Beneficiaries, Equity, and Trade-Offs in Estuarine and Coastal Ecosystem Services

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Abstract

Estuarine and coastal ecosystems support human populations in myriad ways. Traditionally, researchers have focused on the biophysical processes that underlie these benefits and their economic values. In the decade since the 1st Treatise, the literature on cultural ecosystem services, human health benefits, and the equitable distribution of societal benefits and burdens has grown tremendously. In this chapter we outline three dimensions of equity as they relate to estuarine and coastal ecosystems: procedural, recognitional, and distributional equity. We then apply the dimensions of equity to a suite of provisioning, regulating, and cultural ecosystem services. Finally, we explore trade-offs and beneficiaries of these ecosystem services using three case studies that consider equity in a variety of estuarine and coastal management decisions.

Key Points

- Estuarine and coastal science considers multiple dimensions of equity, including recognitional, procedural, and distributional equity.

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- Quantifying ecosystem services in multiple biophysical, economic, and societal metrics is useful for bringing together diverse communities with different interests and values, yet more work is needed to consistently disaggregate ecosystem service assessments so that they can be used to advance distributional equity.
- Many cultural ecosystem services are difficult to assess and attempts at quantification may misrepresent Indigenous ways of knowing, thus perpetuating existing inequalities rather than fostering recognitional equity.
- Transdisciplinary, co-development, translational and other similar approaches are improving procedural equity in estuarine and coastal science and practice, yet these efforts are challenged by power dynamics, structural barriers, and the limited capacity and fatigue of communities and community-based organizations to participate.

Introduction

Estuarine and coastal ecosystems lie at the interface between land-based society and ocean-based economies and environments. Saltmarshes, corals, seagrasses, mangroves, beaches, dunes, oyster reefs, and other shoreline and marine ecosystems provide communities with sources of sustenance, opportunities for recreation and cultural fulfilment, and buffers from natural hazards (Barbier *et al.*, 2011). Decisions about how to manage these ecosystems and their societal benefits can influence ecological structure and function, as well as the human populations that depend upon them (Arkema *et al.*, 2006; Tallis *et al.*, 2010). With coastal communities on the front lines of climate change–and at the nexus of an increasing intensity and diversity of coastal and ocean-related sectors–it is essential to understand which communities will be most affected by changes in estuaries and coasts, their cultural norms and values, and how to involve diverse groups in decision-making (Aminpour *et al.*, 2021; Crosman *et al.*, 2022; Halpern *et al.*, 2013).

The publication of the 1st Treatise on Estuarine and Coastal Science came on the heels of the Millennium Ecosystem Assessment (MEA; Millennium Ecosystem Assessment, 2005). The MEA catalysed a massive effort to characterise and quantify the benefits that natural systems provide to people (termed "ecosystem services"). For some time after the MEA, natural scientists focused their research on strengthening our understanding of production functions–essentially how ecosystem structure, function, and biodiversity influence provisioning of services (Beaumont *et al.*, 2007; Tallis and Polasky, 2009). Economists focused on developing and applying approaches to valuing benefits of natural systems, especially those not typically valued by markets, such as regulating services (Barbier *et al.*, 2008; Kareiva *et al.*, 2011). Combining ecological data and economic information, ecosystem service assessments were often conducted as desktop studies, with limited interaction among scientists, policy-makers, and communities and with minimal uptake into decision-making (Daily *et al.*, 2009; van Oudenhoven *et al.*, 2018). Relatively little attention was paid to exploring cultural ecosystem services, human health benefits, or the distribution of societal benefits of estuarine and coastal ecosystems among different groups of people (Chan *et al.*, 2012; Mandle *et al.*, 2021).

