

REVIEW

A review of participatory mapping in conservation science and practice

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Funding information

National Science Foundation Graduate Research Fellowship Program, Grant/Award Number: 240310

Abstract

Participatory mapping is a collaborative process through which participants and cartographers co-develop maps to represent their knowledge, experiences, and preferences regarding a relevant area, enabling communities to visualize and analyze their environment and potentially spur transformative social change. There has been a recent increase and diversification in the use of participatory mapping in the field of conservation; however, methodological standards remain both disjointed and confounding. We conducted a comprehensive review of the conservation participatory mapping literature, providing a road map to the diverse studies of this field and best practices for incorporation into science and practice. We synthesized geographical, temporal, and topical trends across a total of 398 peer-reviewed studies to provide current findings, common pitfalls, ethical standards, strengths and weaknesses. We offer future directions to increase methodological cohesion, propel the field forward, and introduce interested conservation researchers and practitioners to participatory mapping.

KEYWORDS

participatory GIS, participatory research, public participatory GIS, volunteered geographic information

1 | INTRODUCTION

Maps have been used widely across millennia as a means of effective communication and spatial representation, with the earliest known wall painting in Catal Huyuk dating to 6200 BC and evolving into modern geographic information system (GIS) technologies (Chambers, 2006). Spatial participatory mapping (PM) arose out of rapid rural appraisal and participatory action research methodologies in the latter half of the 20th century (Chambers, 2006; Cochrane & Corbett, 2018; Sieber, 2006) through a movement to transition closed, inaccessible GIS research and top-down

mapping efforts into more open and democratic frameworks capable of elevating community voices (Denwood et al., 2022; Mukherjee, 2015). PM can integrate multiple ways of knowing from various ontologies and epistemologies to build consensus and create holistic solutions to complex problems (Raymond et al., 2010). This approach typically draws from a wider array of voices than are normally represented in mapping efforts, by including perspectives from the public, academics, non-governmental organizations (NGOs), and government agencies (Stosch et al., 2022). For Indigenous and other disadvantaged communities, formally mapping participant-sourced spatial data

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can legitimize non-dominant knowledge and tenure and rights claims through the lens of Western scaffolds, facilitating sovereignty in natural resource management, decision-making, and policy spheres (Sletto, 2009; Tripathi & Bhattacharya, 2004). Through the co-development of spatial knowledge, these interested parties can form long-standing, sustainable relationships and a healthy sense of ownership over mapping outcomes (Ndzabandzaba, 2019). These methods are also readily scalable, allowing local spatial knowledge to inform policy at regional and national levels at fractions of the cost of other methods such as expensive wildlife collars and systematic ecological surveys (Asmolov, 2020; Loerzel et al., 2017; Pédarros et al., 2020). PM offers a unique way to visually represent community perceptions of material and sociocultural place values. It has been recognized as a transdisciplinary tool for transformative change, bridging gaps that unilateral frameworks fail to address (Cochrane & Corbett, 2018; Ernoul, Mathevet, et al., 2018).

Given the extensive suite of methodological advantages and transformative potential, PM has become a broadly applied research technique. Publications that employ PM have been increasing steadily since 2015, across a variety of fields (Denwood et al., 2022), including crisis management, urban planning, public health, education, transportation, and insurance, among others (Chambers, 2006; Mukherjee, 2015; Ndzabandzaba, 2019). Despite this proliferation, participatory spatial mapping as a field remains methodologically disjointed and without consensus on best practices, ethics, or basic definitions. Depending on the approach, PM can be facilitated through a variety of mediums, spatial attributes, and analyses (Brown, 2017; Denwood et al., 2022). Although the purpose of PM is to elevate the voices of underrepresented groups and democratize mapping, challenges extending from sampling biases (Brown et al., 2014) and ethical lapses can emerge, potentially harming communities if power dynamics are not carefully managed (Sletto, 2009; Smith et al., 2017).

Given conservation science is inherently an interdisciplinary endeavor, integrated PM frameworks can be ideal for accurate valuation of ecological, social, and economic dimensions of conservation (Ernoul, Mathevet, et al., 2018). Hundreds of conservation studies using participatory mapping have been carried out on every continent on wide-ranging topics, including fisheries management (Dineshbabu et al., 2012), ecosystem services (Brown & Fagerholm, 2015), conservation planning (Lechner et al., 2015), introduced species (Luizza et al., 2016), conflict resolution (Kujirakwinja et al., 2019), climate change (Vargas et al., 2022), human-wildlife conflict and coexistence (Wilkinson et al., 2021), and disease vectors (Bersacola et al., 2021). Such studies have utilized both quantitative and qualitative mapping methodologies (Brown et al., 2017), with subjects ranging from groups

of thousands of participants using public internet-based polls with predefined spatial typologies (Brown et al., 2018) to a few experts answering semi-structured interview questions (Gerhardinger et al., 2009). PM has even produced land use/cover models that outperform satellite imagery accuracy at local scales (Vergara-Asenjo et al., 2015). Regardless of these achievements, PM in conservation mainly constitutes a long list of discipline-specific case studies without a central unified framework.

Conservation science and practice would benefit greatly from a narrative summation and synthesis of current findings, common pitfalls, ethical standards, technical strengths and weaknesses, and future directions that can move the field forward and introduce interested researchers to these methodologies. Here, through a comprehensive literature review of the geographic, temporal, and topical trends in conservation-related PM efforts, we provide such a roadmap to the diverse uses, best practices, and key considerations for the future use of participatory mapping in conservation science and practice.

2 | DEFINING “PARTICIPATORY MAPPING”

There is significant ambiguity and conflation in how terms and techniques related to PM are reported in the literature (Brown, 2017; Tulloch, 2008). The traditional methodological terminology of PM includes public participation GIS (PPGIS), participatory GIS (PGIS), and volunteered geographic information (VGI) (Brown & Kyttä, 2014). PPGIS is most commonly used by government agencies and academic institutions in Global North countries to enhance public participation in urban and environmental planning using digital mapping software and probability sampling at the individual or household level (Sieber, 2006). PGIS is usually deployed by NGOs in rural regions of developing countries to enhance social capital and community development among specific groups through purposeful sampling and non-digital mapping techniques in a collective setting (Rambaldi et al., 2006). VGI is a crowdsourcing technique to collect spatial information on a topic of concern from interested community members through convenience sampling in a digital medium (Goodchild, 2007).

However, based on our review, these terms are often described subjectively and interchangeably (Brown & Kyttä, 2014). For example, PGIS surveys are increasingly distributed digitally (Bergh et al., 2023), PPGIS studies sometimes utilize convenience sampling (Korpilo et al., 2022), and sample-selection bias corrections are being developed for VGI (Cameron & Kolstoe, 2022). We suggest rigorous reporting of sampling design (e.g., participant

demographics, representativeness, recruitment strategies, and mapping prompts) and generalizing PM methodology definitions using the Denwood et al. conceptual framework based on the mapping medium: (1) PGIS, encompassing all the digital approaches to PM, (2) sketch mapping with a physical base map, and (3) mental mapping, freehand drawing without base map contextualization (Denwood et al., 2022). By directly articulating methodological protocols, instead of relying on potentially misspecified labels, this reporting structure will increase clarity and parsimony, reproducibility, and transparency in conservation PM.

