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.
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, 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. It aims to improve local ecological and social sustainability, to ensure long-term productivity, and to sustain and potentially increase the ability to provide ESs to humans.

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. 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. Therefore, understanding public perceptions of ESs provided by NBS is crucial for the development and communication of sustainable management and policies. Public satisfaction remains a key output that interests the managers of NBS projects, and the participation and support of citizens in the management of blue-green infrastructure is usually upon their understanding of ESs. Moreover, existing research has shown that sets of ESs could appear together repeatedly, as an ESs bundle. Understanding the interconnections among ESs can help the managers with the synergy between ESs and promote management policies that improve the benefits to humans.

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%. The existing natural wetlands also face the challenge of ecosystem degradation. Since 2004, China has built a large number of wetland parks (WPs), as an NBS, to protect, compensate, and rationally utilize wetland resources. Up to the end of 2017, in Chinese Mainland, a total of 1,699 WPs have been created.

The design and construction of WPs often employ three strategies: 1) inspired by natural wetlands (e.g., constructed vertical
2) in natural wetland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认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([21])。

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。

流量或浅层湿地,浮岛系统;2) 在自然湿地基础上进行改造,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

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([21]), 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).
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\[^{26}\]); 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 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...
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) |
|------------------|----------|-------------------------------------------------------------------------------------------------|------------------|----------|-------------------------------------------------------------------------------------------------|
| 食物 Food | P1 | 来源于植物、动物和微生物的食物名称（如农作物、野果、菌、鱼)；收获食物的活动 Name of food products that are produced from plants, animals, and microbe (e.g., crops, wild fruits, and fish); activities to harvest food | 优粉 Pollination | R8 | 植物群落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 | 由流量、水深、含水层储量、保持和供应淡水 Fresh water storage, retention, and supply by watersheds, reserves, and aquifers | 生物防治 Biological control | R9 | 疾病调控、害虫调控及生物群落动态规律（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 (e.g., wood and silk), construction materials (e.g., timber), fuel (e.g., firewood), and fodder | 调节服务 Regulating service | R4 | 调节服务 Regulating service |
| 装饰资源 Ornamental resource | P4 | 收集并装饰使用的观赏动植物产品 Collect ornamental animal and plant products for decorative use | 调节服务 Regulating service | R7 | 土壤形成的调节（例如土壤的风化和有机物质的积累） Soil formation process (e.g., weathering of rock and the accumulation of organic matter) |
| 基因资源 Genetic resource | P5 | 用于动植物物种和生物技术的遗传和遗传信息 Genes and genetic information used for animal and plant breeding and biotechnology | 支持服务 Supporting service | R2 | 支持服务 Supporting service |
| 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 | 支持服务 Supporting service | R3 | 支持服务 Supporting 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）; 空气质量更优 Regulate the atmospheric chemical composition (e.g., carbon dioxide and oxygen balance, and air quality control); better air quality | 支持服务 Supporting service | R1 | 支持服务 Supporting service |
| 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 | 支持服务 Supporting service | R4 | 支持服务 Supporting service |
| 干扰调节 Disturbance regulation | R3 | 灾害预防、防洪防旱、早灾恢复、风灾消除等 Storm protection, flood control, drought recovery, hurricane reduction, etc. | 支持服务 Supporting service | R5 | 支持服务 Supporting service |
| 水量调节 Water regulation | R4 | 径流、洪水和水资源补给的时间和幅度（如自然降雨、干旱期的） The timing and magnitude of runoff, flooding, and aquifer recharge (e.g., natural irrigation and drought prevention) | 支持服务 Supporting service | R6 | 支持服务 Supporting service |
| 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 (leaner water) | 支持服务 Supporting service | R7 | 支持服务 Supporting service |
| 侵蚀控制和沉积物滞留 Erosion control and sediment retention | R6 | 土壤保持（例如防止水土流失；防止风蚀、径流或其他搬运过程造成的土壤流失; 在湖底和河床中储存粘土） 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) | 支持服务 Supporting service | R8 | 支持服务 Supporting service |
| 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 matter) | 支持服务 Supporting service | R9 | 支持服务 Supporting service |

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。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。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。

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。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、连词、介词和量词）和一些实词（如湿地公园的名称，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。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也似乎呈现”[38][39]。此规则用于识别X和Y之间的内在关联，以理解消费者的购买习惯。它已被广泛用于关系数据库、数据仓库和文本数据库（参见参考文献[39]）。
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.

