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Mitigation for one & all: An integrated framework for mitigation of development impacts on biodiversity and ecosystem services

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ABSTRACT

Emerging development policies and lending standards call for consideration of ecosystem services when mitigating impacts from development, yet little guidance exists to inform this process. Here we propose a comprehensive framework for advancing both biodiversity and ecosystem service mitigation. We have clarified a means for choosing representative ecosystem service targets alongside biodiversity targets, identified servicesheds as a useful spatial unit for assessing ecosystem service avoidance, impact, and offset options, and discuss methods for consistent calculation of biodiversity and ecosystem service mitigation ratios. We emphasize the need to move away from area- and habitat-based assessment methods for both biodiversity and ecosystem services towards functional assessments at landscape or seascape scales. Such comprehensive assessments more accurately reflect cumulative impacts and variation in environmental quality, social needs and value preferences. The integrated framework builds on the experience of biodiversity mitigation while addressing the unique opportunities and challenges presented by ecosystem service mitigation. These advances contribute to growing potential for economic development planning and execution that will minimize impacts on nature and maximize human wellbeing.

1. Introduction

Governments, health organizations, aid agencies, and more recently, conservation organizations, have goals to improve the lives of people through development that also preserves the life support systems of the planet. Simultaneously achieving these goals is challenging and nearly all countries have approached this dilemma by creating legal and policy requirements for mitigating the environmental impacts of development (Morgan, 2012). Impact mitigation frameworks applied by many governments and lending institutions around the world are consistent in their strong support for the mitigation hierarchy, which involves first evaluating whether avoiding and minimizing these impacts are possible, and where not feasible or sufficient, offsetting or compensating for residual effects (Lawrence, 2003; McKenney and Kiesecker, 2010). The stakes for implementing strategic development goals are especially high: the rate at which energy, water, and infrastructure development projects are growing is accelerating with total investments expected to exceed $53 trillion between 2010 and 2030 (OECD, 2012).

To help inform impact mitigation, the scientific community has responded with decades of research establishing best practices for applying the mitigation hierarchy to biodiversity impacts (Race and Fonseca, 1996; Geneletti, 2002; Landis, 2003; BenDor et al., 2008; Canter and Ross, 2010; BBOP, 2012b). Despite these efforts, the approach has fallen short in practice for both biodiversity and the benefits it provides to society—ecosystem goods and services (collectively referred to as ecosystem services, or ES, for simplicity). Minimizing and offsetting impacts on biodiversity and ecosystem function have been the primary focus of mitigation historically, but such efforts can fail to avoid impacts on critical habitats (Clare et al., 2011), often do not account for cumulative impacts at a landscape scale (Canter and Ross, 2010; Kiesecker et al., 2010), inconsistently and inadequately account for ecological equivalency in losses and gains (Quétier and Lavorel, 2011) and seldom succeed in returning lost biodiversity and ecosystem function (Zedler and Kercher, 2005; Maron et al., 2012). These shortcomings largely stem from a historic approach to mitigation that is reactive, with actions focused at small spatial scales and on a project-by-project basis.

To address these shortcomings, biodiversity mitigation policies and programs are now moving away from site-based, piecemeal mitigation to a scale that can more comprehensively account for cumulative impacts of development within a region (Saenz et al., 2013a,

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2013b, Villarroya et al., 2014) and even at a national scale (Kormos et al., 2014). There is general consensus now among researchers and practitioners that biodiversity and ecosystem function mitigation should consider whole systems, anticipate impacts, and proactively recommend compensatory actions (Kiesecker et al., 2010; Hayes, 2014). This larger-scale approach is supported by researchers and practitioners and is expected to more accurately capture ecological dynamics, and allow for more strategic and proactive mitigation planning. Instead of simply requiring replacement of impacted resources in similar sites in close proximity to the impacts, compensatory mitigation can be steered to priority areas for both ecological and socio-economic investment, likely resulting in better outcomes (Wilkinson et al., 2009).

At the same time that improvements in biodiversity mitigation have been recognized and solutions put forth, there is growing recognition that ecosystem services have largely been forgotten (Brownlie et al., 2012; Bos et al., 2014). Ironically, many of the laws that establish mitigation requirements were designed to protect people from environmental degradation associated with development: in other words, to guard against ecosystem service loss (Villarroya et al., 2014). The language in these laws ranges from the general to the specific. For example, Australia's National Strategy for Ecologically Sustainable Development is designed to "enable development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends". In much more detail, the U.S. Clean Water Act §404 that establishes the foundation for wetland and stream mitigation states that "management programs shall conserve such [clean] waters for the protection and propagation of fish and aquatic life and wildlife, recreational purposes, and the withdrawal of such waters for public water supply, agricultural, industrial and other purposes".

