

运用社交媒体探索 基于自然解决方案中的 生态系统服务感知 USING SOCIAL MEDIA TO EXPLORE PERCEPTIONS OF ECOSYSTEM SERVICES BY NATURE-BASED SOLUTION PROJECTS

翟雪竹
谢菲尔德大学景观学院博士研究生

埃卡特·兰格
谢菲尔德大学景观学院教授

ZHAI Xuezhu
PhD Student of the Department of Landscape Architecture, The University of Sheffield

Eckart LANGE*
Professor of the Department of Landscape Architecture, The University of Sheffield

*Corresponding Author
Address: Floor 12, the Arts Tower, The University of Sheffield, Western Bank, Sheffield, S10 2TN, UK
Email: e.lange@sheffield.ac.uk

摘要

自然湿地在维持区域水量平衡、调节区域气候和维持生物多样性方面发挥着至关重要的作用。近年来,由于城市的不断扩张,中国的自然湿地显著萎缩;为了补偿损失的自然湿地并降低城市脆弱性和灾难风险,包括建设湿地公园在内的众多基于自然的解决方案被提出。中国在过去10年中创建了成百上千座湿地公园,它们有的受自然湿地的启发而新建,有的依托现有湿地生态系统进行建造。目前,大多数关于湿地公园生态系统服务的研究都集中在技术层面,很少针对公众感知展开;亦缺乏公众对湿地公园感知方面的研究。本研究探究了大量来自社交媒体(即新浪微博)的基于时间和地理粒度的数据,对微博文本进行语义分析,以了解公众如何感知广州湿地公园的生态系统服务,并与专业机构所宣传的生态系统服务进行比较,来探寻影响这些感知的因素。研究结果表明,就公众感知到的和机构宣传的生态系统服务而言,游憩、美学和栖息地服务是感知最频繁的三种服务,且游憩服务与美学服务之间紧密关联。观花植物和彩叶乔木是促进公众对美学服务感知的最重要因素,而鸟类是促进栖息地服务感知的关键。研究结果能够帮助更好地管理湿地公园等基于自然解决方案的项目,使其进一步满足公众期望。

关键词

基于自然的解决方案;湿地公园;生态系统服务;感知;社交媒体

ABSTRACT

Natural wetlands play a vital role in maintaining regional water balance, regulating regional climate, and maintaining biodiversity. Due to urban sprawl in China, the loss of natural wetlands has been dramatic. In recent years, nature-based solutions, including wetland parks, have been advocated to compensate for this loss and to reduce vulnerability and disaster risks. As a result, inspired by natural wetlands or building on existing wetland ecosystems, hundreds of wetland parks have been created in China over the last decade. Most research on ecosystem services of wetland parks has to date focused on technical perspectives, with only a few addressing public perception; the public's perception of wetland parks is not well understood. This research used social media (i.e. Sina Weibo) to access large volumes of data and provide temporal and geographic granularity. A semantic analysis of microblogs was performed to understand how the public perceives the ecosystem services of wetland parks in Guangzhou. This study explored the public's perceptions and compared these with the ecosystem services as communicated by professional institutions, and probed into the factors that affect these perceptions. The results showed that the top three ecosystem services perceived by both the general public and communicated by institutions are recreation, aesthetics, and refugia / habitat. There is a strong interconnection between the perceptions of recreation and aesthetics services. Flowering plant species and colored-leaf trees are the most important stimuli affecting perceptions of aesthetics services, and birds are key to the perception of refugia / habitat services. These results provide a basis for better aligning management of projects utilizing nature-based solutions, such as wetland parks, with expectations from the public.

KEYWORDS

Nature-Based Solutions; Wetland Park; Ecosystem Services; Perception; Social Media

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编辑 田乐 王颖 翻译 翟雪竹 王颖

EDITED BY Tina TIAN WANG Ying TRANSLATED BY ZHAI Xuezhu WANG Ying

1 引言

1.1 基于自然的解决方案与生态系统服务感知

人类的可持续发展面临着气候变化、城市化、水资源供给和灾害风险等诸多挑战。受自然启发、由自然支持或模拟自然而生成的基于自然的解决方案(NBS)^[1]即旨在应对这些挑战。NBS以最小干预的方式直接利用生态系统或依据自然规律来修复生态系统。这些颇具成本效益的长期解决方案代表了一种跨学科的综合方法,其汲取了来自工程学中的“蓝绿基础设施”、经济学中的“自然资本”和“生态系统服务”,以及环境规划领域中的“景观功能”等既有概念^{[2]-[4]},旨在改善当地的生态和社会可持续性,确保生产力的长期发展^{[2][5]},维持并提高面向人类的生态系统服务供给能力^[2]。

生态系统服务是人们从生态系统中获得的直接或间接收益,主要可分为以下4类:支持服务、供给服务、调节服务和文化服务^{[6][7]}。从生态系统功能到生态系统服务的供给,再到人类获益,层层递进的过程表明,这些服务取决于人类的活动或需求^[8]。因此,了解公众对NBS所提供生态系统服务的感知,对于此类项目的可持续管理及政策的制定与沟通至关重要^[9]。公众满意度仍是NBS项目管理者关注的核心内容^[10],而市民群体对于生态系统服务的理解则决定了他们将如何参与和支持蓝绿基础设施管理^[11]。此外,已有研究表明,某些生态系统服务可以反复同时出现,成为生态系统服务簇^[12]。了解各生态系统服务之间的内在关联可以帮助NBS项目管理者充分利用生态系统服务的协同作用,进一步提升人类的收益^{[13][14]}。

1.2 湿地公园——一种基于自然的解决方案

近几十年来,中国的湿地急剧减少并不断退化。1978~2008年,全国的湿地面积减少了约33%^[15]。现存的自然湿地也面临着生态功能消失、生态系统退化的严峻问题^[16]。自2004年以来,中国已建设了大量湿地公园,以通过这种基于自然的解决方案来保护、补偿和合理利用湿地资源^[17]。截至2017年底,中国大陆共建设了1 699座湿地公园^[18]。

湿地公园的设计与建造通常采用三种策略:1)从自然湿地中获取灵感,如垂直流人工湿地、潜流湿地和具有浮筏系统的人工湿地;

1 Introduction

1.1 Nature-Based Solutions and Perceptions of Ecosystem Services

Human sustainable development is facing many challenges such as climate change, urbanization, water supply, and disaster risks. Nature-Based Solutions (NBS), which refer to actions inspired by, supported by, or copied from Nature^[1], have been proposed for coping with these challenges. NBS involves directly utilizing the ecosystems with minimum intervention and restoring the ecosystems by following natural laws. These cost-effective long-term solutions represent an interdisciplinary umbrella approach that encompasses experience from existing concepts such as “blue-green infrastructure” in Engineering, “natural capital” and “ecosystem services (ESs)” in Economics, and “landscape function” in Environmental Planning^{[2]-[4]}. It aims to improve local ecological and social sustainability, to ensure long-term productivity^{[2][5]}, and to sustain and potentially increase the ability to provide ESs to humans^[2].

ESs are the direct or indirect benefits that people get from the ecosystem. Mainly, ESs are grouped into 4 categories: supporting, provisioning, regulating, and cultural.^{[6][7]} There could be a cascade from ecosystem functions to ESs, and finally to benefits, indicating that the definition of an ES depends on human activities or wants^[8]. Therefore, understanding public perceptions of ESs provided by NBS is crucial for the development and communication of sustainable management and policies^[9]. Public satisfaction remains a key output that interests the managers of NBS projects^[10], and the participation and support of citizens in the management of blue-green infrastructure is usually upon their understanding of ESs^[11]. Moreover, existing research has shown that sets of ESs could appear together repeatedly, as an ESs bundle^[12]. Understanding the interconnections among ESs can help the managers with the synergy between ESs and promote management policies that improve the benefits to humans^{[13][14]}.

1.2 Wetland Parks: A Nature-Based Solution

Recent decades have seen a sharp decline and degradation of wetlands in China. From 1978 to 2008, the total area of the country's wetlands decreased by about 33%^[15]. In the remaining natural wetlands, ecological functions are disappearing, and the ecosystems have deteriorated^[16]. Since 2004, a large number of wetland parks (WPs), as an NBS, have been built in China to protect, compensate, and rationally utilize wetland resources^[17]. Up to the end of 2017, in Chinese Mainland, a total of 1,699 WPs have been created^[18].

The design and construction of WPs often employ three strategies: 1) inspired by natural wetlands (e.g., constructed vertical

2) 在自然湿地的基础上进行改造, 如苏州太湖国家湿地公园; 3) 通过简易技术, 模拟自然湿地, 如构建与自然沼泽相似的表面流型人工湿地。

湿地公园能够显著提高生态修复的速度、保护城市水资源、维持区域水量平衡、调节区域气候、减少污染物、保护生物多样性及提供游憩设施^{[19][20]}。此外, 湿地公园的建设有助于动员全社会力量参与湿地保护, 增强有利于人类福祉的生态系统服务^[17]。然而, 当前针对公众对湿地公园所提供生态服务的感知的研究仍然较为缺乏。

1.3 通过社交媒体研究生态系统服务感知

得益于互联网的数据采集功能, 人们能够在短时间内跨地理区域访问数量空前的自述数据^[21]。近年来, 越来越多的中国公众通过微博、微信等社交媒体发表观点、记录出行、分享情感和体验等。这种自述报告式的信息已被用于研究人们对环境的感知, 例如, 有学者通过模型模拟了维也纳市中心的可感知边界并确定了当地的热门地标^[22], 有研究将在线评论数据用于北京历史文化街区的使用后评估研究^[23], 亦有研究将人们在社交媒体上发布的照片用于探索文化服务(如美学、游憩和地方本土性等)与景观特征之间的关系^[24]。

本研究以新浪微博为数据来源。作为中国最受欢迎的社交媒体之一, 新浪微博是一款类似于推特的微型博客平台。2019年, 微博的月活跃用户约4.65亿, 日活跃用户约2.16亿^[25]。所有用户均可访问平台中公开发布的文本、图片、视频和链接等^①。

新浪微博的用户可以以个人或机构名义注册账户。本研究所考察的机构类型的用户包括政府部门、湿地公园管理部门、公共媒体、学术研究机构、非政府组织和非营利组织等, 这类用户通常拥有庞大的粉丝群体。除湿地公园管理部门外, 其他机构尽管不直接参与公园的运营管理, 但它们的宣传在一定程度上能够反映公园的管理情况, 也是公众针对公园相关问题进行反馈的渠道。研究对比了微博平台中个人用户和机构用户发布的相关内容, 以了解大众(即“个人”)所感知的生态系统服务与专业人员(即“机构”)所宣传的生态系统服务之间的异同。

flow or subsurface wetlands, floating raft systems); 2) supported by natural wetlands (e.g., the Taihu Lake National Wetland Park in Suzhou); 3) imitating natural wetlands with low-tech or easily-operated measures (e.g., free-water surface constructed wetlands which are similar to natural swamps).

