Coastal Wetlands in the Baja California Peninsula: Ecosystem Services and its Valuation

This report was prepared for the following project:

Examining Cross-Border, Nature-Based Market Solutions to Protect Blue Carbon Coastal Ecosystems in the Californias

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List of Acronyms

BMLC: Bahia Magdalena Lagoon Complex
CBCRM: Community-based collaborative resource management
CO_2e: Carbon dioxide equivalent units
CONAPESCA: Mexican National Fisheries and Aquaculture Commission
CVM: Contingent valuation method
HIP: Cooperative State-Federal Migratory Bird Harvest Information Program
ICDP: Integrated conservation and development project
LMMA: Locally managed marine area
MP: Market price
NDC: Nationally determined contribution
NFI: Net factor income
PES: Payments for ecosystem services
PHKA: Ministry of Forests – Natural and Protected Forest Management Agency of Indonesia
SCC: Social cost of carbon
USFWS: US Fish and Wildlife Service

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The Institute of the Americas has prepared a project to examine cross-border, nature-based market solutions to protect coastal blue carbon ecosystems in Baja California and Baja California Sur (the "Las Californias Project").

The project seeks to identify sources of finance to fund conservation and restoration projects of blue carbon ecosystems in Baja California and Baja California Sur, both for the richness of ecosystem services they provide to communities and for the role they can play in mitigation and adaptation of climate change. These ecosystems provide an important range of services for the surrounding communities and the region as a whole, in the form of food security, storm protection, and ecotourism. Furthermore, today's climate crisis is putting an increasing value on carbon sequestration and climate mitigation—something blue carbon assets such as mangroves can support, which could lead to carbon credits being issued in the international carbon markets, thus providing another source of income for the conservation of these ecosystems.

This report presents an overview of the range of ecosystem services provided by coastal wetlands, with an emphasis in the Bahía Magdalena Lagoon Complex in Baja California Sur. It is broken down in sections describing the different categories of ecosystem services provided by mangrove forests, as follows: carbon sequestration; habitat protection species; water quality enhancement; coastal protection; eco-tourism; and social capital. It concludes with key takeaways and recommendations.

Other papers in this series include (1) an analysis of potential funding sources for the Baja California Peninsula blue carbon ecosystems under California law, (2) an examination of market-based carbon mechanisms as a potential source of financing for blue carbon restoration and conservation in Mexico, (3) an in-depth discussion of key habitats and species of interest in the region, and (4) a legal analysis of where Mexico stands in leveraging blue carbon assets.

Abstract

Mangrove forests provide a multitude of ecosystem services. Among many other benefits, they are a cradle for a diverse array of life, support the livelihoods of local communities, and sequester carbon from the atmosphere. Because of the public good, non-market nature of many ecosystem services, mangroves are undervalued and subject to deforestation around the world, including Baja California. This report uses the Bahia Magdalena Lagoon Complex (BMLC) as a case study and reviews several conservation policies that may be used to conserve mangrove forests. A key challenge is the need to create mechanisms that allow landowners and local communities to benefit from mangrove conservation and management programs. Therefore, it reviews several policies used in Mexico that take this approach, including Payments for Ecosystems Services (PES) programs and Integrated Conservation and Development Projects (ICDPs). It concludes that coexistence of payment programs (*i.e.* PES, carbon emission trading credits, philanthropy) and an ICDP in a proper sequence, while reinforcing intrinsic value-based attitudes, could facilitate meeting conservation management goals. Cross-border cooperation between the United States and Mexico is also essential for conservation because of the interconnected nature of ecosystems that do not follow political borders.

Introduction

The sustainable provisioning of goods and services from natural ecosystems (*i.e.* ecosystem services—ESS) are essential to the wellbeing, survival and economic prosperity of society. Mangrove forests are biologically complex and productive ecosystems providing a multitude of ecosystem services (Fig.1). These services are often under-appreciated due to the public good, non-market nature of many ecosystem services. This leads to mangroves being undervalued, justifying deforestation in favor of projects that appear to have a higher value or that provide tangible benefits to society. Mangrove forests in Baja California were destroyed at a rate of 0.205% annually from 2005-2015[1] and worldwide, and an estimated 20%–35% of global mangrove extent was lost over the last 50 years.[2] Land use change is the leading cause of mangrove deforestation and, in key sites in Baja California Sur, conversion to shrimp aquaculture continues to be a major economic driver of mangrove loss.[3]

