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Beyond carbon: Conceptualizing payments for ecosystem services in blue forests on carbon and other marine and coastal ecosystem services

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ABSTRACT

Marine and coastal ecosystems are increasingly being degraded or destroyed even as human dependence on their ecosystem services is increasing. New conservation tools are continually being developed, but successful implementation is constrained by lack of adequate funding. Recent reports on the potential ability of "blue forest" coastal ecosystems to sequester significant amounts of carbon is pointing the marine conservation community toward carbon credit as a potential management as well as financing tool. Marine and coastal ecosystems provide a multitude of ecosystem services beyond carbon sequestration, such as coastal protection, fish nursery, water purification, and marine biodiversity. The opportunity exists to develop payments for these ecosystem services and capture their as yet uncaptured value to finance their protection. This paper explores the use of payment for ecosystem services (PES) in marine and coastal settings and focuses on those services found in "blue forests". The challenges and necessary considerations for developing coastal and marine PES are discussed and the conceptual framework for developing payment schemes for five characteristic ecosystem services in blue forests are presented.

1. Introduction

Marine and coastal environments are increasingly being degraded and losing their ability to provide the fundamental services upon which human wellbeing depends. Fishery catches continue to decrease, despite increasing efforts, and are switching to lower value species; coastal and marine pollution has led to large-scale hypoxia events and harmful algal blooms; coastal habitats are losing biodiversity and other basic functions as they are being converted and degraded; to name a few examples of declining services (Rashid et al., 2005; Worm et al., 2006, 2009; Laura et al., 2008). The loss of these basic coastal and marine ecosystem services will only be further exacerbated by climate change impacts. Various marine and coastal resource management tools in which the ecosystem services framework can be applied include integrated coastal zone management, ecosystem-based management, community-based coastal management, marine protected areas, marine spatial planning, and ocean zoning (Agardy, 2010; Granek et al., 2009; Pomeroy and Carlos, 1997; Post and Lundin, 1996). This bag of tools continues to expand as lessons and models from terrestrial conservation, such as various incentive-based mechanisms, are being adapted for marine and coastal conservation. Payment for ecosystem services (PES), in particular, has received much attention as one of the potential cross-over tools.

The success of management strategies depends on many factors, but a common and frequent barrier to achieving full effectiveness and wider adoption of these tools is the lack of adequate financing [e.g., (Emerton and Tessema, 2001; Milnea and Christie, 2005)]. For example, establishing a global network of marine protected areas with 20–30% coverage alone is estimated to cost US $5–19 billion annually (in year 2000 dollars) – about two orders of magnitude higher than current funding for marine conservation (Balmford et al., 2004). Although a two order-of-magnitude increase in conservation funding seems unattainable, the return on investment from increased fishery catches, job growth, protection of coastal infrastructure, and continued and improved provisioning of other ecosystem services are estimated to exceed the investment (Balmford et al., 2004). The key is translating these theoretical values to real financing that can become innovative sources to sustainably finance marine and coastal conservation.

Recent reports have highlighted the potential of coastal "blue forests", such as mangroves, sea grasses, kelp, and salt marshes, to capture and store as much, or more, carbon than tropical forests (Laffoley Dd' and Grimsditch, 2009; World Bank, 2010; Nellemann

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et al., 2009; and articles in this special issue). Accordingly, the marine conservation community has begun to investigate whether "blue" carbon (carbon sequestered in marine and coastal environments) and blue carbon credits/offsets can be part of the management strategy for these habitats and generate the necessary financing for their conservation (Murray et al., 2010 and other papers in this special issue). While payment for blue carbon sequestration may represent one mechanism to capture part of the value of coastal ecosystem services and help finance their protection, coastal environments simultaneously provide a multitude of different ecosystem services, in addition to carbon sequestration. The issue is whether analogous mechanisms can be developed to finance the protection of these other services.

There can be as many types of PES as there are conservation needs, conservation goals, and stakeholders involved. Few examples exist in the marine and coastal context, and more experience is required to understand how PES may apply in coastal and marine environments. Following the focus of this special issue, this paper explores the ecosystem services found in blue forest habitats with the potential to generate payments beyond one-off contributions, including blue carbon payments, as potential innovative sources of funding for implementation of coastal and marine management and conservation plans. This paper will introduce marine and coastal ecosystem services and their value, provide definitions of PES, analyze the applicability of PES design elements in coastal and marine settings, and propose a framework for developing PES in coastal blue forest ecosystems. The objective is to facilitate more testing of marine PES to generate the experiences necessary for identifying the contexts and scenarios for which PES may be an effective policy and financing tool for marine conservation.

2. Value of marine and coastal ecosystem services

2.1. Marine and coastal ecosystem services

Ecosystem services are the benefits that people derive from the environment, whether they be tangible goods or intangible functions. The Millennium Ecosystem Assessment (MEA) reports were the first large-scale syntheses that highlighted the importance of marine and coastal ecosystem services for human wellbeing (Rashid et al., 2005). Marine and coastal ecosystems are highly productive areas and their services support disproportionately the world's populations, with nearly 40% (as of 2005, likely higher today) living within coastal areas (within 100 km from the ocean), which cover only about 5% of earth's landmass, and inland populations also deriving benefits from oceans and coasts (Rashid et al., 2005).

The MEA divided ecosystem services into four broad categories: 1) provisioning, 2) regulating, 3) supporting, 4) and cultural (Table 1). Provisioning services are familiar to most people as they represent the goods – such as fish and other seafood, minerals, and energy – that are extracted from the environment. Regulating services include carbon sequestration, weather regulation, and coastal protection from storms and hurricanes. Supporting services are the foundational functions such as photosynthesis, nutrient cycling, and basic soil, sediment and sand formation. Cultural services represent the spiritual, educational, and recreational enjoyment derived from the marine and coastal environment. While many of the services are non-extractive, non-market goods, they underpin our economies and support our wellbeing.

