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PERSPECTIVE

Achieving biodiversity benefits with offsets: Research gaps, challenges, and needs

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Abstract Biodiversity offsets are becoming increasingly common across a portfolio of settings: national policy, voluntary programs, international lending, and corporate business structures. Given the diversity of ecological, political, and socio-economic systems where offsets may be applied, place-based information is likely to be most useful in designing and implementing offset programs, along with guiding principles that assure best practice. We reviewed the research on biodiversity offsets to explore gaps and needs. While the peer-reviewed literature on offsets is growing rapidly, it is heavily dominated by ecological theory, wetland ecosystems, and U.S.-based research. Given that majority of offset policies and programs are occurring in middle- and low-income countries, the research gaps we identified present a number of risks. They also present an opportunity to create regionally based learning platforms focused on pilot projects and institutional capacity building. Scientific research should diversify, both topically and geographically, in order to support the successful design, implementation, and monitoring of biodiversity offset programs.

Keywords Conservation · Design · Mitigation · Offsets

INTRODUCTION

Biodiversity offsets are mechanisms intended to balance development and environmental goals by compensating for residual impacts of projects after appropriate steps have been taken to first avoid and minimize impacts (BBOP 2012; Bull et al. 2013). Offsets have taken on a number definitions, synonyms, and flavors over the past few decades (e.g., compensatory mitigation, mitigation, or biodiversity banking). In general, biodiversity offsets are viewed as "measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development after appropriate prevention and mitigation measures have been taken. The goal of biodiversity offsets is to achieve no net loss and preferably a net gain of biodiversity on the ground with respect to species composition, habitat structure, ecosystem function and people's use and cultural values associated with biodiversity" (BBOP 2012). Many developing and developed countries have established or are in the process of creating offset policies in an attempt to scale environmental conservation efforts and help meet national biodiversity goals (Maron et al. 2015). Further, while many offset programs are driven by regulation or by lender safeguards (e.g., IFC Performance Standard 6), there is also growing interest in the design of voluntary programs (Doswald et al. 2012; Benabou 2014; Gelcich and Donlan 2015). Although not yet mainstreamed, at least 30 companies have corporate goals around no net loss or net positive impact, many of which explicitly include biodiversity (Rainey et al. 2015). Biodiversity offsets are becoming increasingly common across a portfolio of settings: national policy, voluntary conservation programs, international lending, and internal governance structures of businesses.

While biodiversity offsets are becoming more common, they are the target of strong critiques. Some have criticized offsets for lacking formal design methods and requirements (Quétier and Lavorel 2011). Others have criticized their

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temporal nature and time lags—trading immediate habitat loss for projects that promise future biodiversity benefits (Bekessy et al. 2010). Wetland offsetting programs in the United States have often failed to meet their objectives, and have a mediocre track record of effective implementation and monitoring (Robertson and Hayden 2008; Moreno-Mateos et al. 2012). Others have voiced concerns over the commodification of nature and the appropriation of land for environmental ends (Fairhead et al. 2012; Penca 2013). Critiques also relate to the concern that by attaching the slogan "no net loss" to biodiversity bartering, politicians can appear to take action while continuing to serve development interests, while ignoring or perhaps exacerbating biodiversity loss.

Given the diversity of ecological, political, and socio-economic systems where offsets may be applied, the successful design and implementation of a biodiversity offset program is a complex endeavor. A *one size fits all* approach is likely to fail. Rather, place-based research is needed for success, along with guiding principles and methodologies that assure best practice (BBOP 2009; Donlan 2015). The challenges surrounding offset programs, along with various opinions of researchers and practitioners, are polarizing discussions. Optimistic and pessimistic views of offsets are now common in the literature (McAfee 2012; Bull et al. 2013; Gonçalves et al. 2015; Maron et al. 2015). Science-based research can inform the design and implementation of offset programs, as well as help define the risks and limitations of the approach. Yet, such research is arguably of limited utility if it is not applicable to the local conditions where a program is being targeted. In fact, research inappropriately applied in different settings could even have negative impacts on the design and execution of biodiversity offset programs, along with the overall reputation of the approach.

Several overarching frameworks that stress important aspects for designing, implementing, and enforcing offset policies and programs have been developed (McKenney and Kiesecker 2010; Quétier and Lavorel 2011; BBOP 2012). Similarly, several research efforts have evaluated transactional aspects of offset programs, like the creation of credits and other ecological metrics (Cochrane et al. 2015; Donlan 2015; Gonçalves et al. 2015). Yet, offset programs require information on non-ecological factors for success, such as socio-economic and local governance aspects. These elements represent an important gap because research to-date on offsets has been overwhelmingly focused on ecological topics. We surveyed the offset research literature to illustrate the gaps and needs (See supplementary materials for details on methods, including the specifications of our literature review).