3 | LITERATURE REVIEW METHODOLOGY

This literature review was conducted using Web of Science Core Collection (15 January 2024) using four different search strings to account for the different terminologies of the PM field: [1] (ALL = (conservation)) AND (ALL = (PPGIS OR public participation GIS OR public particip* GIS)); [2] (ALL = (conservation)) AND (ALL = (PGIS OR participatory GIS OR particip* GIS)); [3] (ALL = (conservation)) AND (ALL = (VGI OR volunteered geographic information OR volunt* geogr* information)); [4] (ALL = (conservation)) AND (ALL = (participatory mapping)). Only studies in the English language were reviewed and titles and abstracts of search results were read to determine relevance, though we recognize that this could have led to bias in the information we are presenting, ignoring important studies that exist in other languages (Amano et al., 2021; Kelsey et al., 2025). All titles and abstracts of search results were reviewed and included in our analysis if they were participatory mapping studies or reviews that focused on topics relevant to conservation science and management. Studies were excluded if they were participatory studies related to conservation science and management that did not include mapping exercises (e.g., surveys without spatial components) or participatory mapping studies that were not related to conservation science and management (e.g., archaeology). We screened for additional relevant studies by snowball sampling of included studies' reference sections. Each included study was then categorized by continental region, country, publication year, and into one of the following 13 domains based on their primary scope within the field of conservation (Table 1): Climate Change, Conflict Resolution, Conservation Values, Disease Mapping, Ecosystem Services, Environmental Justice, Fisheries Management, Human-Wildlife Conflict, Introduced Species, Land Use Planning, Methodology, Natural Resource Management, and Species

Distribution Mapping. Given the interdisciplinarity of PM research, some studies secondarily addressed multiple domains, but were only categorized based on their primary scope. If a study was conducted on multiple continents or countries, we tallied each country-specific mapping effort separately to better reflect mapping activity geographically and chronologically. Relevant review studies without physical mapping efforts are explicitly mentioned in the results to capture the full extent of conservation PM literature, but were not included in summary statistics to avoid reporting duplication of site-specific studies.

4 | RESULTS

The Web of Science searches produced the following number of search hits ($n = 1932$): Public Participation GIS ($n = 220$), Participatory GIS ($n = 765$), Volunteered Geographic Information ($n = 300$), and Participatory Mapping ($n = 647$). After accounting for studies common to the four Web of Science searches ($n = 381$) and excluding studies irrelevant to this review ($n = 1239$), 312 studies were collectively included. An additional 86 relevant studies were included through snowball sampling. In total, the Web of Science searches and snowball sampling produced 398 included studies (Figure S1). These 398 studies were then further categorized into 455 individual mapping efforts based on continent and country (Table S1).

4.1 | Geographic and temporal trends

The first PM study related to conservation that emerged from the literature review was published in 1995 (Lewis, 1995). Over time, conservation PM mapping efforts have steadily increased from 2012 to a peak of 59 mapping efforts in 2019. Mapping effort has decreased since, but started to rebound in 2023 (Figure 1). Mapping studies were initially concentrated in Africa, Asia, and North America in the mid-1990s, with uptake in Europe, Oceania, and South America in the mid- to late-2000s, and Antarctica coming substantially later (2018). When aggregated by continent (Figure 2), most conservation PM efforts were conducted in Europe ($n = 105$) and North America ($n = 80$), followed by Asia ($n = 69$), Africa ($n = 68$), South America ($n = 57$), Oceania ($n = 44$), and Antarctica ($n = 2$). Reviews of other conservation PM studies ($n = 29$) were not attributed to a geographic location. In total, mapping efforts were conducted in 102 different countries.

TABLE 1 Utilization of participatory mapping across 13 conservation domains with example publications.

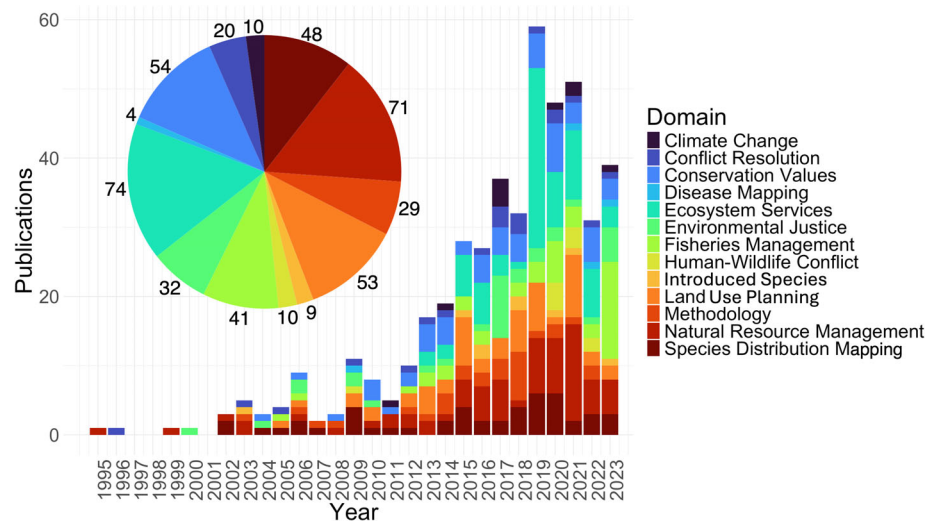
Conservation domain	Participatory mapping utilization	Example publications
Climate Change	Understand how climate change will impact natural resources and communities, helping communities prioritize adaptation strategies to enhance resilience	Raymond and Brown (2011), Scoville et al. (2021), Vargas et al. (2022)
Conflict Resolution	Identify and mediate conflicts between groups of people over land and resource use rights by mapping competing party interests and claims, negotiating compromises, and building consensus	Brown and Raymond (2014), Fox et al. (1996), Kujirakwinja et al. (2019), Lechner et al. (2020), Stosch et al. (2022)
Conservation Values	Spatially quantify sociocultural and ecological values and preferences associated with locations and natural resources to inform conservation planning, public policy, and acceptance of conservation initiatives	Bryan et al. (2011), Ernoul, Mathevet, et al. (2018); Ernoul, Wardell-Johnson, et al. (2018), Pietilä and Fagerholm (2016), Ruiz-Frau et al. (2013), Whitehead et al. (2014)
Disease Mapping	Track and manage zoonotic and wildlife diseases by mapping their spread and predicting potential risk areas	Aminu et al. (2022), Bersacola et al. (2021)
Ecosystem Services	Conduct spatially-explicit mapping of ecosystem service bundles to quantify their benefits, threats, and flows between natural resources and community wellbeing	Cusens et al. (2022), Delgado-Aguilar et al. (2019), Palomo et al. (2013), Ramirez-Gomez et al. (2013), Van Riper and Kyle (2014)
Environmental Justice	Highlight disparities in conservation impacts and restore or ensure equitable distribution of environmental benefits and burdens	Chambers (2006), Corbett et al. (2016), Cochrane et al. (2017), Ernoul, Mathevet, et al. (2018); Ernoul, Wardell-Johnson, et al. (2018), Smith et al. (2017)
Fisheries Management	Gathering local socioecological knowledge from fisheries users to enhance marine conservation policy and protected area management	Aswani and Lauer (2006), Dineshbabu et al. (2012), Fagerholm, Eilola, et al. (2019); Fagerholm, Torralba, et al. (2019), Karnad (2022), Selgrath et al. (2018)
Human–Wildlife Conflict	Holistically assess the multidimensional drivers of conflicts arising between communities and wildlife to identify mitigation and coexistence opportunities	McInturff et al. (2021), Read et al. (2021), Robinson et al. (2022), Salerno et al. (2020), Wilkinson et al. (2021)
Introduced Species	Track expansion fronts, monitor spread, and inform control strategies for introduced species	Azzurro and Cerri (2021), Brewington (2018), Hawthorne et al., (2015, Luizza et al. (2016)
Land Use Planning	Operationalize public spatial knowledge and preferences as a decision support tool to complement traditional land use planning frameworks and guide sustainable development acceptable to local communities	Brown et al. (2015), Brown et al. (2018), Lechner et al. (2015), Milligan et al. (2020), Vergara-Asenjo et al. (2015)
Methodology	Refine and advance conservation-related participatory mapping techniques to improve participation, data collection, analysis, and conservation decision-making	Denwood et al. (2022), Fagerholm et al. (2021), Gray et al. (2018), Kahila-Tani et al. (2019), Raymond et al. (2020)
Natural Resource Management	Measure, monitor, and manage the spatial distribution of natural resources, such as timber stocks, hunting practices, etc., to improve conservation outcomes	Basupi et al. (2017), Dunn and Smith (2011), Herrmann et al. (2014), Lewis (1995), Loerzel et al. (2017)
Species Distribution Mapping	Create or enhance the accuracy of distribution maps of animal and plant species with local spatial knowledge to better inform population estimates and conservation efforts	Austin et al. (2009), Fagandini Ruiz et al. (2021), Matias et al. (2017), Pédarros et al. (2020)