WPs can considerably improve the rate of ecological restoration, conserve urban water sources, maintain regional water balance, regulate regional climate, reduce pollutants, protect biodiversity, and provide recreational opportunities^{[19][20]}. Furthermore, they are created to help mobilize social strengths to participate in wetland protection and enhance the ESs that benefit human well-being^[17]. However, research on the public perception of the ESs offered by WPs is insufficient.

1.3 Using Social Media to Study Public's Perception of ESs

Massive data collection from the Internet enables us to access unprecedented amounts of self-reported data across geographic domains in a short period of time^[21]. In recent years, more and more Chinese citizens express their opinions, post travels, and share moments and experiences via social media such as Weibo and WeChat. Such self-reported data have been used to study people's perception on environmental elements. For example, scholars modelled the perceived boundaries of the city center and identified popular landmarks in Vienna^[22]; online feedback data were used for a post-occupancy evaluation of urban historic conservation areas in Beijing^[23]; photos posted on social media can be a source for exploring the relations between cultural ESs (e.g., aesthetics, recreation, and local identity) and landscape features^[24].

Sina Weibo, one of the most popular social media in China, is used as the data source for this research. It is a microblogging platform similar to Twitter. In 2019, Sina Weibo served 465 million active users monthly and 216 million daily^[25]. Users can post texts, pictures, videos, and links openly^①, which are accessible to all users.

The users of Sina Weibo can register their accounts as individuals and institutions. Institution users, in this research, include government departments, park management offices, public media, academic institutes, NGOs, and NPOs, which usually have a large number of followers. Apart from official WP management entities, other institutions do not directly involve the management or operation of WPs. Still, their publicity will, to some extent, reflect the management of WPs as well as citizens' feedback on related aspects, and could provide guidance to the public. This research compares the microblogs by individual and institution accounts, to probe into the similarities and differences between the general public's (i.e. individuals) perceptions of ESs, and the value of ESs expected by the professionals (i.e. institutions).

① 由于设置了“仅自己可见”和“仅粉丝可见”的微博涉及个人隐私, 对这部分内容的抓取不符合道德规范及新浪微博的《微博服务使用协议》和《个人信息保护政策》, 故本研究未考察此类数据。

① This study excluded the microblogs that set as “to me only” and “to followers only,” because such data might involve privacy concerns, and the use of these data would violate ethics and be not allowed by the Terms and Conditions and Personal Information Protection Policy of Sina Weibo.

② 限定该位置的另一层考虑是广州湿地公园的访客可能在广州及周边城市中居住和发布微博。尽管搜索位置的设定可以帮助验证微博中提及的湿地公园确为本研究的对象,但也可能导致部分“禁用位置服务”的微博被遗漏。

② The location setting up is for another reason that many people visiting the WPs in Guangzhou live or post microblogs in the city or other adjacent cities. Admittedly, though this setting verified the locations of the WPs studied in this research, the microblogs that "disable location services" may be omitted.

尽管用户发布的微博内容可能无法涵盖其感知的所有生态系统价值或收益,但他们在社交媒体上主动记录或与朋友分享的内容可能是他们认为最值得关注的生态系统服务。研究旨在探寻以下4个问题:

1) 公众可以从湿地公园中感知到哪些生态系统服务? 2) 感知到的生态系统服务之间有什么关联? 3) 公众所感知到的生态系统服务是否与机构所强调的服务相吻合? 4) 哪些因素会影响人们对生态系统服务的感知?

2 研究区域概况与研究方法

2.1 研究区域

广州是华南地区的一座特大城市,总面积达7 434.4km²,常住人口约1 500万^[26]。珠江水系的三大干流东江、西江和北江在此汇集并注入中国南海,城市中水量丰沛,却也极易遭受洪水影响。在过去的40年中,广州的湿地面积急剧减少,大量的滩涂被城市建设所取代^[27]。为保护湿地资源、增强抗洪防灾能力,广州近10年来建设了20座湿地公园^{[28][29]}。

2.2 研究方法

2.2.1 数据收集

本研究使用网络爬虫“集搜客”爬取2019年的新浪微博相关数据。首先利用微博高级搜索引擎,以20座湿地公园的名称为关键词进行搜索,将搜索结果的统一资源定位符复制到“集搜客”中获取数据。由于某些湿地公园的名称可能与其他省市的公园重名(例如白云湖湿地公园和山东省济南市白云湖国家湿地公园),研究将搜索位置设定为广州市所属的广东省^②;只有当湿地公园名称与广东省其他县市公园重名的情况下(例如大沙河湿地公园和深圳市大沙河公园),才将搜索位置设置为广州。研究主要采集文本内容(图片、视频等内容暂未分析,将在未来研究中进一步探索)、发布日期和时间、用户名和用户类型(个人/机构)等信息,共收集到10 633条公开发布的微博数据。

本研究所有数据收集和分析均基于匿名数据(即未收集或分析任何个人身份数据),并遵守新浪微博的《微博服务使用协议》和《个人信息保护政策》;“集搜客”严格遵守《Robots协议》。同时,本研究已通过谢菲尔德大学景观学院执行的道德审查程序,获得道德批准。

Although a user's comment may not cover all the perceived values or benefits of the ecosystems, what a person is willing to record or share could be the most noteworthy ESs. This research attempts to answer 4 questions: 1) What ESs do the public perceive from WPs? 2) What are the interconnections between perceived ESs? 3) Do the public perceive the same ESs as what professionals identify? and 4) What factors could affect people's perceptions on ESs?

2 Research Area and Methods

2.1 Research Area

Guangzhou is a mega-city in southern China, covering a total area of 7,434.4 square kilometers, with around 15 million residents^[26]. As a region where the rivers of the Pearl River system meet and flow to the South China Sea, Guangzhou has abundant water resources, but is extremely vulnerable to floods. Over the past 40 years, the area of wetlands in Guangzhou has decreased dramatically; large areas of mudflats have been replaced with urban development^[27]. To protect wetland resources and strengthen the city's resilience to floods, 20 WPs have been created in Guangzhou in the last decade^{[28][29]}.

2.2 Methods

2.2.1 Data Collection

This research used GooSeeker as web crawler to crawl the data from Sina Weibo throughout the year of 2019. The names of the 20 WPs were used as keywords to search the microblogs on the Advanced Search Engine of Weibo with their Uniform Resource Locator copied to GooSeeker for data collection. The search location was set as Guangdong Province, to which the City of Guangzhou belongs, to screen out the WPs with same names in other provinces in China (e.g., there is another Baiyun Lake Wetland Park in Shandong Province)^②; only for those with similar names in Guangdong Province (e.g., there is another Dasha River Park in Shenzhen), the search location was set as Guangzhou. Text content, post date and time, user ID, and user type (individual or institution), were collected. The research obtained text contents of 10,633 public microblogs (picture and video contents will be analyzed in future studies).

All data collection and analyses relied on anonymous data (i.e. no personally identifiable data was collected or analyzed) and adhered to the Terms and Conditions and Personal Information Protection Policy of Sina Weibo. Additionally, the GooSeeker strictly abides by the Robots Agreement. This research has been ethically approved via The University of Sheffield's Ethics Review Procedure, as administered by the Department of Landscape Architecture.

2.2.2 数据预处理

社交媒体数据通常具有嘈杂、结构零散和异质性等特征^[22]。由于搜索引擎的断句功能存在偏误，研究会不可避免地采集到一些无关数据。但本研究中的“相关数据”仅包括表达了用户对湿地公园的体验、感知和反馈意见的原始微博。因此，不相关微博、由个人或机构转发的微博、由相同个人或机构发布的重复微博均被手动剔除。但考虑到不同机构面向不同的粉丝群体，本研究保留了由不同机构发布的非转发性的、具有相同或几乎相同内容的微博文本。

2.2.3 生成生态系统服务类别和编码

在已筛选出的某些相关微博中，仅部分文字包含与湿地公园相关的评论或用户体验。同时，部分微博文本也可能使用某些网络用语，容易与用于识别生态系统服务的关键词相混淆——例如，“鸭”既可代表语气词“呀”，也可指示栖息地服务（生态系统服务的一种）。这意味着如果仅依赖单个的词语进行分析，难免会产生偏差。并且，尽管在自然语言处理过程中意义分析的基本单元是句子，但句子并非单个词语的线性组合^[30]。基于此，本研究剔除了相关微博文本中的无关部分，并对句子进行人工审核，再依据句子含义手动编码。

本文依据被广泛采纳的生态系统服务分类体系^[7]制定了生态系统服务分类与编码标准（表1），每一个子类以其所属的大类生态系统服务和数字命名。当微博中提及的生态系统服务价值较低时，使用负号（“-”）进行编码。例如，当微博内容表明缺乏美学价值（“杂乱”“不好看”）时，会被标记为“C2-”（即对美学服务的负面感知）；当提及入侵物种造成的危害时，将其编码为“S2-”（即对栖息地服务的负面感知）^③。

2.2.4 湿地公园受欢迎程度分析

本研究基于微博中各湿地公园的出现频率（即相关微博数）进行分析，以探讨湿地公园的受欢迎程度。一般而言，某湿地公园在微博上的相对出现频率越高，即越受欢迎^[34]。因此，研究采用“相对出现频率”——单位面积湿地公园的相关微博数——来代表公园的受欢迎程度。本研究中各湿地公园的名称^{[28][29]}、湿地类型和面积根据相关总体规划和官方文件确定。为了核验生态系统服务的提及率是否与受欢迎程

2.2.2 Data Pre-processing

Social media data is often noisy, unstructured, or heterogeneous^[22]; inevitably, irrelevant data will be collected because of the incorrect segmentation of the search engine. Only original microblogs, expressing the users' experience, perception, or feedback of visiting the WPs, were regarded as "relevant data." Thus, the searched irrelevant microblogs and reposted messages by individuals or institutions were excluded manually. Duplicated messages posted by the same individual or institution were also excluded. However, considering different institutions have different followers, non-repost messages with the same or almost the same content posted by different institutions were included.

2.2.3 Generating Categories and Coding of ESs

The study further screened out the irrelevant information from the relevant microblog texts. Besides, sometimes cyber language causes confusion with keywords for identifying ESs. For example, the character “鸭” (duck) can be a signpost to the refugia / habitat services (an ES), but recently microbloggers tend to use it as an alternative to the modal particle “呀” (“ah”). Therefore, the analysis might be biased if depending merely on words filtering. The basic unit of meaning analysis in natural language processing is sentence, which yet is not a simple linear sequence of words^[30]. Hence, the irrelevant information of the collected relevant microblogs was also manually excluded, and the sentences were manually audited and coded according to their meaning.

The categories and coding criteria of ESs (Table 1) were generated under the most-adopted ESs classification systems^[7]. Each ES sub-category was coded with its corresponding category and a number. Microblogs that stated the value of a perceived ES as low were coded with a negative mark (-). For example, when a microblog described that a WP has a low aesthetics value (e.g., messy, not attractive), it was coded with “C2-” (negative perception of aesthetics service); when one mentioned the harm caused by an invasive species, it was coded with “S2-” (negative perception of refugia / habitat service)^③.

