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Review

How effective is community-based management of freshwater resources? A review

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ABSTRACT

Despite the existence of numerous research studies on community-based conservation, relatively few focus on the particularities of freshwater ecosystems. Freshwater ecosystems are distinct from terrestrial and marine ecosystems, exhibiting both greater concentrations of biodiversity and elevated threats. In addition, freshwater resources have distinct social, legal, political, and economic characteristics which limit the generalizability of community-based conservation research from other ecological domains. We examine peer-reviewed literature on community-based management of freshwater resources to understand and assess project contexts and outcomes. Our review indicates that studies of freshwater community-based management are limited in number and representativeness. While positive outcomes for both biodiversity and human well-being are commonly reported, limitations due to study design constrain the ability to infer the significance or causality of these effects. Overall, our analysis indicates that there are several gaps in the available research: across geographic regions, freshwater ecosystem types, intervention types, and environmental and human well-being outcome types. Given the importance of freshwater resources to Indigenous Peoples and local communities, our review highlights the critical need to generate evidence across more diverse contexts to achieve greater clarity on whether and how community-based projects can be most effective.

1. Introduction

With approximately one-quarter to one-half of the world's surface area under community management (Garnett et al., 2018; Rights and Resources Initiative, 2020), communities are at the forefront of pressing conservation issues (Díaz et al., 2019). Their participation in, and promotion of, conservation actions is critical for achieving global sustainable development and conservation goals (Díaz et al., 2019; United Nations General Assembly, 2015). At the same time, governments have increasingly devolved rights back to communities, motivated in part by human rights concerns and instrumental perspectives (Erbaugh et al., 2020; Garnett et al., 2018; Hodgson, 2006, 2016). Conservation actors (e.g., funders, environmental non-governmental organizations) have in turn shown a resurging interest in community-based conservation (CBC) (Adams and Hulme, 2001; Berkes, 2009; Child and Barnes, 2010; Mahajan et al., 2020) as they seek to advance conservation goals while simultaneously supporting and empowering local communities to achieve desirable sustainable futures (Berkes, 2004; Maxwell et al., 2020; Robinson et al., 2018; Schlager and Ostrom, 1992).

Despite enormous research and syntheses of CBC projects in terrestrial systems, we still know little about its efficacy for freshwater resources[1] (FWR) management and/or freshwater biodiversity conservation. Freshwater ecosystems are distinct from terrestrial and marine ecosystems in terms of the amount of biodiversity concentrated within a comparatively limited area: while freshwater habitats comprise less than one percent of the Earth's surface area, they support nearly 10 percent of all known species and nearly one-third of vertebrate species (Strayer and Dudgeon, 2015; Tickner et al., 2020). The outsized biodiversity importance of freshwater ecosystems is further emphasized by the magnitude of threats faced within these habitats. For example, freshwater species face a cascade of effects from headwaters to estuary including loss of connectivity, streamflow changes, water quality

Abbreviations: CBC, Community-based conservation; FWR, Freshwater resources; FW-CBC, Freshwater community-based conservation.

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[1] Freshwater resources (FWR) defined as water supply, water quality, and the species and habitats that live in and are supported by freshwater systems such as rivers, lakes, wetlands, and aquifers.

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impairment, instream habitat degradation, invasive species, and direct fishing pressures, among others (Dudgeon, 2019; He et al., 2019). Because freshwater ecosystems and species are globally imperiled at higher rates than their terrestrial counterparts (He et al., 2019; World Wildlife Fund, 2020), additional strategies are needed to combat these declines and community-based management of FWR could be a valuable tool.

Several reviews have synthesized evidence on CBC for a variety of contexts and natural resources (e.g., coastal fisheries, forests, rangelands, marine resources). These include case study reviews (Hajjar et al., 2021), narrative reviews (Ban and Frid, 2018), meta-analyses (Evans et al., 2011), scoping reviews (Ban et al., 2019), and systematic reviews (Brooks et al., 2013, 2012; Brooks, 2017; d'Armengol et al., 2018; Galvin et al., 2018; McKinnon et al., 2016, 2015). Many of these reviews are inclusive of all resources (Brooks et al., 2013), focus on a specific geography (Galvin et al., 2018), narrowly focus on specific resources, such as small-scale fisheries (d'Armengol et al., 2018) or forests (Hajjar et al., 2021), or examine particular community-based mechanisms such as water user associations (IWMI, 2011). Others have focused more on the processes that likely lead to successful CBC projects (Nilsson et al., 2016). These reviews provide important insights about the efficacy of CBC projects and key project features that increase the likelihood of positive human well-being and ecological outcomes. However, whether or not insights from these reviews generalize to various FWR remains an open question and, as a result, these reviews do not provide adequate insights to the management of FWR because of the unique characteristics of these resources.