THE STATE OF BIODIVERSITY OFFSET RESEARCH

The peer-reviewed literature focused on offsets is rapidly growing (Fig. 1). Eighty-eight percent of the studies were published after 2000, and 50 % within the last 5 years. Research has focused heavily on ecological factors (77 %, Fig. 1). Common research topics include approaches to quantifying biodiversity impacts and benefits, applying ecological theory to offsets, and assessing the potential role of offsets under specific scenarios. Research where the

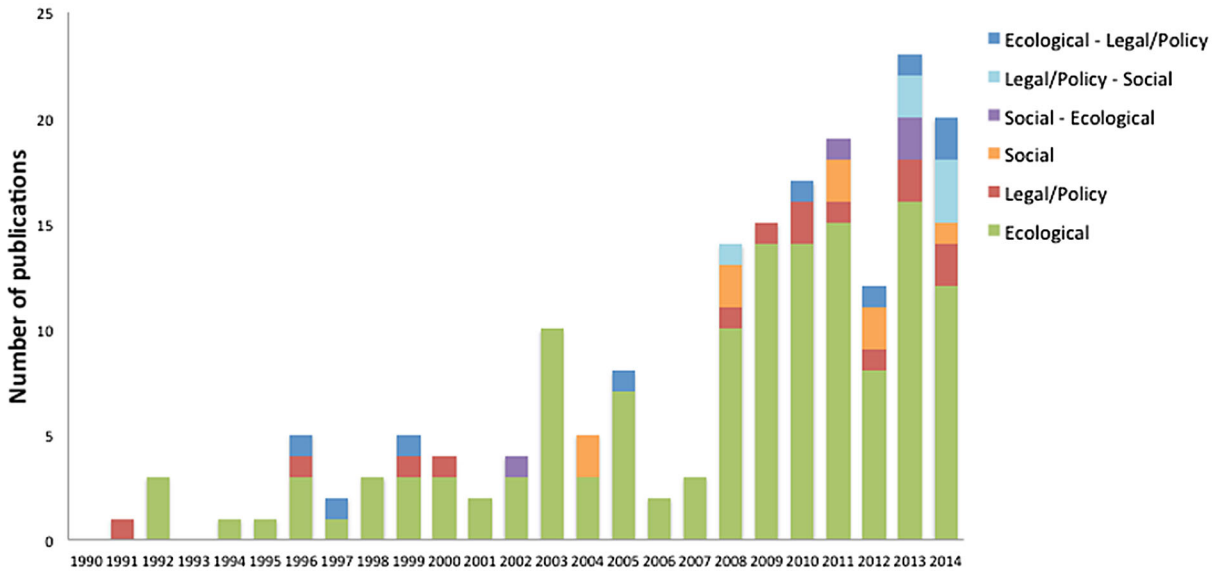

Fig. 1 Number of research publications on biodiversity offsets from 1990 to 2014, and their principal disciplinary focus. See Supplementary Material for details on methods

main focus is on social and policy issues is less common: 5 and 8 %, respectively. Social research was first published in 2002, when researchers considered stakeholder perceptions, attitudes, and opinions within biodiversity offset programs (Stone 2002). Research that integrated multiple disciplines is also rare (11 %; Fig. 1). Research exploring the interaction of social and policy aspects of biodiversity offsets was first published in 2008 (BenDor et al. 2008). Of the 179 research publications on offsets identified in our review, a mere four applied a social-ecological approach, which involved assessing values of decision makers and stakeholders around markets and conservation credits (Stone 2002; BenDor and Stewart 2011; Bunn et al. 2013; Coggana et al. 2013). Research publications whose secondary focus included an economic dimension represented ~20 % of the literature. While there is a well-developed literature focused on the economics of carbon offsets (e.g., van Kooten et al. 2004; Osborne and Kiker 2005; Siikamäki et al. 2012), little empirical economic research has been conducted on biodiversity offsets (see Pascoe et al. 2011 for an example). Thus, while socio-political and interdisciplinary research on biodiversity offsets has increased over the past 5 years, research on offsets is still strongly dominated by ecology.