2.2.4 Analysis of the Popularity of WPs

This analysis audited the occurrence frequency of various WPs (i.e. microblogs relevant to WPs). Generally, the higher the relative occurrence frequency of a WP on Weibo is, the more popular it will be^[34]. Thus, in this study, the popularity, i.e. the relative occurrence frequency of each WP was obtained by dividing total relevant microblogs by its area. The names^{[28][29]}, wetlands types, and area of WPs were sourced from official documents (including masterplans) of each WP. To examine whether the ESs occurrence is correlated to popularity, the proportion of microblogs which

③ 尽管入侵物种的出现表明该湿地公园为其提供了栖息地，但同时大大降低了为更多乡土物种提供栖息地的可能（参见参考文献[31]）。例如，广州常见的入侵植物物种微甘菊（*Mikania micrantha*）和白花鬼针草（*Bidens alba*）可威胁乡土植物的生存并导致生物多样性减少（参见参考文献[32][33]）。

③ Although the appearance of invasive species shows that the WP provides a habitat for invasive species, the possibility of providing habitats for a lot more native species is reduced considerably [Source: Ref. [31]]. For example, *Mikania micrantha* and *Bidens alba*, common invasive plant species in Guangzhou, could threaten the survival of native plants and result in a reduction in biodiversity [Source: Ref. [32][33]].

表1: 微博内容中的生态系统服务分类与编码标准
Table 1: Categories and coding criteria of ESs for microblogs

生态系统服务 ES		编码 Code	编码标准 (当微博提及以下内容时) Coding criterion (when a microblog mentions following contents)	生态系统服务 ES		编码 Code	编码标准 (当微博提及以下内容时) Coding criterion (when a microblog mentions following contents)
供给服务 Provisioning service	食物 Food	P1	来源于植物、动物和微生物的食品名称 (如农作物、野果、鱼); 收获食物的活动 Name of food products that are produced from plants, animals, and microbes (e.g., crops, wild fruits, and fish); activities to harvest food	调节服务 Regulating service	传粉 Pollination	R8	植物种群繁殖过程中花粉的运动 Movement of floral gametes for the reproduction of plant populations
	水资源供给 Water supply	P2	由流域、水库、含水层储存、保持和供应淡水 Fresh water storage, retention, and supply by watersheds, reservoirs, and aquifers		生物防治 Biological control	R9	疾病调控、害虫调控及种群营养动力学规律 (受捕食者控制) Disease regulation, pest regulation, trophic-dynamic regulations of populations (predator control)
	原材料 Raw material	P3	获取原材料, 包括纤维 (如木材、丝绸); 建筑材料 (如木材); 燃料 (如木柴); 饲料 Get raw materials, including fiber (e.g., wood and silk), construction materials (e.g., lumber), fuel (e.g., firewood), and fodder		降噪 Noise reduction	R10	降低噪音; 更加安静 Noise reduction; quieter
	装饰资源 Ornamental resource	P4	收集供装饰用的观赏动植物产品 Collect ornamental animal and plant products for decorative use	支持服务 Supporting service	营养循环、光合作用和初级生产 Nutrient cycling, photosynthesis, and primary production	S1	养分循环的过程 (例如固氮、磷循环) The process of nutrient cycling (e.g., nitrogen fixation, and phosphorus cycle)
	基因资源 Genetic resource	P5	用于动植物育种和生物技术的基因和遗传信息 Genes and genetic information used for animal and plant breeding and biotechnology		栖息地 Refugia / habitat	S2	野生动植物栖息地; 与野生动植物有关的活动 Habitat for wildlife resident and transient populations; do activities related to wildlife
	天然药物 Natural medicine	P6	从生态系统中获取天然药物 Get natural medicines from the ecosystem	文化服务 Cultural service	游憩 Recreation	C1	进行娱乐活动 (如生态旅游、垂钓和其他户外休闲活动) Recreational activities (e.g., eco-tourism, sport fishing, and other outdoor recreational activities)
调节服务 Regulating service	空气质量调节 Air quality regulation	R1	大气化学物质成分调节 (如碳氧平衡、硫氧化物水平控制); 空气质量更佳 Regulate the atmospheric chemical composition (e.g., carbon dioxide and oxygen balance, and sox levels control); better air quality		美学 Aesthetics	C2	欣赏美丽的风景或赞赏芬芳 Enjoy beautiful scenery or fragrance
	气候调节 Climate regulation	R2	调节当地和全球的温度、降水及其他生物调节的气候过程 Regulate local and global temperature, precipitation, and other biologically mediated climatic processes		文化多样性 Cultural diversity	C3	反映区域文化的景观特征 Landscape features that reflect regional culture
	干扰调节 Disturbance regulation	R3	暴雨防御、洪水防控、旱后恢复、飓风消减等 Storm protection, flood control, drought recovery, hurricane reduction, etc.		精神价值和宗教价值 Spiritual value and religious value	C4	视场地为宗教场所或神圣场所 Regard the place as a religious or sacred place
	水量调节 Water regulation	R4	径流、洪水和含水层补给的时间和幅度 (如自然灌溉、干旱预防) The timing and magnitude of runoff, flooding, and aquifer recharge (e.g., natural irrigation and drought prevention)		教育与知识体系 Education and knowledge system	C5	从湿地公园获得知识 (即正规和非正规教育) Gain knowledge from the WP (i.e. formal and informal education)
	水体净化 Water purification	R5	过滤并分解与水有关的生态系统有机废物或营养物质; 更好的水质 / 更干净的水 Filter out and decompose organic wastes or nutrients introduced to water related ecosystems; better water quality / cleaner water		社会关系 Social relation	C6	组织和参加可与他人互动或结交朋友的活动; 标记网络名人推荐的地点并与朋友分享以获取社会归属感 Organize or attend events to interact with other people or make friends; mark the places recommended by web celebrity and share with friends to gain social belongings
	侵蚀控制和沉积物滞留 Erosion control and sediment retention	R6	土壤保持 (例如防止山体滑坡; 防止因风、径流或其他搬运过程造成的土壤流失; 在湖泊和湿地中储存黏土) Soil retention (e.g., prevention of landslides; prevention of loss of soil by wind, runoff, or other removal processes; storage of silt in lakes and wetlands)		文化遗产价值 Cultural heritage value	C7	反映当地历史、传统和智慧的景观特征 Landscape features that reflect local history, traditions, and wisdom
	土壤形成 Soil formation	R7	土壤形成过程 (例如岩石的风化和有机物的积累) Soil formation process (e.g., weathering of rock and the accumulation of organic material)		灵感 Inspiration	C8	为艺术、诗歌等的创作提供灵感 Get inspiration for art, poems, etc.
			场所感 Sense of place	C9	人们在特定环境中的特殊体验 (刺激、快乐等) A person's special experience in a specific environment (feeling stimulating, happy, etc.)		
			生态系统负面服务 Ecosystem Disservice		ES-	被认为对人类福祉不利的生态系统功能 Functions of ecosystems that are perceived as negative for human well-being	

注
编码标准参考自参考文献[7]。

NOTE
The coding criteria were adopted from Ref. [7].

度相关, 研究亦计算了提及生态系统服务的微博在总相关微博中的占比; 湿地类型的影响也是考察内容之一。此外, 研究从百度地图^④获取湿地公园的位置数据(经纬度), 并通过ArcMap软件对公园的空间分布和受欢迎程度进行了可视化呈现。

2.2.5 语义分析

研究使用Python 3.7软件对与湿地公园中各生态系统服务相关的微博文本进行了语义分析, 以识别影响生态系统服务感知的关键因素(即感知关键词)。分析单元为与湿地公园中某项生态系统服务相关的所有微博。

与以空格来整齐分隔文本的英语不同, 中文文本需要首先进行分词(断句)处理, 以识别构成话语的词语^[30]。本研究使用了Python 3.7软件中的中文分词组件“结巴”。尽管“结巴”可以识别和记录新单词, 但自定义术语(即用户词典)编辑功能可以确保审核准确率更高^[35]。文本集有时可能包含一些使用频率非常高的无意义单词, 会增加嘈杂数据的干扰和文本相似度。利用这些无意义的词语来构建停用词词典, 可以提高关键词的密度, 使关键词更加集中和突出^[36]。

本研究根据微博内容手动扩展了用户词典、停用词词典和同义词词典, 以提高分词的准确性和有效性^[37]。用户词典由专有名词(如景点名称、动植物种类、技术术语)、成语(如“络绎不绝”)和短语(如“雨洪调蓄”)组成。停用词词典包括功能词(即副词、连接词、结构助词、语气词、连词、介词和量词)和一些实词(即湿地公园的名称, 行政区、城市、地区、国家名称, 日期和时间)。同义词词典由含义相同的词语组成。

文本数据可通过Python 3.7软件中的WordCloud库以词云的形式可视化呈现。重要的文本信息被准确、快速地提取出来^[37]。本研究提取了每个湿地公园中最频繁出现的20个词汇并对其进行了可视化。

2.2.6 可感知的生态系统服务之间的关联

本研究进一步开展了关联规则挖掘, 以探索感知到的生态系统服务之间的关联。关联规则是指“以X→Y呈现的表达式, 每当X出现, Y

mentioned ESs associated with relevant microblogs was also counted. The influence of wetland type was also examined. Furthermore, the location data (i.e. longitude and latitude) of the WPs, sourcing from Baidu Map^④ were processed with ArcMap to visualize the spatial distribution and the popularity of the WPs.

2.2.5 Semantic Analysis

Semantic analysis of the microblog texts relevant to each ES in a WP was conducted by using Python 3.7 to identify the key factors (i.e. keywords for perception) that affect the perception of ESs. All microblogs relevant to an ES sub-category in a WP were analyzed as an analysis unit.

Unlike English, which delivers text in the form of words neatly delimited by spaces, Chinese texts require first a segmentation process to identify the words that make up an utterance^[30]. Jieba, a Chinese word segmentation module in Python 3.7, was used in this study. Although Jieba can recognize and record new words, editing customized terms (i.e. user dictionary) ensures a higher audit accuracy^[35]. Text sets sometimes contain high-occurrence but meaningless words, which causes noise and increases the confusion between texts. Using these meaningless words to construct a stop-word dictionary can increase keyword density and make the keywords more concentrated and prominent^[36].

According to the microblog contents, this study manually expanded the user dictionary, stop-word dictionary, and synonym dictionary, to improve the accuracy and validity of the segmentation^[37]. The user dictionary is constituted of proper nouns (e.g., names of scenic spots, animal and plant species, technological terms), idioms (e.g., visitors in a steady stream, “络绎不绝”), and phrases (e.g., storm water regulation and retention, “雨洪调蓄”). The stop-word dictionary includes function words (i.e. adverbs, connectives, structural particles, modal verbs and particles, conjunctions, prepositions, and quantifiers) and some notional words (i.e. names of WPs; names of districts, cities, regions, and countries; dates; time). The synonym dictionary consists of different expressions with the same meanings.

The text data was visualized in form of a word cloud with the WordCloud Library in Python 3.7. Important text information was accurately and quickly extracted^[37]. The most frequent 20 words of each WP were extracted and visualized in this research.

