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SPECIAL ISSUE: CONCEPTS AND CONTROVERSIES IN TIDAL MARSH ECOLOGY REVISITED

Ecosystem Services: Delivering Decision-Making for Salt Marshes

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Abstract

Tidal marshes are one of the world's most economically valuable habitats; yet, they have experienced large and persistent declines globally. Increased knowledge of the ecosystem services delivered by marshes has become a powerful tool to conserve and restore them. But hesitancies regarding valuations and their application in decision-making remain. Here we draw on the literature and collective experience of participants in the "Concepts and controversies in tidal Marsh ecology revisited" workshop, November 2 and 3, 2019, Mobile, AL, to provide a concise snapshot of the current field of salt marsh ecosystem service valuation, discuss the possible risks in salt marsh valuation, and the importance of stakeholder engagement to mitigate them. We provide examples of the application of valuation in conservation-related decision-making, illustrating the growing operationalization of ecosystem services in incentivizing salt marsh conservation and restoration. Ecosystem service quantification and valuation is already playing an important role in decision-making by coastal risk managers, insurers, engineers, and policy makers. While there are legitimate criticisms of valuation techniques and remaining uncertainties in ecosystem service delivery that arise both through natural variability across space and time and through differing and shifting cultural values, our perspective is that the rise of big data, the development of valuation techniques, a growing understanding and application of environmental justice practices, and increasing interdisciplinarity to tackle these complex issues are paving the way for valuation to play a critical role in decision-making around salt marshes.

Keywords Ecosystem service · Tidal marsh · Salt marsh · Coastal protection · Coastal management · Valuation

The Value of Salt Marshes

It has been over a decade since Daily et al. (2009) called for a world in which "…institutions appreciate natural systems as vital assets, …and routinely incorporate their material and intangible values into decision-making." Salt marsh valuation is increasingly common, and the values of ecosystem services derived from these systems are now widely recognized. Less than 1% of the earth is covered by tidal marshes; yet, they are estimated to account for ~20% of the global value of ecosystem services (Costanza et al. 2014). This value arises primarily from the provision of nutrient cycling, fisheries enhancement, carbon sequestration, coastal protection, and recreational opportunities (de Groot et al. 2012). These ecosystem services

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are primarily the product of both the physical structure of the salt marsh reducing wave energy and trapping sediments as well as providing refuge for fish (Shepard et al. 2011; zu Ermgassen et al. 2021). Their influence on nutrient cycling and creating abiotically diverse microhabitats for microbes is also widely appreciated (Cao et al. 2008).

Salt marshes are widely recognized to have high societal value, which is one reason why wetland conservation has a high net return (Bradbury et al. 2021). Salt marshes are key contributors to "blue carbon" sequestration, with total carbon burial rates similar to that of mangroves (218 ± 24 g C m^{-2} $year^{-1}$ and 226 ± 39 g C m^{-2} $year^{-1}$ respectively), and far exceeding burial by seagrass (138 ± 38 g C m^{-2} $year^{-1}$) (Mcleod et al. 2011). They can play a key role in stripping out and regulating nutrients in the coastal zone, delivering services worth thousands of dollars per hectare as estimated through synthetic replacement costs (de Groot et al. 2012).

Marsh restoration can be a cost-effective means of improving coastal defenses, particularly in comparison with other hard infrastructure measures (Reguero et al. 2018). Salt marshes do this by attenuating waves and storm surge and by reducing flooding and erosion (Shepard et al. 2011; Narayan et al. 2016; Narayan et al. 2017; Siverd et al. 2020). Narayan et al. (2017) used a widely accepted insurance industry risk model to estimate that salt marshes reduced property damages during Hurricane Sandy by as much as $625 million dollars and 16% annually in New Jersey. In the Gulf of Mexico, wetland and oyster reef restoration can bring more than $7 in direct flood damage reduction benefits for every $1 spent on restoration (Reguero et al. 2018).

The contribution of salt marshes to fisheries productivity in coastal waters is believed to be significant (e.g., Turner 1977; Baker et al. 2020), primarily due to their role in providing important nursery grounds for juvenile fish and invertebrates at the marsh edge (zu Ermgassen et al. 2021), but also production within the wider estuarine and coastal systems through the export of organic matter (Deegan et al. 2000; Bennett et al. 2021). This habitat value benefits both commercially harvested species and recreational catches.