In addition to these legal precedents, there is a growing demand for ecosystem service impact assessment and mitigation by international organizations and multi-lateral lending agencies. For example, the Organization for Economic Co-operation and Development (OECD) has developed guidance for addressing ecosystem services in Strategic Environmental Assessment (SEA) (OECD, 2008). Within the financial sector, the Performance Standards of the International Finance Corporation (IFC) now require that projects they finance adhere to the mitigation hierarchy for both biodiversity *and* ecosystem service impacts (IFC, 2012). Current implementation, however, does not meet the intent of these laws and new standards. For example, in the U.S., wetlands damaged by development in urban centers are being mitigated for in more rural areas with lower population densities. Even if these mitigation actions meet biodiversity mitigation needs, they will still fail to return wetland-related ecosystem service benefits to the people who have lost them (BenDor et al., 2008).

2. An integrated framework for biodiversity and ecosystem service mitigation

Although suggestions have been made for how to include biodiversity or ecosystem services separately for specific kinds of assessments (e.g., SEAs, Geneletti, 2011) and in specific contexts (e.g., Kiesecker et al., 2010; Tallis and Wolny, 2010), a systematic and unified approach for integrating services with biodiversity into the mitigation hierarchy is lacking. To address this gap, we build on previous work to propose an integrated framework that allows regulators to determine potential, cumulative impacts on biodiversity and ecosystem services (BES) at a landscape, watershed, or seascape scale and to assess the compatibility of development with environmental and social goals. Our recommendations stem from decades of research on best practices for mitigating development impacts on biodiversity in terrestrial landscapes, which are relevant for and can be tailored to freshwater and marine systems (Bos et al., 2014). The framework addresses development siting, impact estimation and offset assessment, which are all iterative steps in an adaptive assessment and mitigation process (Fig. 1).

Clearly this integrated treatment of BES in mitigation is challenging given that BES are unique, non-interchangeable, and determined by related, but often different environmental factors. As such, there are few places in the mitigation hierarchy where the same data, analytical processes, and activities can be applied consistently for both components. Here we review the current state of the art for biodiversity mitigation and compare and contrast biodiversity approaches with the conceptual challenges of ecosystem service mitigation. We discuss each step of the mitigation hierarchy in detail below, highlighting potential BES synergies and outstanding research needs with the goal of advancing integrated best practices for impact mitigation that more holistically account for people and nature.

2.1. Siting

In the first phase, development options (both individual and suites of projects) would best be placed within a landscape or seascape context to guide their appropriate siting. Targets are selected, the spatial extent is determined, and conservation plans (Fig. 1A) can be used to capture potential cumulative impacts and guide the selection and avoidance of development sites.

2.1.1. Selection of targets

Although a comprehensive consideration of BES would be ideal (Geneletti, 2011; IFC, 2012), data and resource limitations will ultimately restrict the number of species, habitats, and ES that can be considered in impact mitigation assessments. Despite such constraints, it is important to recognize that biodiversity and ES are not interchangeable, either across their own respective elements or across groups. A woodpecker is not the same ecologically or in terms of social value as a leopard, and water for irrigation is not the same as crop pollination. Beyond this obvious statement of uniqueness, BES often exhibit different spatial and temporal patterns, and so should not be considered as consistent surrogates for each other (e.g. Egoh et al., 2008; Naidoo et al., 2008; Cardinale et al., 2012). Given the hundreds to thousands of options for targets to use in a BES impact assessment, and the fact that the choice of targets greatly determines the outcomes of mitigation (Eiswerth and Haney, 2001), a systematic selection procedure is needed to ensure that the subset of BES targets chosen is as representative as possible.

Biodiversity targets should be selected based on their ability to approximate the complete biological diversity of a region or site and to indicate key changes in ecological conditions due to predicted local or landscape-scale changes including development impacts and climate change. Common approaches for selecting adequately representative biodiversity targets have been reviewed and discussed extensively (Margules and Pressey, 2000; Poiani et al., 2000; Groves et al., 2002; Kiesecker et al., 2009) (Fig. 2a). In practice, mitigation tends to focus on sites and species with protected status (e.g. nature reserves, Sites of Special Scientific Interest, IUCN Red List taxa), on economically important game species or charismatic species, or on at-risk habitats and species (e.g., rare, threatened, or endemic species). Greater adherence to existing recommendations, such as a focus on multiple 'umbrella species' that span different development threat categories (Roberge and Angelstam, 2004), will better capture the full suite of biodiversity impacts in the development region (Geneletti, 2002; Gontier et al., 2006).

As with biodiversity, we face a major challenge in effectively representing the diverse set of ES provided in any given area. Provisioning services, such as food production, water supply and timber production, are over-represented in research and data collection (Millennium Ecosystem Assessment, 2005; Russell et al., 2013). The selection of representative targets in the ES realm can be achieved in part by considering a suite of services that fall under the broad categories of provisioning, regulating, and cultural services as defined by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005; Fig. 2b). Not all ES will be relevant in all development contexts, but consideration of all categories will help to ensure