2.2.6 Interconnections among Perceived ESs

Association rule mining was then conducted to explore the interconnections between the perceived ESs. The association rule is “an expression of the form X→Y that whenever X seems, Y also tends to appear”^[38]⑤. Here, the Frequent-Pattern growth

④ 百度地图是来自中国的一款网络地图服务应用程序, 可提供全面且不断更新的地图信息。

⑤ 关联规则挖掘的最初应用目标是找到顾客购买的不同商品之间的内在联系, 以了解顾客的购买习惯。它已被广泛用于关系数据库、数据仓库和文本数据库中(参见参考文献[39])。

④ Baidu Map is a web mapping service application in China that offers the widest-covering and dynamic map information.

⑤ Initially association rule mining was used to identify the inner links between different goods that customers bought to understand customer buying habits. It has been widely used in relational databases, data warehouses, and text databases [Source: Ref. [39]].

- ⑥ 例如，在数据集{A, B, C, D}、{A, D}、{A, B, C}、{B, C}、{B, D}和{A, B}中，A出现4次，表示为{A: 4}；在这4次中，B同时出现3次，表示为{A: 4, B: 3}，即B: 3是A: 4的分支。
- ⑦ 在SPSS软件中进行的双变量皮尔逊相关性分析结果也表明二者间的相关性不具有统计学意义(Sig.=0.548)。
- ⑥ For example, in dataset {A, B, C, D}, {A, D}, {A, B, C}, {B, C}, {B, D}, and {A, B}, A appears 4 times, which is expressed as {A: 4}; among these 4 times, B appears simultaneously 3 times, which is expressed as {A: 4, B: 3}. Here, B: 3 is the branch of A: 4.
- ⑦ A bivariate Pearson Correlation analysis was also ran in SPSS. As a result, the correlation was not statistically significant [Sig. = 0.548].

也会趋于出现”^{[38]⑤}。本研究采用了关联规则挖掘方法中最为高效的频繁增长模式(FP增长)算法^{[38][40]}。

FP增长算法的输出结果以FP树形式呈现，其根节点是一个空集，其他每个节点代表一个元素及其出现频率。此外，代表相似元素的节点之间通过链接相连，相连的元素可被视为链表。同一元素可以在FP树中多次出现，根据不同的位置，对应于不同的频繁项集^⑥。本研究中的FP树根据彼得·哈林顿^[41]提供的脚本在Python 3.7中构建。

3 研究结果

3.1 数据集概况

研究共抓取了2019年发布于新浪微博平台的10 633条微博，其中约有50%的微博(5 358条)与研究主题相关，由3 602名个人用户和125个机构用户发布。就个人用户而言，有112人针对某一湿地公园的一次游览发布多条微博，275人多次游览同一湿地公园且发布多条微博，43人多次游览同一湿地公园且每次发布多条微博，172人发布了与多个湿地公园有关的微博(其中90%的个人访问了两个湿地公园)。在相关微博中，每座公园平均有46%提到了生态系统服务。如表2所示，在20个被研究的湿地公园中，2019年有4个湿地公园暂未向公众开放，只有6个湿地公园具有足够数量(>100)的相关微博数据以供分析。因此，后文主要对这6个湿地公园——即海珠国家湿地公园、白云湖湿地公园、天河(大观)湿地公园、花都湖湿地公园、南沙湿地公园和挂绿湖湿地公园——进行分析。

3.2 湿地公园的受欢迎程度

2019年全年，各湿地公园的受欢迎程度存在明显差异。从表2和图1可见，6座湿地公园中有5座较受欢迎(受欢迎程度>0.5)，其中4座位于广州市中心地区，另一处南沙湿地公园位于城市边缘区；有5座拥有内陆开放水域(如人工湖、库塘)。滨河及滨海湿地公园的受欢迎程度较低。由图1可知，生态系统服务的提及率(即提及生态系统服务的微博在总相关微博中的占比)与湿地公园受欢迎程度之间尚无显著联系^⑦。

3.3 湿地公园中的生态系统服务感知

图2展示了个人用户和机构用户在6个湿地公园中的生态系统服务感知百分比频率。百分比频率即提及某一特定生态系统服务的微博

(FP-growth) algorithm, the most efficient algorithm to identify frequent item sets for association rule mining^{[38][40]}, was adopted.

The output of the FP-growth algorithm is an FP tree. The root node is an empty set, and each node is a single element, which stores its occurrence frequency in the dataset. Besides, the nodes with similar elements are inter-connected by links, which can be regarded as a linked list. A same element can appear multiple times in the FP tree, corresponding to different frequent item sets depending on the location^⑥. In this research, the FP tree was built with Python 3.7 according to a script proposed by Peter Harrington^[41].

3 Results

3.1 Dataset Description

In total, 10,633 microblogs generated in 2019 were crawled; approximately 50% of them (5,358) posted by 3,602 individuals and 125 institutions were audited as relevant. Specifically, 112 individuals posted more than one message for a single visit; 275 individuals posted about a same WP more than once; 43 individuals posted more than one microblog for one trip and visited a same WP for more than once; and 172 individuals posted about more than one WP (90% of these individuals visited two WPs). Among the relevant microblogs, on average, 46% mentioned ESs in each WP. As shown in Table 2, among the 20 examined WPs, 4 were not open to the public in 2019, and only 6 had enough relevant microblogs (> 100) for analysis, i.e. Haizhu National Wetland Park, Baiyun Lake Wetland Park, Tianhe (Daguan) Wetland Park, Huadu Lake Wetland Park, Nansha Wetland Park, and Gualyu Lake Wetland Park, which are scrutinized in this study.



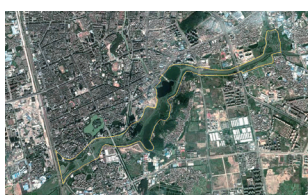

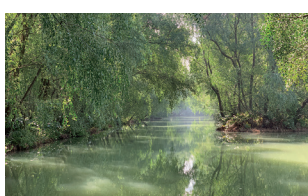


3.2 Popularity of WPs

Throughout the year, the popularity of each WP varied considerably. As can be seen from Table 2 and Figure 1, among the 5 relatively popular WPs (popularity > 0.5) regarding the 6 WPs, 4 are located in the central area of Guangzhou and the other, Nansha Wetland Park, is situated at the city border; 5 of them are with inland constructed open water bodies, including lakes, reservoirs, and ponds. Less attention was paid to riverine and coastal WPs. According to Figure 1, no obvious conclusion could be made about the relation between the rate of mentioned ESs (i.e. microblogs mentioned ESs divided by total relevant microblogs) and the popularity of the WPs^⑦.

3.3 Perceived ESs in WPs

Figure 2 presents the results of the percentage frequency of perceived ESs in the 6 WPs, by both individuals and institutions. The percentage frequency is the microblogs which mentioned a given

表2: 广州市湿地公园概况及微博提及情况
Table 2: Overview of WPs in Guangzhou and related microblogs to them

编号 No.	名称 Name	类型 Type	面积 Area (hm ²)	相关微博数 Number of related microblogs	受欢迎程度 (微博数 / hm ²) Popularity (piece / hm ²)	提及ES的微博数 Number of microblogs mentioned ESS	ES提及率 Rate of mentioned ESS (%)	平面图 Master plan	照片 Site photo
1	海珠国家湿地公园 Haizhu National Wetland Park	人工湖、河流、果基 鱼塘 Artificial lake, river, orchard fish ponds	891	2,538	2.85	1,201	47.32		
2	白云湖湿地公园 Baiyun Lake Wetland Park	人工湖 Artificial lake	187	904	4.83	335	37.06		
3	天河(大观)湿地公园 Tianhe (Daguan) Wetland Park	库塘 Reservoir and ponds	46.8	756	16.15	325	42.99		
4	花都湖湿地公园 Huadu Lake Wetland Park	滨河、人工湖 Riverine, artificial lake	256.6	606	2.36	359	59.24		
5	南沙湿地公园 Nansha Wetland Park	滨海、红树林 Coastal, mangroves	376	234	0.62	122	52.14		
6	挂绿湖湿地公园 Gualyu Lake Wetland Park	人工湖 Artificial lake	307	109	0.36	94	86.24		

续表见下页 / Continued

表2: 广州市湿地公园概况及微博提及情况
Table 2: Overview of WPs in Guangzhou and related microblogs to them

编号 No.	名称 Name	类型 Type	面积 Area (hm ²)	相关微博数 Number of related microblogs	受欢迎程度 (微博数 / hm ²) Popularity (piece / hm ²)	提及生态系统服务 的微博数 Number of microblogs mentioned ESs	生态系统服务 提及率 Rate of ESs mentioned (%)
7#	知识城凤凰湖湿地公园 Fenghuang Lake Wetland Park, Knowledge City	人工湖 Artificial lake	34	55	1.62	31	56.36
8#	贝岗湿地公园 Beigang Wetland Park	滨河、人工湖 Riverine, artificial lake	38.4	2	0.05	0	-
9#	风云岭湿地公园 Fengyunling Wetland Park	滨河、人工湖 Riverine, artificial lake	33.69	10	0.30	8	80.00
10#	鹤之洲湿地公园 Cranes' Islet Wetland Park	滨河 Riverine	7	14	2.00	11	78.57
11#	海鸥岛湿地公园 Seagulls' Island Mangrove Wetland Park	滨海、红树林 Coastal, mangroves	186	11	0.06	9	81.82
12#	大沙河湿地公园 Dasha River Wetland Park	滨河 Riverine	55	1	0.02	0	-
13#	南沙滨海绿道湿地公园 Nansha Coastal Greenway Wetland Park	滨海、红树林 Coastal, mangroves	13	1	0.08	1	100.00
14#	南岗河文教园区湿地公园 Nangang River Wetland Park	滨河 Riverine	15	0	-	0	-
15#	流溪温泉湿地公园 Liuxi Hot Spring Wetland Park	滨河 Riverine	46	0	-	0	-
16#	石马龙湿地公园 Shimalong Wetland Park	水库 Reservoir	22	0	-	0	-
17*	白海面湿地公园 Baihaimian Wetland Park	人工湖 Artificial lake	110.5	1	0.01	0	-
18*	湾咀头湿地公园 Wanzuitou Wetland Park	人工湖 Artificial lake	19.5	1	0.05	0	-
19*	赤坎湿地公园 Chikan Wetland Park	滨河、人工湖 Riverine, artificial lake	61	0	-	0	-
20*	草河湿地公园 Caohe River Wetland Park	滨河 Riverine	28	0	-	0	-

注

1. 湿地公园信息来源于参考文献[27][28], 湿地公园平面图来源于Google地球, 湿地公园实景图由作者拍摄;
2. “#”代表该湿地公园未能获取足够的分析数据, “*”代表2019年该湿地公园尚未向公众开放。