Economic analysis is valuable in decision-making when allocating scarce resources in a competitive and demanding society. Traditional economic analysis tends to underestimate the long-term benefits of natural resources of coastal ecosystems due to the difficulty in quantifying ESS in comparable terms to economic services, productivity, and manufactured capital. However, the sustainability of human societies may be ultimately compromised if the value of mangroves are neglected further in policy decisions. Ecosystem services valuation can assist in estimating the 'incremental' or 'marginal' value (the estimated rate of change of value compared with changes in ecosystem services from their current levels) of services to inform policy-makers, economists, ecologists, and the general public.[4]

Designing conservation and management policies that seek to protect ecosystems requires that we recognize that the services and goods they provide do not adhere to international or political borders and land ownership rights. This means that the services they provide can have a positive impact well beyond the natural boundary of the ecosystem itself. For example, mangroves are intricately connected to the ocean and surrounding coastal ecosystems due to shared natural processes and species.[6] Many of the benefits generated by mangroves are intangible (carbon sequestration, coastal stability, cultural value, etc.); however, they can also provide tangible benefits to communities through eco-tourism (*i.e.* bird watching and diving/snorkeling[7,8]), flood protection, and as a food source.

In Mexico, private land-owners and *ejidos* (community managed rural lands[5]) own parcels of lands that may include mangrove forests. Conserving the parcels where mangrove forests are present can result in costs to the landowners and *ejidatarios* in the form of forgone income since they can't develop the land and any other modification of the ecosystem is prohibited by law.

The challenge lies in creating innovative methods that allow landowners to benefit from mangrove conservation and management programs. Such methods have been used successfully in Mexico, and they include the monarch butterfly conservation program and the creation of an international market for to protect migratory birds.[9–11] These programs create a direct benefit to the landowners, but the positive impact goes beyond the protected area's boundary. Clean air, water purification and economic spill-over from revenues from tourism are a few examples of how Mexican communities benefit, while species migrating back to their summer habitats in other countries help sustain economies there.

Policies and tools that create positive incentives for private landowners and local communities are not the only thing needed in conservation. Cross-border cooperation is essential when ecosystems or their services are shared by neighboring states or countries. To create programs that achieve ecosystem conservation while sustaining and improving human wellbeing requires an in-depth understanding of how ecosystems work. For mangrove conservation, this means improving our understanding of the ecosystem as a whole, the species that live in it and the natural processes that are required to maintain a steady flow of services and benefits.

In this document, we use the Bahia Magdalena Lagoon Complex (BMLC) as a case study to show the importance of implementing conservation programs to protect ecosystems and the services they provide. The mangrove forest lining the coastline along the lagoon complex are among the healthiest in the Baja California Peninsula, and help sustain local and regional economies through ecotourism and fishing. Valuing these, and other ESS these mangroves provide, is the first step to designing a long-term conservation strategy that creates benefits for both Mexico and the United States. See *Table 1* below for the range of ESS addressed throughout this study and *Table 2* at the Appendix of this paper for a summary of the monetary values assigned to ecosystem services provided by mangroves in the BMLC, extracted from a range of global and regional studies.

Table 1

Classification of ecosystem services by Millennium Ecosystem Assessment

Provisioning Services	**Regulating Services**	**Cultural Services**
Products obtained from ecosystems	*Benefits obtained from regulation of ecosystems processes*	*Nonmaterial benefits obtained from ecosystems*

• Commercial fisheries species	• Carbon sequestration • Water quality enhancement	• Recreation and eco-tourism • Social capital
Supporting Services *Services necessary to produce all other ecosystem services* • Coastal protection • Habitat protection • Nursery habitat		

Overview of Ecosystem Services Provided by Mangroves

Carbon Sequestration

The creation of carbon markets attests to the international desire for carbon reduction mechanisms—as part of a global consciousness regarding the urgent need to tackle climate change. Mexico specifically noted their goal to reduce carbon emissions, including through nature-based solutions, in its 2020 Nationally Determined Contribution (NDC).[1,13] Mangrove forest conservation can play a key role in meeting these goals. These coastal ecosystems naturally mitigate emissions and store carbon,[14] while also increasing the capacity for human adaptation to climate change and furthering sustainability goals. At less than 0.1% of the world's surface[15], mangroves sequester 13.5 Gt of carbon annually,[16] accounting for 3% of the total forest carbon sequestration globally.[16] Importantly, mangroves hold 3 times more carbon in their soil than other forests.[18]

The ability of mangroves to sequester and store carbon has been the focus of scientific research in the past years, and understanding how they compare to other types of forests and ecosystems can have important implications for conservation. The fringe mangrove and mudflats of Bahía Magdalena, Mexico, were found by Zulueta et al. (2013) to sequester 23-81 times more carbon than the surrounding desert scrub.[17] Ezcurra et al. (2016) found that mangroves and salty scrubs

[1] NDCs are national climate plans highlighting climate actions, including climate related targets, policies and measures governments aim to implement in response to climate change and as a contribution to global climate action in the framework of the 2015 Paris Agreement, both in terms of mitigation of greenhouse gasses and of adaptation and resiliency to a changing climate and warmer global temperatures.

in the Gulf of California jointly store 28% of the total belowground carbon pool in the entire region.[19] Destroying these coastal forests would lead to the release of large carbon stocks back into the atmosphere, resulting in increased CO_2 and CH_4 emissions[20,21] and the ecosystem's ability to sequester carbon would be reduced.