In the decade since the 1st Treatise, the field of social-ecological science has evolved tremendously (Daily and Ruckelshaus, 2022; Guerry *et al.*, 2015; IPBES, 2019). There is now a massive literature on ecosystem services, with a variety of well-established approaches for quantifying the societal benefits of nature using multiple biophysical, economic, and social metrics that resonate with diverse stakeholders (Guerry *et al.*, 2015; Tallis *et al.*, 2011). Several international initiatives, such as the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) and the 2030 United Nations Sustainable Development Goals (SDGs), reflect the growing awareness and interest in ecosystem services from international communities of research and practice (Díaz *et al.*, 2018; Tallis *et al.*, 2012). The global environmental, geopolitical, and social context has also changed since the 2011 Treatise publication. Climate change has come to the forefront, and the COVID 19 pandemic, and various social movements, such as "Black Lives Matter" and "Me Too", have highlighted disparities in access to societal, economic, and natural resources in the United States and beyond. As in many fields, all of these factors have come together to create a greater focus on beneficiaries, cultural and indigenous perspectives, equity, and trade-offs in estuarine and coastal social-ecological science. Yet major gaps still remain (Chan *et al.*, 2017; Pascua *et al.*, 2017). Studies frequently neglect to disaggregate beneficial and detrimental ecosystem services by different groups of people and to consider worldviews, values, rights, responsibilities, and capabilities. Power dynamics in research and in decision-making may often be overlooked in ecosystem service and equity assessments (Chan *et al.*, 2017; Loos *et al.*, 2023).

In this chapter, we discuss advancements and limitations in the estuarine and coastal literature on beneficiaries, equity, and trade-offs in ecosystems services since publication of the 1st edition of the Treatise. In the first section, we outline dimensions of equity as they relate to the particular context of estuaries and coasts. In the second section, we apply these dimensions of equity to a suite of provisioning, regulating, and cultural ecosystem services. Finally, we explore trade-offs and beneficiaries of these ecosystem services using three case studies that consider equity to inform a variety of estuarine and coastal management decisions.

A Framework for Equity In Estuarine and Coastal Ecosystem Services

Traditionally, conservation science, coastal management, and other natural resource related disciplines have understood equity as the distribution of income and other benefits of nature among different groups of people. More recently, considerations of social

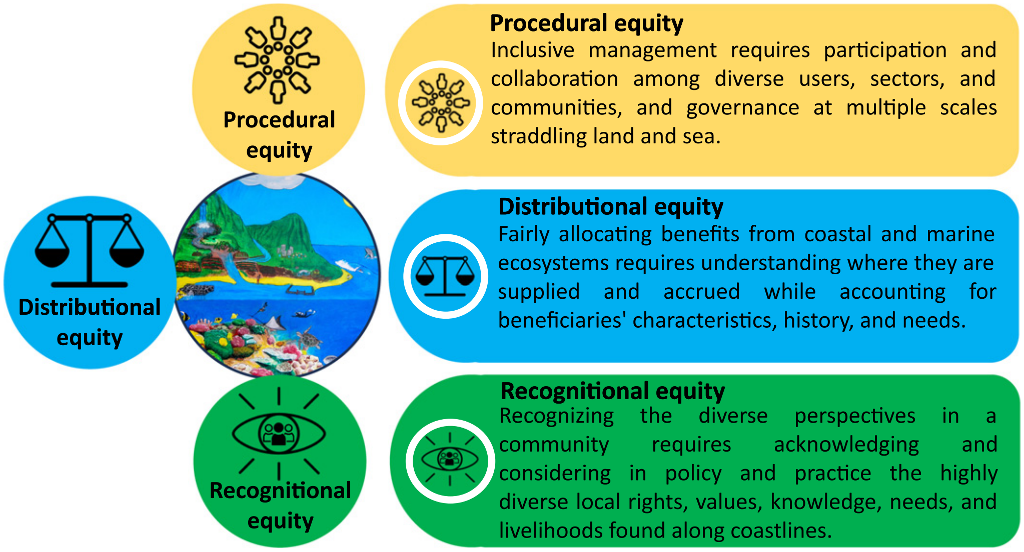

Fig. 1 Three dimensions of equity - procedural, distributional, recognitional - as they relate to estuarine and coastal ecosystem services and participatory processes. Artwork from Nick Brown, icons from the Noun Project.

equity have increased in sophistication, with researchers, government agencies, non-governmental organizations, industries, and communities recognizing multiple dimensions of equity (**Fig. 1**, (Loos *et al.*, 2023; Pascual *et al.*, 2014). In this chapter we focus on three dimensions that are well-known determinants of people's behaviour and discuss their relevance to estuarine and coastal social-ecological systems: procedural, recognitional, and distributional equity.