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 (FP-growth) algorithm, the most efficient algorithm to identify frequent item sets for association rule mining, 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. In this research, the FP tree was built with Python 3.7 according to a script proposed by Peter Harrington.

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 \(A: 4\).

A bivariate Pearson Correlation analysis was also ran in SPSS. As a result, the correlation was not statistically significant (Sig. = 0.548).
| 编号 | 名称                        | 类型                      | 面积 (hm²) | 相关微博数 (微博数 / hm²) | 受欢迎程度 (微博数 / hm²) | 提及ES的微博数 (提及率 ESs (%) ) | 平面图 | 照片 |
|-----|----------------------------|---------------------------|------------|------------------------|------------------------|--------------------------------|--------|-------|
| 1   | 海珠国家湿地公园           | 人工湖、河流、果基鱼塘   | 891        | 2,538                  | 2.85                   | 1,201                          | 47.32  |       |
| 2   | 白云湖湿地公园             | 人工湖                    | 187        | 904                    | 4.83                   | 335                            | 37.06  |       |
| 3   | 天河（大观）湿地公园       | 库塘                      | 46.8       | 756                    | 16.15                  | 325                            | 42.99  |       |
| 4   | 花都湖湿地公园             | 河流、人工湖              | 256.6      | 606                    | 2.36                   | 359                            | 59.24  |       |
| 5   | 南沙湿地公园               | 库塘、红树林              | 376        | 234                    | 0.62                   | 122                            | 52.14  |       |
| 6   | 挂绿湖湿地公园             | 人工湖                    | 307        | 109                    | 0.36                   | 94                             | 86.24  |       |
### 表2：广州市湿地公园概况及微博提及情况

| 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 | 河、人工湖 Riverine, artificial lake | 38.4            | 2                              | 0.05                                      | 0                                     | -                                         |
| 9#    | 风云岭湿地公园 Fengyunling Wetland Park | 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 | 河 | 7               | 14                             | 2.00                                      | 11                                    | 78.57                                     |
| 11#   | 海鸥岛湿地公园 Seagulls’ Island Mangrove Wetland Park | 河、红树林 Coastal, mangroves | 186              | 11                             | 0.06                                      | 9                                     | 81.82                                     |
| 12#   | 大沙河湿地公园 Dasha River Wetland Park | 河 | 55              | 1                              | 0.02                                      | 0                                     | -                                         |
| 13#   | 南沙滨海绿道湿地公园 Nansha Coastal Greenway Wetland Park | 河、红树林 Coastal, mangroves | 13               | 1                              | 0.08                                      | 1                                     | 100.00                                    |
| 14#   | 南滨河国家森林公园 Nanjiang River Wetland Park | 河 | 15              | 0                              | -                                        | 0                                     | -                                         |
| 15#   | 虎门海心沙湿地公园 Huimen Heart Island Wetland Park | 河 | 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*   | 岭南明珠湿地公园 Liangnanhuizhen Wetland Park | 人工湖 Artificial lake | 19.5            | 1                              | 0.05                                      | 0                                     | -                                         |
| 19*   | 赤坎湿地公园 Chikan Wetland Park | 河、人工湖 Riverine, artificial lake | 61               | 0                              | -                                        | 0                                     | -                                         |
| 20*   | 黄阁湿地公园 Huangge Wetland Park | 河 | 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。

所有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%），在白云湖湿地公园、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...
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...
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（C1和C2在海珠国家湿地公园中出现13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
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相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.
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

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知的刺激更为多样化。在南沙湿地公园中游憩服务（C1）的感知中，机构宣传中的“跑步”一词出现频率为10件，而个人感知中为20件。

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.
知的因素更加多样。就个人用户而言，“摄影”活动在海珠国家湿地公园、天河（大观）湿地公园和挂绿湖湿地公园中最常被提及，“游船”活动在南沙湿地公园最常被提及。而机构用户则主要利用微博推广人们可在湿地公园中进行的赛事和特殊游憩活动（如马拉松、公益活动等）。

microbloggers reported about “running.” For individuals, “taking photos” was the most frequently mentioned activity in Haizhu National Wetland Park, Tianhe (Daguan) Wetland Park, and Gualyu Lake Wetland Park; in Nansha Wetland Park, “boating” was the most frequently mentioned activity. Comparatively, institutions mainly posted about games, events, and special recreational programs (e.g., marathon and public welfare activities).
“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.
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\(^{[48][49]}\); 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\(^{[52]}\) and be perceived together\(^{[53]}\). 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\(^{[54]}\). 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员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：鉴于现场调查通常耗时且代价高昂，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它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特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：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;
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.

NOTE

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