Valuing carbon stocks in a particular area can be thought of as the value of carbon that is lost when deforestation occurs. Kumagai et al. (2018) used a current estimate of the social cost of carbon (SCC),[22] and multiplied it by the carbon stocks of aboveground biomass, belowground biomass, soil and litter (all converted to carbon dioxide equivalents (CO_2e))[1]. The SCC reflects the economic cost of an incremental unit of CO2, meaning it represents what society is willing to pay today to avoid the future damages or costs caused by an additional ton of carbon emissions. The SCC represents the externality costs on society derived from climate change, and it is a useful tool to assess the expected economic damages resulting from climate change, and thus to quantify the benefits of a policy that reduces emissions.[2] Discount rates are necessary to account for economic factors such as inflation and opportunity costs of investing elsewhere. A SCC of 40 US$ Mg^{-1} was estimated based on a 3% discount rate, a conservative discount rate commonly used in carbon valuation literature[2,23]. Importantly for Bahia Magdalena, deforestation rates and carbon stocks of Mexican mangroves were estimated to predict a social cost of 392.0 (± 7.4) million US$ over 25 years of continued deforestation. The carbon stock values of Mexican mangroves were compared to potential investment and costs of conservation and it was found that when considering the value of carbon stocks alone, the average value of a hectare of Mexican mangrove was 38,100 (± 4,300) US$, while the cost of investment was between 44.7 US$ and 182.5 US$ per hectare. In addition, the per-hectare basis was calculated per *municipio* (comparable to a U.S. county and similarly governed). Results indicated that society could save on average between 10,800 US$ and 31,900 US$ in avoided damages per hectare for every *municipio* by protecting mangrove forests in the next 25 years. On a per-hectare basis, the cost of investment to protect mangroves was less than the carbon stock value, not including the value of all other ecosystem services, for every *municipio* in Mexico.

The significant value of this blue carbon ecosystem incentivizes conservation efforts internationally. The Las Californias project is addressing the need to ensure the BMLC obtains carbon credits that are sold in the international voluntary markets, properly valued. This should incentivize landowners and local communities to conserve their blue carbon assets. This funding mechanism can be combined with other forms of blended financing taking into account other ecosystem services provided by the mangroves of the BMLC.

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2 Prosperity, S. (2011). The Value of Carbon in Decision-Making: The Social Cost of Carbon and the Marginal Abatement Cost.

Habitat Protection for Migratory Species

Ecosystems, watersheds, and migratory species (*e.g.*, marine turtles, gray whales, waterfowl and shorebirds) do not recognize international political borders or land tenure. Ecosystem services are dependent on ecological units that span these boundaries and benefits– when properly managed – are shared by neighboring countries. This links the welfare of human communities across borders and underscores how stakeholder intervention in one country can affect ecosystem services and human welfare in neighboring countries.[24] Mapping, quantifying, and describing these interactions and how benefits flow can assist in the incorporation of ecosystem services into policymaking as decision-makers can understand where and who will receive benefits.[25]

Migratory animals are a key component of this flow of ecosystem services due to seasonal transitions across borders. However, this also makes them vulnerable to impacts at each stage in their journey. For example, migratory birds depend on specific habitats along their range to progress through various life stages and are thus vulnerable to habitat deterioration.[10] These birds provide a suite of ecosystem services through their functional roles as predators, seed dispersers, and ecosystem engineers yet also provide recreational services through hunting and bird watching.[26,27]

The Pacific Flyway hosts a migration route through Canada, the U.S. and Mexico, for 27 waterfowl species numbering in the millions (Rubio-Cisneros et al. 2014). Mexico's Pacific coast winters between 7-17% of all of the migratory waterfowl in North America[28]. Importantly, this wintering takes place in coastal lagoons where waterfowl rely on habitat for courtship, feeding, molting, and the prey species associated with marine vegetation such as mangroves and seagrasses[29–35]. The waterfowl return north to breed in springtime, where they then are a source of income for the recreational hunting and tourism industries in the U.S. and Canada[36]. Rubio-Cisneros and colleagues (2014) tested the hypothesis that a flow of benefits is sent from the wintering habitats in Mexico to consumers of hunting and recreational activities in the United States[11]. They found that due to the existence of this cross-border ecosystem service in North America, there will be a loss of benefits if abundance of waterfowl decreases via habitat size or quality decline of Mexico's coastal lagoons.