2.2. Multiple benefits and linkages

Although ecosystem services can be categorized into the four distinct types, in practice these services are inter-connected, and any one coastal and marine habitat or ecosystem will provide a whole suite of ecosystem services that may be tightly linked just as the particular ecosystem itself may also be tightly coupled to adjacent ecosystems. This is particularly true of coastal blue forest habitats.

Table 1
Examples of Marine and Coastal Ecosystem Services. [Adapted from 1].

Ecosystem service Category	Examples
1. Provisioning	Food (e.g., fisheries and aquaculture) Fuel (e.g., mangrove wood and offshore oil and gas) Alternative energy (e.g., offshore wind and wave energy) Natural products (e.g., sand, pearls, diatomaceous earth) Genetic and pharmaceutical products Space for ports and shipping
2. Regulating	Weather regulation Carbon sequestration Shoreline stabilization Natural hazard protection (e.g., from storms, hurricanes, and floods) Nutrient regulation Waste processing
3. Supporting	Soil, sediment, and sand formation Photosynthesis Nutrient cycling
4. Cultural	Tourism Recreation Spiritual values Education Aesthetics

Mangroves, for example, can sequester carbon in both above and below ground plant biomass and through sediment accretion (Nellemann et al., 2009; Bouillon and Kairo, this issue), protect villages from cyclones (Saudamini and Vincent, 2009), increase fishery catches (Aburto-Oropeza et al., 2008), and enhance fish biomass and diversity by serving as nursery habitats (Mumby et al., 2004), among other functions. Seagrass beds, similarly, sequester carbon, cycle nutrients, support fishery yields, reduce turbidity, and provide coastal protection functions (Waycott et al., 2009). Moreover, the productivity of mangrove and coral reef ecosystems are also mutually enhanced by salt marshes as fish move among the different habitats for food and refuge and during different life stages (Mumby et al., 2004; Saintilan et al., 2007). While each of these ecosystem functions may be quantified individually, their production is tightly linked. The ability of each habitat to provide services is also interdependent on the health of connected systems whether they are marine, coastal, freshwater or terrestrial (Rashid et al., 2005). This linkage implies that any impacts, whether positive or negative, on one ecosystem service or habitat could have cascading impacts on the other ecosystem services and habitats.

2.3. Valuation of marine and coastal ecosystem services

The ecosystem services concept has provided the needed shift for how we frame conservation and allows for development of mechanisms to capture the non-market value that ecosystems provide to human wellbeing. By classifying marine and coastal ecosystem services into the different service types, the tool exists now for estimating values for services other than extractive ones, like fisheries.

Marine and coastal ecosystems and their services, both market and non-market, are extremely valuable. For example, the world's coral reefs are estimated to provide US$29.8 billion (net present value in 2003) annually in total net benefits (Cesar et al., 2003). Of this, tourism and recreation contribute 32%; coastal protection, 30%; and fisheries and biodiversity each contribute 19%. When compared, the non-market worth of coastal protection and biodiversity are similar to those services (tourism, recreation, and fisheries) that currently generate market value. The wetlands of Muthurajawela Marsh, Sri Lanka, yield even higher shares in non-market values – flood attenuation accounted for 67% and industrial wastewater treatment, 22% of the total (direct and indirect) economic benefits (Rs 726.49 million/year) while firewood, fishing and tourism and recreation contributed 1% or less (Emerton and Kekulandala, 2003). The World Resources Institute's Reefs-at-Risk Program estimated that in Belize the shoreline protection value of coral reefs and mangroves, even in their current degraded state, amount to US$ 120–180 million and US$ 111–167 million, respectively, in avoided damages (in 2007 dollars) (Cooper et al., 2009). As a point of reference, these values are equivalent to approximately 9–14% of Belize's Gross Domestic Product (GDP), but as they are non-market values, they are not actually reflected in the GDP. In Mexico, mangrove fringe and associated habitats in the Gulf of California are estimated to generate US $37,500 per hectare annually in fisheries production, an amount greater than all previous estimates for all services combined in mangroves, suggesting that the values of mangroves worldwide are likely to be much higher than previously thought (Aburto-Oropeza et al., 2008). Recent estimates of potential blue carbon payments indicate that they may be sufficient to offset the private income generated from mangrove conversion to shrimp farms in Thailand (Murray et al., 2010).

The values listed here are just examples of the benefits coastal and marine ecosystems and their services are providing to society. Comprehensive inventories and syntheses of coastal and marine valuation studies and initiatives continue to emerge, such as The Economics of Ecosystems and Biodiversity (TEEB) study and reports[1]; Marine Ecosystem services Partnership[2]; and the global compilation for coral reefs, mangroves and seagrasses sponsored by the International Coral Reef Initiative (Conservation International, 2008). It is important to note that some services, e.g., fisheries, will be easier to estimate while others, e.g., biodiversity, may be more difficult to estimate due to limitations of valuation methods and the complex nature of such ecosystem functions and the interdependence of the services.

Policy and economic decisions have been undervaluing (often with a value of zero) what intact nature is worth. Economic valuation of ecosystem services allows for the analysis of tradeoffs between development and habitat conservation from a policy standpoint, and the "return on investment" that nature conservation provides from an economic and business standpoint, in order to effect better decision-making about resource management.

3. Payment for marine and coastal ecosystem services

3.1. Definitions of payment for ecosystem services

New policy tools and management mechanisms have emerged to correct for undervaluation and market failures, to capture ecosystem service values, and to help maintain ecosystem service flows and delivery. Payment for ecosystem services is an emerging resource management tool that provides incentives for behavioral changes to increase the provision of ecosystem services, e.g., by discouraging overharvesting of resources or destruction and degradation of habitat. It represents one way to capture some of the non-market values discussed above.

Several definitions for PES have been proposed in the literature. The earliest one proposed by Wunder (2005) characterized PES through the lens of a market-type transaction: "a *voluntary* transaction where a well-defined *environmental service*, (or land use likely to secure that service), is 'bought' by a (minimum one) *service buyer* from a (minimum one) *service provider* if and only if the service provider secures service provision (*conditionality*[3])" (Wunder, 2005). Because of the market and quasi-market criteria, this definition is somewhat restrictive as an operational framework for developing PES schemes. Few actual PES cases have met these criteria since the definition's scope – voluntary buyer and seller with conditionality – is more narrowly market focused and does not apply to many ecosystem service scenarios.

