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Of sets of offsets: Cumulative impacts and strategies for compensatory restoration

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ABSTRACT

Biodiversity offsets are increasingly advocated as a flexible approach to managing the ecological costs of economic development. Arguably, however, this remains an area where policy-making has run ahead of science. A growing number of studies identify limitations of offsets in achieving ecologically sustainable outcomes, pointing to ethical and implementation issues that may undermine their effectiveness. We develop a novel system dynamic modelling framework to analyze the no net loss objective of development and biodiversity offsets. The modelling framework considers a marine-based example, where resource abundance depends on a habitat that is affected by a sequence of development projects, and biodiversity offsets are understood as habitat restoration actions. The model is used to explore the implications of four alternative offset management strategies for a regulator, which differ in how net loss is measured, and whether and how the cumulative impacts of development are considered. Our results confirm that, when it comes to offsets as a conservation tool, the devil lies in the details. Approaches to determining the magnitude of offsets required, as well as their timing and allocation among multiple developers, can result in potentially complex and undesired sets of economic incentives, with direct impacts on the ability to meet the overall objective of ecologically sustainable development. The approach and insights are of direct interest to conservation policy design in a broad range of marine and coastal contexts.

1. Introduction

Biodiversity offsets are increasingly considered as an option to compensate for the ecological costs of development, with 72 countries identified as having some form of legislative requirement for compensatory biodiversity restoration either already in place or under development (Madsen et al., 2011). The growing popularity of voluntary offsets is also noted, with the use of offsets expected to increase in the future (Maron et al., 2012). Biodiversity offsets refer to actions taken at an offset site intended to compensate for a loss of biodiversity at an impact site. They may include a wide range of interventions, at species, community or whole-of-ecosystem levels, which can be carried out as part of voluntary or mandatory regimes, with the aim to compensate for on-going and anticipated ecological loss. While often vaguely defined, the objective of "no net loss" (Gordon et al., 2011; Gardner et al., 2013) is central to offsets and increasingly offset policies require demonstration of the equivalence between what is created and what is lost.

Despite their increasing popularity as a flexible approach to the reconciliation of economic development with biodiversity conservation, a number of studies have pointed to the potential limitations of offsets in achieving ecologically sustainable outcomes (Morris et al., 2006; Maron et al., 2012). In particular, studies have demonstrated that the no net loss objective may only be achieved with high offsets ratios (i.e. where more ecological assets are protected or created than are lost) if at all, and with intensive monitoring efforts, even in cases that would normally be considered ideal for

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implementation of an offset strategy based on biology and habitat characteristics (Pickett et al., 2013). Where such characteristics are not present, there is a risk that the offsets may not provide services equivalent to those that were lost. In such cases, the development of markets in which offsets are traded may in fact increase, rather than decrease, environmental degradation, as Palmer and Filoso (2009) discuss in the context of aquatic ecosystems.

In a recently published review of offset-focused biodiversity restoration programmes, Maron et al. (2012) identify a number of potential limitations to offsets, which include time lags in the recovery of ecological systems. Indeed, understanding of key ecological, as well as social responses, will be crucial in determining circumstances under which offsets may be (in) effective as biodiversity conservation tools. First, ecological responses to the implementation of an offset, and in particular delays and threshold effects, will determine when, if ever, a set of impacted services is recovered. Second, societal responses to perceived (vs. actual) changes in the availability of ecological services may influence acceptability of an offset action. Third, although difficult to predict (Mitchell and Parkins, 2011), lags in societal response to losses of ecosystem services may in turn affect the potential effectiveness of offsets. These lags may arise from a lack of understanding of ecological systems, poor measurement of system properties or natural inertia in the social processes that determine collective action.