While data may not always exist to quantify habitat value on a per-hectare basis, a method to confer the value of the habitat is through Willingness-To-Pay.[37] In the case of waterfowl, Willingness-To-Pay for hunting stamp sales can be used as a proxy to estimate the value of a coastal ecosystem. Cooperative efforts between the United States, Canada, and Mexico have consolidated five major waterfowl monitoring programs, which together comprise the largest dataset of any wildlife group in the world. These annual surveys collect data on populations, production (breeding), habitat, banding, and harvest (hunting)[38]. These data, combined with national harvest data from the Cooperative State-Federal Migratory Bird Harvest Information Program (HIP), and Duck Stamp Sales Revenue data from the US Fish and Wildlife Service (USFWS) Division of Migratory Bird Management, were used to estimate economic flows from Mexico to the United States.

Rubio-Cisneros and colleagues estimated Willingness-To-Pay for hunting stamps in the U.S. to be US $1,640 per square kilometer ($164 per hectare) of coastal lagoon. This accounts for US $4 million annually and an additional US $3-6 million dollars annually in other economic benefits. These surplus benefits suggest a possible source of funding to conserve habitat beyond the borders of the U.S. In other words, investing to protect coastal lagoons and wetlands in Mexico can result in economic benefits for the waterfowl hunting industry in the U.S. However, there is further research needed to provide a true value of the services mangroves provide to migratory species.

Water Quality Enhancement

As economies and human populations increase along coasts, coastal lagoons are at high risk of deterioration, which could lead to loss of water quality and quantity, biodiversity, and other ecosystem services could be affected as well. Coastal lagoons are especially vulnerable to nutrient enrichment due to the limited water exchange with the ocean so eutrophication (excessively high phytoplankton growth) can be a problem in these ecosystems. Under these conditions, the clarity of the lagoon water decreases, limiting the light available for seagrasses and other benthic photosynthesizers. Bacteria feeding on the excess phytoplankton can draw down oxygen levels, resulting in hypoxic conditions that are detrimental to crabs, fish, and other organisms. This is known to cause regime shifts where the structure and function of the lagoon ecosystem is severely impacted.[39–44] Human health, fisheries, eco-tourism, and aquaculture can all be negatively impacted by eutrophication.[45]

De Wit and colleagues (2017) assessed the marginal economic value that could be gained by an increase in water quality that would result from lagoon restoration and found that 77% of residents and 71% of tourists preferred a scenario that combined the highest degree of water quality enhancement through restoration and construction of additional footpaths with hides and other additional measures to protect waterfowl from disturbance of hikers. The willingness to explicitly contribute financially to the restoration project was confirmed with 70% of residents and 66% of tourists. The multiple contingent valuation, importantly, suggests that locals and tourists alike value water quality enhancement and are even willing to contribute financially to the restoration of the local lagoon, allowing them to continue to enjoy this ecosystem service.

Another method used to value water quality enhancement at the local scale is the benefit transfer method.[48] Li and colleagues (2010) carried out a valuation study utilizing ecosystem service values and data on land use retrieved via ARCVIEW GIS.[49] Land use can be used as a proxy measure of ecosystem services by matching the land use categories with equivalent biomass and ecosystem service valuation. The authors found that water supply and waste treatment were the top two ecological functions with high service value, contributing about 40% of the total value of services. The overall rank for each ecosystem function based on their contributions to overall value was, from high to low, as follows: water supply, waste treatment, soil formation and retention, biodiversity protection, climate regulation, gas regulation, raw materials, recreation and culture, and food production. Areas with high services level were mainly located in the southwest coast, due to wetland (mangroves), and southeast part (due to woodlands), while those with low services level expanded from the city center. Results from this case study indicate that water supply and water purification offered by mangroves have a combined value of US$5040.16 per ha. These estimates for the water purification service can be extrapolated to the BMLC with further data acquisition.