Procedural equity

Procedural equity involves inclusive, accessible, and authentic engagement and representation in a decision-making process that resolves conflicts and/or develops or implements programs or policies to allocate resources (Mcdermott *et al.*, 2013; Pascual *et al.*, 2014; Schlosberg, 2009). A chief goal with procedural equity is to address the processes that can lead to injustice by giving marginalized groups a voice, and fostering decision-making that responds more directly to the needs of disadvantaged groups (Lubchenco and Haugan, 2023; Schlosberg, 2009). Procedural equity is also relevant to research processes, especially to those in which scientific information is used to inform decision-making. A major shift in the study of social-ecological systems over the past decade is the mainstreaming of approaches typically referred to as "transdisciplinary research", "community-based participatory research", "translational research", "knowledge co-production", and "community-engaged research" (Hacker, 2013; Lang *et al.*, 2012; Ruckelshaus *et al.*, 2020). These approaches involve close collaboration among scientists, civil society, policy makers, and community members to conduct research that is both fundamental and solutions-oriented (Clark *et al.*, 2016; Lang *et al.*, 2012). A key goal of so-called transdisciplinary research in estuarine and coastal ecosystem management is to direct science capacity and innovation towards understanding and addressing real-world problems at the boundary between terrestrial and marine systems (Arkema and Ruckelshaus, 2017). The hope is to break-down patterns of parachute science in which scientists and funders from outside a community or region extract research questions and local knowledge with little practical or professional return to local populations and little to no help solving the challenges they face (Stefanoudis *et al.*, 2021).

Realizing procedural equity in science and practice can be particularly challenging in coastal and nearshore systems, both of which are often considered as a commons: a non-state, non-private shared resource that can only be protected if stakeholders who depend on it take collective responsibility for preservation and restoration (Brodie Rudolph *et al.*, 2020; Ostrom, 1990). Furthermore, because estuarine and coastal ecosystems bridge terrestrial and marine ecosystems, their management requires effective and inclusive participation by multiple actors and governance across multiple scales and sectors. Establishing jurisdiction over various resources can be complex and requires coordination among national, regional, and local authorities, as well as numerous users, including coastal communities, small-scale fishers, Indigenous groups, renewable energy developers, and neighbouring states to name just a few (Brodie Rudolph *et al.*, 2020; Crosman *et al.*, 2022).

Efforts to realise procedural equity can vary from enacting basic rights in decision-making and judicial processes to affirmative action for groups historically marginalised with respect to natural resources, such as women, the landless, and ethnic minorities (Lubchenco and Haugan, 2023). Other best practices include iterative engagement, investments of time and funding in long-term relationships, and compensation for participation. Yet, implementing these practices is not straightforward. Capacity is a major barrier for small communities, community-based organizations, and marginalized groups and it can be difficult for these groups to receive resources to support their participation. A major challenge to realizing procedural equity involves developing strategies for ensuring diverse representation in deciding how–and by whom–the ocean will be managed, conserved, and developed. Central to this challenge is determining how benefits and burdens will be distributed and who will be responsibile for environmental and social outcomes.

Distributional Equity

Distributional equity occurs when programs and policies result in fair allocation of benefits and burdens across all segments of a community, prioritising those with highest need (Mcdermott *et al.*, 2013; Pascual *et al.*, 2014). However, access to natural resources is rarely equitably distributed. Many of nature's benefits are accumulated by a few, and harms from development are frequently borne by the most vulnerable (Birkmann *et al.*, 2022). While patterns of inequity are often driven by historical events and contemporary processes, rather than a lack of information, ecosystem service data and tools can nevertheless help to shed light on distributional effects before decisions are made (Kittinger *et al.*, 2015). To address these information needs, the social-ecological literature has shifted from a focus on quantifying the total value of ecosystem services in an area of interest (locally, nationally, globally) towards understanding who is most likely to benefit from natural systems, where, how, and when (Arkema *et al.*, 2013; Brück *et al.*, 2022; Kittinger *et al.*, 2015; Mandle *et al.*, 2015a). A variety of metrics are increasingly being used to quantify benefits, including not just biophysical and economic metrics, but also beneficiary weighted, cultural, and health metrics, although there is still room for improvement (Mandle *et al.*, 2021). Multiple metrics are particularly important for understanding distributional effects because different metrics can lead to different answers about where to direct investments in nature to support vulnerable populations (Mandle *et al.*, 2015a).