Based on examination of actual examples, Muradian et al. (2010) proposed a more encompassing, less restrictive definition, which states that PES is "a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in management of natural resources" (Muradian et al., 2010). This much broader definition presents a framework that encompasses the social, political, and economic dimensions, and is better suited to evaluating the broader implications for PES and its applicability under different socio-economic conditions.

Most recently, Taconni (Tacconi, 2012) presented yet another definition of PES that, like Muradian *et al.*'s, is much broader than Wunder's and recognizes that PES includes and extends beyond market-type transactions and involves consideration of the social and political dimensions, but also explicitly requires some accountability. Taconni defines PES as "a transparent[4] system for the additional[5] provision of environmental services through conditional payments to voluntary providers". Because Taconni's definition is broad enough to apply to real-world cases, offers specific design elements for guidance, and is the easiest of the three definitions to operationalize, this paper will adopt Taconni's definition for designing a framework for piloting and testing PES in blue forests ecosystems.

3.2. Applicability of Taconni's PES design elements in coastal and marine

Currently, the value of marine and coastal ecosystem services are captured mostly for provisioning services, such as fisheries and energy, and some value-added cultural services, such as ecotourism and aesthetic price premium for coastal and beach front properties. There is still a big gap in approaches for capturing the value of much of the regulating, supporting, and cultural services provided by coastal and marine environments. Can PES be a mechanism for capturing some of those values and for providing incentives toward ecosystem service protection over development and over-exploitation in coastal and marine environments?

[1] www.teebweb.org.

[2] http://www.marineecosystemservices.org/.

[3] Conditionality refers to the terms of a PES agreement in which payment is made to the provider only if the service is provided or the requisite management action is implemented, in the case where the ecosystem service cannot be measured directly. In many real-world examples, conditionality is often taken on faith without an established baseline (before PES implementation) or monitoring (during implementation often because of the high costs of monitoring).

[4] Transparency refers to providing all relevant stakeholders with reliable information in a timely manner. It is important for fair and equitable negotiations, prevention of corruption, and verification to meet the conditionality criterion, especially in cases where verification is taken on faith rather than actual monitoring.

[5] Additionality refers to the state of a PES scheme in which the payment is the direct cause of the improvement in the trajectory of the provision of the ecosystem service. In other words, in the absence of the payment, the trajectory of the ecosystem service provisioning or its management impact(s) would not have improved relative to the business-as-usual trajectory.

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The design elements put forth by Tacconi (Tacconi, 2012) can be broadly summarized as follows: (1) clear articulation of the ecosystem service, or the management proxies shown to provide the ecosystem service, at appropriate spatial scales; (2) identification of a base of voluntary providers, including examination of eligibility, e.g., property rights; and (3) process for setting the terms of the contract, including the incentives, the performance measures, and the monitoring and evaluation requirements. It is also important to consider the role of the PES scheme and analyze the tradeoffs between efficiency and equity, and the potential for poverty alleviation. Conditionality, additionality, and transparency are considered to be important characteristics of PES and are captured in these design elements and the consideration of scope. The rest of this section discusses how these design elements and the supplementary considerations apply to coastal and marine contexts. A marine and coastal management example akin to a PES that specifically illustrates each design element is provided.

3.2.1. Ecosystem services and management proxies

An admitted challenge to designing a PES scheme is the ability to clearly define the ecosystem service around which to build a PES scheme and the subsequent ability to demonstrate the causal relationship between ecosystem protection and quantifiable service delivery. Because ecosystem services are inter-connected and interdependent, it is not always easy to clearly define in space and time the ecosystem service of interest. Itemization of the ecosystem services in any area can be problematic because it assumes these services can be separated while in fact the ecosystem functions that produce the ecosystem services may overlap or may be the foundation of the others, e.g., biodiversity (Kosoy and Corbera, 2010). Special care is needed in identifying the specific environmental goal(s) of the PES scheme and in recognizing the underlying assumptions about the ecosystem and its functions. This is especially important if multiple services or multiple PES schemes are being considered in one geographic area (see Section 3.4).

Compared to terrestrial environments, marine and coastal systems are even more data poor. However, there is sufficient ecological understanding of what types of management activities can lead to better resource protection and ecosystem service provision in marine and coastal environments [e.g., Granek et al., 2009; Post and Lundin, 1996]. Fishery no-take zones have been demonstrated to improve fish populations within the protected area as well as fisheries yield outside (Williamson et al., 2004); marine protected areas (MPA) are known to provide biodiversity and fisheries benefits (Edgar et al., 2007). Recent tradeoff analysis of marine spatial planning shows that it can be an effective tool for managing the different uses of coastal and marine environments, thus minimizing conflicts, and for maximizing ecosystem service delivery and economic benefits across multiple sectors (White et al., 2012).

Defining the geographical boundaries may be more difficult as coastal and marine systems are dynamic and can be influenced by factors from faraway, e.g., pollution from upstream watersheds and rivers, and physical forces from offshore currents and waves. In some cases, such as coastal protection from uncertain storm frequency and intensity, boundaries can be difficult to delineate, but in other cases, such as establishment of no-take zones, boundaries relevant to the ecosystem service can be defined. Linking the target ecosystem service with other services is particularly desirable in the coastal context and is possible (see example below). New tools such as Marine InVEST can model ecosystem service demand and supply and linkages within a landscape/seascape (Natural Captial Project, 2012). It should also be recognized that increases in scientific knowledge can be an iterative process, whereby new knowledge can be generated in the course of the feasibility assessment, during the implementation phase, and through impact assessment.