Coastal Protection

Coastal development, population growth, climate change, habitat loss and other human induced pressures are increasing coastal flooding impacts.[50–56] Adaptation to climate change will require resilience in the face of sea level rise and increasing storm surges,[57–60] however, mangrove forests can provide natural coastal protection from flooding and storm surge. Because many mangroves vertically accrete, they can cope with rising sea levels by building up their soil as sediments wash into the root systems while preventing coastal erosion.[61–65] The mangrove forests of BMLC do not vertically accrete since they are situated on the coast of gently sloped desert sedimentary plains that expand eastward for around 50 km into the foothills of the *Sierra de La Giganta*. This gentle slope facilitates inward colonization of the black mangrove (*Avicennia germinans*) as sea-level rises or flooding occurs[66]. The mangrove forests of Bahia Magdalena span a 200 km long complex of lagoons and the coasts are lined with fringing red mangroves. These fringing mangroves capture sediment associated with continental run-off in their prop roots, which also play an important role in absorbing wave energy during the infrequent but intense and regular tropical storms (typically originating in the Gulf of Tehuantepec).[66–68,70]

Menéndez et al. (2020) provide the first global analysis of the social and economic value of mangroves for flood risk.[71] Menéndez and colleagues calculated coastal flooding by analyzing more than 7,000 historical cyclones and 32 years of regular waves and sea level data (storm surge, astronomical tide and mean sea level). Global flood protection benefits were quantified by estimating the property damages from flooding across 700,000 km of mangrove coastlines globally. The difference between flood damages is the averted damages (or avoided costs) in areas with mangroves. This benefit provided by the mangroves can be valued in terms of expected costs of annual damages, a metric that expresses the probability of expected damages in any year across the full spectrum of storms.

Globally, mangroves annually reduce property damage by more than $US 65 billion and protect more than 15 million people. If current mangroves were to loose 29% more land, 28% more people and 9% more property would be damaged every year. These values and benefits can be much higher in some regions, are not limited to urban areas and can extend to less populated coastal floodplains. According to Menéndez's study, some of the nations that enjoy the greatest economic benefits of coastal protection from mangrove forests include the USA, China, India, and Mexico. In fact, in some cities like Miami in the U.S.A and Cancun in Mexico, mangroves provide more than $US 500 million in avoided property damages every year.

A method used to evaluate Coastal protection at the local scale can be evaluated by estimating the expected damage to a coastline. Barbier (2007) used a 10%-15% discount rate over a 20-year period and found an annuity value of US$8966-10,821 per ha for storm protection[72]. While infrequent, hurricanes do occur, and winter storms also negatively impact Baja California Peninsula's coastal communities. This method could be applied in BMLC to estimate the value of coastal protection provided by these small desert mangroves.

Furthermore, Sathirathai & Barbier (2001) provide a soil erosion valuation case study in Southern Thailand[73] where they found that in order to replace the storm protection services provided by mangrove forests (known as replacement cost), the cheapest (although effective) solution would be to build break water structures along the coast[73]. The cost of this solution, according to the Harbor Department of the Ministry of Communications and Transport, is US$116,667 per ha. Using a 10% discount rate over a 20-year period, an annuity value for soil erosion prevention of US$12,263 per ha was estimated. For an even more conservative value, the authors took into account the "demand" for shoreline stabilization—which resulted in a value of US$3,679 per ha. These values combined and using the 10% discount rate, amounts to a conservative estimate of US$14,500 for coastal protection provided by mangrove forests.

Mangrove cover, especially red mangrove fringe which is where most of the storm surges are absorbed and where sediments are stabilized, continues to decline and the resulting risk to coastal communities continues to increase.[66,74–76] More accurate and detailed estimates of the value of coastal protection, including protection from erosion and storm events, are needed to incentivize the conservation and restoration of specific mangrove forests for the benefit of nature and for coastal communities to avoid significant damage costs.[77] There are surprisingly few specific valuations for coastal protection from mangrove forests, especially soil erosion prevention, and no valuations for desert mangrove forests such as those found in Bahia Magdalena Lagoon Complex. However, estimates as those discussed above can serve as a baseline to infer the value of the ecosystem services provided by BMLC's mangroves and inform decisions regarding their conservation.

Nursery for Target Commercial Fishery Species

Fishing is central to the food and economic security of billions of people worldwide, especially in developing countries. Globally, small scale fisheries are the main source of food, income, and livelihoods for coastal communities and employ 90% of fishermen[78–81]. Mangrove forests engage in complex relationships with adjacent marine habitats resulting in areas of biological importance and high species diversity.[6,84] Most notably, the red mangrove's prop root system (a major feature of fringing mangrove forest) provides a nursery habitat for commercially important crab and fish species during critical and vulnerable early life stages[85,86]. In Mexico, 97% of fishing is small-scale[82] and they depend on healthy mangrove ecosystems to sustain the fish and invertebrate populations that sustain the fisheries. In Baja California Sur, where the BMCL is located, 31.7% of the small-scale fishery comprised species related to mangrove forests,[83] which shows just how important this ecosystem service is to maintaining the state's economy.