NOTE

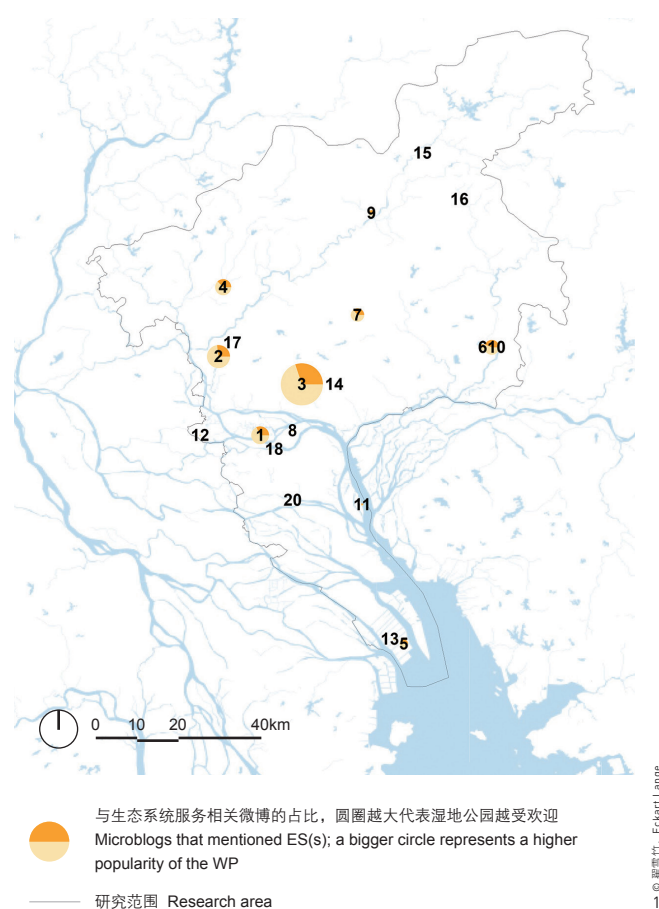
1. Information of the WPs were sourced from Ref. [27][28]; site plans of the WPs were sourced from Google Earth; and photos of the WPs were shot by the authors;
2. “#” means WPs with insufficient data for analysis, “*” means WPs that were not open to the public in 2019.

在所有提及生态系统服务微博中的占比。水资源供应 (P2), 原材料 (P3), 基因资源 (P5), 土壤形成 (R7), 传粉 (R8), 生物防治 (R9), 营养循环、光合作用和初级生产 (S1), 以及精神价值和宗教价值 (C4) 等8种生态系统服务未出现在任何相关微博中。

文化服务是所有生态系统服务中感知百分比频率最高的: 1) 就每个湿地公园而言, 有35.0%~66.4%的微博提及游憩服务 (C1); 相比之下, 南沙湿地公园中游憩服务的感知百分比频率最低; 2) 美学服务 (C2) 在天河 (大观) 湿地公园中的感知百分比频率最高 (73.5%), 在白龙湖湿地公园、花都湖湿地公园、南沙湿地公园和挂绿湖湿地公园

ES divided by the total number of microblogs that mentioned ESs. 8 types of ESs, namely water supply (P2), raw material (P3), genetic resource (P5), soil formation (R7), pollination (R8), biological control (R9), nutrient cycling, photosynthesis, and primary production (S1), and spiritual value and religious value (C4), never mentioned by any of the relevant microblogs.

Cultural services were the most perceived ESs: 1) 35.0% ~ 66.4% of the microblogs mentioned recreation (C1) in each WP; comparatively, the recreation services of the Nansha Wetland Park had the lowest percentage frequency of perceived ESs; 2) In terms of aesthetics services (C2), Tianhe (Daguan) Wetland Park had the highest percentage frequency (73.5%), while Baiyun Lake Wetland Park, Huadu Lake Wetland Park, Nansha Lake Wetland



园中的感知百分比频率较低（低于22.0%）；3）能够感知到湿地公园所提供生态系统服务的用户中有9.0%~25.5%提到了社会关系服务（C6）；4）在所有湿地公园中，教育和知识体系服务（C5）和场所感服务（C9）的感知百分比频率均低于5%；5）在大多数湿地公园中，文化多样性（C3）、文化遗产价值（C7）和灵感（C8）等服务很少被感知。

只有极少数的微博用户（少于10%）认为供给服务、调节服务和支撑服务是值得关注的。食物供给服务（P1）在挂绿湖湿地公园中的感知频率最高，主要涉及钓鱼活动。装饰资源（P4）和天然药物（P6）供给服务较少为微博用户所关注：仅有两人展示了由海珠国家湿地公园或花都湖湿地公园中的落叶制成的拼贴画，一人展示了用海珠国家湿地公园中采集的花朵制成的书签；一人记录了花都湖湿地公园中的鸡蛋花（*Plumeria rubra*）的药用价值。空气质量调节服务（R1）的感知频率在该类型服务中相对较高。而即便在天河（大观）湿地公园）等专为防洪和水体净化而设计的湿地公园中，干扰调节（R3）和水体净化（R5）服务也很少被个人用户感知。在所有6个湿地公园中，降噪服务（R10）偶尔被提及。水量调节（R4）及侵蚀控制和沉积物滞留（R6）服务仅分别在海珠国家湿地公园和南沙湿地公园中各被提及1次。此外，在6个湿地公园中，人们对栖息地服务（S2）的感知存在巨大差异：该服务在南沙湿地公园中的感知百分比频率为

Park, and Gualyu Lake Wetland Park had a lower percentage frequency (less than 22.0%); 3) 9.0% ~ 25.5% of the microbloggers who perceived ESs in the WPs mentioned about social relation services (C6); 4) The percentage frequencies of perceived education and knowledge system services (C5) and sense of place services (C9) were less than 5% in all WPs; and 5) Cultural diversity (C3), cultural heritage (C7), and inspiration (C8) were rarely perceived in most WPs.

Only a minority of the microbloggers (less than 10%) perceived provisioning, regulating, and supporting services as noteworthy. The provision of food (P1) was mostly perceived in the Gualyu Lake Wetland Park and relevant microblogs were mainly about fishing activities. The provisioning services of ornamental resources (P4) and natural medicines (P6) were rarely perceived as noteworthy—only two individual microbloggers showed the collages made with fallen leaves collected from the Haizhu National Wetland Park and Huadu Lake Wetland Park; another individual posted the bookmark made with the flowers collected from the Haizhu National Wetland Park; a microblog recorded the medical use of *Plumeria rubra* found in the Huadu Lake Wetland Park. The percentage frequency of perceived air quality regulation (R1) was relatively high across all the regulation services. Disturbance regulation (R3) and water purification (R5) services were little perceived, even in WPs designed for flood control and water purification, such as Tianhe (Daguan) Wetland Park. Noise reduction (R10) was casually perceived in all the 6 WPs. Water regulation (R4) as well as erosion control and sediment retention (R6) were only perceived once in Haizhu National Wetland Park and Nansha Wetland Park. The perception of refugia / habitat services (S2) showed a vast disparity among the 6 WPs: 70.5% for the Nansha Wetland Park, while only less than 5.0% for the Tianhe (Daguan) Wetland Park, Huadu Lake Wetland Park, and Gualyu Lake Wetland Park.

Although the percentage frequency of perceived ecosystem disservices (ES-), i.e. the negative impacts on human well-being accompanied the ESs, was low, it was sometimes perceived in all the WPs.

3.4 Interconnections among Perceived ESs

The analysis of association rules (Fig. 3) shows a strong interconnection between aesthetics (C1) and recreation (C2) services in 5 of the 6 WPs (except the Nansha Wetland Park). Sometimes social relation services (C6) were related to recreation services (C1): 31 times in Haizhu National Wetland Park, 11 times in Baiyun Lake Wetland Park, 26 times in the

2. 6个湿地公园中人们感知到的生态系统服务百分比频率
2. Percentage frequency of perceived ESs in the 6 WPs

70.5%，而在天河（大观）湿地公园、花都湖湿地公园和挂绿湖湿地公园中均不足5.0%。

尽管生态系统负面服务（ES-，即生态系统功能对人类福祉的负面影响）的感知百分比频率不高，但该项服务在各湿地公园中均曾被感知。

3.4 感知到的生态系统服务之间的关联规则分析

关联规则的分析结果（图3）显示，除南沙湿地公园外，其他5座湿地公园中美学服务（C2）和游憩服务（C1）之间存在很强的关联性。社会关系服务（C6）与游憩服务（C1）时而一同被提及：例如，海珠国家湿地公园中共同出现31次，白云湖湿地公园11次，天河（大观）湿地公园26次，花都湖湿地公园27次。在天河（大观）湿地公园中，游憩服务（C1）、美学服务（C2）和社会关系服务（C6）被同时提及17次。在海珠国家湿地公园和南沙湿地公园中，栖息地服务（S2）与美学服务（C2）或与游憩服务（C1）通常会被同时提及；有时以上三项服务同时被感知。空气质量调节服务（R1）和游憩服务（C1）或美学服务（C2）有时被同时感知（R1和C1在海珠国家湿地公园中出现13次、花都湖湿地公园6次；R1和C2在海珠国家湿地公园中出现12次）。其他生态系统服务之间的关联不明显（即频数不超过5次）。