A key concern about the generalizability of past reviews of CBC projects to FWR is highlighted by the distinct features of FWR, which suggest CBC projects for FWR may require additional considerations (Zhang et al., 2020). Freshwater is essential to all life and is recognized as a human right by the United Nations (United Nations General Assembly, 2010), and it is a necessary and irreplaceable economic, domestic, and environmental resource. Because of its multiple and essential functions, it is at the core of the UN Sustainable Development Goals (Pahl-Wostl et al., 2013). Yet FWR continue to be overexploited or unsustainably managed. For instance, globally in the past century water withdrawals grew 1.7 times faster than population growth (Food and Agriculture Organization, 2021). In most locations across the world, especially in arid climates, there are multiple claims and users of often limited FWR, which can lead to higher extractive pressures relative to terrestrial resources. Multiple users and claims to FWR across watersheds and natural resource boundaries can increase the risk of negative externalities. Upstream users can affect the quality and quantity of FWR available for downstream users, which can affect human well-being and ecosystem health and function (Meinzen-Dick and Nkonya, 2007). Likewise, upland activities can significantly modify the condition of FWR by altering the volume, timing, and constituents of return flows (Dudgeon et al., 2006). Governance challenges of FWR are compounded by the mismatch between social and political boundaries as opposed to hydro-ecological boundaries (Gupta et al., 2013). Rivers and the numerous associated FWR, for instance, can cross multiple political jurisdictions. The health and functioning of FWR systems are dependent on connectivity and health across entire watersheds, and nested governance of FWR must coordinate across multiple scales. Many FWR such as fish and groundwater are also mobile and difficult to directly observe, which can increase the cost and overall effort for measuring and monitoring FWR.

Several organizations and institutions have sought to design projects to address the unique features of FWR. Notable examples include water user associations (IWMI, 2011), projects utilizing integrated river basin management (Pahl-Wostl et al., 2008), investments in watershed services (Bremer et al., 2016), and social-ecological frameworks for managing small-scale fisheries (Basurto et al., 2013). Yet, we are unaware of any review that has examined the evidence-base for CBC projects designed to manage the full breadth of FWR, including water supply, water quality, and freshwater species and habitats. Here, we report on a scoping review that examined 65 studies of community-based management of FWR, covering studies from eight freshwater ecosystem types in 28 countries across three continents. We focus our review broadly on *freshwater community-based conservation* (FW-CBC) which we define according to two primary criteria: (1) The project has a strong connection to freshwater biodiversity by focusing on the protection and/or conservation of freshwater species and/or ecosystems and the services they provide; (2) The project is focused on Indigenous Peoples and local communities as users and beneficiaries of the freshwater resources. As part of this scope, we include both freshwater conservation projects as well as projects more broadly focused on water resource management (e.g. irrigation co-management). While the latter can often impair freshwater ecosystems due to tradeoffs between human and environmental needs, we consider improved management of these modified freshwater ecosystems as fundamental to global freshwater conservation goals. Hence, understanding the nature of these projects can provide insights into whether and how community-based management can support improved outcomes for freshwater ecosystems and biodiversity.

We investigate five broad sets of questions regarding published studies of community-based management of FWR (1) What are the primary characteristics (e.g., location, study design) of published studies on community-based management of FWR? (2) What kinds of FWR are managed by these projects (3) What intervention types (e.g., irrigation management, fisheries management) have been associated with these projects? (4) What is the quality and breadth of published evidence on project outcomes? (5) Does community-based management of FWR increase the likelihood that freshwater biodiversity objectives will be achieved in addition to human well-being outcomes? We then provide a discussion of key gaps and future directions for research with the aim to advance both research and practice of FW-CBC.

2. Methods

Evidence review and synthesis from published literature is widely viewed as the most reliable basis of evidence for health practice (Aromataris and Pearson, 2014; Munn et al., 2018) and is now widely practiced in the environmental sciences and, to a lesser extent, in evaluation of environmental policy (Miljand, 2020). Here we follow evidence synthesis guidelines provided by the Collaborative for Environmental Evidence (Petrokofsky, 2018). This includes the procedures for search, eligibility screening, data coding and extraction, critical appraisal, data synthesis and interpretation of findings.

2.1. Publication search

The design of search strategy for an evidence review involves four considerations: (1) database selection; (2) inclusion criteria; (3) exclusion criteria; and (4) characterization criteria. Following other reviews of similar topics (Brooks, 2017; d'Armengol et al., 2018), we focused on scholarly articles in three databases that cover environmental science and environmental policy: Web of Science, Agricultural and Environmental Science Collection, and Scopus. We searched these databases for English-language articles and book chapters in peer-reviewed publications.

Our selection of search terminology focused on four primary components of community-based management of FWR: governance type, FWR type, evaluation type, and outcome type. We applied the same search terms and strings for all three databases, only modifying database-specific syntax as necessary. The following search query for Web of Science formed the basis for all three database searches: TS= ((“participatory governance” OR “participatory management” OR “community management” OR “community governance” OR “community-based” OR “co-management” OR “water user$ association” OR “community organization”) AND (“small-scale fishery” OR groundwater OR wetland OR lake OR river OR peat OR floodplain OR riparian OR

irrigation OR "spring protection" OR watershed) AND (assessment OR impact OR performance OR evaluation OR outcome) AND (livelihood OR income OR poverty OR gender OR empowerment OR equity OR equality OR "food security" OR subsistence OR "benefit sharing" OR biodiversity OR ecosystem)). We tested several iterations of the search string and did preliminary reviews of search results to refine the search string.

