits are realized when labor and capital (often in the form of human effort) are added to final ecosystem goods and services (Landers and Nahlik, 2013).
Ecosystem services: broadly, biophysical outputs of ecosystem processes from which humans derive benefits (after Harwell et al., 2017).
Final ecosystem goods and services (FEGS): components of nature directly enjoyed, consumed, or used to yield human benefits. FEGS are biophysical outputs, qualities, or features of nature that need minimal translation for relevance to human ***well-being*** (Boyd and Banzhaf, 2007).
Final ecosystem goods and services classification system (FEGS-CS): a hierarchical framework for defining and classifying final ecosystem services and associated human beneficiaries (Landers and Nahlik, 2013)
Great Lakes Area of Concern: geographic areas designated by the Parties of the Great Lakes Water Quality Agreement (Annex 1 of the 2012 Protocol) where significant impairment of beneficial uses has occurred as a result of human activities at the local level.
Intermediate ecosystem goods and services: ecological processes, functions, structures characteristics, and interactions that are essential to the existence of FEGS, but are usually not directly enjoyed, used, or consumed by human beneficiaries (Landers and Nahlik, 2013).
Relative valuation (of benefits): non-monetary comparison among preferences for ecosystem benefits based on percentages, weights, ranks or other relative scale.
Human well-being: the condition of humans and society, defined in terms of the basic material needs for a good life, freedom, choice, health, wealth, social relations, and personal security (after MEA, 2005)

but is not yet widespread (Andrew et al., 2015; Casalegno et al., 2013; Guerrero et al., 2016). We are aware of only a few applications of this approach in the Great Lakes. Allan et al. (2015, 2017) used crowdsourced birdwatching hotspots and geotagged photographs of Great Lakes beach-use to map these cultural/recreational services around the Great Lakes. Annis et al. (2017) also used crowdsourced birdwatching hotspot data to inform coastal conservation planning. Hoellein et al. (2015) used the number of photographs of Lake Michigan beaches posted to social media as a proxy measure of beach visitation rate.

Information derived from social media can support decision making at a variety of scales from regional restoration and conservation planning (see Allan et al., 2015) to local projects. Our focus here is using AOC-scale information to address AOC and restoration project scale decisions. Our objective was to explore the potential for using photographs posted to photo-sharing sites to quantify relative valuation of ecosystem benefits in Great Lakes Areas of Concern. We addressed several questions: 1) what percent of photographs taken in each of two Great Lakes AOCs and posted to three different social media photo-sharing sites (PSSs) depicted an ecosystem service or associated ecosystem benefit?; 2) does the percentage vary among PSSs or between AOCs?; 3) are there user gender or user origin (e.g., local or non-local) biases in the data that can be identified using available metadata; 4) what are the most often-depicted ecosystem benefits and do they vary across PSSs or AOCs?; 5) are there spatial patterns in what is depicted in photographs within and across AOCs?; and 6) how might relative valuation of ecosystem benefits derived from social media photographs be translated into information useful in AOC decision-making, in particular restoration project planning and design?

Methods

We downloaded photographs and metadata from PSSs for two AOCs, the St. Louis River, a tributary to western Lake Superior and a border water between Minnesota and Wisconsin, and the Milwaukee Estuary in Wisconsin, which includes rivers tributary to Lake Michigan (see Appendix A1 for area maps and boundaries). The St. Louis River (67.4 km^2) has extensive open water areas including estuarine lower reaches and a more riverine upper reach. Lake Superior proper is excluded from the AOC in this analysis. The St. Louis River AOC becomes progressively less industrial or otherwise developed in the upriver direction. The Milwaukee Estuary AOC (56.8 km^2) includes several long river reaches, and a section of Lake Michigan. The St. Louis River is adjacent to Duluth, Minnesota and Superior, Wisconsin, with a combined population of 113,509 and density of ≈500 people/km^2 (United States Census Bureau, 2017). Milwaukee, Wisconsin has a population of 594,738 and a density of ≈6000 people/km^2. We selected these AOCs for analysis to support our ongoing ecosystem services research there and because they afford a comparison between a highly developed urban AOC (Milwaukee Estuary), and a partly undeveloped AOC (St. Louis River).

We wrote scripts (Debbout, 2017) to connect to each photo-sharing site's application programming interface (API) to allow us to download geotagged photographs and videos (Instagram only) from Panoramio, Instagram and Flickr. Panoramio.com, owned by Google, Mountain View, CA, was launched October 2005 and closed November 2016. Flickr.com, owned by Yahoo!, San Francisco, CA was launched February 2004. Instagram.com, owned by Facebook, Menlo Park, CA, was launched October 2010. Ninety-four million photographs had been uploaded to Panoramio by the time it closed (Trull, 2017). As of May 2015, 10 billion images had been uploaded to Flickr; up to 25 million new images are uploaded each day (DMR, 2017) Thirty-five billion photographs have been shared on Instagram (Statistic Brain, 2017). We chose Instagram and Flickr because they were the most popular photo-sharing sites in the world when we downloaded images (eBizMBA, 2017). We included Panoramio because, although it is closed to new images, the archived data are available, and previous studies have used Panoramio data (e.g., Casalegno et al., 2013; Figueroa-Alfaro and Tang, 2017).

We downloaded all available public photographs and metadata as of August 2016 from within each AOC plus a 100 m AOC boundary buffer (Appendix A1). For the Milwaukee Estuary AOC there were >70,000 posted Flickr photographs. To reduce effort and make the sample size more equitable between AOCs, we randomly extracted 5000 Milwaukee Estuary Flickr photographs for classification. We included the boundary buffer to capture riparian and AOC-adjacent terrestrial habitats that may be relevant for restoration. We used geotags to identify photographs taken within the target area. Instagram photographs are tagged with the name of a location with generalized coordinates, rather than unique coordinates, such that there may be hundreds of photographs posted by different users at different times with the same place-name tag and coordinates. This introduces some location error into the data which is relevant when the named place is near or outside the boundary of the AOC. Of 22,059 original downloaded photographs, 3.8% were outside the target area, and 1.7% had bad hyperlinks.

We viewed every photograph and video with a working hyperlink. We did not filter out or classify photographs using image tags or titles. This metadata was missing for many images and when present rarely provided sufficient detail to classify the depicted subject matter using our classification scheme (described below). For each usable photograph, we attempted to determine the user's gender and origin (Flickr only for origin), the subject matter of the photograph, and if the photograph depicted an ecosystem service or benefit.

For each photograph we used a two-part characterization of the subject matter (i.e., level 1 subject + level 2 subject) to classify the photographs which we then linked to the Final Ecosystem Goods and Services Classification System (FEGS-CS; see Table 1). FEGS-CS has some advantages for our purpose: it provides clear rules for what is and is not an ecosystem service; it explicitly links human beneficiaries to FEGS; and it prevents double counting of benefits (Landers and Nahlik, 2013; Boulton et al., 2016). In some classified photographs, an ecosystem