4.2 | Trends in conservation topic and PM purpose

Overall, ecosystem services ($n = 74$), natural resource management ($n = 71$), conservation values ($n = 54$), land use planning ($n = 53$), and species distribution mapping ($n = 48$) were the five conservation domains with the most studies (Figure 1). Meanwhile, disease mapping ($n = 4$), introduced species ($n = 9$), climate change

($n = 10$), human–wildlife conflict ($n = 10$), and conflict resolution ($n = 20$) were the five conservation domains with the lowest mapping effort (Figure 1). Natural resource management, conflict resolution, environmental justice, species distribution mapping, and conservation values were the earliest conservation domains studied using PM, emerging in the late 1990s and early 2000s. Meanwhile, excluding outliers ($N = 1$ study >10 years prior to subsequent domain publication records), climate

FIGURE 1 Counts of participatory mapping studies across years and 13 conservation domains. Pie chart inset represents the total number of publications per conservation domain.



change, ecosystem services, and introduced species domains started in the early- to mid-2010s, with human-wildlife conflict and disease mapping domains more recently investigated using PM in the 2020s (Figure 1). Conservation PM in North America and Australia have largely focused on studying conservation values, species distribution mapping, and land use planning (Figure 2). Meanwhile, the largest conservation domain studied in South America, Africa, and Asia is natural resource management. The primary focus of PM mapping efforts in Europe is ecosystem services, with conservation values and fisheries management representing important

domains as well. PM reviews mostly addressed methodological and environmental justice topics.

5 | DISCUSSION

5.1 | Geographic and temporal trends in use of PM for conservation science and practice

As the field of conservation continues to grapple with and pivot away from its colonial roots (Mullenbach

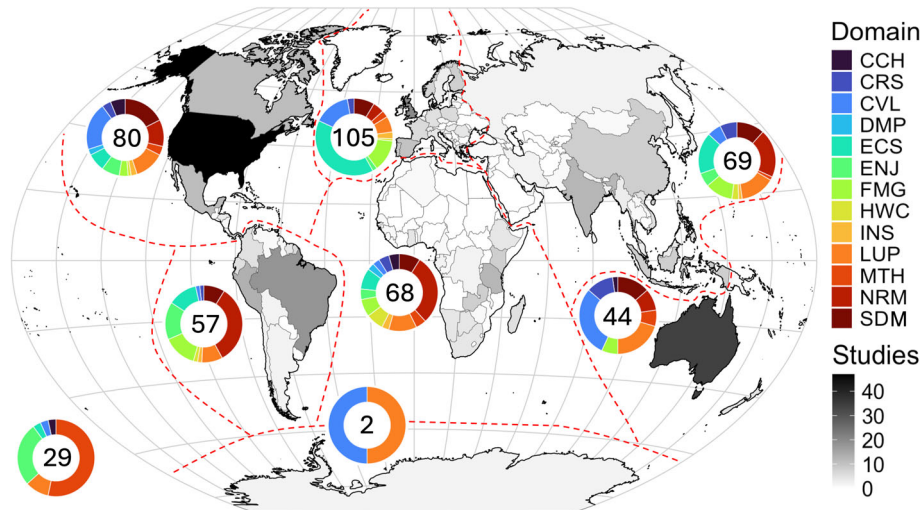


FIGURE 2 Global map of conservation participatory mapping effort as determined from a literature review of English-language peer-reviewed publications from 1995 to 2023. The number of conservation participatory mapping studies published per country is plotted on a continuous grayscale. Red dotted lines generally denote continental regions of North America, South America, Africa, Europe, Asia, Oceania, and Antarctica. Donut charts show the total number of studies and the proportion of each continent's conservation participatory mapping studies that fall within each of the 13 conservation domains: Climate change (CCH), conflict resolution (CRS), conservation values (CVL), disease mapping (DMP), ecosystem services (ECS), environmental justice (ENJ), fisheries management (FMG), human-wildlife conflict (HWC), introduced species (INS), land use planning (LUP), methodology (MTH), natural resource management (NRM), and species distribution mapping (SDM). Twenty-nine participatory mapping studies were classified as secondary reviews of existing participatory mapping studies. These studies and their conservation domains are included in the lower left corner.

et al., 2022), it is no surprise that PM has increased in utilization across many conservation domains that involve spatial mapping components. It is also not surprising that the onset of the Covid-19 pandemic coincided with a decrease in PM mapping effort by roughly half between 2020 and 2022 (Heo et al., 2022). Both conservation and PM are fields that largely require long-term, in-person, local engagement to be effective and resultant global lockdowns significantly hamstrung this type of research for several years. Additionally, the conservation industry as a whole experienced many negative impacts from the pandemic, including reduced funding from tourism and philanthropy and governments deprioritizing environmental protection, limiting the resources available to conduct research (Gibbons et al., 2022). With 2023 mapping efforts increasing from 2022, we expect the use of PM for conservation to continue to increase beyond the 2019 high point in the years to come.