We conducted our search on all three databases on August 22, 2020, which resulted in 702 records. We identified duplicate entries (n = 457) via automated search and verified by manual review, resulting in a consolidated dataset of 245 unique publication records (see *Appendix B*).

2.2. Eligibility screening

We screened all 245 publications according to eligibility criteria addressing four primary attributes. Specifically, a publication met eligibility criteria if it included: (a) Explicit qualitative or quantitative information on outcomes; (b) Significant relevance to inland freshwater ecosystems (i.e., we excluded publications primarily associated with coastal or marine ecosystems); (c) Direct participation in the project by Indigenous or local community groups; (d) Publication through peer review. This initial screening excluded 98 publications resulting in a revised dataset of 147 publications.

For each of the remaining publications, we obtained the full published manuscript and reviewed each to confirm whether the publication met the eligibility criteria noted above. The resulting dataset of 65 publications comprises the full dataset presented in the results and discussion that follow (see *Appendix A-2*).

2.3. Data coding and extraction

Our coding scheme prioritized three thematic elements to understand the nature of these studies and their reported outcomes: (a) study attributes; (b) community and freshwater context; and (c) outcomes. Within each of these thematic elements, we identified specific variables of interest through an iterative coding process. Following initial variable selection, we explicitly defined all variables and further defined any applicable value coding (i.e., categorical values). Subsequently, we selected a random subset of 20 publications split across four reviewers (AA, NK, SK, and YJM) and conducted data extraction and coding. We also conducted independent paired reviews for half of these publications, identifying discrepancies in data extraction and coding. We used the initial reviews and paired reviews to revise variables, coding, and definitions, noting where variable or coding definitions were unclear.

This iterative coding process resulted in selection of 23 variables (see Table 1 and *Appendix A-1*). Each of the 65 publications was randomly assigned for review by one of four reviewers. Each reviewer then carried out data collection for all specified variables for a given paper. To ensure consistency and efficiency in data collection across reviewers, the coding process included a step whereby reviewer's uncertainty was actively disclosed for any given publication and variable. Each uncertainty occurrence was then subjected to consultative review by two or more reviewers until a clear consensus was achieved for the given occurrence.

Table 1
Summary of variables collected for the 65 publications. Parenthetical counts note the number of variables for each respective variable category. See *Appendix A-1* for additional description of each variable along with coding definitions.

Theme	Variables
Study attributes	Publication year (1); study design (2); study validity (1); equity considerations (1)
Community and freshwater context	Country locations (1); freshwater ecosystem types (1); community freshwater use types (1); intervention types (1)
Outcomes	Environmental outcomes (5); human well-being outcomes (5)

We analyzed the data using descriptive statistics to characterize the study sample set, as well as highlighting key results through the examination of specific studies to highlight gaps and/or elements of our synthesis that were indicative of the overall study set.

3. Results

3.1. Studies exhibit diverse attributes though representativeness and validity are limited

Sixty-five studies met our search and eligibility criteria (see *Methods*). Our sample includes studies published between 2003 and 2020 (see *Appendix A-3*) representing a diversity of disciplinary or topical outlets, including agriculture, development, ecology, economics, irrigation, and policy. In aggregate, our review captured studies with broad regional representation with studies covering 26 countries (Fig. 1a). However, a closer examination reveals either overrepresentation or evidence gaps for key parts of the world harboring significant FWR. For instance, 25 studies (38%) examined community-based management of FWR in Sub-Saharan Africa, of which nine studies were in Malawi, six in Kenya, and four in Ethiopia. Ten studies were in Latin America, of which eight studies examined community-based projects in Brazil. There was a total of 16 studies in South Asia, of which seven and three studies were from Bangladesh and India, respectively. Countries were often overrepresented because multiple studies examined the same projects (e.g., Malawi (Russell and Dobson, 2011a, 2011b) and Kenya (Etiegni et al., 2019, 2020)). We find significant geographic gaps, particularly in the Global North including North America, Europe and Australia, as well as areas in Central and South America and Northern Africa.

Based on study designs, we find that very few studies had high internal validity, as most employed case studies (n = 24; 38%) and lacked comparison or counterfactuals in their studies (Fig. 1b). A total of ten studies used mixed methods, and these studies frequently combined case studies (60% of mixed methods studies) with other approaches, such as descriptive statistics using cross-sectional data. Only two studies (3%) used a non-randomized control design when assessing project effects on environmental or human well-being outcomes. These results suggest low confidence in our ability to infer causal (or likely causal) effects of community-based management of FWR on reported environmental or human well-being outcomes, necessitating reliance on illustrative cases to highlight possible mechanisms and explanations around reported efficacy of these projects.

Our study set covered a diverse range of freshwater ecosystem types (Fig. 1b). Twenty-seven studies (42%) examined projects associated with more than three freshwater ecosystem types, with one study covering nine freshwater ecosystem types. Among all studies, permanent rivers (57% of studies), artificial freshwaters (45%), and permanent lakes (35%) were the three most commonly observed, with brackish (3.1%) and seasonal rivers (7.7%) being the least commonly observed. While seasonal marshes and floodplain lakes are relatively common across these studies and countries (Lehner and Döll, 2004), studies describing projects with these freshwater ecosystem types were primarily restricted to Bangladesh (n = 7; 39% of studies on marshes) and Brazil (n = 5; 28% of studies on marshes).