Here, we explore several conceptual issues relating to the effectiveness of alternative biodiversity offsetting approaches, using a marine system as an example. Where offset policies apply equally to coastal and marine systems as to terrestrial, as is the case for Australia's Commonwealth Government's offset policy (Department of Sustainability, 2012), experience with their use in the marine context is generally less well developed. We propose a modelling framework to assess stylized offset management strategies under alternative scenarios relating to (i) ecological response to the implementation of multiple developments and offset actions – or sets of offsets, in particular the time delays involved in ecological recovery, and (ii) societal response to the damages caused by development, which determines the objectives for compensatory restoration actions. In particular, we consider circumstances in which actual losses of ecosystem services do not directly translate into a policy requirement for restoration. This may be due, first, to a lack of awareness of the loss of service, because actual losses are difficult to detect, at least until they become relatively large. In addition, even if losses are detectable, it may still be difficult to evaluate their full extent (due for example to lack of historical knowledge of the ecosystem or to lack of previous analogous changes). Second, people may be willing to accept low levels of losses in ecosystem services, such that actual losses, although detected, are not perceived as being problematic, or that the expected benefits of imposing constraints on development are not seen to outweigh the costs of doing so, including in particular the coordination costs of collective action.

Our management strategies capture differences in the way in which the "no net loss" objective is interpreted, including restoration scaling approaches that rely on habitat-to-habitat modelling, and value-to-value methods that explicitly account for the value to society of ecosystem changes. While the former approaches are the most commonly encountered interpretations of the "no net loss" objective, it can be argued that offsets should be determined in relation to the value of lost ecosystem services, such that the objectives of a biodiversity offset policy should be defined in terms of "no net value loss".

The management strategies considered in this analysis also capture contexts in which developments are assessed and approved, and offsets determined, on a project-by-project basis despite being components of a regionally-based strategic approach. Consistent with the conservation biology literature on this topic, the analysis focuses on the case of so-called "direct offsets" involving the provision of either averted ecological losses or restoration gains at least equivalent to the ecological impacts of a particular development in a given region (see model description below), rather than offsets involving actions with indirect outcomes such as financial compensation (Maron et al., 2012).

The modelling framework we propose is built to reflect a marine-based example, where the abundance and hence utility of a biological resource depends on a habitat that is affected by development or exploitation. This is representative of many marine situations involving fish and shellfish species of commercial interest, and their dependence on, for example, seagrass (Anderson, 1989), mangrove (Barbier et al., 2002) and coastal marshes (Lynne et al., 1981), coral reefs (Foley et al., 2010), freshwater bodies (Knowler et al., 2003) or seafloor habitat (Lindholm et al., 2001). The model captures four main processes spanning both the physical and human components of the system within which offsetting occurs: (i) a biological resource which provides a range of ecosystem services, (ii) a habitat which supports the biological resource and is negatively impacted by economic development, (iii) a regulator which assesses the level of restoration required for a development proposal to be approved and (iv) a social process which determines the permitted extent of ecosystem service loss over a given time horizon.

The model is stylized in that:

- it employs simple logistic equations to describe the dynamics of a single, homogeneous, non-spatially resolved biological resource and its habitat;
- simple equations are used to describe the generation of utility associated with the ecosystem services supported by the resource;
- the level of offsets is limited only by the areal extent of the habitat;
- it is assumed that all important quantities can be accurately and objectively measured; and
- there is no uncertainty in the development impacts and ecological responses to offsets (although the occurrence of lags in detecting and acting upon losses of ecosystem service and in implementing offsets is explicitly represented).

Although stylized, the model allows exploration of key issues which may arise from the cumulative impacts of approved developments under alternative offset management strategies.

2. The model

A conceptual diagram of the model is presented below, and a full description of the model is provided in the appendix. We consider a biological resource, the biomass X of which is a function F of habitat H availability. This biological resource provides a number of ecosystem services, which may include provisioning services (e.g. commercial or subsistence fishing, extraction of molecules with medicinal properties), cultural services (e.g. recreational fishing or diving, aesthetic services), as well as supporting and regulating services (Millennium Ecosystem Assessment, 2005). We consider the case of an extractive use, such as commercial fishing with a fixed level of harvesting effort yielding harvest h a function of harvestable biomass. The resource biomass thus evolves according to:

$$X_{t+1} = X_t + F(X_t, H_t) - h(X_t) \quad (1)$$

where t is time. The harvest generated by the fishery produces social welfare which we define as the utility U_t derived from this provisioning service. We assume that this can be measured in monetary terms. Given that harvest is fixed, U_t is directly proportional to the resource biomass X_t (Fig. 1).