Counterintuitively, PM mapping effort was higher in the Global North countries of Europe, North America (46 in the United States, 11 in Canada), and Oceania (34 in Australia) than in Global South regions (Figure 2). This was not expected, given the early establishment and widespread use of PM by NGOs in the Global South as a tool for environmental justice (Brown & Kyttä, 2014; Norris, 2014). While the early use of PM for conservation in Africa and Asia was anticipated given the establishment of rapid rural appraisal and participatory action research on these continents, the shorter publication history from South America seems improbable and likely due to the restrictions of our literature search to the English language and peer-reviewed journals (Amano et al., 2021; Kelsey et al., 2025). Further, publishing in academic journals is not necessarily a high priority for NGOs focused on delivering social change. Europe's mapping effort was substantially increased by three recent collaborative mapping efforts across 10 or more countries in the European Union in 2019 (Fagerholm, Torralba, et al., 2019; Plieninger et al., 2019) and 2023 (Hughes et al., 2023). These studies highlight the synergistic benefits of pooling resources from multiple institutions to greatly increase mapping productivity.

The development of the PM conservation domains outlined in this review tracks with both the direct convertibility of pre-existing conservation priorities to PM and the emergence of new conservation priorities that dovetailed with the strengths of PM. Investigations into natural resource management, species distribution mapping, and land use planning are core topics in conservation research that have also historically relied on GIS (Wadsworth & Treweek, 1999). Thus, these domains were readily available subject areas to apply PM methodologies to during the conception of the field in relation to

conservation, resulting in their high representation in this literature review (Figure 1). Spatial characterization of participant conservation values and perceptions is a key innovation that PM has brought to conservation research (Brown et al., 2020). Studies in this domain started in the early 2000s and remain a unique core component of the conservation PM field. The tenets of environmental justice and conflict resolution are well-suited for conservation PM studies and were adopted early by practitioners in the field; however, these domains are less common (Figure 1), at least in terms of volume of material published in academic journals.

Meanwhile, other domains emerged later on from novel conservation priorities conceived after PM's establishment and creative uses of PM techniques. The ecosystem services paradigm was popularized much later in the conservation field, in the early 2000s (Daily et al., 2000), and surfaced in the PM literature around a decade after that. Although ecosystem services can be difficult to evaluate monetarily (Daily et al., 2000), spatial valuation provides an alternative means to identify and measure these services (Palomo et al., 2013), which could be a contributing factor in the rapid increase in PM utilization in this domain. More recently, the scope of conservation PM research has begun to proliferate with innovative studies addressing introduced species (e.g., Luizza et al., 2016), climate change (e.g., Vargas et al., 2022), human-wildlife conflict (e.g., Wilkinson et al., 2021), and zoonotic disease mapping (e.g., Bersacola et al., 2021). Use of PM in these domains will likely bring new perspectives to conservation work in these fields and incorporation of PM methods into new conservation domains is likely to continue.

5.2 | Current and future conservation applications of participatory mapping

This review distinguished 13 conservation domains that have been utilizing PM to advance basic and applied science in the field (Table 1). The following sections synthesize themes uncovered in the literature from each of these domains, with specific examples from our review, before highlighting ethical pitfalls and providing a roadmap for future inquiry.

5.2.1 | Predicting and reducing climate change effects

Global climate change is a looming threat with far-reaching, complicated effects on biotic systems, often exacerbating existing conservation dilemmas (Scheffers

et al., 2016). Here PM remains an apt, if underutilized, instrument to gain insight into how local ecological changes affect both species of conservation concern and anthropogenic systems. By employing a holistic mapping approach, Vargas et al. (2022) were able to co-develop solutions to a climate-induced human–wildlife conflict in the Andes mountains, with pastoralist communities elected to (1) rehabilitate degraded winter ranges more insulated from drought and (2) establish ecotourism operations in the scenic and wildlife-rich summer ranges.

Current climate models are dominated by artificial intelligence and machine learning algorithms and often only consider abiotic and environmental variables. Growing reliance on technological “black boxes” can reinforce systemic inequalities and asymmetric power relationships (Mahony & Hulme, 2018). Incorporating PM into these pipelines increases the distributive power of interested parties and provides opportunities to have their preferences reflected in climate policy (Scoville et al., 2021). For example, Raymond and Brown (2011) developed a place-based framework to enable government agencies to deploy targeted adaptation strategies on local and regional scales based on associations between mapped perceptions of landscape values and climate change risk in Southern Australia. Public participation in climate change planning has largely been limited to education campaigns, rather than genuine efforts to incorporate local spatial knowledge through collaborative planning, and this study provides a rational structure to accomplish the latter (Raymond & Brown, 2011).

5.2.2 | Conflict resolution regarding natural resource use

The conservation of natural resources, functions, and services is often in conflict with their use and this conflict manifests quite readily between groups of people in practice. These conflicts have implicit spatial dimensions, but few conservation practitioners explicitly evaluate these human dimensions (Brown & Raymond, 2014). Ideally, conflict is identified and mediated prior to proceeding with a conservation project. Brown and Raymond (2014) provide a detailed conceptual framework to measure land use conflict through several value- and preference-based conflict indices, as well as subsequent model extensions (Brown et al., 2017; Karimi & Brown, 2017; Wolf et al., 2018). In Malaysia, Lechner et al. (2020) further innovated upon this model by accounting for within-community conflict in tourism development preferences to identify spatially explicit locations for tourism operations acceptable to both pro-nature and pro-development community groups.

Existing conservation conflict can also be remediated through PM methods. PM of cattle grazing in Nepal revealed that, without government subsidies to remove cattle from the landscape, conflicts with red panda (*Ailurus fulgens*) conservation would likely be difficult to resolve (Fox et al., 1996). To rectify the unexpected and unilateral gazettement of the Itombe Massif in the Democratic Republic of the Congo, communities living within the reserve were engaged in a PM process that resulted in a larger core conservation area and lands set aside for sustainable hunting, timber extraction, and agriculture, without removing Indigenous peoples from their ancestral lands (Kujirakwinja et al., 2019). PM also provides great value in resolving conflicts between interested parties in management roles, such as watershed conflicts in Scotland between farm advisors, water management companies, environmental regulators, and academics (Stosch et al., 2022).

5.2.3 | Understanding and elevating conservation values

Perhaps the most fundamental use of PM in conservation is in understanding the spatial distribution of conservation values and the mechanisms through which they are influenced. According to our literature review, there is consensus in the PM literature that successful conservation outcomes critically rely on both public acceptance and scientific validity of proposed policy and protected areas, yet social values are too often omitted in the planning process in favor of ecological value (Bryan et al., 2011; Ernoul, Wardell-Johnson, et al., 2018; Whitehead et al., 2014). Integrating spatially explicit social values and priorities with biological values at the onset of conservation planning can identify socially acceptable and conflict zones to optimally funnel limited conservation resources. For example, one could implement education-based community awareness programs and incentive schemes in areas with high ecological, low social value to encourage uptake of conservation practices, while diverting resources from already well-protected high ecological, high social value regions (Bryan et al., 2011). Along with ecological data and social values, public development preferences can also be incorporated into conservation prioritization scenarios, to identify locations suitable for protected areas with meaningful community engagement and development zones with low ecological impact (Whitehead et al., 2014).