Salt marshes also benefit human well-being in a broader way by improving health, social cohesion, spiritual and cultural fulfillment and through a connection to nature (Rendón et al. 2019). The contribution of salt marshes to human well-being is, however, likely to vary by distance to the salt marsh, with local populations more likely to also be impacted by potential disservices arising from salt marshes, such as mosquitoes or allergies (Rendón et al. 2019). Thus, the value of ecosystem services is fundamentally a product of stakeholder perceptions/preferences, and the values attributed to them often vary with culture, socio-economic status and location (Zoderer et al. 2019).

Evidently, the key drivers of salt marsh value are well characterized, and the ecosystem services identified above are among the most widely recognized and valued (de Groot et al. 2012). But how do we ensure this broad information base is really delivering for salt marshes within the contemporary management paradigm? We consider this question by providing a concise snapshot of the current state of ecosystem service valuation for salt marshes, including discussion of some of the factors motivating valuation, some examples of how this supports decision-making, and potential risks associated with how this is approached. We believe that the delivery of ecosystem service valuation into the decision-making process lies at the nexus of research and communication, and highlight some opportunities that may assist researchers and practitioners, particularly ecologists, to continue the development of ecosystem service valuation, and its role in decision-making around salt marsh ecosystems.

Why Quantify the Value of Ecosystem Services?

The growing understanding of the value of salt marshes and the importance of the services and benefits they support has led to a slowing down of the historic losses. However, many threats still remain, such as land use change, coastal squeeze, invasive species, pollution and, increasingly, sea level rise (Gedan et al. 2009; Valiela et al. 2009). Quantification of the ecosystem services derived from salt marshes allows this information to be incorporated into quantitative decision-making frameworks, alongside other considerations. It can be a useful decision-support tool—one that allows for market and non-market benefits of habitat conservation and restoration to be assessed by comparing them against alternative management scenarios.

Quantification of ecosystem services has additionally proven effective in attracting both traditional and non-traditional funding sources from a wide range of stakeholders (Goldman and Tallis 2009; Matzek and Wilson 2021). This is exemplified in salt marshes by the growing pool of funding for natural infrastructure for flood risk reduction and other services. Increasingly funding for nature-based flood protection is recognized as a specific purpose in Europe and by development organizations, and increasingly often addressed through post-disaster recovery funds in the US (Colgan et al. 2017; Beck et al. 2019). Further, recent innovations such as catastrophe and resilience bonds offer potential approaches to combining recovery and risk reduction, while green bonds may provide pre-disaster financing under appropriate conditions (Colgan et al. 2017; Beck et al. 2019). These opportunities are currently underutilized, but increasing valuation efforts and interdisciplinary experience means investing in coastal habitats for coastal defense and other ecosystem purposes will become more commonplace.

Taking quantification a step further and attributing monetary values to the benefits/costs, has further functions. One potential application is that monetary valuation can be a first step in the creation of financial instruments that aim to incentivize conservation, such as payments for ecosystem services (Gómez-Baggethun and Ruiz-Pérez 2011). Monetary valuation also allows for the translation of the value of ecosystem services into a common unit that can be compared "like-for-like" with other considerations within the framework of monetary cost-benefit analysis. Additionally, valuation provides a means to communicate some of the less tangible ecosystem services in a way that is more meaningful or comparable for various stakeholders, such as nutrient removal expressed in terms of the cost for remediation, rather than simply the mass of nutrients removed.