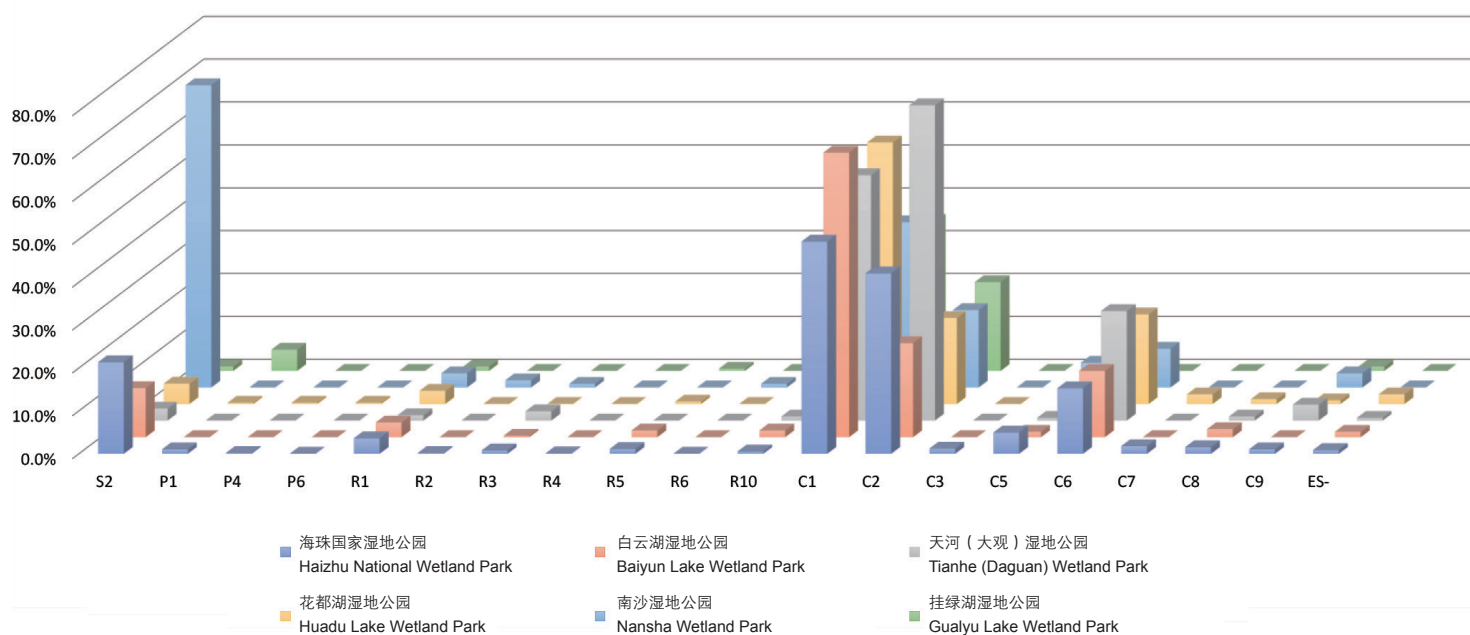
3.5 个人感知与机构宣传

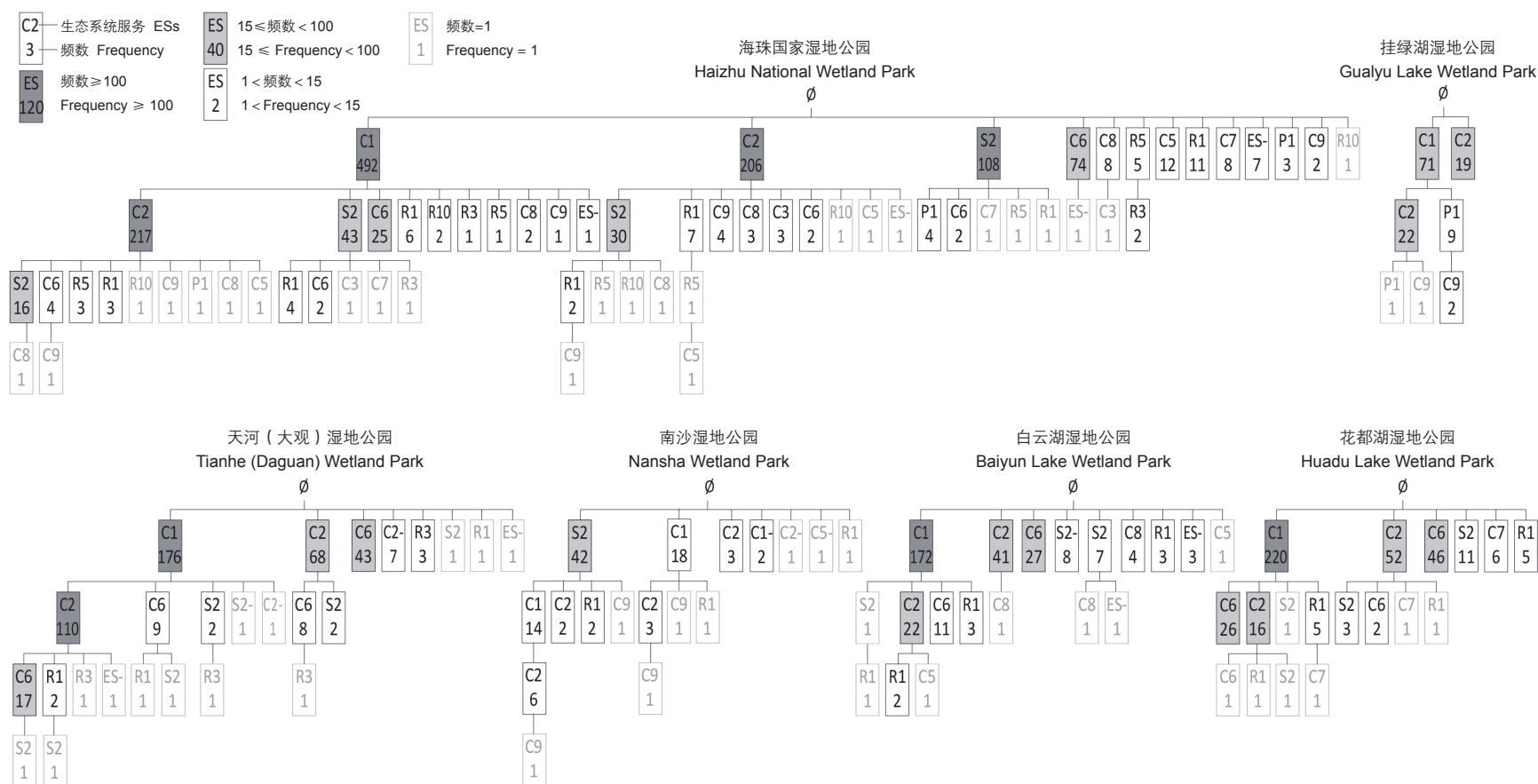
图4比较了个人用户和机构用户对生态系统服务的感知百分比频率。个人用户和机构用户对游憩服务（C1）的感知百分比频率均最高，其次是美学服务（C2）；然而，就同一项生态系统服务的感知而言，个人用户与机构用户之间差异明显，前一项服务的感知百分比频率

Tianhe (Daguan) Wetland Park, and 27 times in Huadu Lake Wetland Park. In Tianhe (Daguan) Wetland Park, recreation services (C1), aesthetics services (C2), and social relation services (C6) were mentioned 17 times simultaneously. In Haizhu National Wetland Park and Nansha Wetland Park, refugia / habitat services (S2) were often perceived along with aesthetics services (C2). Sometimes, air quality regulation service (R1) and recreation (C1) or aesthetics (C2) services were perceived simultaneously (for R1 and C1: 13 times in Haizhu National Wetland Park, 6 times in Huadu Lake Wetland Park; for R1 and C2: 12 times in Haizhu National Wetland Park). The interconnections among other ESs were not obvious (i.e. frequency less than 6 times).

3.5 Individuals' Perceptions versus Institutions' Publicity

Figure 4 compares the percentage frequency of perceived ESs by individuals and institutions. The percentage frequency of perceived recreation services (C1) ranked top for both individuals and institutions, seconded by aesthetics services (C2); whereas, the disparity between individuals and institutions was significant—33.1% versus 93.3% and 23.3% versus 73.7%, respectively. The other two most frequently mentioned ESs were refugia / habitat services (S2) (perceived by 7.7% of individuals and 64.8% of institutions) and social relation services (C6) (perceived by 8.5% of individuals and 58.1% of institutions). 26.8% of microblogs posted by institutions mentioned the education and knowledge system service (C5), which was rarely





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分别为33.1%和93.3%、后一项服务为23.3%和73.7%。除此之外，两个最常被感知的生态系统服务是栖息地服务（S2）（7.7%的个人用户和64.8%的机构用户曾提及）和社会关系服务（C6）（8.5%的个人用户和58.1%的机构用户曾提及）。机构用户发布的微博中有26.8%提到了教育与知识体系服务（C5），而个人用户极少（0.7%）认为该服务值得关注。

本文进一步选择了数据充足的游憩（C1）、美学（C2）和栖息地（S2）三项服务进行分析，以比较全年中个人感知和机构宣传之间的差异，但未发现明显的月分布模式。就栖息地服务（S2）而言，机构用户发布的微博数对个人发布的比例较高，这一特征在南沙湿地公园和白云湖湿地公园尤为明显。在白云湖湿地公园中，对栖息地服务（S2）的负面感知（以“-”标记）较多，其中多数由个人用户指出。针对挂绿湖湿地公园，机构用户发布的生态系统服务相关内容较少。

3.6 生态系统服务感知促进因素

词云分析结果（图5）表明，在6座湿地公园中，促进生态系统服务感知的因素各不相同。词云中词语/单词的尺寸越大，表示它出现的频率越高、促进效果越大。尽管在一些湿地公园中，促进某些生态系统服务感知的因素较为相似，但这些因素的影响程度存在差异——

perceived as noteworthy by individuals (0.7%).

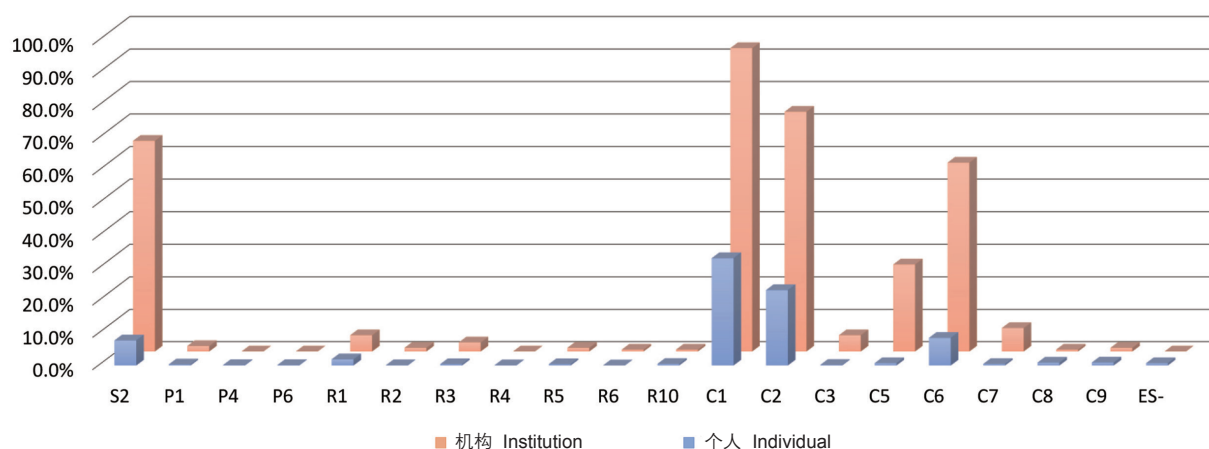
This study further selected three ESs, namely recreation (C1), aesthetics (C2), and refugia / habitat (S2), due to the sufficient data collected, to compare the perception differences between individuals' perception and institutions' publicity throughout the year. There was no obvious monthly distribution pattern found in frequency of perceived ESs. The ratio of the number of microblogs posted by institutions, compared with individuals, is higher in refugia / habitat services (S2), especially in the Nansha Wetland Park and Baiyun Lake Wetland Park. In Baiyun Lake Wetland Park, the number of microblogs related to negative perception of refugia / habitat services (marked with “-”) was high, especially indicated by individuals. Institutions posted little about ESs in the case of Gualyu Lake Wetland Park.

3.6 Stimuli to ESs Perceptions

The word cloud analyses (Fig. 5) display the stimuli to the positive perception of ESs varied across the 6 WPs. The larger the size of a word is, the more frequently it occurs and the more important it is. The identified stimuli were commonly found in the WPs but seeing a varied degree of influence—for instance, Ardeidae

- 6个湿地公园中人们感知到的生态系统服务的频繁模式树
- FP-tree of ESs perceived in the 6 WPs

4. 针对6个湿地公园中游憩服务（C1）、美学服务（C2）和栖息地服务（S2）的个人感知与机构宣传之间的对比
4. Overall and monthly comparison between individuals' perceptions and institutions' publicity of recreation (C1), aesthetics (C2), and refugia / habitat services (S2) in the 6 WPs.