Aburto-Oropeza et al. (2008) analyzed the relationship of mangrove cover and the production of many important commercial fishery species in the Gulf of California[83] by comparing the volume of fisheries landings in 13 coastal sites with their respective mangrove cover. The fisheries data collected included 9,146 landing records registered between 2001 and 2005 in 25 local offices of the Mexican National Fisheries and Aquaculture Commission (CONAPESCA) in the coastal states of Baja California Sur, Sonora, Sinaloa, and Nayarit. Among several environmental variables (estuary size, sea-grass beds, latitude, local rainfall, and fishing effort) only mangrove forest area had a significant correlation with landings. A positive relationship between mangrove area and fish and blue crab landings was found—which means that the more fringe mangrove occupying the coast, the higher the populations of fish and blue crab. The study found that 31.7% of small-scale fishery landings during that time period relying on these coastal forests. Furthermore, the 11,600 tons of fish and blue crab landed during the years investigated, generated an average annual income of US$19 million for fishers in the 13 fishing regions; 2,508 tons of this seafood were caught in Bahia Magdalena. With these numbers, Aburto and his colleagues estimated that the value of the productivity of a hectare of mangrove was US$37,500 annually.

Smaller mangrove ecosystems (like those located in the Baja California peninsula) were characterized by high profit fish such as snappers and snooks. The findings of Aburto and colleagues suggest that the fisheries-based long-term productivity value of one hectare of fringe mangrove in 6 years is 200 times higher than the standard value established by the Mexican National Forest Commission of US$1,020 per hectare. The values attained were conservative with a 5% discount rate and lack of consumer surplus inclusion. Given Mexico's annual population growth greater than 1% and global declines in fisheries catches, supply shortage will most likely increase the value of fishery services provided by mangroves, rather than decrease the estimates attained. Food production has important implications for human welfare and research shows that investing in conservation and restoration of mangrove forests to guarantee healthy critical habitats for commercially important fish and invertebrate species can result in significant benefits to society.

Eco-Tourism

Coastal ecosystems represent between 40% and 70% of the estimated economic value of all ecosystems on Earth.[87] Fisheries provide essential income to coastal communities, however; there are climate-change related losses to global fish catches extending to the U.S. $ 10 billion by 2050, predominately in developing countries with high fisheries dependence.[88] In the short term, non-climatic drivers such as overexploitation are threatening the fisheries and thus the economic well-being of coastal communities.[89] Alternative livelihoods or supplemental income must be sought for affected coastal communities to remain resilient.[90] When coastal ecosystem conditions have a higher abundance of sea life and are sustainably managed, increased resiliency and recovery potential have been shown.[8,91–94] As mentioned previously, mangrove ecosystems and lagoons are reservoirs of biological diversity as they are nurseries connected with coral and rocky reefs and seagrass beds.[84–86] Increased abundance and diversity of marine life provides a valuable economic opportunity for the eco-tourism sector which can become permanent sources of benefits if sustainably managed.[91,92,95]

Eco-tourism is currently a major source of income for coastal communities globally[96,97] through diving, bird watching, sport fishing, and whale watching. The high willingness-to-pay of tourists to observe pristine marine life has been shown;[99] for example, dive tourism and the associated service industry are currently a billion-dollar global industry.[98] Arcos-Aguilar and colleagues (2021) estimated the economic importance, gross and net revenues, of the diving industry in Mexico[8] at US$455 million and US$725 million annually using data from 864 diving sites. These estimates are comparable to the revenues produced by the combination of artisanal and industrial fisheries in Mexico, leading the authors to suggest that small-scale diving operations have the potential to facilitate a sustainably managed eco-tourism industry. This can support steady economic growth in coastal communities in Mexico and can be used as a model for other areas that have not harnessed their full eco-tourism capabilities.

Whale watching is another ecotourism activity with significant economic potential. Whale watching of the “Baja born” gray whale in the BMLC generated a net benefit of Pesos 3.4 million (US$260,000) for local communities during the 3-month annual whale watching season according to Schwoerer and colleagues (2016).[100] Gardea-Ojeda and colleagues (2002) used the Travel Cost Method to valuate ecotourism in Baja California Sur, using the records of visitors kept by the local tour operators[101]. This study found that total travel costs incurred by tourists visiting Laguna San Ignacio in 2002 were estimated in US$4,842,948 and their mean travel cost for visiting was around US$1,440 per individual tourist. These studies and others show that the considerable amounts of money paid by tourists may represent a good index of a general willingness to pay for visiting Baha California Sur and therefore of its high economic value.

Further research is necessary to pinpoint an exact value for eco-tourism in the BMLC directly related to mangrove. The BMLC is already known to be a tourist hotspot for SCUBA diving, snorkeling, bird watching, sport fishing, and whale watching—thus the expected value of the ecosystem services provided by BMLC’s mangrove forests is significant.