Ensuring a more equitable distribution of goods and services provided by estuarine and coastal ecosystems is a major challenge. Overwhelming evidence suggests that current access to benefits of nearshore ecosystems, as well as exposure to harms, is distributed inequitably (Lubchenco and Haugan, 2023). This results in negative effects on the environment and human health, loss of livelihoods, limited financial opportunities for vulnerable groups, and challenges to nutritional and food security. Coastal zones are at the forefront of transitions related to renewable energy, minerals, and food, and bear the brunt of climate change (Crain *et al.*, 2008; Halpern *et al.*, 2008). In contrast to terrestrial systems, where benefits are often generated in relatively close proximity to where they are delivered, estuarine and coastal systems may generate benefits, such as coastal risk reduction or fisheries, that are delivered or experienced by communities many kilometres away. Central to predicting the distributional outcomes of decisions that affect estuaries and coasts is understanding who needs to be considered at what scale and conducting ecosystem service assessments that disaggregate benefits to include perspectives of the most vulnerable actors in the system. Who are the individuals, the households, the communities, and the inter-generational groups potentially affected by changes in estuaries and coasts and what are their dependencies on these ecosystems (Crosman *et al.*, 2022; Selig *et al.*, 2019)? Complicating these questions is the recognition that cultural norms, values, and historical experiences influence the extent to which communities experience and perceive benefits of estuaries and coasts; accounting for these differences can clarify which resources are available to whom and how they contribute to human wellbeing (Loos *et al.*, 2023).

Recognitional Equity

Recognitional equity is the "acknowledgement and consideration of local rights, values, visions, knowledge, needs, and livelihoods in policy and practice" (page 2 in Bennett, 2022; Loos *et al.*, 2023). Fostering recognitional equity involves examining which worldviews and assumptions are given power, and the extent to which different value sets are prioritized in decision-making processes. For example IPBES reflects the importance of considering recognitional equity in two main ways (Díaz *et al.*, 2018). First, the IPBES framework acknowledges that natural systems do not just provide societal benefits; they can also produce disservices for people. Furthermore, whether a particular ecosystem function is a service or disservice depends in part on cultural perspectives, norms, and experiences. In other words, what one group might find to be positive, such as open space within an urban area, another group might find to be negative. Second, the IPBES framework acknowledges that the very concept of ecosystems in service to people is misaligned with Indigenous values, which are often less human centric and more ecocentric (Lucero and Gonzalez Cruz, 2020). IPBES goes as far as to retire the ecosystem services concept, instead referring to "nature's contributions to people" to acknowledge that nature contributes to societal wellbeing, but that the worth of ecosystems is not solely for human gain. Recognitional equity involves elevating those differences in perspective, especially those which have traditionally been marginalized (Loos *et al.*, 2023).

Differences in perspectives about the services or disservices of estuarine and coastal ecosystems and species are many and varied. They range from conflicts between Indigenous groups and conservation organizations over whale hunting (Deutsch, 2017), to conflicts between federal and state agencies over approaches and priorities for renewable energy development to address climate change (Kotek, 2023), to positive versus negative interactions between people and wetlands that seem to have persisted for centuries (Friess, 2016). Accounting for how historical and cultural context influences shared understandings of justice is also a central part of recognitional equity (Pascual *et al.*, 2017). For instance, considering the complex legacies and effects of colonialism on current policies is key for researchers, managers, and local communities in estuarine and coastal ecosystems (Loos *et al.*, 2023). Examining recognitional equity requires explicit attention to the frames that governance actors, researchers, and communities apply to the diverse relationships between humans and the ocean. These frames can then be used to better understand and manage the suite of benefits people rely upon from estuarine and coastal ecosystems.