The distribution of community uses of FWR indicates the types of activities most frequently observed across these freshwater ecosystems (Fig. 1b). Forty (62%) and 31 (48%) studies examined projects where FWR were used for irrigation and fisheries purposes, respectively. The least studied community uses of FWR concerned livestock, cultural services, and recreational activities, with each accounting for just three studies (4.6%). Twenty-four studies (37%) examined only one community use type, and 92 percent of these involved communities managing irrigation systems. Forty-one studies (63%) examined more than one community use type, with 58% of these studies examining two use types. Two studies (Kundu et al., 2010; Richards and Syallow, 2018) examined

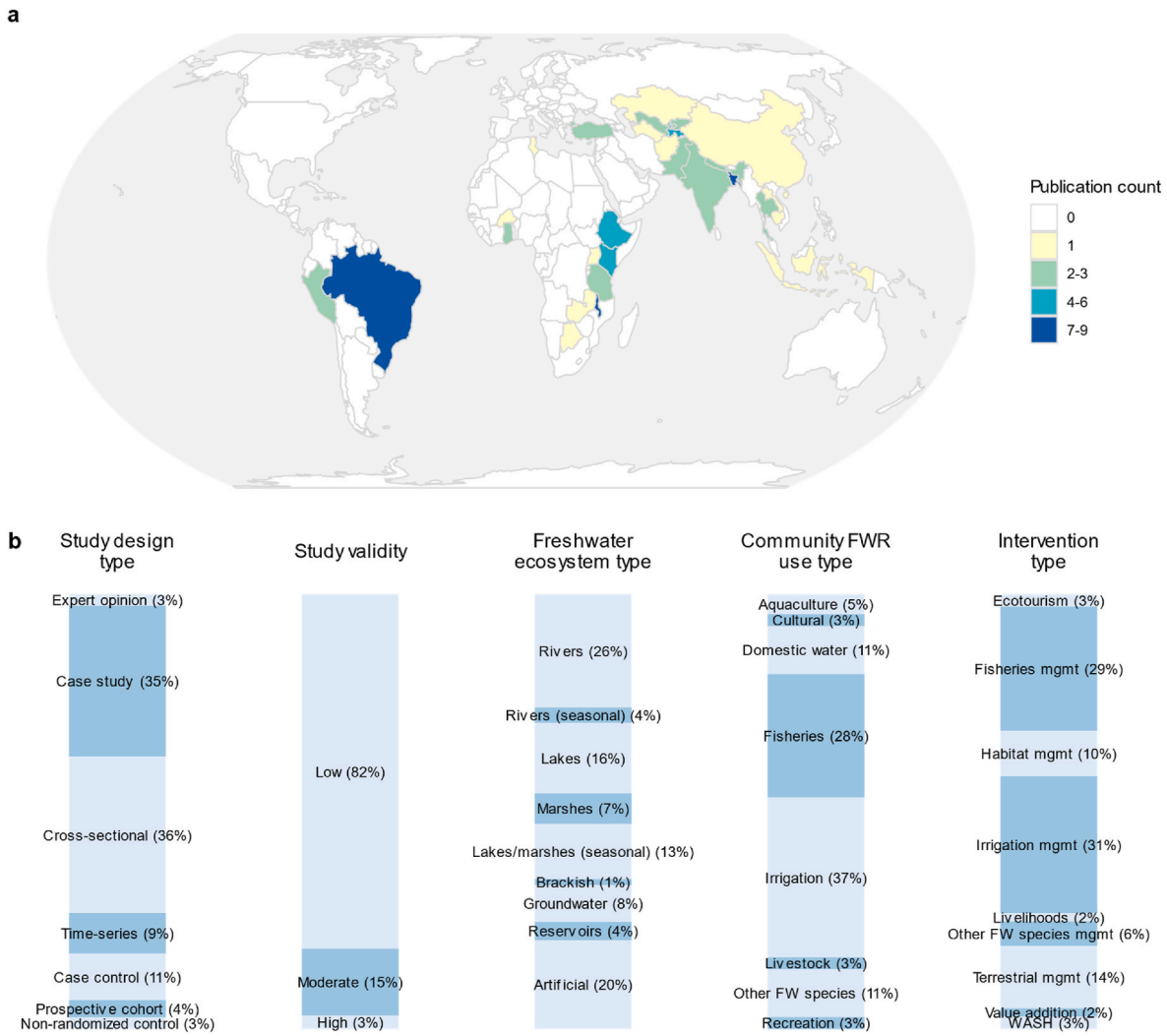

Fig. 1. (a) Count of publications by country location where a given study may span multiple countries, and (b) summary of primary study attributes. For study validity, percentages reflect counts relative to the total number of reviewed publications (n = 65). For all other variables, percentages reflect counts of all observations for the reviewed publications, where a given study may be counted multiple times (e.g., a single publication may include observation of both river and lake freshwater ecosystem types).

projects where communities reported six use types (fisheries, management of other freshwater species, domestic water use, irrigation, recreational activities, livestock, and other uses).