Research on biodiversity offsets is largely focused on a single ecosystem in one developed country: wetlands in the United States. Seventy percent of publications that reference a specific geography focused on the United States, and 72 % of publications that focus on a specific ecosystem-targeted wetlands. Importantly, over 90 % of all offset research that reference a specific geography has occurred in a developed country (Fig. 2). We identified 15 countries where empirical biodiversity offset research has occurred, with the majority of countries consisting of a single study (Fig. 2). Seven of those geographies included middle- and low-income countries: Madagascar, Morocco, South Africa, Thailand, India, Uzbekistan, Colombia, and Brazil. We identified a similar pattern with first author affiliation: researchers affiliated to developed countries are responsible for 98 % of biodiversity offset publications. Only two publications had first authors

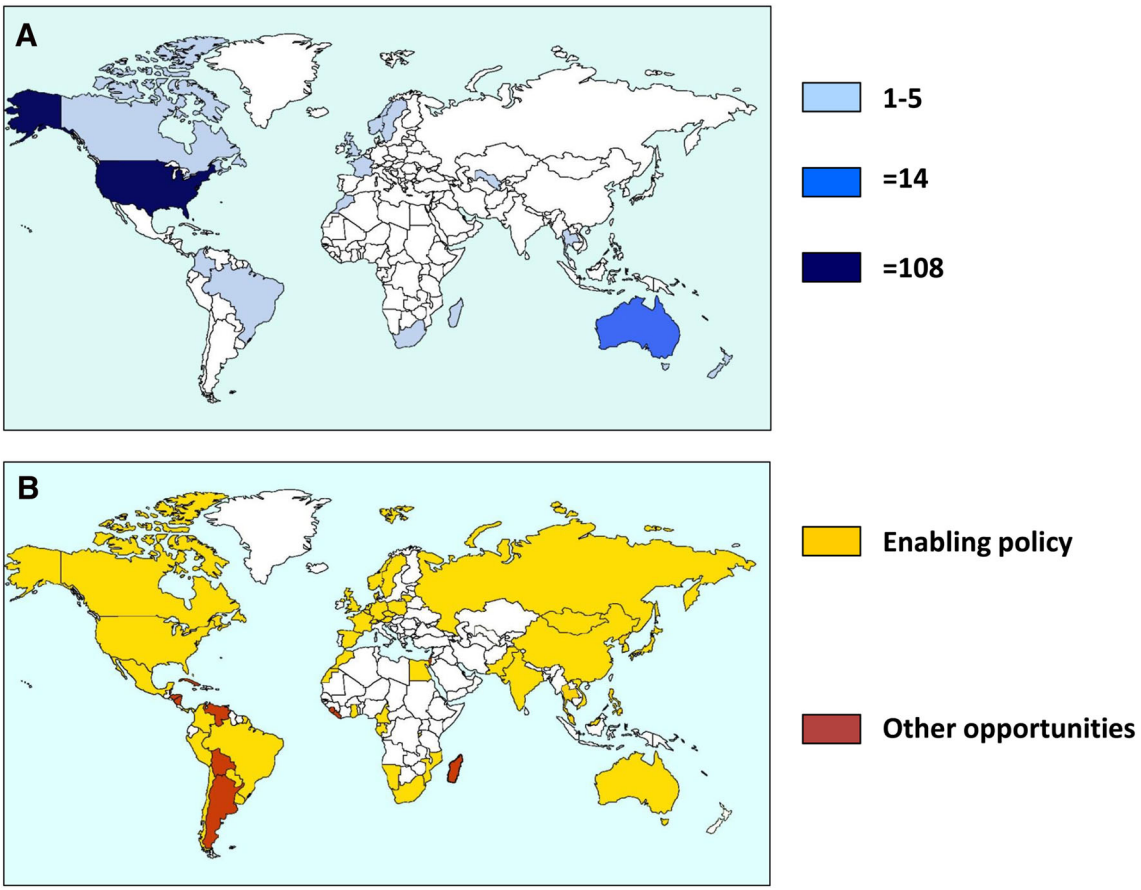

Fig. 2 **a** Number of biodiversity offset publications and the countries where they are focused. **b** Countries which policies or regulations potentially enable aspect of biodiversity offsets (*yellow*), and countries where opportunities might exist for biodiversity offsets within the impact assessment framework (*orange*). See Supplementary Material Tables S1 and S2 for details on policies or regulations

from developing countries (i.e., India and South Africa). A similar situation exists with ecosystem type: little offset research on marine ecosystems exists (7 %), compared to terrestrial (31 %) and wetlands (72 %).