Social Capital

Social capital can be broadly defined as relationships of trust, reciprocation between individuals, and networks among people that can be drawn upon for individual or collective benefit[102]. The significance of social capital as an asset that groups of diverse stakeholders can use to increase the success of management goals is apparent[103,104] in the context of community-based collaborative resource management (CBCRM). A group of diverse stakeholders voluntarily working together to manage a natural ecosystem, can obtain goals more readily with increased social capital[102]. Social capital, as it is a form of cooperation, can lead to opportunities such as an increase in financial capital, human capital (as knowledge is combined), and natural capital (in the form of natural resources) resulting in increased overall resilience of local communities.[105,106]

The link between natural capital and strong social bonds at the community level can enhance ecosystem service flows in the long term through sustainable management of natural resources.[107,108] Community bonds can then, at the same time, be affected by ecosystem change. As natural ecosystems are increasingly productive, stocks of social capital increase, or social stocks could decrease upon ecosystem degradation.[52,109]

Social capital is a cultural ecosystem service and a primary constituent of human well-being derived from many other ecosystem services.[26] Barnes-Mauthe and colleagues (2015), valued social capital and explored its role in facilitating management goals in a locally managed marine area.[110] Importantly, social capital was operationalized by developing a context dependent framework driven by qualitative information on what social capital meant to the local community. How the community understood social capital to be related to ecosystem service flows agreed with the definition provided in the Millennium Ecosystem Assessment 2005.[26] Discrete choice experiments, rating/ranking games and face-to-face surveys were conducted to explore local stakeholders agreement that the community-based restoration project Velondriake Locally Managed Marine Area [LMMA]) had increased social cohesion between villages. The importance of social cohesion was ranked among other ecosystem services and 86% of participants agreed that it increased due to the Velondriake Management Committee facilitating community decision-making. Participants valued social cohesion above commercial fisheries and short-term income from fishing. This suggests communities are willing to make trade-offs to support long-lived increases in social capital. Notable was that cultural bequest—the value put on future generations using the community's natural ecosystem—was strongly valued and prioritized over social cohesion, at times.

Where humans benefit from ecosystem services offered by the natural world, a social-ecological system is created which must be considered when conserving valuable ecosystem services.[113] Even the most technically feasible conservation projects can fail without long term involvement by local community members.[111] Unsustainable exploitation of natural ecosystems can continue if social interventions are not carried out and local community members are not involved in local resource management.[111] Aburto and colleagues (2018), found that co-management and participatory management were key to achieving economic sustainability in the Punta Abreojos small-scale fishery.[112] Brown and colleagues (2014), proved the effectiveness of CBCRM process to resolve both biophysical and socio-political issues underscoring mangrove forest degradation in Indonesia.[103] Socio-political adaptations included land tenure settlement, increased use of training programs, gender assessments and sensitization, enhanced community organizing, coordination with numerous government agencies, and participatory monitoring. As such, in Indonesia, the CBCRM process has been recommended by the Ministry of Forests – Natural and Protected Forest Management Agency (PHKA) for a project involving restoration of 4000 ha of mangroves and is also being considered for an 60,000 ha mangrove restoration project.[103]

Polyzou et al. (2011) explored the determinants of willingness-to-pay for ecosystem services[114] and found that four components of social capital were emphasized. Those components were: (1) social trust concerning trust towards people in general or to specific social groups; (2)

institutional trust, referring to trust in institutions functioning in a community (e.g. Government, Local authorities, NGOs); (3) social networks and civic participation, relating to the involvement of individuals in formal and informal networks and also their interest for collective issues; and (4) compliance with social norms, hence the tendency of individuals to comply with formal or informal community rules that protect the common good. Using a Contingent Valuation Method (CVM), the authors concluded that social capital is a significant explanatory parameter of willingness-to-pay.

Orlowski and Wicker (2015) estimated the actual monetary value of social capital[115] by including social capital in a well-being function and estimating the shadow price for social capital. This empirical analysis was based on individual income and preference of social capital components data from the European Values Survey covering 45 European countries of in-person surveys. The authors found that a one standard deviation increase in interpersonal trust (people's helpfulness) is worth an extra US$10,060 per individual per year on average in terms of foregone income. The same increase in the importance of meeting nice people in one's leisure time is worth an extra US$2,809 per individual on average annually.

There is an increasing body of research on the various ways to estimate the monetary value of intangible and non-market goods generated by ecosystems and their biodiversity. As efforts to conserve and manage BMLC, including its mangrove forests, social capital needs to be considered and valued to understand the true value of this lagoon complex. In doing so, we will be creating the best possible conditions for conservation efforts to successfully run in the long term.