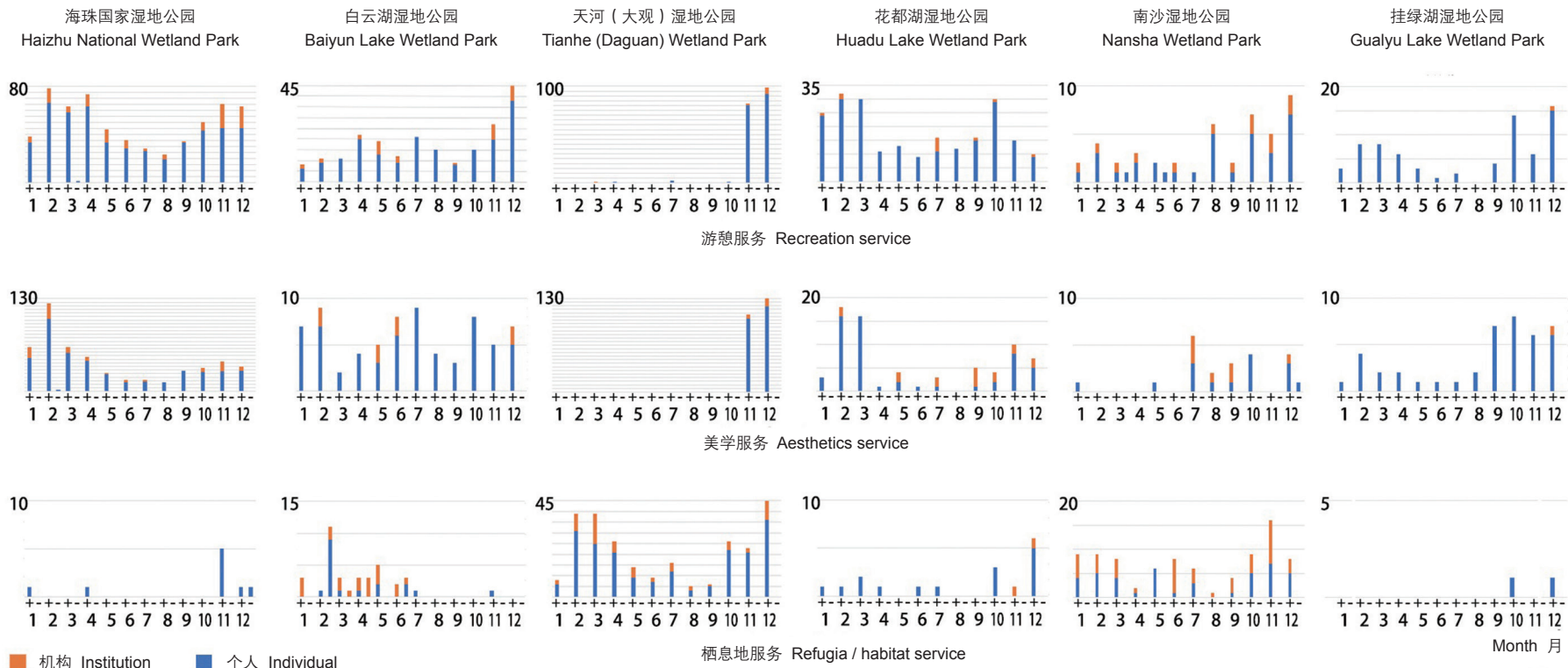
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例如，鹭鸟（Ardeidae）作为栖息地服务（S2）感知的促进因素，在花都湖湿地公园中发挥的作用要大于南沙湿地公园。

在不同的湿地公园中，促进人们感知游憩服务（C1）的因素差异显著——即微博文本分析显示，人们所进行的游憩活动多种多样。在与白云湖湿地公园有关的微博中，“跑步”一词的出现频率较高；相比之下，海珠国家湿地公园和挂绿湖湿地公园中促进人们对该服务感

as a stimulus for the perceptions of refugia / habitat services (S2) was more important in Huadu Lake Wetland Park than in Nansha Wetland Park.

Stimuli to recreation services (C1) saw a variety among different WPs, i.e. people reported that they took part in varied recreational activities: stimuli were more diverse in the Haizhu National Wetland Park and Gualyu Lake Wetland Park, compared with Baiyun Lake Wetland Park where most



- 注
- “+”代表积极感知，“-”代表消极感知；
 - 纵坐标的单位刻度为5条微博。

- NOTE
- “+” means positive perception and “-” means negative perception;
 - The scale unit for the vertical coordinate is 5 pieces of micrablogs.

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在美学服务 (C2) 的感知中, “摄影” 和 “赏花” 在6座湿地公园中均是最常被提及的活动。落羽杉 (*Taxodium distichum*) 等彩叶乔木和百日草 (*Zinnia elegans*)、波斯菊 (*Cosmos bipinnatus*)、荷花 (*Nelumbo florida*) 和黄花风铃木 (*Tabebuia chrysantha*) 等观花植物是湿地公园中能够促进美学服务 (C2) 感知的因素 (南沙湿地公园除外); 在南沙湿地公园中, 鸟类、红树林和芦苇 (*Phragmites australis*) 是最重要的促进因素。

除白云湖湿地公园外, 鸟类是促进个人用户和机构用户宣传湿地公园栖息地服务 (S2) 的重要因素, 并且机构用户提及的鸟类种类较个人用户更加多样。促进个人用户感知栖息地服务 (S2) 的鸟类主要为海珠国家湿地公园中的雁鸭鸟类 (Anatidae)、花都湖湿地公园中的鹭鸟和南沙湿地公园中的黑脸琵鹭 (*Platalea minor*)。蝴蝶、蜜蜂和一些植物也可以促进对栖息地服务的感知。此外, 与白云湖湿地公园相关的栖息地服务 (S2) 主要涉及大型入侵掠食性鱼类鳄雀鲂 (*Atractosteus spatula*), 是人们对栖息地服务的负面感知 (S2-)。

就干扰调节服务 (R3) 而言, 仅天河 (大观) 湿地公园的相关数据较为充分, 能够进行词云分析: “海绵城市” 和 “生态景观” 均为刺激个人用户感知和机构用户宣传该服务的主要因素, 表明个人感知与机构宣传之间存在相似之处。在海珠国家湿地公园、白云湖湿地公园和天河 (大观) 湿地公园中, 遭蚊虫叮咬是造成生态系统负面服务 (ES-) 感知的主要原因。

4 讨论

4.1 基于湿地公园中生态系统服务感知的思考

研究表明, 大多数受欢迎程度较高的湿地公园均位于广州市中心区域, 便捷的交通可能是其中一个影响因素。此外, 湿地公园和生态系统服务的品质也会影响公众的造访频率。湿地公园的受欢迎程度在一定程度上反映了公众的偏好: 拥有人工湖等内陆开放水域的湿地公园比仅包含河流或红树林的湿地公园更受欢迎。造成这一偏好的原因可能是中国的风水观念或传统的水景设计^[42]对公众审美趣味的影响。同时, 这一发现指出了当前研究的一项空白: 尽管已经有研究证明植被和沉积物的存在^[43]、水体的颜色和清澈程度^{[43][44]}和水量^[44]等会影响人们对湿地的感知和偏好, 但有关湿地形态对感知的影响尚缺乏研究。

“Photography” and “flower-viewing” were the activities most frequently mentioned in the perceptions of aesthetics value (C2) in the WPs. Colored-leaf trees (e.g., *Taxodium distichum*) and flowering species (e.g., *Zinnia elegans*, *Cosmos bipinnatus*, *Nelumbo florida*, and *Tabebuia chrysantha*) were the stimuli for the perception of aesthetics services (C2) in 5 WPs, except for the Nansha Wetland Park. For the Nansha Wetland Park, birds, mangroves, and *Phragmites australis* were the most important stimuli.

Birds were the most important stimulus for the individuals' perception and institutions' publicity of refugia / habitat services (S2) in the WPs, except for the Baiyun Lake Wetland Park. Institutions mentioned a more diverse range of bird species. The most mentioned bird species for individuals were Anatidae in Haizhu National Wetland Park, Ardeidae in the Huadu Lake Wetland Park, and *Platalea minor* in Nansha Wetland Park. Butterflies, bees, and plants were also the major stimuli for some WPs. Besides, refugia / habitat services (S2) mentioned in the Baiyun Lake Wetland Park related mainly to the negative perception of the large invasive predatory fish species *Atractosteus spatula* (S2-).

Only the data collected about Tianhe (Daguan) Wetland Park was sufficient for the word cloud analysis of disturbance regulation services (R3). “Sponge city” and “ecological landscape” were the dominant stimuli for both types of microbloggers, revealing that there was a similarity between the public's perception and the institutions' publicity. Suffering mosquito bites was the key factor for the perceptions of ecosystem disservices (ES-) in Haizhu National Wetland Park, Baiyun Lake Wetland Park, and Tianhe (Daguan) Wetland Park.

4 Discussion

4.1 Thoughts on the Perceptions of ESs in WPs

It was found that most of the popular WPs are located in the central area of Guangzhou. The easy accessibility in the central area could be an explanation for this. Also, the quality of WPs and the delivered ESs could affect people's visits. The popularity of WPs reflects public's preferences to some extent: the WPs with open inland water bodies (e.g. lakes) are more popular than the ones that only contain rivers or mangroves. A possible reason might be that the public are aesthetically influenced by Chinese Fengshui ideas or traditional waterscape styles^[42]. This finding pointed to a research gap: although it has been proved that the presence of vegetation and sediment^[43], water color and transparency^{[43][44]}, and amount of water^[44] can impact people's perceptions and preferences for wetlands, research about the impact of wetland forms is scarce.