In Tanzania, Chumbe Island Coral Park is a user-financed MPA where the operating company Chumbe Island Coral Park Ltd. (CHICOP) has a lease agreement with the government of Zanzibar to manage the 30-ha coral reef sanctuary surrounding the island (and the 22-ha coral-rag forest reserve) in exchange for operating an ecotourism park on the island. (The Nature Conservancy, 2012a). Through CHICOP's management activities, overfishing and destructive fishing practices have been reduced in the MPA and the health of coral reefs is among the best in the region. Through employment and education of the local communities and collaboration with the University of Dar es Salaam, knowledge about the ecology and conservation of the Park continues to be generated.

3.2.2. Voluntary providers and property rights

Because many marine and coastal systems are in the public domain, the state is often the rights holder. Correspondingly, the state or the appropriate government management agency will usually act as the ecosystem service provider. For example, in Kiribati through a "reverse fishing license" scheme, the government of Kiribati sold "fishing licenses" to two international non-government organizations for conservation purposes rather than to commercial fishing fleets (The Nature Conservancy, 2012a). In addition, new models of ocean governance are arising that confer property rights in the form of access and use rights, e.g., community-based management, ocean zoning, management concessions, and marine conservation agreements (Agardy, 2010; Pomeroy and Carlos, 1997; The Nature Conservancy, 2012a). These new institutional arrangements allow non-state actors to be considered in the pool of eligible voluntary providers. PES for open ocean (high seas) marine resources (those beyond the Exclusive Economic Zone), however, would likely not be feasible at this point as they are considered to be part of the global commons.

One example of use rights resulting in a PES scheme is in Fiji (The Nature Conservancy, 2012a). There, coastal communities are granted management and use rights in the form of government-recognized locally managed marine areas (LMMA). Because of this management arrangement, the aquarium company Walt Smith International contracts with (and trains) local villages in the LMMA to sustainably culture and harvest "live" rocks (rocks covered with marine plants and organisms) for use in aquaria rather than harvesting native rocks covered with organisms, thereby paying for the ecosystem service of "live" rock culturing in these coastal waters.

3.2.3. Incentives, performance measures and monitoring

The purpose of a PES scheme is to use incentives to change behavior around resource use. From working examples, the incentive itself can be either monetary or in-kind, such as capacity building, alternative livelihoods training, infrastructure building (e.g., schools) as well as a codification of property, use, or access rights. In open access systems, such as coastal and marine environments, the codification of rights can have the added benefit of preventing any single user from deriving personal profits by destroying the service-generating habitat for short term profit. The form of the incentive will likely depend on the cultural and socio-economic context of the providers, and the amount will likely be based on the opportunity and implementation costs. Just as for terrestrial PES schemes, the use of incentives could have negative impacts because it can erode the cultural and ethical motivations for conserving nature, especially for communities that are already doing so (Kosoy and Corbera, 2010). Those types of circumstances may not be the best cases for developing and testing marine and

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coastal PES until more experiences are gathered. In such cases, other conservation strategies may be more appropriate.

In theory, the payment should be conditional on the additional provisioning of the ecosystem service, i.e., in the absence of payment the ecosystem service delivery would decrease or remain at the same level. In practice, experience with terrestrial PES schemes indicates that many do not actually meet the conditionality criterion primarily because of the high monitoring and enforcement costs (Tacconi, 2012; Farley and Costanza, 2010). Instead, trust among stakeholders, with each other and with the agreed management plan, often replaces monitoring (Muradian et al., 2010).

A central feature of the conditionality criterion is the ability to measure performance against a baseline. The assessment can occur either for the ecosystem/ecosystem service itself (e.g., the natural processes and functions, or the stocks and flows of the resources), or the human behavior impacting the resources (management through direct improvement of environmental conditions and/or sustainable extraction). The key will be to select indicators or proxies that have been shown to be associated with ecosystem service performance and that can be measured reliably and repeatedly at reasonable costs. The geographic and time scale used for baselines, frequency of monitoring, and overall length of the project will also be important measurement factors.

In coastal and marine environments, the monitoring itself and/or the costs of monitoring and enforcement can be significant issues. Because ecosystem service science is still a relatively new field, especially in coastal and marine environments, there are few methodologies for directly measuring ecosystem service quantity. Nonetheless, certain environmental and ecological indicators or resource management approaches with known ecological benefits may be able to serve as proxies.

In some cases, such as improving fish nursery function, increased fisheries yield can serve as a proxy. In other cases, such as shoreline protection from storms and waves, it may be more difficult to measure actual protection provided, but methods exist for measuring avoided loss. For example, carbon offset credits have developed methodologies for calculating baseline scenarios and can model avoided deforestation. The insurance industry has developed methods for calculating risks from disasters and accidents. Similar methodologies can be developed for the coastal and marine ecosystem services. Certain management activities are also known to protect the ecosystems that provide a range of ecosystem services of interest. For example, marine protected areas (MPA) can conserve whole of areas that harbor important biodiversity, serve as nursery grounds, protect habitats that buffer the impacts of storms and waves, as well as remove excess nutrients and pollutants from the water. Implementation of MPA management plans and activities, and the degree of implementation may be able to serve as proxies for delivering ecosystem service outcomes.

From the cost perspective, because of where marine and coastal ecosystem services are generated, monitoring activities will likely require special techniques or equipment. For example, monitoring fish populations or coral reef health would require a boat and diving equipment in addition to specialized training. The use of automatic *in-situ* sensors and sampling equipment would require even more specialized scientific instruments that are often very expensive. Enforcement would similarly require boat patrols in what could be a very large area. Fortunately, many management agencies already carry out some of these monitoring activities and patrols. It may simply be working with them to have access to the data they already collect, to add some indicators or monitoring stations to their current protocols, or increase the frequency and area of patrol, the costs of which can be supported by PES.

In New Zealand a market-based mechanism has been developed to manage their fisheries (Newell et al., 2003). Fishermen were initially allocated individual transferable quotas (ITQ), transferable rights to catch and land a share of certain species of fish. The absolute amount of fish landed, or the total allowable catch (TAC), is different each year and is determined by the Ministry of Fisheries based on biological, environmental, social, and economic factors. By setting an ITQ system and setting the TAC, the Ministry of Fisheries has placed the responsibility and costs of maintaining their fish stocks in the hands of the fishermen. By and large, this system has demonstrated improvements in fish stocks as well as profitability in the fishing industry. In this example, the indicator for baseline assessment and monitoring was quite clear, but for other intangible services, like biodiversity, choosing an appropriate performance indicator may not be as easy.