Spatially explicit social values are important for public acceptance of conservation policy initiatives, such as management of tourism or target species, like greater flamingo (*Phoenicopterus ruber*) management in agricultural river

deltas in France (Ernoul, Wardell-Johnson, et al., 2018). For example, a study in Norway found strong alignment between conservation policy and local priorities to restrict land development while permitting small-scale consumptive use in protected areas, and thus determined use-based conservation messaging was likely to resonate more with local communities than preservation and rewilding narratives (Engen et al., 2018). PM also holds value for developing fine scale, spatially targeted management within protected areas, such as littering interventions (Pietilä & Fagerholm, 2016). Further, mapping socioeconomic valuations can highlight overlooked incentives for conservation, such as the unexpected financial importance of non-extractive marine activities in comparison to commercial fisheries prone to closures on the Welsh coast (Ruiz-Frau et al., 2013).

5.2.4 | Mitigating transmission of zoonotic diseases

The field of conservation has yet to deploy PM widely in conservation-related epidemiological research, even though these techniques have immense potential in this context. Following the discovery of leprosy in chimpanzees in 2015, Bersacola et al. (2021) utilized PM to understand how human–wildlife interactions influenced transmission risk. Comparing the intensity of chimpanzee space use with locations where residents shared resources with wildlife allowed for the identification of potential transmission hotspots to proactively minimize human–wildlife interactions. In Ngorongoro Conservation Area, Tanzania, Aminu et al. (2022) harnessed community knowledge to measure the environmental covariates of high-risk anthrax areas, model infection probability, and identify priority intervention zones for tangible public health benefits. With continuing population growth and ever-expansive human activities, there is growing recognition that humans and wildlife will be increasingly sharing landscapes. With this comes an expectation of increased infectious zoonotic diseases, which has serious repercussions for both wildlife conservation and public health objectives. Especially in the context of emerging zoonotic disease threats, PM is well suited to identify spatially explicit transmission vectors and will become an increasingly important tool in this field.

5.2.5 | Quantifying and conserving ecosystem services

Ecosystem services represent the goods and benefits implicitly received from healthy ecosystems that support human well-being (Daily et al., 2000). When mapping

ecosystem services, participants spatially demarcate the direct and indirect benefits of ecosystem services by identifying provisioning, regulating, and cultural services constructed through personal experience. This contrasts markedly with traditional methods used to measure ecosystem services, such as literature-based data proxies and process modeling (Brown & Fagerholm, 2015). Between the two approaches, PM can foster trust, interest, communication, and a more holistic management scope in difficult-to-reach, marginalized communities, which non-participatory methods cannot provide (Cusens et al., 2022; Ramirez-Gomez et al., 2013). Mapping ecosystem services allows analysis of the flow of ecosystem services from service provision hotspots to service-benefiting areas, such as from Spain's Doñana National Park into surrounding urban cities (Palomo et al., 2013), identifying areas in need of future interventions that may otherwise go undetected (Delgado-Aguilar et al., 2019). Alongside intangible cultural services (Van Riper & Kyle, 2014), incorporating monetary valuation, psychometrics, logic chains, and deliberative structures can result in a more comprehensive understanding of ecosystem service valuation—as was the case in a Scottish peri-urban coastal landscape (Kenter, 2016).

5.2.6 | Furthering environmental justice

When implemented as intended, PM has great potential to balance social and environmental equity in systematically marginalized and disadvantaged communities through counter-mapping—a cartographic practice that leverages community-created maps to disrupt the power structures inherent in traditional maps. For example, Korpilo et al. (2022) created an intersectional clustering framework that highlighted the urban green and blue space planning preferences of respondents with low perceived societal recognition and procedural justice to increase the inclusivity and justness of planning exercises. In Indigenous contexts, PM has been used to establish land restitution, cultural resource protection, and natural resource access with Maidu in the United States (Middleton, 2010), Trio and Wayana in Suriname (Ramirez-Gomez et al., 2013), and Andean communities in Peru (Norris, 2014). However, it has been limited in empowering Ngäbe in Panama (Smith et al., 2017) and systematically extractive towards Maasai in Tanzania (Homewood, 2017). The majority of PM reviews in this domain address critical evaluations of the lack of tangible socioecological change achieved by PM to date relative to expectations for the discipline—highlighting the challenges of effectuating true justice (Asmolov, 2020; Cochrane et al., 2017; Corbett et al., 2016; Elwood, 2006;

Laituri et al., 2023). We discuss the biases and ethical issues limiting further progress in more detail in a titular section below.

5.2.7 | Fisheries management

Fisheries are notoriously difficult resources to manage sustainably, due to limitations in measuring marine resources and conflicts that arise from competing socio-cultural values (Caddy & Seijo, 2005). Indigenous and artisanal fishers, who have an innate and multifaceted understanding of the consumptive fisheries they rely upon, can use PM to delineate habitat structure, species distributions, sensitive spatiotemporal events (e.g., spawning aggregations, migrations), human foraging strategies, and alternate conceptions of resource use (Aswani & Lauer, 2006). This knowledge is evident in the ability to create accurate and precise maps of endangered species distributions with just six fishers (Fagerholm, Eilola, et al., 2019). Community-led mapping efforts in the Solomon Islands relied on Indigenous knowledge of reef habitats, fishery seasonality, and fisher behavior to establish a network of small marine protected areas that protected sensitive ecological zones, without disrupting fishing effort, resulting in a 70%–90% social acceptance rate (Aswani & Lauer, 2006).

Beyond establishing acceptable marine protected areas, PM can be used to increase fisheries efficiency, such as preventing trawling along India's Mumbai coast during specific seasons and areas to reduce bycatch of juvenile commercial species or prey species without any market value based on spatiotemporal distribution and abundance of catch data (Dineshababu et al., 2012). Historical PM can also contextualize circumstances found in the current seascape. Selgrath et al. (2018) found that non-spatial fishing effort underestimated increases in spatial fishing effort by a factor of 19 over the course of five decades in the Philippines. Although individual effort remained consistent over the timeframe of the study, aggregate effort (population growth), spatial extent, diversity of gear, intensity of gear, and overlap of gear use increased substantially.