Societal Benefits of Estuarine and Coastal Ecosystems

In this chapter we use the terminology "ecosystem services", "nature's contributions to people," and "natural capital" interchangeably and employ the most recent IPBES framework to explore the societal benefits of estuarine and coastal ecosystems (Díaz *et al.*, 2018; IPBES, 2019). For each broad category of ecosystem service–provisioning, regulating, and cultural–we discuss in more detail three subcategories of benefits that are most relevant to estuarine and coastal systems (**Table 1**). For each subcategory, we provide a brief introduction to the ecosystem service, explaining both the biophysical and socioeconomic components of the service. Next, we discuss metrics typically used to measure societal values of the service. Finally, we explore the three dimensions of equity, including 1) how disaggregating beneficiaries can help reveal inequities in the distribution of each benefit, 2) how better accounting for stakeholder, knowledge, norms, and values can advance the science and practice of estuarine and coastal ecosystem services, and 3) approaches for inclusivity in decision-making processes affecting estuarine and coastal ecosystems.

Provisioning Services

The first category of benefits that we explore in this chapter is provisioning services. Provisioning services are products that can be extracted from estuarine and coastal ecosystems, such as fish, seaweed, shells, minerals, and marine compounds. These products serve numerous purposes ranging from food, fuel, medicine, and other uses (IPBES, 2019; Millennium Ecosystem Assessment, 2005). In the following section we discuss three subcategories of provisioning services flowing from estuarine and coastal ecosystems: 1) Food and feed, 2) Materials, and 3) Energy.

Food and feed

Coastal and estuarine ecosystems sustain communities worldwide by providing opportunities to harvest fish and invertebrates which have economic, social, and health benefits (Worm *et al.*, 2006). More than 2,200 wild species are caught and more than 600 are farmed in estuarine and coastal systems, including fish, invertebrates, algae, and aquatic plants (FAO, 2021). In 2020, the global value of fisheries and shellfish was an estimated USD 406 billion with 112 million tons harvested from marine waters; 33 million tons from aquaculture and 79 million tons from capture fisheries (FAO *et al.*, 2022). The beneficial qualities of seafood, also called "blue foods," make its availability an important part of global food security (Béné *et al.*, 2015), and it accounts for 17% of the global population's animal protein intake and 6.5% of all protein consumed (FAO, 2014). The livelihoods of millions of people are also supported by this service, with an estimated 38 million people directly employed in wild capture fishing and an estimated 800 million people deriving their livelihoods from some part of the seafood sector (Marine Stewardship Council, 2023).

While this chapter focuses on food benefits derived from fish, invertebrates, and aquatic plants, fisheries are unique for the variety of services they provide including, but not limited to, nutrient cycling, sustaining culture, and recreational opportunities (Holmlund and Hammer, 1999) (**Fig. 2**). Aquaculture, the organised rearing, feeding, propagation, or protection of aquatic resources for commercial, recreational, or public purpose (FAO, 2018), provides benefits like water filtration and coastal protection, in addition to being a source of food (Alleway *et al.*, 2019). Coastal and estuarine ecosystems support these important ecosystem services by serving as nursery (Beck *et al.*, 2001; Lefcheck *et al.*, 2019) and adult (Arkema *et al.*, 2019; Grabowski *et al.*, 2012) habitat, as well as being critical for feeding and spawning for many globally important commercial species (Seitz *et al.*, 2014). In the United States, an analysis from the early 2000s showed that 68% of the value of commercial fish and shellfish landed were estuarine species, as was 80% of the recreational catch harvested (Lellis-Dibble *et al.*, 2008).

While seafood is often recognized for its value as a healthy and important source of protein, it may be even more valuable as a source of micronutrients and lipids (Allison, 2011). Seafood contains important micronutrients like A and B vitamins, calcium, iron, zinc, and iodine, in addition to several essential amino acids and omega-3 long-chain polyunsaturated fatty acids (Béné *et al.*, 2015; Golden *et al.*, 2021). Increased consumption of seafood may reduce diet-related chronic diseases like hypertension, obesity, and certain types of cancers (Golden *et al.*, 2021), as well as the alleviation of issues associated with micronutrient deficiencies like anemia, rickets, and childhood blindness (Bennett *et al.*, 2018). While the micronutrient contribution of seafood is increasingly recognized, metrics used to measure these societal benefits are often over simplified to a few types of fish, or aggregated under the banner of 'seafood' in dietary recommendations and projections, which fails to recognize the heterogeneity in nutrient content in seafood (Naylor *et al.*, 2021; Tlusty *et al.*, 2019).