研究结果印证了以往研究的观点,即城市居民更容易直观感受到文化服务一类的生态系统服务^[11]。其中最为有趣的发现是,尽管栖息地服务(S2)通常并不能直接为人类带来裨益^{[7][8]},但在本研究着重关注的6座湿地公园中,许多人都能够感知到这一服务。然而研究结果尚不足以推断栖息地服务(S2)之所以颇受关注,是因为人类可以直接从中获益,还是因为其与游憩(C1)和美学(C2)服务高度关联。另一个值得一提的结果是,装饰资源(P4)、噪声调节(R10)和场所感(C9)等在以往湿地或公园研究中较少被关注的生态系统服务^{[45]-[47]},在一些湿地公园中曾被感知。以往的研究表明,湿地和湿地公园通常难以提供精神价值和宗教价值(C4)、水资源供应(P2)和原材料服务(P3)等^{[48]-[50]},而本研究的结果显示,在6座湿地公园中,基因资源(P5)、土壤形成(R7)、传粉(R8)、生物防治(R9),以及养分循环、光合作用和初级生产(S1)这5项生态系统服务同样几乎未被感知,人们需要具备一定的生态知识才能感知这些服务^[51]。此外,研究结果还表明,教育与知识体系服务(C5)和干扰调节服务(R3)这类由湿地公园着重提供的生态系统服务,却只被少数人感知到。以上发现可能缘于公众通常缺乏生态系统服务相关知识^[52]。人们往往倾向于在美学服务(C2)等更具视觉吸引力的生态系统服务上发表更多的观点。鉴于此,可以通过提升公众教育来弥合这种供需之间的差距^[51]。

研究结果进一步表明,游憩服务(C1)与美学服务(C2)密切相关,与社会关系(C6)或栖息地(S2)服务时而关联,符合生态系统服务簇理论,即某些生态系统服务可反复同时出现^[12]且能够一同被感知^[51]。然而,尚未在其他有关湿地公园、湿地或NBS中生态系统服务感知的研究中发现类似关联,其中一个可能的原因是通过社会偏好研究生态系统服务簇的文献较少。同时,由于收集到的数据较为有限,研究尚未发现其他生态系统服务之间的明显关联;因此,需要更多的数据来验证以上发现。

本研究表明某些景观特征可以促进人们对生态系统服务的感知。例如,观花植物和彩叶乔木能够促进对美学服务(C2)的感知,鸟类、红树林和芦苇能够促进对栖息地服务(S2)的感知。不同湿地公园中促进生态系统服务感知的因素也存在明显差异,因此可着重考虑公园中蓝绿空间的规划和设计,以强化人们的感知^[53]。此外,结果也表明,个人感知与机构宣传之间存在相似之处;可能的原因是这些机构

The research results corroborated the proposition that cultural services can be more easily and intuitively understood by people in the city^[11]. The most interesting finding was that, although the refugia / habitat services (S2), were often considered to not directly benefit human well-being^{[7][8]}, they were perceived by many people in the 6 studied WPs. Results were insufficient to infer whether refugia / habitat services (S2) can directly benefit human well-being or whether it is just because of the association with recreation (C1) and aesthetics (C2) services that many people perceived them as noteworthy. It is also interesting to note that ornamental resource (P4), noise reduction (R10), sense of place (C9), and other ESs which were little studied among previous research on ESs of wetlands or parks^{[45]-[47]} were considered noteworthy in some WPs. Spiritual value and religious value (C4), water supply (P2), and raw material (P3) services are usually not considered to be provided by wetlands and WPs^{[48]-[50]}; this research indicated that the other 5 ESs—genetic resource (P5), soil formation (R7), pollination (R8), biological control (R9), and nutrient cycling, photosynthesis, and primary production (S1)—were hardly perceived in the 6 WPs, the perception of which is often stimulated by ecological knowledge or concerns^[51]. Another finding was that only a minority of individuals perceived some of the expected ESs by WPs, such as education and knowledge system (C5) and disturbance regulation (R3). These findings may result from that the public often lack knowledge about ESs^[52]. Inevitably, people tend to comment more on visually attractive ESs, like aesthetics (C2). Thus, such a gap between the supply and demand of ESs could be bridged by improving public education^[51].

The results further showed that the recreation (C1) and aesthetics (C2) services are strongly interconnected, and sometimes connect to social relation (C6) or refugia / habitat (S2) services, which support the ESs bundle theory that ESs can repeatedly appear together^[12] and be perceived together^[51]. However, the same interconnections are not found in other studies about perceived ESs in WPs, wetlands, or NBS, because of the paucity of research on ESs bundles through social preference. The finding that there was no obvious interconnection among other ESs may result from the limited data collection; a larger amount of data is needed to verify this finding.

This study explored the stimuli to the perception of ESs: for example, flowers and colored-leaf trees to the aesthetics (C2) services, and birds, mangroves, and *Phragmites australis* to the refugia / habitat services (S2). The stimuli are varied in different WPs, and the composition and design of blue-green spaces could influence people's perception of ESs^[53]. Moreover, the research found the overlaps between the ESs that the public perceived and that the professional institutions expected. A possible explanation

通常在微博平台拥有较大的影响力。由此可见，机构能够在有关生态系统服务的公众教育中发挥更大作用。

4.2 方法论意义

已有的景观感知研究力求探寻专业人士和公众对景观的诠释，其中有关公众对景观感知的研究主要通过视觉或偶尔借助听觉来进行评估^{[44][54][55][56]}。在视觉景观评估中，照片^[44]和沉浸式虚拟现实技术^{[57][58]}常被用作视觉刺激。然而，事实上人们是通过所有的感官去感知环境的；鉴于现场调查通常既耗时又代价高昂，只有较少的研究以实际景观为评估的刺激物。因此，本研究通过社交媒体来收集用户体验，以更加高效和经济的方式来分析人们对生态系统服务更真实的感知。此外，相比通过绘制参与式地图来确定给定生态系统服务的感知分布情况^[59]或通过问卷或访谈形式对给定生态系统服务进行评级^{[60][61]}等方法，使用来自社交媒体的自述数据可以帮助研究人员发现当前研究中较少被关注的生态系统服务。

本研究首次应用关联规则挖掘来揭示生态系统服务之间的关联。相比以往根据土地覆盖和生态系统服务空间分布情况进行分层聚类分析，进而探索生态系统服务簇在大尺度空间中分布的研究^{[13][51]}，本研究所采用的方法无需明确生态系统服务的空间分布，即可探索生态系统服务簇及生态系统服务之间的关联。

与此同时，本文的方法论也存在一定的局限性。尽管根据句子含义手动编码而非仅分析形容词，可以有效提取相关信息，但与使用了语义差别法等进行的研究相比，无法量化生态系统服务的感知。此外，尽管社交媒体平台面向所有人开放，但年轻人却是使用主力：约四分之一的中国人口使用新浪微博，但其中18~40岁的成年用户占90%^[25]。因此，研究使用微博数据进行分析，不可避免地会忽略未成年人和40岁以上成年人的感知情况。另外，与社交平台相关的特定活动（例如网红景点打卡并与朋友分享）可能在一定程度上影响结果。例如，与使用其他研究方法相比，人们对社会关系服务（C6）的感知数

for this is that the institutions often have a greater influence on the Sina Weibo, which means that institutions can play a more influential role in public education about ESs.

4.2 Methodological Implications

Existing landscape perception studies have been carried out by understanding professionals and public interpretations of landscape of which the studies on public's landscape perceptions were mainly conducted through visual assessment of landscape, or aural sometimes^{[44][54][55][56]}. In visual landscape assessment, photographs^[44] and immersive virtual reality techniques^{[57][58]} can be used as stimuli. However, people perceive the environment by all senses. Only a few of studies used actual landscapes as stimuli for assessment, but such on-site surveys are often time-consuming and costly. Thus, this research relies on collecting social media users' authentic experience to report a more realistic perception of ESs time- and cost-efficiently. Moreover, compared with previous ESs perception studies which usually employed participatory mapping to identify the perceived distribution of given ESs^[59], or ratings on given ESs through questionnaires or interviews^{[60][61]}, this method using self-reported data from social media could help researchers find the ESs that have been less focused on in previous studies.

Methodologically, this study first applied association rule mining to reveal the interconnections among ESs, instead of the hierarchical cluster analysis to explore ESs bundle distribution in large-scale spaces according to the land cover typologies and ESs spatial distribution^{[13][51]} commonly employed in previous research. The method in this study makes it possible to explore the ESs bundle and interconnections among ESs without specifying the ESs spatial distribution.

There are also some limitations to the methodology. Coding manually upon semantic analysis of sentences, instead of analyzing adjectives, so as to effectively extract relevant information, might compromise the opportunity to quantify the perceived ESs, e.g., if using the semantic differential method. In addition, though social media are accessible to everyone, young adults are more likely than people of other ages to use them: Sina Weibo is used by about a quarter of the Chinese population, and 90% of the users are adults aged 18 to 40^[25]. In this research, using Weibo data would inevitably neglect perceptions from children under 18 and adults over 40 years old. Furthermore, activities specific to social programs, such as marking online-popular places and sharing with friends, may have an impact on the results to some extent; for instance, the result of the perceived social relation services (C6) could be higher than using other methodology. Data collected over one year is not "big" enough;

据可能会偏高。鉴于此，仅基于一年的数据稍显不足，可以通过多年的比较分析获取更多结果，以更好地了解公众对生态系统服务的感知和偏好。

4.3 在可持续景观管理中的应用

研究结果有助于明确未来景观规划和设计工作的重心，尽可能提高人类福祉并确保公众可以感知到这些益处。例如，规划和设计可以更加关注常常被忽视的生态系统服务，例如降噪、装饰资源和场所感。对于某些人们可以感知到的但公园或项目管理者不愿提供的生态系统服务（如访客摘花作装饰用途），可以通过设计策略来引导公众与这些生态系统服务进行良性互动。此外，当设计者期望使用者感知的生态系统服务未能被有效感知时，可以通过改善与该服务相关联的服务及提升景观特征来促进感知。例如，基于美学服务与栖息地服务之间的关联，可以通过改善栖息地服务来增强美学价值。

5 结语

本研究概述了以广州为例的湿地公园中生态系统服务的感知情况。研究结果指出了公众对生态系统服务的关注重点及相关专业机构对NBS项目的预期，对于未来湿地公园和其他NBS项目的规划、设计和管理具有启发意义。此外，研究结果明确了有助于生态系统服务感知的因素，以及感知到的生态系统服务之间的协同作用，能够促使NBS项目的管理更加贴近公众的期望，使公众最大限度地感知NBS项目带来的裨益。基于社交媒体的高效低成本分析方法可以为其他有关景观感知和生态系统服务的研究提供参考。未来的研究可关注于如何帮助公众更好地认识NBS项目中的生态系统服务及其关联，也可进一步验证以社交媒体为数据源的研究方法的可行性。LAF

注释

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multi-year comparative analysis may reveal more findings for understanding public perception and preferences on ESs.

4.3 Suggestions on Sustainable Landscape Management

The results in this study reinforce the future focus in planning and design to maximize the benefits for human well-being and ensure that these benefits could be perceived by the public, especially the overlooked ESs, such as noise reduction, ornamental resource, and sense of place. And for some ESs that people can perceive, but may not be willingly offered by park managers (e.g., visitors picking flowers for ornamental use), design strategies to suggest proper ways for the public to interact with these ESs may work. In addition, when the designated ESs are less perceived, improving the quality of relevant landscape features may become a solution due to the interconnections among ESs. For instance, the synergy between aesthetic and refugia / habitat services may enhance the perception of the aesthetic value by improving the refugia / habitat services.

5 Conclusion

This study gives an overview of perceptions of ESs in WPs in Guangzhou. The findings may inspire future planning, design, and management of WPs and other NBS projects by pointing the public's focus of ESs and professional institutions' expectation for NBS projects. Furthermore, the findings identify the factors which facilitate perceptions of ESs, and synergies among the perceived ESs. As a result, a better alignment of the work by park managers with the general public's expectations may maximize the latter group's perceptions of the benefits brought by NBS projects. The time- and cost-saving methodology of social-media-based analysis could provide reference for other studies of landscape perceptions and ESs. Future studies may focus both on improving the public's understanding of ESs perceptions and interconnections of ESs within NBS projects, and developing further validation for using social media as a data source. LAF

NOTE

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