5.2.8 | Understanding and mitigating human–wildlife conflict

The task of mitigating human–wildlife conflict has always been intricately intertwined with sociocultural and land use dynamics and some recent studies have turned to PM to gain a more nuanced understanding of this complex issue. For example, Wilkinson et al. (2021)

found significantly divergent hotspots of perceived and recorded conflict when mapping livestock depredation risk in central Kenya, underscoring the importance of managing both of these risk landscapes to foster sustainable mitigation and the role different social and ecological drivers play in shaping this duality. Using similar methods, McInturff et al. (2021) also found a strong contrast between perceived and recorded coyote depredations, determining livestock producers conceptualize and respond to depredation risk at the pasture scale due to low risk tolerance rather than a lack of knowledge. By mapping spatiotemporal risk perception of encountering dangerous wildlife and tracking people's movement with GPS units, Read et al. (2021) were able to use integrated step selection functions to demonstrate perceived risk altered villagers' "habitat selection", movement speed, and directedness when traveling through risky areas. A fisher-shark conflict study that stratified their mapping sample by fishery type was not only able to delineate conflict hotspots, but highlight how disproportionately reef fishers were impacted by changes in fishery policy and catch depredation in comparison to pelagic fishers, as well as how this influenced their support for shark conservation (Robinson et al., 2022). By incorporating PM of spatially explicit risk perceptions into study designs, these studies were able to contribute meaningfully to human–wildlife conflict theory in ways that would be impossible when solely considering ecological variables, while making practical recommendations for policy and management interventions.

5.2.9 | Managing introduced species

Although many different methods have been used to map non-native species introductions, there are few examples utilizing PM methodologies. Brewington (2018) revealed divergent perceptions between national park personnel and farmers on introduced guava (*Psidium guajava*) spatial extent, land cover change, and perceived value in Galapagos, leading to opportunities for synergistic conservation schemes inclusive of farmers that are more likely to be accepted and carried out. While Hawthorne et al. (2015) used citizen science PM to crowd-source the extent and intensity of nine introduced plant species, normally chronically under-documented at the local level, to inform eradication and restoration efforts. Ethiopian pastoralists identified locations of the highly invasive rubber vine *Cyrtostegia grandiflora*, previously unknown to science, government agencies, or NGOs operating in the Afar region (Luizza et al., 2016). Their local knowledge was used to create regional models of invasion risk and organize targeted early-detection

responses. While there is a bias in the literature towards introduced plants, there is no reason why PM techniques cannot be used with introduced wildlife species, such as mapping the distribution and abundance of introduced fish and crustaceans (Azzurro & Cerri, 2021). Insight from these studies can be invaluable in evaluating distributions and processes of large-scale, rapidly shifting expansion fronts when action is urgently needed to alter the system's ecological trajectory and there is inadequate data availability. These insights will be instrumental as we aim to increase ecosystem and species resilience to climate change and its interaction with increased introduced species spread (Weiskopf et al., 2020).

5.2.10 | Land use planning

Public spatial knowledge has been shown to have high accuracy and completeness in identifying high-value conservation areas, though blind spots can arise in (1) urban, (2) private, and (3) small, geographically distant areas (Brown et al., 2015). Some of these issues can be solved by oversampling blind spot areas and mapping attributes that are easier to conceptualize by participants, such as environmental threats from hunting, fishing, and agriculture in the Brazilian Amazon (Castro & Albernaz, 2016). While PM likely cannot completely replace traditional planning strategies involving expert opinion and ecological surveys (Castro & Albernaz, 2016), it can provide complex, complementary sociocultural information that other planning methods cannot provide through consistency, compatibility, and conflict potential analyses (Brown et al., 2018). Inadequate consideration of sociocultural values often leads to poor land use planning, misguided decision-making, and negative conservation outcomes (Homewood, 2017).

When implementing projects that may impact private land, engaging the public early through PM can increase legitimacy and acceptance of planning outcomes, as well as identify the most suitable and least divisive implementation locations (Mekonnen & Gorsevski, 2015). Frequency of engagement is also vital to consensus building among diverse interested parties in uncommons where areas with multiple realities exist and co-evolve with one another (Milligan et al., 2020), such as co-managed marine protected areas or national parks zoning recreational activities to protect endangered species (Eadens et al., 2009; Strickland-Munro et al., 2016).

Land use and land cover classifications sometimes fail to accurately discern between similar habitat types, like primary forest and logged forests (Herold et al., 2011). PM offers a useful complement to this method. For example, Indigenous communities have been able to map

degraded forests and land use change with much higher accuracy than traditional machine learning algorithms in remote, undeveloped areas to greatly improve land cover monitoring and inform policy in ways overlooked by scientific surveys (Vergara-Asenjo et al., 2015). Conditional on legitimate engagement with Indigenous data sovereignty, these PM contributions could inform more accurate algorithms at scale. These methods are also particularly well-suited for modeling the effect of wildlife corridors and ecological restoration on regional landscape connectivity under different conservation orientations and future development scenarios (Lechner et al., 2015) and for target species of conservation concern (Needham et al., 2020).

5.2.11 | Participatory mapping methodologies

With the proliferation of PM utilization came an equal proliferation of methodological and analytical approaches. Mental and sketch mapping promote more creativity and permit mapping of attributes investigators may have overlooked, but are inherently more challenging to quantify outputs than PGIS techniques (Denwood et al., 2022). Spatial attributes can signify (1) values, experiences, or perceptions, (2) behavior and activity patterns, (3) future preferences, or (4) crowdsourced observational data for phenomena of interest (Brown, 2012; Fagerholm et al., 2021). These spatial attributes are most often represented by points, followed by polygons, "spraycan" (to denote vague areas), freehand drawings, and lines (Denwood et al., 2022). Spatial validity of point and polygon data tends to converge at higher sample sizes, but see Brown and Pullar (2012) for tradeoffs between the two and guidelines for aggregating point data into polygons. Spatial attributes with discrete boundaries are more appropriate for vector frameworks, while more amorphous, intrinsic attributes are well-suited for rasters (Raymond & Brown, 2006). See Pánek (2015) for guidance on more specific mapping techniques and the circumstances to employ them, and Fagerholm et al. (2021) for a detailed discussion of common spatial analysis techniques.

5.2.12 | Natural resource management

Beyond planning landscapes for effective conservation management, PM also has a role to play in the active management and monitoring of natural resources, such as charismatic and endangered wildlife populations (Cox et al., 2014) or seasonality of streams for soil moisture

management (Kuriakose & Pugazhendi, 2005). The sustainability of hunting practices in particular is frequently assessed, with sample studies in Honduras (Dunn & Smith, 2011), Scotland (Fiorini, 2013), and Gabon (Walters et al., 2015). In environments where even cursory data on natural resources are limited, PM can greatly enhance local decision-making efficacy and inherently drive new ways of thinking about resource management (Meredith et al., 2002). Early work in Zambian community-managed game reserves highlights numerous achievements of grassroots PM in allowing local chief-taincies to improve their returns from trophy hunting while maintaining wildlife populations and their land tenure rights (Lewis, 1995). More recent studies integrate advanced technology to delve into more nuanced natural resource phenomena, such as using PM to train machine learning classifiers on Landsat imagery (Woodward et al., 2021).

Oftentimes, extended monitoring for conservation is infeasible, due to financial or logistical constraints, and could be aided by PM. For example, in the US Virgin Islands, occupational underwater divers were able to map coral reef health and threats for a fraction of the cost of systematic underwater visual surveys, aiding the development of a decision-support matrix for management prioritization based on recovery potential of individual reefs (Loerzel et al., 2017).