Natural resource managers are interested in both the absolute and relative values of salt marsh habitats. In this context, the absolute value is, for example, the dollar-value or number of people benefiting from marsh services. The relative values are the percent differences in values, which are used for comparison purposes when values such as dollars are difficult to assess or not appropriate for decision-making. For degraded salt marsh systems, the absolute value is useful for assessing the potential benefits of restoration against the costs of repair, or against retaining existing land uses. Additionally, the absolute value is essential for the development of Natural Capital Accounts, which are being increasingly adopted as a mechanism for tracking changes in natural capital stocks to complement and address shortcomings in the main economic progress indicators such as gross domestic product (Ruijs et al. 2019). The relative value is useful to prioritize competing areas or habitats for conservation or enhancement. In south-eastern Australia, for example, much of the salt marsh area that is still available for potential repair and restoration has been converted to agriculture (Taylor et al. 2018). Farmers often have reasonably precise knowledge of the per-hectare value of this reclaimed land, such as the crop-biomass it can produce or the value for cattle grazing. Valuing the ecosystem services from salt marsh habitats for fisheries (for example), provides values to compare with these other land uses. These comparisons can be used to mount an economic case for restoration. The development of robust business cases supported by economic analyses is now a relatively standard requirement for access to public funds such as those for hazard mitigation and climate adaptation (Colgan et al. 2017). Consequently, the valuations of ecosystem services derived from salt marsh are increasingly essential to access many funding sources. The valuation of ecosystem services such as flood protection from wetlands and other coastal habitats, also offers opportunities to finance their conservation and restoration. Colgan et al. (2017) showed that, once these benefits are quantified and monetized, many of the financial tools used to fund gray infrastructure (such as seawalls) can be applied to natural infrastructure. These financing measures cover a wide range of tools including infrastructure bonds, special purpose tax districts and resilience bonds. Values can be used to inform benefit:cost ratios required for support of hazard mitigation and disaster recovery projects from state and federal agencies. Coastal risk managers, insurers, engineers and policy makers are increasingly incorporating the values and benefits of nature-based ("green") defenses for reducing risk from storms and sea level rise in their tools, guidelines and policies. For example, new policies at FEMA "allow for easier inclusion of nature-based solutions into risk-based mitigation projects." The US Army Corp has a research program on Engineering with Nature and will soon release guidance on the use of natural and nature-based features for coastal defense (Bridges et al. in press). The insurance industry is including ecosystem services in its data and tools (Retsa et al. 2020). Insurance is also being used to protect habitats such as the Mesoamerican reef from storm damage and the industry is exploring other tools for insuring nature (Kousky and Light 2019; Reguero et al. 2020).

Salt marsh habitats also provide recreational, cultural and other benefits that should similarly be accounted for when making coastal investment decisions, including for restoration (e.g., as for oyster reefs; zu Ermgassen et al. 2016) and adaptive management. Furthermore, where the biotic and abiotic drivers of ecosystem services are understood, salt marsh conservation can be designed to maximize the ecosystem services of greatest interest to stakeholders (Gilby et al. 2020).

How Risky is Quantifying Value?

While ecosystem service quantification and monetary valuation have an important role to play in informing environmental management, monetary valuation in particular comes with potential risks (Silvertown 2015). There are a variety of quantification methods of varying rigor, from direct measurements of the change in ecosystem service delivery resulting from a specific ecological or management intervention, through to value transfer approaches where values derived in certain contexts are transferred to other contexts. A key criticism of valuation is that some forms of value are "incommensurable"; i.e., they are from separate value domains and cannot be adequately translated into the same units to permit like-for-like comparison, such as within monetary cost-benefit analysis (Martinez-Alier et al. 1998). Participants in valuation studies may form some of their values in ways that defy measurement using current valuation methods and thus are often omitted from valuation. For example, complex emotional connections that people can have with coastal ecosystems cannot be completely captured in a monetary form for cost-benefit analysis (although deliberative valuation can partially address this (Kenter et al. 2016)). Economic justifications and tools for incentivizing salt marsh conservation must therefore be applied appropriately. For example, it is not appropriate to use purely economic justifications and messaging to motivate salt marsh conservation in communities with pre-existing cultural or intrinsic motivations to care for, or interact with, salt marshes. While ecosystem service assessments can be helpful in engaging stakeholders (Friedrich et al. 2020), a two-way process of stakeholder engagement can also allow for the relative importance of values, including cultural values to be identified (Darvill and Lindo 2016). Therefore, a well-managed stakeholder engagement process has the potential to largely mitigate the risk of decisions being made on the basis of economic valuations alone, while allowing valuation to inform the process. Stakeholder processes must, however, account for power relationships in order to ensure an equitable outcome (Felipe-Lucia et al. 2015).