The importance of the nutritional, food security, and livelihood benefits of seafood is distributed unequally across coastal communities (Selig *et al.*, 2019), and assessing the benefits of seafood on a large scale can mask the variability in the importance of those benefits. Declines in fish populations are predicted to result in micronutrient and fatty-acid deficiencies in over 10% of the global population in the next few decades, especially in developing countries close to the Equator (Golden *et al.*, 2016). Already 63% of fish populations are below levels where sustainable harvest is likely possible, and many of the communities that depend upon those depleted stocks have food security concerns (Costello *et al.*, 2016). The nutritional benefits are particularly important for Indigenous communities where seafood is part of a traditional diet. The per capita consumption of seafood by coastal

Table 1 Categories and subcategories of ecosystem services based on the IPBES framework and modified to apply to estuarine and coastal ecosystems with examples of societal metrics and beneficiaries (IPBES, 2019). Procedural, distributional, and recognitional justice considerations should be accounted for in the processes to identify, characterise and, where appropriate, quantify ecosystem services, benefits and societal metrics.

Estuariane and coastal ecosystem services				
Category	*Subcategory*	*Beneficiaries (examples from text)*	*Societal metrics (examples from text)*	
Provisioning	Food	Production of food from wild or managed fisheries and aquaculture.	Coastal Indigenous communities; small-scale fishers; women subsistence fishers; women of childbearing age; coastal communities in low income countries; children; elders; people with chronic health issues.	% daily protein; micronutrient and fatty-acid content; employment in fisheries subsectors (e.g., small-scale fisheries; commercial fishers; gender); proportion of diet that is seafood; market value ($).
	Materials	Production of materials derived from organisms in cultivated or wild ecosystems for construction, clothing, ornamental, and other purposes (e.g., wood, shells, fibers).	Coastal Indigenous communities	# of uses of local materials from coastal ecosystems (e.g., firewood, construction materials, medicines); % of revenue from fishery exported for shells and jewelry; market value ($); % of income from selling local materials; access to harvest locations.
	Energy	Production of biomass based fuels (e. g., peat) and renewable energy from wind, waves, tides, and thermal gradients.	Remote coastal and island communities.	kW or MW of renewable electricity generated; BTUs of heat generated from biomass; access to reliable energy resources.
Regulating	Climate	Climate regulation by ecosystems through carbon storage and sequestration.	Global population, especially low lying communities, people in hottest parts of the world, people in poverty, elders, youth, people with disabilities.	Avoided social costs of carbon; acres of restored blue carbon ecosystems.
	Coastal water quality	Regulation-through filtration of particles, pathogens, excess nutrients, and other chemicals–by ecosystems or particular organisms, of the quality of water used directly (e.g., swimming) or indirectly (e.g., aquatic foods).	Resident population, tourists, children, elders, consumers of seafood.	Intermediate service; societal endpoints are in terms of contribution of water quality to other services; direct benefit often measured as cases of illness avoided.
	Coastal hazards	Amelioration, by ecosystems, of the impacts on humans or infrastructure caused by coastal flooding, erosion, storms, hurricanes, and other natural hazards.	Elders; youth, children, people with disabilities.	# of people, elderly, children, families below the poverty line, property values at risk; avoided damages from storms and sea-level rise.
Cultural	Physical and psychological experience	Provision, by coastal landscapes and seascapes of opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, tourism and esthetic enjoyment (e. g., hiking, recreational fishing, birdwatching, snorkeling).	Coastal residents; lower income households; older adults, especially living close to blue space; visitors to ocean and coastal environments; recreationists in ocean-based activities; participants in eco-tourism related sector.	# of visitors; tourism related expenditures; nature prescriptions; self-reported health outcomes (e.g., mood) from surveys; physiological outcomes (e.g., blood pressure, heart-rate).
	Learning and inspiration	Provision, by landscapes and seascapes of opportunities for the development of the capabilities that allow humans to prosper through education, acquisition of knowledge, and development of skills for human well-being, information, and inspiration for art and technological design.	Indigenous communities, youth, adults, researchers, women.	Stories, poems, songs, spiritual practices, place names etc. linked to estuarian and coastal ecosystems.
	Supporting identities	Coastal landscapes and seascapes as the basis for religious, spiritual, and social cohesion, including	people whose cultural heritage (including employment) depends on coastal and	custom-tailored, locally negotiated metrics are better than generic metrics when