Analyzing the effects of legislative policy on natural resources is an important focus of conservation work, but baseline data prior to policy implementation are not always available. PM with targeted interested parties is also very effective at analyzing the effects of legislative policy on natural resources. Using PM, Basupi et al. (2017) were able to quantify the effects of a 1975 policy facilitating privatization, subdivision, and fencing of Botswana's Ngamiland rangelands on seasonal pastoralist movements, overstocking, and ultimate rangeland degradation. Time-series PM frameworks are also useful to evaluate significant cultural or economic causes of land use change, their effects on natural resource use, and alternative development options to reduce adverse indigenous livelihood impacts, such as the extensive impact of mining on caribou (*Rangifer tarandus*) (Herrmann et al., 2014).

5.2.13 | Assessing species distributions and habitat use

Information on wildlife distributions, abundance, and habitat utilization forms the decision support of many management choices in conservation. However, this information is not always readily available through

traditional ecological surveys, due to a variety of reasons ranging from logistical access, technological constraints, time or financial constraints, sampling biases, rare and elusive species, wide-ranging and migratory species, etc. Where scientific understanding is incomplete, PM provides an alternative avenue to acquiring this baseline ecological information, cross-validating existing models, or enhancing them (Austin et al., 2009). For example, in a landscape where the benefits (hunting, tourism) and costs (browsing pressure, property damage) of deer (*Dama dama*, *Capreolus capreolus*, *Muntiacus reevesi*) abundance needed to be carefully managed across interested parties, integrating participatory community knowledge of deer distributions with a model based on roadkill improved deer density estimates for management (Austin et al., 2009). Meanwhile, Pédarros et al. (2020) developed a PM framework to model chacma baboon (*Papio ursinus*) habitat suitability through participant sightings that was consistent with GPS-based suitability models derived from collared baboons, but was non-invasive, rapid, low-cost, and raised conservation interest. If more technical knowledge is needed, key informants can be sourced to enhance distribution models. Indigenous experts in the Philippines co-developed spatial distributions of giant honey bee (*Apis dorsata*) nests with researchers to more sustainably manage their honey resources (Matias et al., 2017). Lastly, local spatial knowledge is not only limited to mapping wildlife distributions, but can be informative for agricultural systems when cataloging the diversity of wild crop relatives for in situ conservation and system resilience, such as in the case of wild quinoa (*Chenopodium quinoa*) in the Peruvian Andes (Fagandini Ruiz et al., 2021).

5.3 | Biases and ethical issues inherent to PM approaches

A serious issue that plagues the PM field today is representation (McCall, 2021). Consistent with survey sampling research, PM responses from the general public reported as random samples are biased towards older, more highly educated, affluent, and male-identifying participants, while underrepresenting marginalized groups, which can severely bias the spatial attributes identified and mapped (Brown, 2012). Though beyond the scope of this review, there are a wealth of studies on the impacts of digital literacy (Gottwald et al., 2016; Kahila-Tani et al., 2019), spatial discounting (Brown et al., 2013, 2020), special interest groups (Brown & Kyttä, 2014), mixed mapping methodologies (Brown et al., 2014, 2017), and local participation (Brown, 2017; Moore et al., 2017; Sletto, 2009) on representation in PM. Taken together,

these factors have important implications for decision support in conservation policy and land use planning when determining who is being surveyed and whose interests count more on a map. Ideally, random-sampling methods would be utilized to create as even a sample as possible, but meaningful effort would be placed in encouraging participation from marginalized sections of society through purposeful sampling (Brown, 2017).

A complicated question in the field of PM is: should this knowledge be mapped? Cartographic outputs can flatten rich, multidimensional pools of knowledge into 2D Cartesian planes without due consideration for process and are inextricably driven by power, with the most influential maps drawn to exert control over territory, taxes, etc. (Cochrane & Corbett, 2018). PM is a tool capable of both empowerment and cultural extraction, which must be utilized carefully with disadvantaged communities where mapping and being mapped can theoretically be equally harmful (Larrain & McCall, 2019). Best practice dictates community members should be granted as much authority and decision-making power as possible over mapped resources at every stage of the PM project, especially in the not uncommon scenario where researcher and community objectives are not aligned (Asmolov, 2020; Laituri et al., 2023). For example, Indigenous peoples may wish to counter-map and publish their knowledge in the public domain to protect or reassert their ancestral claims, while in other situations they may want sacred information to remain confidential, neither of which may be the goals of the PM facilitators (Larrain & McCall, 2019). Preserving participant autonomy is important. Considerable onus rests on the PM practitioner to intentionally consider conceptual divides, power imbalances, representation, flexibility in scheduling, and time needed to ensure mutually agreed upon processes and deliverables (Laituri et al., 2023; Larrain & McCall, 2019; Mukherjee, 2015; Tripathi & Bhattarya, 2004). Creating and implementing PM projects with these dynamics in mind is especially important in the realm of conservation, with its history in colonialism and modern-day neocolonial dynamics.

Critical engagement with these issues is not yet fully realized in conservation PM studies. Participation can be invoked in name only as a means to extract information, especially within academia, or to justify post-colonial appropriations and expansion of state control (Corbett et al., 2016; Homewood, 2017; Laituri et al., 2023; Sletto, 2009). Explicit measurement of mapping outcomes is necessary to achieve meaningful community enfranchisement (Cochrane & Corbett, 2018; Denwood et al., 2022; Gray et al., 2018). There is a fundamental difference between mapping as an end and mapping as a means to an end. A map without subsequent action can be harmful when it (1) symbolically increases awareness

but does not contribute to a solution, (2) systematically funnels limited funding away from map-enabled activities, (3) empowers authorities to pacify and subvert public opposition with faux-transparency and accountability, or (4) coerces public support through superficial participation (Asmolov, 2020; Cochrane & Corbett, 2018). Despite decades of calls to integrate political, social justice, and economic components to PM, the field remains focused on technical improvements to some extent (Cochrane et al., 2017; Ndzabandzaba, 2019). In various cases, this has allowed continued reliance on expert opinion by risk-averse political and regulating bodies, which reinforce dominant societal power structures at the expense of broader social valuation and bottom-up frameworks (Brown et al., 2020). When left unaddressed, these extractive mapping practices undermine the community relationships upon which effective conservation outcomes fundamentally depend.

Even when PM is carried out considerably and ethically from an external standpoint, there may be unintended consequences due to internal inequalities leading to heterogenous empowerment and disempowerment, digital divides, and exacerbation of latent conflicts (Sletto, 2009; Smith et al., 2017; Tripathi & Bhattarya, 2004). Successful PM outcomes can also be foiled by top-down frameworks limiting participation, rifts between Cartesian and non-Cartesian world views, centralized industrial power preempting decentralized resource governance objectives, lack of legal support, and lengthy outcome timelines with ambiguous results (Norris, 2014). Taking time to understand local community priorities and power dynamics, managing expectations with honesty and transparency, and building trust can help guard against community harm, disillusionment, aggravating divisions between interested parties, and exposing participants to physical danger and reprisals (Brown & Kytta, 2018; Chambers, 2006; Tripathi & Bhattarya, 2004). Explicitly engaging these biases and ethical challenges is central to the integrity and long-term effectiveness of PM as a mechanism for equitable conservation.