3.2.4. Considerations of efficiency, poverty alleviation, and equity

Efficiency, or cost effectiveness, is an important aspect of a PES scheme, especially in light of the funding shortage to properly manage coastal and marine ecosystems sustainably. The more efficiently the funds are spent, the more conservation could, in theory, be incentivized by the same pool of funds. However, as has been noted by Engel et al. (2008) and Muradian et al. (2010) efficiency often cannot be disconnected from equity or poverty alleviation considerations. The poor, especially those in coastal communities, rely disproportionately on ecosystem services for their livelihoods and have few means for alternatives, but often are also the ones with the lowest opportunity costs (in absolute monetary amount) to changing resource use. From a cost efficiency perspective, the poor may be able to provide the ecosystem service for the lowest payment (e.g., due to low wages or earnings from the resource). From an equity perspective, the burden of ecosystem service provisioning would fall disproportionately on the poor, and they may not necessarily be in the position to refuse the payments due to their circumstances, which brings into question the idea of "voluntary" providers as discussed above. A PES scheme may also lock them into agreements that prevent more profitable uses of their resources should (market) circumstances change. Utmost care must be exercised during contract negotiation to incorporate clauses that allow for fair renegotiations and timely adjustments to the terms. In a scenario where coastal developers cut down mangrove forests for lucrative coastal developments but coastal communities receive much smaller payments to maintain their mangroves, the question of fairness and equity would no doubt arise. These decisions are best made by society, including whether coastal development resulting in habitat destruction is desirable, or whether PES is suitable for this situation.

PES schemes by design will alter access to resources. Coastal and marine resources have traditionally been open access, public goods and are the main source of livelihoods and sustenance for many rural coastal communities, especially those in developing countries where over one billion people rely on fish as their main or sole source of protein (Rashid et al., 2005). Any change in the allocation of use and access rights, whether formal or de facto, will have profound impacts on these communities, as well as the acceptability and ultimately the success and cost-effectiveness of a PES scheme in delivering positive environmental outcomes.

While the goal of PES schemes is not to alleviate poverty, equity and poverty alleviation will likely have to be addressed in the development of marine and coastal PES schemes. Lessons can be learned from terrestrial examples to maximize the livelihood benefits from PES schemes. There have been marine conservation schemes with consideration of both livelihood and ecosystem service benefits. For example, the Government of the Seychelles, prior to enacting a national law to protect the hawksbill sea turtle

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Table 2
Examples of the five characteristic ecosystem services provided by mangroves, seagrasses and salt marshes.

Type of service	Type of ecosystem		
	Mangroves[a]	Seagrass[b]	Salt marshes[c]
Carbon Sequestration	Store carbon in aboveground tree biomass as well in belowground roots and soils	Store carbon in belowground root matrix and soil	Store carbon in belowground root system and soils
Shoreline Protection	Absorb wave and wind energy; reduce erosion and storm surges; accrete sediment for adaptation to sea level rise	Absorb wave energy	Absorb wave energy; accrete sediment for adaptation to sea level rise
Fish Nursery	Serve as nursery habitats, refugia, and feeding grounds for many tropical fish species and invertebrates	Serve as nursery habitats, refugia, and feeding grounds for many fish species	Serve as nursery habitats for fish, shellfish, and crustaceans
Biodiversity	Maintain important biodiversity on land (e.g., birds), coasts (fish and invertebrates), and oceans (e.g., coral reefs)	Sustain filter-feeding invertebrate species and particularly the endangered dugong	Provide feeding grounds for migratory birds and waterfowl and home to invertebrate species
Water Quality	Filter pollution and waste; treat excess nutrients (e.g., nitrogen and phosphorus from land); trap sediments	Filter sediment from water column; reduce turbidity	Treat and filter excess nutrients (e.g., nitrogen and phosphorus from land); trap sediments

[a] References (Nellemann et al., 2009; Bouillon and Kairo, this issue; Saudamini and Vincent, 2009; Aburto-Oropeza et al., 2008; Mumby et al., 2004; Saintilan et al., 2007).
[b] References (Nellemann et al., 2009; Waycott et al., 2009; Saintilan et al., 2007).
[c] References (Saintilan et al., 2007) and http://oceanservice.noaa.gov/facts/saltmarsh.html.

and ban all commercial sales of their shells, administered a buyout and retraining program (co-funded by the Global Environment Facility) for tortoiseshell artisans, in an attempt to ensure their livelihoods[6] (Mortimer, 1999). Since the implementation of this buyout increased nesting has begun to be observed in protected areas and seas turtles have become a major draw for their tourism sector (Troëng and Drews, 2004).

3.2.5. *Buyers*

Although not an explicit design element, the range of potential buyers (both in number and in diversity of sectors) is also an important component of the design process. Potential buyers can be found in both the private (e.g., businesses) and public sectors (e.g., governments). National PES schemes with government as the buyer can be found in Mexico (Muñoz-Piña et al., 2008) and in Costa Rica (Pagiola, 2008). Some ecosystem service schemes are more amenable to securing private sector buyers, such as carbon credits where a market already exists; others may require a public buyer or intermediary, such as payment for watershed services or biodiversity through marine protected areas. Whereas the voluntary participation of the providers should be an objective, it is less important or may not be possible for the buyers (e.g., the ultimate users of public utilities). Intermediaries, such as governments, non-profit organizations, or project developers, can and often do act as buyers on behalf of the final users or beneficiaries. The nature of PES transactions can be composed of private–private, public-private, and public–public actor pairings and will depend on the specific social, political, and environmental contexts.

3.3. *Framework for designing PES in coastal blue forest ecosystems*

The marine conservation community has begun to explore PES and is keen for more guidance. While there are some challenges, the above analysis of theory, definition, and design elements indicate that the conditions are present for further testing of PES in marine and coastal environments in order to produce more lessons learned and best practice guidelines. A framework is presented here for developing a PES scheme in blue forest habitats that begin with identifying the ecosystem service(s) and habitat of interest, the potential pool of voluntary providers and potential buyers, and performance indicators and management options for structuring the agreement.