Conclusions

The mangrove forest of Bahia Magdalena and other coastal lagoons in the Baja California Peninsula provide a multitude of ecosystem services to both local communities (water quality enhancement, shoreline stabilization/protection, fisheries benefits, income from tourism, social capital) and the world at large (carbon sequestration, migratory species' habitat, eco-tourism). Placing monetary values on natural ecosystems and the services they provide is often criticized by those that believe we cannot "value the priceless" because each natural ecosystem is essential and non-replicable. While this sentiment is understandable, the reality is that society is explicitly or implicitly valuing nature daily as land and resources are consumed or transformed to benefit from them. More often than not, the cost of partially or completely losing an ecosystem service is ignored. Failing to place a value on the opportunity cost of conserving ecosystems, or to value ecosystem services correctly, implies we cannot provide the necessary incentives for communities to invest in conservation since their real worth is not revealed or known.

Understanding the trade-offs, both monetary and non-monetary, involved in land or resource use is essential if society seeks to maintain a sustainable flow of ecosystem services, now and in the future. The more knowledge we have about the value of nature's services, the better our understanding of how positive and negative externalities generated by changes in an ecosystem will be. With this knowledge, decision makers will be better prepared to design policies that benefit society and balance resource use with conservation.

Communities located within or nearby critical ecosystems such as mangrove forests, must perceive that transferred benefits are in their best interest which in turn will become an incentive for them to cooperate in identifying and working towards shared environmental goals. Monetary values are assigned based on the choices people make based on perceptions of their own welfare and their willingness to make particular trade-offs. Market based valuation techniques work under the assumption that the sector of the market that is willing to pay for environmental values (external stakeholders) should compensate local stakeholders for the opportunity costs they incur by forgoing economic production that would otherwise deteriorate the resource or ecosystem in question. A low opportunity cost (e.g. the pay-off is worth giving up certain choices) is the best incentive to choose one alternative over another. Therefore, the willingness of different sectors of society to accept the opportunity costs of conservation is crucial to the long-term success of direct payment strategies.[116] This willingness can only be achieved through a process of bargaining and negotiation among diverse groups of stakeholders and the presentation of an imperative case for conservation based on both ethical and economic grounds.

A variety of strategies have been developed to help create incentives for communities to invest in conservation and management programs. For example, Payments for Environmental Services (PES) were preferred by *La Sepultura Biosphere Reserve*, Chiapas, Mexico community members for their directness and short-term results. Specifically, local stakeholders gravitated towards Integrated Conservation and Development Projects (ICDPs) because they raise environmental awareness, facilitate long-term conservation, and helped build productive capacity and social capital.[117] A coexistence of payment programs (*i.e.* PES, carbon emission trading credits, philanthropy) and an ICDP in a proper sequence, while reinforcing intrinsic value-based attitudes, could facilitate meeting conservation management goals.

"It seems like a reasonable possibility to start giving some fish to mitigate momentary needs while producing rods to ensure long term self-provisioning. We should not forget, however, that no rod would work if there are no fish in the river, i.e. achieving sustainable rural livelihoods will be difficult if in the short term the resource-base is fully degraded."

- Garcia-Amado and colleagues.

Appendix

Table 2

Summary of monetary values for ecosystem services provided by mangroves in the Bahía Magdalena Lagoon Complex (values in $US/ha/year).

Ecosystem service	Mukherjee et al. (2014) Value[a] / adusted value[b]	Salem et al. (2012) Value / adjusted value[b]	Regional Study	Regional study value / adjusted value[b]	Best value[b]
Carbon sequestration	195/256	967/1,144	Kumagai et al. (2020)	380/399	399
Habitat protection for migratory species			Rubio-Cisneros et al. (2014)	164[c]	164
Water quality enhancement		4,748/5,619[d]			5,619
Coastal protection	9,038/11,843[e]	3,116/3,687			11,843
Nursery for target commercial fisheries species	17,090/22,395	23,613/27,943[h]	Aburto-Oropeza et al. (2008)	37,500	37,500[i]

[a] Article used 2007 values.
[b] Value adjusted with inflation to 2021 using the US inflation calculator.
[c] Per hectare of lagoon supported by the mangrove.
[d] Includes air purification.
[e] Summed 8,459/11,085 (coastal protection) + 579/665 (protection from sedimentation) to obtain the table value.
[f] Includes both coastal protection and protection from sedimentation.
[g] Includes fisheries and aquaculture.
[h] Includes commercial and recreational fishing, natural materials harvest and energy sources. Includes values from articles utilizing Net Factor Income (NFI) , Market Price (MP) and all other production functions.
[i] Includes fish and blue crab fisheries only and regional MP was used.

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