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Economic valuation of coral reef ecosystem service of coastal protection: A pragmatic approach

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ABSTRACT

The identification and economic valuation of ecosystem services (ES) are becoming important components of coral reef management. In many contexts, protection of human assets against coastal floods is one of the most important ES provided by coral reefs. The methods utilized to characterize this ES should be able to accommodate situations with low data availability, without sacrificing robustness. In this paper, we suggest such an approach that utilizes expert opinion and does not require copious amounts of data. Our primary objective is to find a balance between simple and complex models that can be used in a data scarce environment, to produce an economic valuation of the coral reef ES of protection against coastal floods. The approach has three steps: (i) identify geographic zones and assets at risk, (ii) identify the contributing role of coral reefs in the protection of coasts and, (iii) value the annual repair costs of assets through the avoided damage cost approach. The proposed method seems appropriate for advocacy with policy makers, but appears to be less effective for small scale approaches, such as those required for Payment for ES negotiations or marine spatial planning.

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1. Introduction

Economic valuations of coral reef ecosystem services (ES) have been undertaken to address several objectives, such as raising environmental awareness among decision-makers and the public, evaluating the costs and benefits gained from different levels of investment in coastal management, incorporating present and future values of both negative and positive impacts via a common metric and fine tuning economic instruments (Burke et al., 2008; Laurans et al., 2013). In addition, valuations can form part of monitoring routines which utilize quantitative indicators to inform management ("we manage better what we can measure") (Beukering et al., 2007; David et al., 2007; Pascal et al., 2012) and used in the implementation of tools such as 'Payment for ES' (PES) (Huwyler et al., 2014). To date, the most common use of economic valuations of marine ES has been for advocacy with policy makers (Waite et al., 2014). In these studies, the priority has been to transmit accurate information on the value of a large range of ES and their beneficiaries, without striving for the highest level of confidence ("science to inform policy"). For other studies, such as those focusing on monitoring or the design of a PES, the level of precision required is much higher (Sale et al., 2014).

Recent work on the economic valuation of coral reef ES shows that it is important to concentrate valuation efforts on three main ES, which under the Millennium Ecosystem Assessment's classification (MEA, 2003) fall under the headings of provisioning, cultural and regulating (Hilmi et al., 2014; Laurans et al., 2013). The first two ES (provisioning and cultural) refer to respectively: (i) fish biomass production; coral reef associated fisheries provide an important source of protein and a basis for livelihoods and (ii) scenic beauty for recreational tourism; coastal recreation and tourism activities generate significant economic value depending on the quality and availability of specific marine ecosystem attributes. This article will focus on coastal protection provided by coral reefs, which falls under the third heading of regulating services.

Coral reefs form barriers which buffer coastal zones from severe weather events and in so doing, protect human lives, coastal properties and economic activities (Barbier et al., 2011). Several

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studies show that reefs reduce ocean swells, which results in wave transformations and rapid attenuation of wave energy (Brander et al., 2004; Kench and Brander, 2009; Lugo-Fernandez et al., 1998). The fringing reef can absorb a large part of this force (Brander et al., 2004; Roberts et al., 1992) up to 90% at low tide (Lugo-Fernandez et al., 1998). Given the expected increase of extreme climatic event occurrences, as well as sea level rise due to climate change (IPCC, 2013), it becomes increasingly important to better understand, communicate and manage this ecosystem service of coral reefs.

Another service related to coastal protection, is the contribution of reefs to the regulation of erosion and sedimentation, which are critical to maintaining beaches and coastlines. Coastlines where coral reefs are located receive coral or algal derived sediments from this ecosystem via various hydrodynamic processes (waves, currents, tides). Accumulation on the coastline of those sediments (sedimentation) is the source of beach formation (Huang et al., 2007).

The ES of coastal protection is therefore relevant both for the protection of human lives and economic activities associated with beaches. Economic valuation of shoreline protection provided by coral reefs is a useful tool in highlighting the importance of this service to decision-makers (Sale et al., 2014).

Characterization (with or without economic valuation) of the coastal protection ES however is extremely challenging, especially in a data scarce environment. Over 64% of coral reef ecosystems lay in developing countries (Bryant et al., 2011) which are often characterised by high population densities in the nearshore and limited government resources for coastal management. The development of ES valuation methodologies adapted to these contexts is a requirement if the full potential of ES valuations is to be realized.

Many factors contribute to make the valuation of coastal protection ES complex. The typology of the reef, its depth and the type of wave that impact it, result in great variability in the assessment of coastal protection (Kench and Brander, 2009). In addition, the role of coral reefs in coastal protection is mixed with other factors which drive the process, such as: bathymetry, currents, geomorphology, and biological cover (Burke, 2004). Some of these factors (e.g. biotic components such as live coral coverage) require complex methods and add another layer of difficulty (Barbier et al., 2008; Cooper et al., 2009; Ferrario et al., 2014; Gourlay and Colleter, 2005; Van Zanten et al., 2014; Yee et al., 2014) This might explain why, to our knowledge, relatively few economic valuation studies (Laurans et al., 2013; Van Zanten et al., 2014) have focused on isolating the role that reefs play in coastal protection. However, taking into consideration the importance of their role for advocacy for policy makers, it is important to improve these valuations, in order to transmit the most accurate values of this ES.

The aim of this article is to propose a relatively easy methodology that will allow for an assessment of the value of coastal protection provided by coral reefs, within a data scarce environment. The methodology has been designed primarily for policy advocacy.

We will discuss if improved characterization of the ES (with or without valuation) can contribute to better management of the coastal ecosystems, as well as being the initial step of a payment scheme with beneficiaries of the ES as suggested by Engel et al. (2008).

2. Material and methods

To fulfill the objective of this paper, five studies were used to illustrate the valuation of coastal protection provided by coral reefs (Table 1). Chosen study areas have many similarities: (i) insular

Table 1
Main characteristics of case studies – ADC stands for Avoided Damage Costs method and RC stands for Replacement Cost method.

Ocean/Regional Seas	Country/Island or specific area Island or specific area	Objectives of the study	Scale of the study	Valuing method	Method particularities	Sources
North West Pacific Ocean/Philippines Sea	Northern Mariana/Is. Saipan	Valuation of total value of ecosystem services provided by coral reefs	Island	ADC	Comparison of damages inflicted by marine flooding based on a reference situation (current geomorphology of reefs) and an hypothetic one (absence of reefs).	Beukering et al. (2006)
North West Pacific Ocean/Philippines Sea	Philippines/Marine Bohol Triangle	Economic valuation of ecosystem services provided by four marine ecosystems (coral reefs, mangroves, beaches or intertidal areas, and marine waters)	Specific area	RC	Only mangroves are considered as acting for coastal protection (the role of reefs is not accounted)	Samonte-Tan et al. (2007)
North West Atlantic Ocean/South East Caribbean Sea	Trinidad&Tobago, Belize, St. Lucia	Economic valuation of coral reefs in the area	Island	ADC	Use of Coastal Protection Index	Burke et al. (2008), Cooper et al. (2009)
South West Pacific Ocean	New-Caledonia	Economic valuation of ecosystem services of coral reefs at the scale of the area	Island	ADC	Method applied in a low-data context	Pascal (2010)
North West Atlantic Ocean/North East Caribbean Sea	Virgin Islands/Saint-Croix	Comparison of existing methods for quantifying shoreline protection at island scale	Island	N/A	Measurement of relative contribution of different habitat types to wave energy attenuation. Use of biophysical features of the reef for characterization of the coastal protection	Van Zanten et al. (2014); Yee et al. (2014)

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