A first step in developing a PES project is the clear identification of the ecosystem service(s) of interest, the habitats where it is found, and the biological and physical attributes contributing to the ecosystem service provisioning. The blue forest habitats of mangroves, seagrasses, and salt marshes provide many different ecosystem services. The five characteristic, though not exhaustive, ecosystem services found in these habitats are carbon sequestration, shoreline protection, biodiversity, water quality, and fish nursery (Table 2). These ecosystem services range from provision of goods with existing market value, such as seafood and carbon credits; to management of environmental risks, such as shoreline protection and water quality; to maintenance of the supply chain and base of operations, such as fish nursery and biodiversity for tourism. They can be found among all three habitat types, but the specific biological and physical functions differ. It is important to remember that ecosystem service provisioning of any of one these services or the habitats they are found in are interdependent and interlinked. The potential for stacking and bundling ecosystem services in the PES scheme should be considered (see Section 3.4).

The range of stakeholders who might be directly involved in the scheme should next be identified. As a starting point, Table 3 provides examples of the types of providers and buyers (or intermediaries) that could be considered in developing a PES scheme around the five characteristic ecosystem services in blue forests. Government and communities, as well as the rare entities with coastal or underwater property or co-management rights, can make up both the pool of providers and the pool of buyers. However, it is also important to look further upstream on land and further out to sea for other potential stakeholders, such as farmers and commercial fishers, who can impact or benefit from the delivery of the service. The same type of stakeholder can be either a potential provider or buyer, depending on the ecosystem service and the specifics of the PES scheme. Government or other collective institutions may serve as an intermediary or third party on behalf of the end users.

The availability and suitability of performance indicators for baseline assessment and monitoring, the measurement uncertainty, and the management activities for achieving desired conservation results will also need to be determined (Table 4). Potential indicators for establishing the baseline conditions and for

[6] The study did not track the whereabouts of the retrained artisans. It is unclear whether the retraining program was successful in providing alternative livelihoods. In designing PES schemes, monitoring the wellbeing of the stakeholders, especially the providers, should be an important element as well.

Table 3
Potential providers and buyers for the five characteristic ecosystem services found in blue forest habitats.

	Voluntary providers (seller)	Potential buyers or intermediaries
Carbon sequestration	• Various levels of government holding resource in the public trust • Indigenous/traditional communities with (de facto) use and access rights similar to forests • Coastal property owners • Private entities with co-management arrangements or concessions • Holders of underwater easements (rare)	• Developers, individuals or companies desiring voluntary carbon offsets • Governments for meeting emission goals • Carbon offset brokers
Shoreline protection	• *Same as for carbon*	• Coastal property owners • Insurance/re-insurance companies • Government agencies and municipalities responsible for disaster management • Coastal developers
Biodiversity	• *Same as for carbon*	• Natural resource management agencies • Non-profit organizations with biodiversity missions • Tourism operators
Water quality	• Upstream farmers • Upstream municipalities • Indigenous/traditional communities with (de facto) property, use or access rights to forests and wetlands	• Government management agency responsible for public health and safety • Coastal tourism industry (to maintain safety) • Fishing industry/fishermen (to maintain seafood safety and prevent closures) • Coastal communities (for aesthetics, recreational and health reasons)
Fish nursery	• *Same as for carbon* • Commercial and artisanal fishermen with legal or de facto fishing rights in habitats of interest	• Seafood industry, especially buyers, processors, and retailers • Commercial fishermen • Sports fishermen • Dive and snorkel industry

monitoring will focus on the physical, chemical and biological conditions of the ecosystems and may be very directly related to the service provisioning, such as for fish counts, or may be proxies or roll-up indices, such as for biodiversity. The certainty level of the measurement also varies depending on available methodologies and the difficulty of measurement. In the case of shoreline protection, it is particularly difficult to characterize the amount of protection delivered because much of it is based on avoided loss, but modeling can help make these estimates. The specific resource management activities for each ecosystem service will depend on the particular threats and the stakeholders involved and will generally involve preventing deforestation, reducing habitat conversion/destruction and degradation, reducing pollution from land, reducing overfishing, and maintaining water flows from rivers into coastal areas. Habitat restoration is an option for enhanced delivery of ecosystem services, but tends to be costly and may not

Table 4
Analysis of potential measurement options and uncertainty, and management activities for PES design of the five characteristic ecosystem services in mangroves, seagrasses, and salt marshes.

	Indicators for baseline assessments and performance measurement	Measurement uncertainty	Proxy management activities
Carbon sequestration	Tons of CO_2 sequestered or in emissions avoided; carbon sequestration rates	Low to High: carbon accounting methodologies under development for seagrass, salt marsh, and mangrove soils but available for aboveground tree biomass	Prevent or reduce deforestation and degradation of mangroves; reduce water pollution to prevent habitat degradation; restore hydrological and natural sediment flows
Shoreline protection	Shoreline conditions and profiles; rate of erosion or accretion; damage sustained in storms	High: very difficult to measure the negative scenario; uncertain trajectory, frequencies, and intensities of storms; reliant on modeling and past experiences	Prevent or reduce deforestation and degradation of mangroves; reduce water pollution and excess sediment to prevent habitat degradation; prevent dredging of seagrass beds and associated underwater habitats
Biodiversity	Number of species and their density/population size of species; presence/absence of key indicator species; a roll-up index based on a majority of the species; genetic diversity	Medium to High: hard to capture the full essence of biodiversity, but the right indicator species may be adequate	Prevent or reduce habitat degradation and destruction and overexploitation of species
Water quality	Various water quality indicators, such as turbidity (for sediment) and concentrations of various pollutants, e.g., nitrogen, phosphorus, other industrial waste, bacterial counts, and solid waste	Low to Medium: protocols for water quality measurements already existing and regularly performed by management agencies; appropriate sampling locations more difficult to determine	Reduce agricultural and industrial chemical input from land; maintain wetlands to reduce sedimentation in water column; reduce non-point source runoff from land
Fish nursery	Population size of target species in nursery habitat or as adults in adult habitats or in fish catch	Low to Medium: possible to sample fish in target areas, but more difficult to catch and identify juveniles to species level; may also need to identify the specific age group to measure; may also depend on adult reproductive success unrelated to fish nursery habitat conditions	Establish no-take zones/protected areas in key fish habitats and spawning grounds; establish minimum take sizes

necessarily deliver the same level or quality of ecosystem services as natural habitats (Palmer and Solange, 2009).