THE NEED FOR NEW BIODIVERSITY OFFSET LEARNING PLATFORMS

While most offset research occurs in the United States, the majority of offset policies and programs are occurring in other counties, often in middle- and low-income ones (Villarroya et al. 2014). This research gap presents a number of risks. For example, offset policies designed under strong environmental laws (i.e., U.S. Clean Water Act and U.S. Endangered Species Act) and that rely on strong institutions, such as the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service, are likely to have limited utility in South American countries with different histories, environmental policies, and institutions. Similarly, programs designed originally for wetland mitigation may not be particularly useful for practitioners designing programs to offset mining impacts in the Amazon or Atacama Desert. Yet, this appears to be the de facto situation: policy-makers, program designers, and practitioners relying on information and approaches developed elsewhere, most often in very different contexts, when designing their own offset policies and programs (Bull et al. 2013).

This glaring geographic gap presents new research opportunities. For example, many South American countries (e.g., Colombia, Peru, and Chile) are in the process of reforming their environmental policies to operationalize biodiversity offset mechanisms. Within their economies, those same countries face similar environmental challenges (e.g., mining and energy generation) where offsets have some potential to reduce environmental impacts. Regionally based learning platforms on the design and execution of offset policies and programs that span multiple countries would likely improve outcomes.

A biodiversity offset program can fail for many reasons: biological, social, or political. While biological research is important, biodiversity offset programs necessarily operate in a larger socio-economic and political environment that is as, or more, complex than the ecological environment. More research is needed focusing on these two disciplines, particularly with respect to creating and maintaining the necessary conditions where an offset program has a reasonable probability of functioning. Such research would also help identify the enabling conditions needed for regulatory-driven and voluntary offset programs. Many offset programs fail not because of bad ecological accounting or metrics; rather, they fail because the program designers fail to sufficiently understand the local socio-economic conditions and governance structures, which allow for a successful program. Yet, these topics have been little studied in developed countries, let alone in developing ones (but see BBOP 2009 for a cost-benefit analysis of offsets).

New offset learning platforms should be research based, interdisciplinary, and centered on transparent pilot projects. Offset program design has largely focused on the needs and concerns of the provider (e.g., the stakeholder impacting biodiversity). However, unlike places with strong private property rights (e.g., Australia and United States), offset programs in low- and middle-income countries will likely be implemented in places where multiple local stakeholders have vague, but often valid, rights or connections to where the offset is taking place. In order to increase success, more focus should be placed on these types of users—local communities affected by offset projects. In some cases, these local communities can even be the offset providers (Donlan 2015; Gelcich and Donlan 2015). More importantly, pilot projects with an integrated scientific research agenda that is place based would promote adaptive learning and the exploration of institutional, social, and political constraints and opportunities.

Institutional capacity building, both technical and scientific, is needed in many countries in order to move from biodiversity offset pilot projects to an operational market (Bovarnick et al. 2010). Thus, capacity building should be a priority and integrated into regional learning platforms. This includes support for the design, implementation, monitoring, and institutionalization of offset programs. For example, many offset programs in OECD countries include financial requirements such as endowments to ensure the longevity of the biodiversity outcome (Carroll et al. 2008). The same issue needs to be addressed and solutions developed in non-OECD countries. In the end, it will be the institutional learning that will allow a biodiversity offset program to move beyond specific sites and be integrated into the larger economic developmental landscape.

Pilot offset projects should be designed to be adaptive and iterative, based on monitoring of experience, in order to maximize learning. This iterative process should not only include assessing ecological performance, but also social and governance performance. By centering research on pilot offset projects and broadening its focus to be more inclusive, including social and governance dynamics, these new learning platforms will be better positioned to support the design, implementation, and monitoring of biodiversity offset programs. Those programs are likely to have a higher probability of succeeding because they are (i) based on an understanding of stakeholders' needs and interests, (ii) iterative and adaptive in nature from ecological, social, and governance perspectives, and (iii) place based—designed for specific local ecological and socio-economic

conditions. If designed properly biodiversity offset learning platforms also set the stage for regionally based institutional learning and serve as a third-party between counterparties (e.g., government and developer), which could provide multiple safeguards (e.g., transparency, accountability, compliance), a role that is likely to be mandatory for programmatic success (Githiru et al. 2015). Given the growing interest of biodiversity offset programs in developing countries and the significant research gaps, scientific research needs to diversify significantly in order to support the design of successful programs and maximize the utility of offsets to contribute to effective biodiversity conservation.

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