6 | IMPLICATIONS AND FUTURE DIRECTIONS

First and foremost, the ostensible origin and a key goal of conservation PM is empowerment through GIS as a vehicle for social change and democratization of policy decision-making, yet astonishingly few studies (5%) report the intended use of mapped material or tangible outcomes (Cochrane & Corbett, 2018; Denwood et al., 2022; Sieber, 2006). For both academic and gray

literature, this should be explicitly stated in manuscripts and a requirement for publication to discourage extractive mapping and encourage accountability in PM researchers and practitioners. Second, PM has an extremely poor track record for reporting even baseline numbers for scientific studies, such as conveying number of participants (78%), gender (60%), age (44%), sample representativeness of a population (35%), and wording of mapping prompts (21%) (Denwood et al., 2022). Populations are not homogeneous (Lechner et al., 2020; Wilkinson et al., 2021). Demographic and sampling reporting protocols need to be standardized and compiled across the field to ensure the transparency, replicability, and validity of conservation PM studies, all factors championed as strengths of the field and key to grounding PM as a rigorous conservation science (Brown, 2017; Denwood et al., 2022). The 4P framework (purpose of the project, process by which public was involved, partnerships formed, and products created) is a useful conception-to-outcome reporting structure (Gray et al., 2018). Also, see Newing et al. (2024) for guidance on enhancing conservation-specific community participation. Third, although recent efforts have been made to collate lessons learned (Brown et al., 2020; Raymond et al., 2020) and best practices (Denwood et al., 2022; Fagerholm et al., 2021), conservation PM still suffers from methodological pluralism, confounding vernacular, and is constituted primarily by individual case studies. If conservation PM is to fulfill its aspirations, that is, become completely operationalized within public institutions and broadly legitimized across decision-making structures, there will need to be at least moderate methodological consensus among researchers and significantly stronger external validity of those methods, in spite of the field's multidisciplinary nature (Bagstad et al., 2016; Brown & Fagerholm, 2015). These three priorities to increase scientific rigor will greatly benefit both those carrying out the research and the participants impacted by conservation policy outcomes.

PM has substantial untapped potential in the field of conservation. It is well-positioned at the intersection of natural and social sciences to holistically address wicked problems (Rittel & Webber, 1973), which constitute many conservation issues and conflicts, despite a lack of social dimension research uptake in the broader conservation spatial planning field (Cobb et al., 2024). This is particularly critical when comparing perceptions with ground-truthed data in fields in which perception may have a larger effect than ecological processes, such as human-wildlife conflict (McInturff et al., 2021; Wilkinson et al., 2021) and human behavior (Clark et al., 2024). Although there have been some anecdotal efforts to understand the temporal trends of conservation

dilemmas (Brown & Donovan, 2014; Mapedza et al., 2003; Selgrath et al., 2018; Sousa et al., 2020), most studies are cross-sectional snapshots of a socioecological system. Temporal dynamics and the underlying mechanisms by which spatial values and perceptions form and change over time at various scales are still woefully under-considered lines of investigation critical to the field (Fagerholm et al., 2021; Hasanzadeh, 2022). This applies to (1) immediate stochastic events like natural disasters, (2) changes in status quo like policy or intervention implementation, or (3) incremental, long-term changes in a variable of interest like wildlife population trends, for which it would be informative to have before and after or longitudinal time series data.

PM can also be better utilized to access data otherwise unattainable by traditional ecological surveys, such as when (1) remoteness (e.g. tropical rainforests) or technological limitations (e.g. underwater diving), (2) lack of finances, logistics, or time (e.g. international field seasons), or (3) security or health concerns (e.g. civil unrest, pandemics) preclude access to study sites or (4) there is a need for historical perspectives of prior ecological states, which are particularly useful as reference data to guard against shifting baselines. Lastly, more often than not broad classes of variables are mapped such as recreation or biodiversity, while participant values, perceptions, or conservation implications often vary within these categories. On a finer scale, PM could easily be utilized to examine landscape values and impacts of different types of recreation (e.g. all-terrain vehicles vs. birding) or more narrow taxonomic groups (e.g. species-specific abundances).

Combining PM techniques with conservation technology and mixed-methods designs provide novel avenues of future inquiry. Technology like drones (Colloredo-Mansfeld et al., 2020), big data from crowdsourcing community science or social media platforms (Muñoz et al., 2020), wildlife-borne data loggers, advanced visualization techniques (e.g. 3D virtual environments), and machine learning algorithms provide opportunities to enhance PM when leveraged correctly but remain largely unexplored. Combining PM data with sophisticated models could generalize spatial attributes and predict realities in different locations, social contexts, or the future (Fagerholm et al., 2021). Meanwhile, incorporating complimentary social science methodologies and deliberative exchange can provide rich explanatory data regarding the manifestation of spatial attributes (Kenter, 2016; Xia et al., 2024; Zeng et al., 2019). Additionally, to the best of our knowledge, PM has not been used to evaluate the outcomes of applied ecological experiments or randomized control trials, which would add an interesting means to measure treatment effects.

Since its inception, PM has made substantial progress in advancing the transition from top-down GIS research to more democratic, inclusive, and transparent mapping approaches. Our review highlights that within conservation, PM has not only proliferated across the seven continents but also diversified across subject areas with novel applications, emerging technologies, and mixed-method frameworks—demonstrating how increasingly valuable these methodologies can be to both the theory of conservation science and practitioners seeking more ethical and effective interventions. At the same time, this expansion has outpaced the development of consistent methodological standards that limit the reproducibility and external validity of many PM efforts, including sampling rigor, consistent terminology, articulating mapping purpose and outcomes. Addressing these key deficiencies offers significant potential to enhance the accuracy, relevancy, and societal impact of participatory spatial research. To conclude, although not a panacea and vulnerable to the same ethical hazards as other scientific methodologies and societal institutions, PM stands to greatly enhance conservation policy, interventions, and outcomes in a more holistic, socially just manner than previous colonial frameworks when facilitated competently and in good faith.

ACKNOWLEDGMENTS

MBK was supported by a NSF GRFP grant (Award Number 2240310). We thank the anonymous reviewers for their time and insightful feedback, which greatly increased the quality of this manuscript.

CONFLICT OF INTEREST STATEMENT

The authors disclose no conflicts of interest.

FUNDING INFORMATION

MBK was supported by an NSF GRFP grant (Award Number 2240310).

DATA AVAILABILITY STATEMENT

The data used to conduct this literature review are included as a Word document in the supplementary information.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Kowalski, M. B., Wilkinson, C. E., Wilmers, C. C., & Ocampo-Peñuela, N. (2026). A review of participatory mapping in conservation science and practice. *Conservation Science and Practice*, e70300. <https://doi.org/10.1111/csp2.70300>