With the above design features identified, one can begin the process of developing the PES deal. In some ways, identifying these features is the easy step in a PES design. The challenging part will be in bringing together the stakeholders, both participants and non-participants, to discuss the goals, roles, and implications of the scheme for resource access that is acceptable to all, a critical step for coastal and marine resources that have traditionally been open access. Trade-offs between efficiency and equity and the role of PES in poverty alleviation will need to be deliberated. The legal context for PES contracts and enforcement will have to be assessed. The terms of the contract, such as the form of payment and conditions for compliance and renegotiations, will have to be negotiated. These details of the PES scheme will depend on the specific socio-economic and political contexts where and with whom the project will take place. These issues have been thoughtfully analyzed by experts in the field of PES and can be consulted for guidance [e.g., (Granek et al., 2009; Muradian et al., 2010; Farley and Costanza, 2010; Jack et al., 2008)]. Various primers have been published that can help structure the PES design process [e.g., (Forest Trends; The Nature Conservancy)], and papers in several special issues can offer lessons learned from PES case studies (mainly terrestrial) to help inform best practices (Farley and Costanza, 2010; Muradian et al., 2010; Engel et al., 2008; Daily and Matson, 2008).

3.4. Capturing multiple services: stacking and bundling

Coastal ecosystems, where the land meets the sea, are considered some of the most productive of all ecosystems on earth. Coastal blue forest habitats, especially, provide many different services simultaneously and collectively. The complexity of ecosystems and the connectedness of ecosystem services may make it difficult to delineate the ecosystem service(s) and geographical boundaries of interest, and it may be desirable to develop PES schemes that can maximize the overall production of ecosystem services, as well as the payments toward their maintenance. It is also important to prevent perverse incentives that reward maximizing payments for one service at the loss of another [e.g., cited in Cooley et al., 2011; Farley and Costanza, 2010]. Moreover, the trend in PES schemes is for increasing attention to the generation of co-benefits, such as reduced emissions from deforestation and forest degradation plus forest conservation, sustainable forest management and enhancement of carbon stocks (REDD+) for carbon offsets.

As a result, PES practitioners are investigating the possibility of PES schemes that can either bundle or stack ecosystem service payments (Fig. 1) (Engel et al., 2008). “Bundling” refers to receiving a payment for multiple ecosystem services grouped together into a single package of conservation outcomes. “Stacking”, also termed “layering”, refers to a separate payment stream for each distinct ecosystem service. There are pros and cons for both approaches.

Because ecosystems are complex and inter-connected, it is likely difficult to reduce the benefits of any one ecosystem into clearly definable and quantifiable separate services. Bundling would recognize the complexity of these systems and allow for payments for services that are not clearly defined but are generated from the whole ecosystem (Farley and Costanza, 2010; Kosoy and Corbera, 2010). For example, wetland mitigation banking in the United States is structured as a bundling mechanism where all the attributes of the wetlands (theoretically) are paid for collectively (Cooley et al., 2011). Precisely due to this complexity and the interlinkages, stacking is problematic since it assumes that services can be clearly delineated and quantified as separate salable “goods” whose production are independent (Kosoy and Corbera, 2010). It is important to remember that developing baselines for either stacking or bundling will be challenging due to tradeoffs across space, time and uncertainties.

Despite its advantages from an ecosystem perspective, bundling may require a larger payment as management and monitoring activities for multiple ecosystem services may require an integrated landscape approach that is more costly than a single service scheme. A potential buyer may be interested in the other ecosystem service benefits, but may not want to pay for them. In situations where no buyer of the whole package of services can be identified, e.g., lack of funds or need for those other services, stacking may be a method for generating multiple revenue streams, assuming services can be reasonably distinguished and measured for the subset of services that can be separated.[7] Transaction costs, however, are likely to be higher than with bundling, as each service will need to be quantified (if possible) and credited separately and more stakeholder groups (especially buyers) will be involved.

In practice, bundling and stacking of payments have been difficult to implement because of the larger number of stakeholders involved or the ability to separately quantify improvements in each of the services, and few successful examples exist [e.g., Asquith et al., 2008]. Some of the impediments to multi-service payment schemes include free-riding, coordination of multiple stakeholder groups, transaction costs, and additionality. Free-riding occurs when a user chooses not to pay for the service of interest because it is already improved by payment from another user group. As the number of services increase, the number of stakeholders with whom to develop a PES scheme or coordinated schemes also increases, increasing the transaction costs. The social dynamics involved to converge on an agreement regarding the management interventions, the type and amount of payments, and the monitoring of compliance become increasingly complex as do the transaction costs. Because it is common for different ecosystem services in any one habitat to be connected, management activities targeted at improving one service will invariably improve another, while potentially not to the same degree. In a stacking situation, which service is considered the “primary” service may impact the additionality of the other services and hence the credits and payments that these other services may generate. Moreover, in Bolivia a dual-service scheme for water and biodiversity highlights how important it is to provide information and build trust among the ecosystem service providers (Asquith et al., 2008). The simplest potential PES pilots may be one with only one (or a few potential buyers) interested in a bundled scheme or two buyers interested in two stacked schemes.