Another criticism leveled at monetary valuation is that it can obscure complicated distributional dynamics and therefore inadvertently create a justification to over-invest in marshes in relatively wealthy areas, and underinvest in relatively poor areas. A key predictor of the value of salt marsh services is the income level of the particular affected community (e.g., Rao et al. 2015 for shoreline protection). Wealthier areas have, on average, more expensive coastal infrastructure, and so valuation derived from "avoided damage costs" will generate systematically higher economic values in these contexts, even if the total number of beneficiaries is the same or greater in a relatively poorer community, and people's level of vulnerability to coastal hazards is lower in wealthier areas. For example, Menéndez et al. (2018) showed that mangrove areas in the Philippines with high value for flood protection of people and particularly people living in poverty, were spatially distinct from mangrove priority areas for reducing the economic damages from flooding; a trend that was also observed in a subsequent global analysis (Menéndez et al. 2020). The risk of this translating into inequitable investment is increased because coastal communities often lack the influence on political processes of decision-makers and landowners (Berbés-Blázquez et al. 2016). As a result, there have been calls to make equity considerations central to investment decisions in coastal habitats through processes that engage with communities and marginalized stakeholders and that emphasize procedural justice and thus address the bias towards the more well-resourced partners (Locatelli et al. 2014). It should be noted that while discrepancies between economic benefit and human vulnerability exist, it is challenging to identify cases where economic benefits are favored over a more broadly perceived benefit. Stakeholder engagement and empowerment of underserved communities are now widely mandated, albeit variably, by existing environmental justice policy in many countries (e.g., Mitchell 2019; Provost and Gerber 2019) and this, alongside a growing public understanding of environmental justice issues, should go some way to addressing these risks.

Another possible risk in monetary valuation is that trust in the outcomes may be eroded because methodological differences result in alternative value estimates for the same service, or misunderstandings can arise. For example, numerous different estimates exist of the social cost of carbon (the estimated monetary cost of emitting a unit of CO2eq), reflecting different, often implicitly ethical, methodological choices. Typically, these values are derived from analytical methods that try to infer the damage cost of carbon, which reflect the welfare loss to society of emitting an extra tonne of CO_2 in the form of human health impacts, environmental disasters etc. (Tol 2011). However, methods differentially incorporate key considerations such as the risk of activating non-linear climate tipping points, the treatment of uncertainty, and discount rates (Dietz et al. 2018), and many important determinants of future damages are still inadequately addressed (DeFries et al. 2019). Effective and transparent communication about the basis of each valuation, along with discussion with stakeholders as to their beliefs or risk thresholds, is therefore critical when using ecosystem services to advocate for marsh conservation.

Where local data are lacking, benefit transfer approaches can be applied but risk resulting in inappropriate site-specific valuations (Himes-Cornell et al. 2018). Nevertheless, in the absence of local data, clearly communicated valuations derived from other locations can play a key role in informing conservation decision-making. For example, stakeholders engaging in bivalve reef restoration in Australia have been motivated to a great extent by fish production enhancement values generated in the U.S. (Gillies et al. 2015). Although the relative and absolute value of the fish production service in Australia was unknown, the fact that this service is driven primarily by the universal ecosystem engineering properties of bivalves (zu Ermgassen et al. 2020), provided sufficient confidence for practitioners to communicate the potential ecosystem service gains of restoration to decision-makers.

The Importance of Communication

The quantification of ecosystem services is an approach through which the values of salt marshes can be communicated, and the economic case for conserving or restoring salt marsh habitats is substantial. But the quantification and valuation of coastal and marine ecosystem services has, until now, had a negligible impact on the policy process around the world (Milon and Alvarez 2019). This deficient impact can be partly attributed to insufficient communication of valuations (Sitas et al. 2014), while lack of a common understanding of the concept of ecosystem services is a barrier to the operationalization of ecosystem services in Europe (Carmen et al. 2018). Effective communication relies on developing a common understanding of ecosystem services across the diverse stakeholder groups. This “translation” between groups takes time and boundary organizations, such as the Cooperative Extension and/or Sea Grant systems in the USA, can help to generate common understanding through their existing roles in supporting communication between science-based and policy-based stakeholders (Carmen et al. 2018).