3.2. *Interventions largely focused on management of FWR, especially fisheries and irrigation*

Most studies (n = 48; 74%) examined community-based projects with one primary reported intervention type (Fig. 1b). One study examined seven intervention types. The most commonly studied intervention combination was fisheries management and terrestrial management (n = 8), followed by irrigation and freshwater habitat and ecosystem management (n = 6) and irrigation and terrestrial habitat and ecosystem management (n = 6).

Studies assessing irrigation management (n = 33; 51%) and fisheries management (n = 30; 46%) were the most prevalent in our sample set, reflective of the most prominent community FWR use types. The prevalence of these two intervention types further suggests considerable imbalance regarding the depth of knowledge on different FWR use types, intervention types, and outcome types. For instance, only 11 studies (17%) reported interventions around freshwater habitat management or restoration (e.g., instream or in-water management, such as habitat restoration or river corridor protection). The emphasis on interventions that manage the direct use of FWR indicates that community-based projects to date may have been driven more by human development interests and the provisioning ecosystem services FWR provide (e.g., food security, reliable water supplies for agriculture) as opposed to ecological ones (e.g., freshwater biodiversity and habitat).

Just five studies (8%) examined interventions that supported alternative livelihoods or value addition, which is one of the purported ways to reduce pressure on extractive FWR activities. For instance, such an intervention may be through increasing terrestrial livelihood activities, such as beekeeping, where the conservation and protection of freshwater species provides incentives in line with development goals. The lack of studies on these topics indicates that evidence remains limited on whether these types of interventions can reduce extractive pressures on FWR.

3.3. *Prevalence of positive outcomes is constrained by considerations of representativeness, study design, and equity*

The majority of studies (n = 58; 89%) reported outcomes for both environmental and human well-being outcome categories (Fig. 2). However, considering specific outcome types, studies tended to report

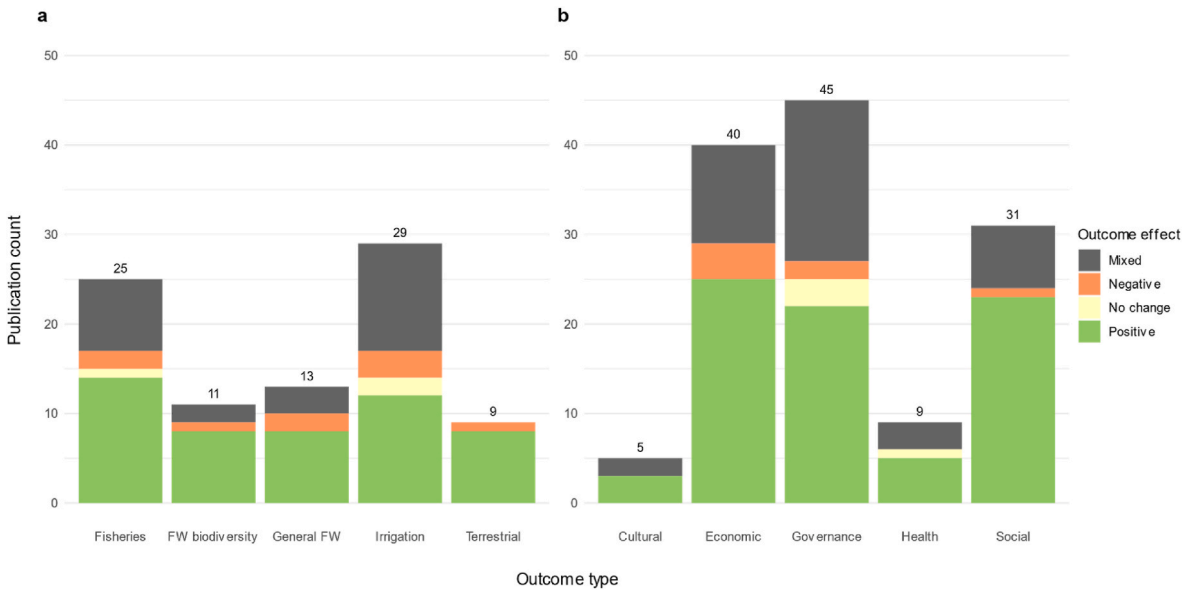

Fig. 2. Publication counts by outcome type and effect for (a) environmental and (b) human well-being outcomes, where a given publication may be counted multiple times across different outcome types (see *Methods* and *Appendix A-1* for additional description of variables and values).

fewer environmental outcome types as compared to human well-being outcome types. Ninety-one percent of studies (n = 59) reported more than one human well-being outcome while just 31 percent of studies (n = 20) reported more than one environmental outcome. This suggests that, for a given study and project, human well-being outcomes are more commonly assessed according to multiple dimensions while environmental outcomes are more narrowly examined. Twelve studies (18%) reported outcomes for either only environmental or only human well-being outcomes (n = 6 for both). This highlights the important distinction between study objectives as opposed to the potential goals of the underlying community-based project. For example, we observe cases where both environmental and human well-being dimensions of FWR use are noted and yet only one of these outcome categories is reported (Baird and Flaherty, 2005; Silvano et al., 2009).

