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Human impacts and ecosystem services: Insufficient research for trade-off evaluation

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ABSTRACT

In order to perform a science-based evaluation of ecosystem service tradeoffs, research is needed on the impacts to ecosystem services from multiple human activities and their associated stressors ('impact-pathways'). Whereas research frameworks and models abound, the evidence-base detailing these pathways for trade-off evaluation has not been well characterized. Toward this end, we review the evidence for impact-pathways using estuaries as a case study, focusing on seagrass and shellfish. Keyword searches of peer-reviewed literature revealed 2379 studies for a broad suite of impact-pathways, but closer inspection demonstrated that the vast majority of these made connections only rhetorically, and only 4.6% (based on a subset of 250 studies) actually evaluated impacts of stressors on ecosystem services. Furthermore, none of the reviewed studies tested pathways based on metrics of ecosystem services value that are most relevant to beneficiaries. Multi-activity tradeoff evaluation and management will require a concerted effort to structure ecosystem-based research around impact-pathways.

Contents

1. Introduction

Despite the importance of coastal ecosystems and the benefits these ecosystems provide to people (i.e., ecosystem services; Daily, 1997; Millennium Ecosystem Assessment, 2005), degradation and loss of ecosystems at the land-sea interface is intense and increasing worldwide (Fig. 1; Halpern et al., 2008; Worm et al., 2006). Coastal ecosystems are faced with multiple and interacting drivers of environmental change, which contribute to loss of ecosystem services, such as reduction in viable fisheries, declining water quality, and decreased coastal protection from flooding and

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Fig. 1. Anthropogenic activities abound in coastal estuaries. South of Prince Rupert, British Columbia log booms, coal and grain terminals, historic pulp mill and coastal infrastructure for rail and roads produce overlapping environmental stressors.

storm events (Carpenter et al., 1998; Hoffman et al., 1984; Salomon et al., 2010; Valiela et al., 2001). The recognition of such interacting drivers across sectors of the economy and components of ecosystems has led to increasing support for ecosystem-based, local management (Granek et al., 2010; Levin and Lubchenco, 2008; McLeod et al., 2005; Ruttenberg and Granek, 2011). This type of management integrates ecological productivity with human well-being across multiple sectors and whole ecosystems, while considering the cumulative impacts of many human activities on the production of ecosystem services (Bennett et al., 2009; McLeod et al., 2005; McLeod and Leslie, 2009). Given its place-based focus on ecological interactions, ecosystem-based management offers an unprecedented opportunity to incorporate ecological research into local or regional decision-making without forgoing human well-being.

While ecosystem management is moving forward in many places, its use varies according to the availability of data and strength of governance (Leslie and Mcleod, 2007; Tallis et al., 2010). To actually do informed ecosystem management, managers may need to curtail or restrain some activities based on their negative impacts or risks for ecosystem service providers (species that provide specific ecosystem services) and the resulting losses of ecosystem service supply and provision (Granek et al., 2010; Tallis et al., 2012; Tallis et al., 2010). Researchers agree that there is sufficient scientific understanding of ecosystem services and their value to begin integrated multi-species ecosystem-based management (Gregr and Chan, 2011; Lester et al., 2010; Price et al., 2009). However, this sufficiency stems from the *adaptive* nature of ecosystem-based management, which implies that management can begin in the absence of information, and be structured to gain the needed understanding through time (Walters, 1986). It is an open question whether there is sufficient scientific understanding to actively *inform* tradeoff evaluation (Leslie and Mcleod, 2007).

While tools to depict such ecosystem-service tradeoffs (Kareiva et al., 2011; Lester et al., 2013; Nelson et al., 2009) and frameworks for characterizing how human activities impact ecosystems and ecosystem-service provisioning ("impact-pathways", described in Fig. 3) (e.g., Knights et al., 2013; Rounsevell et al., 2010) are available, we know of no comprehensive review of whether we have the scientific understanding to populate these across multiple ecosystem services and anthropogenic activities—the understanding of how each of many activities impacts ecosystem services. A piecemeal approach to understanding these impact-pathways is not necessarily sufficient. That is, having some knowledge of a *stressor*'s effect on an ecosystem service *provider*, and some knowledge of a *provider*'s contribution to a *service*, does not necessarily mean having useful knowledge of the effect of a *stressor* on a *service*. For example, there is scientific evidence that shading impacts seagrass beds, and that seagrass is an important provider of numerous services; but it doesn't necessarily follow that the characteristics of seagrass that are affected by shading (e.g., condition, but not density) are those that matter for services (Fig. 2a). Similarly, urban development releases waste-water to estuarine ecosystems, and this results in increased nutrient levels and pathogens, which negatively impact some service providers; but these same pressures may be beneficial to other service providers (Fig. 2b; Hershner and Havens, 2008).

The many published papers detailing ecosystem-service tradeoffs (e.g., Chan et al., 2006, 2011; White et al., 2012) might suggest that there is sufficient science to populate models of multiple impact-pathways in multiple locations. However, these analyses are often done in data-rich places on services and impacts

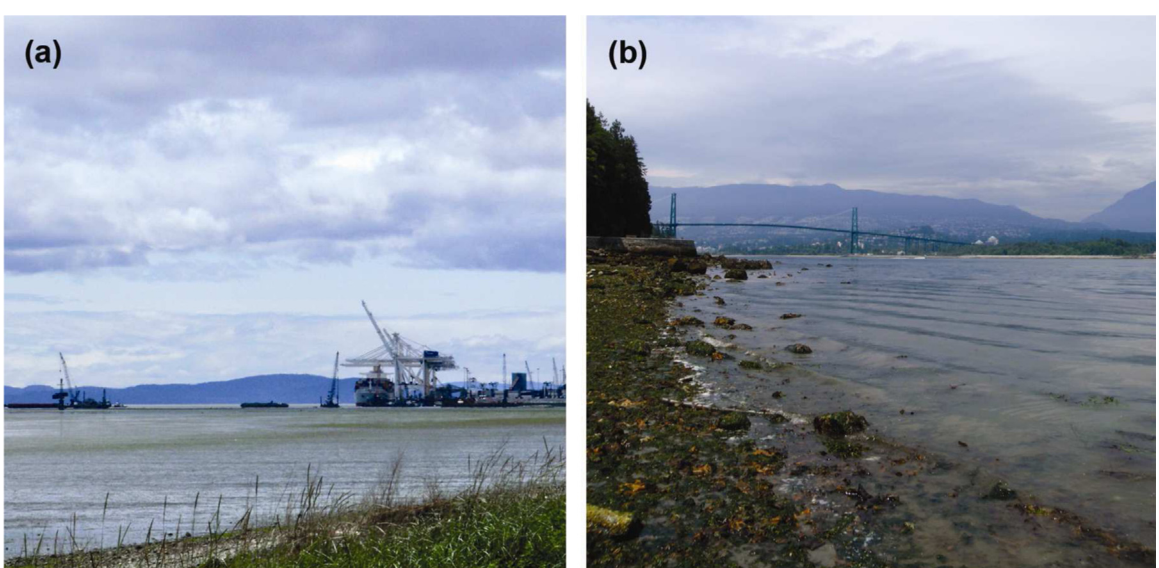

Fig. 2. Coastal activities impact eelgrass beds by producing stressors. Some examples of these stressors include: (a) shading and dredging near shipping terminals (Delta Port, Tsawwassen, British Columbia) and (b) waste water outfall and human trampling in urban areas (Vancouver Harbor, British Columbia).