Despite the complexities and difficulties in developing bundled or stacked payments, it will be desirable and necessary to develop bundled and/or stacked systems for coastal ecosystem services. The opportunity costs of conserving coastal ecosystems tend to be high due to increasing populations, development pressure, and growing aquaculture uses. For example, in the case of blue carbon, the ecosystem service with a clear terrestrial model, estimates of potential blue carbon payments indicate that the revenue from carbon credits may be sufficient to offset the income that can be gained by converting mangroves to shrimp farms in Thailand (Murray et al., 2010). It is, however, hard to imagine that carbon payments alone will be sufficient to prevent developments in popular tourism locations in developed or developing countries. It is also important to avoid situations where planting of monocultures maximizes carbon sequestration, hence carbon credits, but

[7] Some other method(s) still needs to be identified to finance the residual, complementary benefit not paid for through stacking; otherwise, these other services will likely decline.

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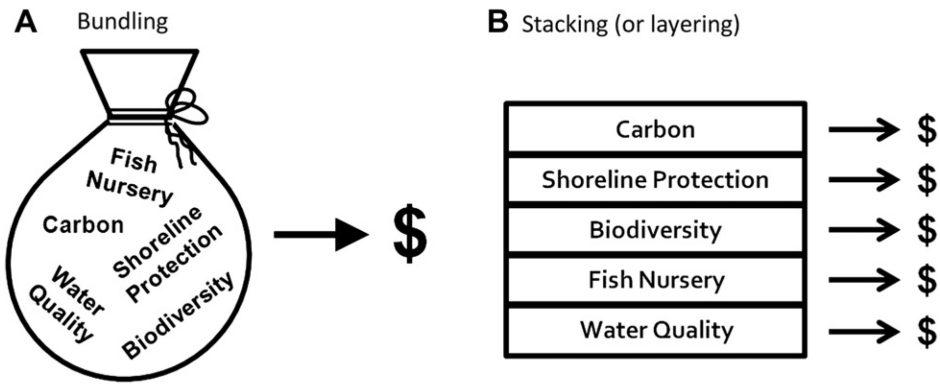

Fig. 1. Models for capturing payments for multiple ecosystem services (e.g., fish nursery, carbon sequestration, shoreline protection, water quality, and biodiversity). A. Bundling, where one payment is received for a package of services. B. Stacking (or layering), where separate payments are generated for each quantifiable and additional service delivered. The relative size of the dollar signs between A and B indicate that the bundled payment would be larger than the individual stacked payments; however, the same size arrow in B does not imply that the payments for the stacked services would be equal.

at the expense of biodiversity and other ecosystem service flows (Cooley et al., 2011; Kosoy and Corbera, 2010). Bundling or stacking of multiple payments may provide enough incentives to, at the very least, scale down any development proposals and protect the areas with the highest values and, at the very best, prevent the development from moving forward all together. The issue of additionality will need to be carefully considered, especially in the blue carbon framework if its development follows that of terrestrial carbon offsets, to keep room for the bundling and stacking of payments for other ecosystem services with the carbon payments.

4. Conclusion

The piloting of PES for marine and coastal conservation appears feasible despite challenges. More experimentation will be required for elucidating the best practices and the situations under which they will be most effective, in order to overcome these challenges. Lessons learned from terrestrial examples will help to inform practitioners and expedite the process. The framework presented above around carbon sequestration, coastal protection, fish nursery, water purification, and marine biodiversity in blue forest habitats shows the potential for developing payments that can generate a larger pool of sustainable, conservation financing – although care will need to be taken to not simply commodify nature (Kosoy and Corbera, 2010).

The various challenges and complexities that will need to be overcome before PES can become a mainstream tool for conserving marine and coastal ecosystems include furthering the body of scientific knowledge about ecosystem services. More (applied) science and economics connecting specific management activities to quantifiable service delivery will help close the information gap and reduce uncertainty about the service/product for which one is paying. Metrics and performance indicators to assess baselines and measure service delivery will also be important for coastal and marine PES development. New institutional frameworks for managing payments and verifying service delivery will be required. As PES is new to the marine and coastal conservation community, resource managers, coastal communities, and businesses, education and capacity building will be essential for necessary stakeholder participation in developing PES schemes.

Because terrestrial carbon markets already exist, the most likely near-term PES at scale in blue forest habitats would be payment for carbon credits. As marine and coastal conservation moves toward carbon payments, it will be important to take into consideration the whole suite of services that these habitats provide. It will be especially crucial to design payment schemes, for and including blue carbon, that do not sacrifice the flow of other ecosystem services as some terrestrial carbon projects have, or the future opportunity to capture their values through payments. For example, managing a mangrove system to maximize carbon sequestration may not necessarily maximize the other services as terrestrial examples have demonstrated (Cooley et al., 2011; Kosoy and Corbera, 2010). For instance, one can imagine a scenario where perverse incentives result in the planting of a fast-growing mono-specific mangrove stand in a restoration site, in order to minimize costs and maximize carbon credits. This type of restoration effort will likely lower biodiversity and provide different (and lower levels of) services than a restoration effort with mixed species that mimic the nearby natural stands.

As has been discussed in recent developments on conceptualizing PES, this tool is by no means a panacea and will only be appropriate in certain situations (Muradian et al., 2010; Engel et al., 2008). The management examples presented in this paper, while akin to PES schemes, need further analysis to assess whether they are good PES models, what should and should not be replicated, and what requires improvement. The key will be to identify those situations for which payments will be effective, cost-efficient, equitable and culturally acceptable, and those for which payments are not. If designed correctly, PES can achieve in marine and coastal settings what has been achieved on land, e.g., clarification of use and access rights, poverty alleviation, funding for implementing sustainable management plans, and more sustainable resource use.

With the many climate change impacts predicted for the oceans and coasts – like increased frequency and severity of storms, sea level rise, sea temperature rise, ocean acidification, changes in global climate leading to unpredictable rainfall and unpredictable freshwater input to coastal systems – it will be important to minimize other impacts to these systems in order to maximize their resilience and ability to adapt to climate change. Governments, resource managers, NGOs, aid and development agencies, and communities are all racing to develop plans to manage climate change impacts. Even the best-laid plans will require adequate financing. PES looks promising to be one tool, in combination with others, that can serve as both (or part of an overall) management strategy and financing mechanism to deal with the challenges ahead.

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