Among environmental outcome types, fisheries and irrigation outcomes were the most frequently observed (n = 25; 39% and n = 29; 45%), reflecting the prevalence of these intervention types within our dataset (Fig. 2a). In addition to their frequency, these also tended to be observed in isolation relative to other environmental outcome types: more than half of the studies (n = 36; 55%) included observation of only fisheries or only irrigation environmental outcome types. Study observations of human well-being outcomes primarily focused on economic, governance, and social outcome types (Fig. 2b). Reporting on health or cultural outcomes was comparatively uncommon within these publications, suggesting important gaps in outcome evidence for these components of human well-being.

The majority of studies reported positive effects from interventions, although fewer reported positive environmental outcomes compared to human well-being outcomes (n = 32; 49% versus n = 41; 63%). Less frequent but still common were observations of mixed effects for environmental and human well-being outcome types (n = 22; 34% and n = 21; 32%). By contrast, comparatively few studies reported negative or null outcomes. Seven studies (11%) reported negative environmental outcomes while just five (7%) reported negative human well-being outcomes. It is likely that publication bias and the consequent under-reporting of adverse outcomes influences these summarized outcome effects, inflating the prevalence of positive outcomes (Franco et al., 2014; Jennions and Møller, 2002; Wood, 2020). These patterns have been widely observed in reviews of the distribution of scientific evidence (Ioannidis, 2005, 2008).

Comparison across both environmental and human well-being outcomes further highlights the high reporting frequency of positive outcome effects (Fig. 3). Irrespective of outcome type, 29 publications (45%) reported positive effects for both environmental and human well-being outcomes. The next most reported effect was mixed for both environmental and human well-being outcomes (n = 13; 20%). For all other effect combinations, seven or fewer studies reported the given effect combination. The body of evidence here affirms the general assertion that community-based management supports beneficial outcomes for both environmental and human systems. However, the significance of this evidence depends heavily on considerations of representativeness and experimental design. If we exclude those publications based only on expert opinion or case studies, just nine publications (14%) reported positive outcomes for environmental and human well-being types. Thus, while the frequency of reported positive outcomes for these publications is notable, considerable evidentiary gaps remain.

Less than half of studies (n = 28; 43%) explicitly examined equity dimensions. These assessments were primarily driven by the recognition that power relations within and across communities and freshwater ecosystems can lead to inequities, and that addressing or directly acknowledging these concerns was important. The most commonly studied subgroups were women (n = 15; 54% of equity subset), lower wealth or income groups (n = 7; 25% of equity subset), geography (e.g., position along a river or canal; n = 6; 21% of equity subset), and caste or ethnic group (n = 5; 18% of equity subset). The remainder looked at subgroups that differed along educational, generational, or other socioeconomic or demographic variables.

The way in which equity was addressed or integrated in assessments also differed. For example, closer examination of studies assessing women's involvement provides insights into how these projects sought to integrate women into governance and activities. Freitas and co-authors (2020) reported on how women's co-management of arapaima in Brazil was largely driven by need rather than through regulatory or other policies, and that this led to increases in women's income compared to communities without co-management. Importantly, they note that women's participation and roles remain unequal to men, but their qualitative analysis indicates that women are, by and large, still benefitting relative to those that did not participate. A common theme across studies was that local gender norms shaped the way in which women could participate and benefit—posing potential challenges for statutory efforts (Udas and Zwarteveen, 2005).