Communication plans need to account for the fact that not all aspects of the environment are equally important to all stakeholders and frame messages accordingly (Chong and Druckman 2007). For example, a recent experiment exploring the optimal messaging for promoting coastal habitat conservation found that messaging framed around economic benefits performed less well than purely factual messages highlighting the social and environmental benefits of coastal ecosystems (Dean et al. 2019). Whether ecosystem service valuation is the correct communication strategy is perhaps best explored through formal and informal needs assessments with specific stakeholder groups.

Finally, communicating exactly what elements of an ecosystem service are and are not included in a valuation, and what the underlying assumptions are of any model, is key to avoid misunderstandings and hence inappropriate application of ecosystem quantification. For example, fish production enhancement estimates from salt marsh edge habitats (zu Ermgassen et al. 2021), represent just one of the many services that salt marshes deliver. Even in the context of the benefits to fisheries, these estimates capture the nursery function of the edge alone, and not the numerous other identified benefits to fish production, such as providing feeding grounds to older fish. Communications and outreach about what is valued and how that value contributes a portion of the total value are key to avoiding perverse outcomes.

Improving Research and Communication About Ecosystem Service Valuation of Salt Marshes

The application of ecosystem service valuation frameworks for salt marsh ecosystems is increasing, and many recent studies demonstrate a variety of approaches which may be useful for quantifying the magnitude and flow of ecosystem services derived from salt marsh (Schmidt et al. 2020). Yet, there is a need to develop valuation approaches further, and in particular to incorporate and quantify non-market values and cultural services (Milon and Alvarez 2019). Although techniques such as hedonic pricing estimates, travel-cost methods and avoided damages or replacement costs can be used to value non-market goods, more pluralistic estimation techniques are needed to effectively capture many cultural values, or the value of satisfaction that such habitats can provide future generations (Chan et al. 2012). Estimation of these values is complex, challenging to validate, or relies on some prior knowledge of what user groups might be willing to pay for these benefits (Prugh 1999). Addressing this suite of conditions will require greater levels of collaboration between stakeholders, ecologists and social scientists, and a transition away from a strong focus on the biophysical underpinnings of value to one that incorporates cultural and social perspectives (Chan et al. 2012). These issues are not unique to valuation of salt marsh systems, and are reflected in wider debates regarding the need to incorporate broader conceptions of value and different value systems into the ecosystem services framework (Martín-López et al. 2014), and a general re-framing of ecosystem services as “nature’s contributions to people” (Díaz et al. 2018).

The assessment of ecosystem services at scales relevant for decision-makers is a critical issue. Research has shown that the magnitude of ecosystem services varies spatially and temporally and is dependent on factors such as habitat area, location, access and environmental setting (Koch et al. 2009; Spalding et al. 2017). Large scale ecosystem service models may not provide decision-makers with the information needed to make decisions at smaller scales. The relevant scale varies with both the physical and the socio-economic context of the decision (Willcock et al. 2016). Improved communication between researchers and possible user groups early on in valuation efforts will help researchers to deliver ecosystem service valuations at relevant scales and within the correct context such that the results can influence real life decision-making (Willcock et al. 2016).

An exciting area of development in ecosystem service valuation is to capture the perceived or actual change in value of ecosystem services through time. Temporal changes are challenging to model because they are a function of the complex of threats salt marshes face (e.g., Colombano et al. 2021), and the culturally determined and fluid attitude of beneficiaries. Yet as big data availability improves (e.g., Kimball et al. 2021), the underlying theory evolves, and greater interdisciplinarity is built into developing methods to capture cultural and social values, ecosystem service valuation science has the potential to meet this demand.

The results of decades of efforts to mainstream ecosystem services into decision-making and capital-allocation processes (Daily et al. 2009) has already unlocked an increasing number of opportunities to invest in salt marsh conservation and restoration. Ecosystem service valuations are already routinely integrated into many important decision-making contexts, from insurance, to government project financing, to marine planning. However, they have not yet reached their full potential. Addressing the temporal, spatial and interdisciplinary complexity associated with the valuation of salt marshes will enable valuations to be applied and adopted in a greater number of situations, and constructively inform salt marsh conservation decisions against a changing climatic and cultural backdrop.

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