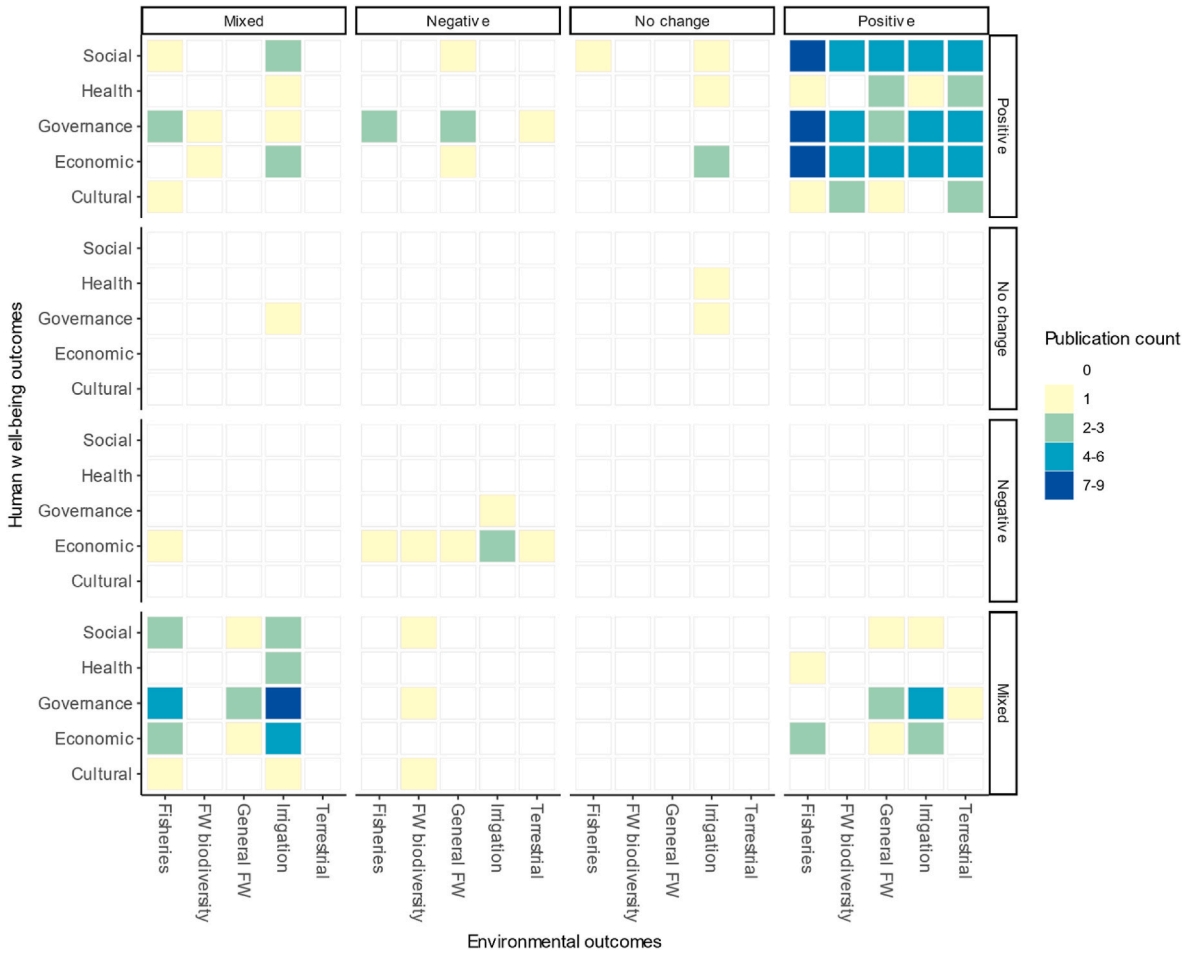

Fig. 3. Comparison of environmental and human well-being outcomes by type and effect. Each colored square represents an observed occurrence of a given outcome type pairing within a given effect category, whereby a single publication may be represented multiple times across squares. Definitions of human well-being and environmental outcome categories are provided in *Appendix A-1*.

4. Discussion

Freshwater community-based conservation remains a critical approach to achieving both conservation and development goals. Our review indicated several areas where community-based approaches have yielded positive outcomes for both people and nature. Yet, our analysis also indicates that there are several evidence gaps related to community-based management of FWR: across geographic regions, freshwater ecosystem types, intervention types, and environmental and human well-being outcome types.

Notably, some geographic regions of the world are not represented within our results, particularly regions within the Global North (including Australia, Canada, Europe and the United States). Our search and inclusion criteria did not explicitly exclude these regions, implying this gap stems from attributes of the published literature and our publication search and eligibility criteria. A review of co-managed small-scale fisheries reported study representation across Australia, Europe and North America (d'Armengol et al., 2018). In reviewing these, we note just two studies of freshwater ecosystems with neither appearing to meet our specified eligibility criteria. A more recent review of community-based conservation projects noted similar underrepresentation in North America and Australia (Fariss et al., 2022).

We also note underrepresentation for regions with significant freshwater depletion (Brauman et al., 2016), such as Mexico and much of Northern Africa, which were largely missing in our study set. This is surprising since communities in these areas are likely to benefit from community-based governance of scarce water supplies for domestic and commercial use, as demonstrated by cases from India (Khandker et al., 2020; Reddy et al., 2014) and Mexico (Basel et al., 2020) (published after our search was completed). It may be that community-based management of FWR exists in these regions but has not been studied and published in English-language peer reviewed publications or that some of these publications did not meet our inclusion criteria or were not captured by our search terms.

Among natural freshwater ecosystems, our study suggests that community-based projects in rivers, lakes, and floodplains are comparatively common, while few studies examined projects in permanent marshes, seasonal rivers, and brackish waters. As with regional gaps, it may be that community-based management is simply understudied in these freshwater ecosystems. A related gap concerns the scale of studied projects relative to the scale of freshwater ecosystems: few studies in our dataset assessed whether interventions led to better management across the entirety of a freshwater system, such as a river basin or lake.

As noted previously, the distribution of intervention types was skewed. Comparatively few studies examined the efficacy of community-based freshwater protected area management (e.g., Koning et al. (2020) published after our search was completed), community-managed freshwater-based ecotourism, other freshwater habitat management, alternative livelihood interventions, and value addition. We hypothesize that this result is indicative of publication bias as opposed to the true prevalence of these intervention types across community-based projects. To evaluate this assertion, we compared the distribution of intervention types from our study with another database on CBC (Equator Initiative Case Study Database) (Equator Initiative,

Global Program on Nature for Development, 2020). Of the 55 FW-CBC cases (out of 225) identified from this database, 83% (n = 46) implemented at least one terrestrial-based intervention such as sustainable agriculture or reforestation and forest management, suggesting that upland watershed interventions are far more prevalent in these projects (T. Smith, unpublished data). Similarly, implementation of alternative livelihoods (60%; n = 33) and ecotourism (35%; n = 19) were also far more common. This preliminary comparison implies significant value and opportunity for the collective research community to conduct further studies on these intervention types.

Analysis of our publication dataset also indicates that studied outcomes are driven primarily by considerations for human development rather than biodiversity goals, where only one-third of studies reported freshwater biodiversity outcomes. Of these, the majority were focused on fisheries management (including fish and turtles). These results beg the question of whether community-based management of FWR, as exemplified by these studies, presents a significant opportunity for protecting and restoring freshwater biodiversity globally. The most significant threats to freshwater biodiversity include water over-abstraction (e.g. for irrigation and urban supply), contamination (e.g., agricultural run-off, mining), flow alteration (e.g., dams, climate change), loss of instream and wetland habitat, overexploitation of freshwater species, and introduction of invasive species (Dudgeon et al., 2006; Reid et al., 2019; Vörösmarty et al., 2010). The publications reviewed here indicate that only a subset of these threats have been studied across community-based projects, suggesting knowledge gaps about the potential role of FW-CBC, and community-based management of FWR more broadly, for mitigating the suite of dominant threats to freshwater biodiversity.

Biodiversity outcomes were largely absent from the 46 studies focusing on community-based irrigation management. This is notable because irrigation withdrawals constitute one of the major global threats to freshwater biodiversity, including reduced fish abundance and diversity (Poff and Zimmerman, 2010), and there are opportunities to manage water diversions to minimize those impacts (Linstead, 2018). Biodiversity outcomes may be largely absent from such projects because they have been primarily motivated by human development concerns including the provision of sufficient water supply. Even where water provision for human enterprise is the sole project concern, there may be significant value to the research community in understanding whether community-management confers reduced adverse impacts for freshwater ecosystems and biodiversity. This represents a missed opportunity to link such projects to broader environmental impacts and suggests important gaps in our understanding of the potential conservation benefits of community-based management of FWR.

Our study provides insights on the state of evidence of community-based management of FWR, but we also note several limitations. Our search focused on English language journals, in particular on studies that were published and had undergone peer review. As a result, it is possible some of the geographic or thematic gaps identified in this paper may in part be addressed if the search was expanded to studies written in other languages. Similarly, our search utilized broad terms around community management of freshwater resources. As such, we may have missed studies of projects which include specific approaches to community-led management of freshwater resources, such as other effective area-based conservation measures (OECMs), integrated conservation and development projects (ICDPs), or customary management. Our coding protocol also did not capture hypothesized enabling conditions for community-based management of FWR because studies often did not report contextual variables (Berkes, 2009; Mahajan et al., 2020; Zhang et al., 2020), such as tenure security and informal and formal institutional capacity. As a result, we were unable to assess whether such factors contributed to the overall project success or failure. Our search terminology may also have missed some relevant publications. For instance, compared to other systematic reviews such as d'Armengol and others (d'Armengol et al., 2018), only four co-managed inland fisheries publications overlap with our search. However, this discrepancy was not due to our initial search strings. Even when we adapted our search terms on fisheries to include those from d'Armengol and others (2018), the search results still yielded the same four overlapping studies. As a result, we consider our results presented here as a study set complementary to other systematic reviews on CBC.

FWR are historically understudied in conservation (Reid et al., 2019), and this is mirrored in a recent meta-analyses of CBC projects across biomes (Fariss et al., 2021). Indigenous Peoples and local communities are often at the forefront of major threats to freshwater biodiversity, and these threats can have immediate and tangible impacts on the health, well-being, and livelihoods of these communities. Therefore, there is an urgent need to advance our understanding of community-based approaches and to generate evidence on the connection between community management of FWR and basin-scale outcomes. The results of this scoping review warrant increased interest in this field including further efforts to conduct robust and representative research studies.

5. Conclusion

Freshwater community-based conservation is a potentially important tool to advance the sustainable use and management of FWR, supporting the well-being of people all over the world while also advancing the protection and restoration of freshwater biodiversity. But the characteristics of FWR mean that community-based management projects must be robustly designed to account for factors such as negative externalities, the mobile and seasonal nature of FWR, and challenges associated with monitoring and measuring often fugitive resources. The evidence reviewed here provides promising indications that community-based management of FWR can yield positive environmental and human well-being outcomes, and that community management can be an effective way to manage critical FWR. But our review also highlights the urgent need to generate evidence across more diverse contexts to achieve greater clarity on whether and how community-based projects can be designed to be effective across a variety of freshwater ecosystems, community types, and socioeconomic contexts. While the evidence is promising, we find that most studies lacked a comparison or counterfactual group making inferences about the causal effects of these projects uncertain. This highlights the urgent need to generate robust evidence on the structure, implementation, and impacts of FW-CBC projects.

Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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