Table 1 Continued

Estuariane and coastal ecosystem services *Category*	*Subcategory*	*Beneficiaries (examples from text)*	*Societal metrics (examples from text)*	
		provisioning of opportunities to develop a sense of place, belonging, rootedness or connectedness (e.g., cultural, sacred and heritage seascapes) and as the basis for narratives, rituals, and celebrations.	ocean resources (e.g., Indigenous communities, fishing communities)	characterizing supporting identity. Non-generalizable metrics with an array of caveats could include number or percent of community engaged in a ritual or celebration directly tied to coasts and estuaries (e.g., salmon festivals)

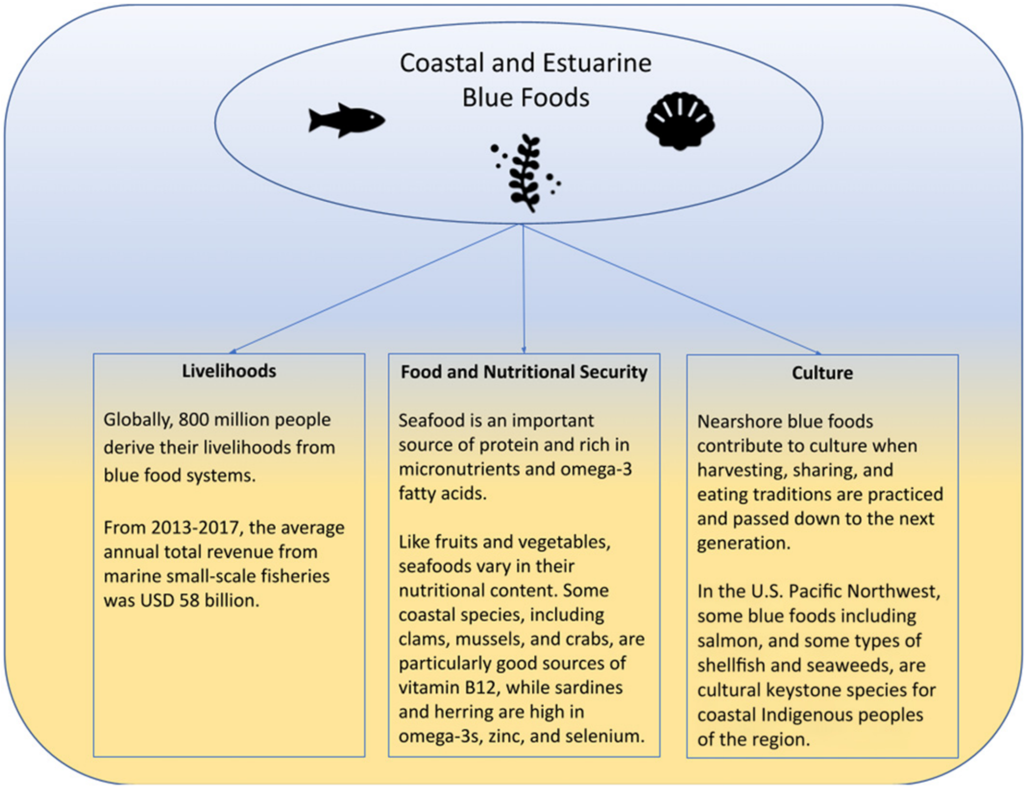

Fig. 2 Some of the benefits humans derive from seafood harvested from coastal and estuarine ecosystems (Garibaldi and Turner, 2004; Golden et al., 2021; FAO, Duke University and WorldFish, 2023, p. 20; Lynn *et al.*, 2013).

Indigenous people is, on average, 15 times greater than non-Indigenous populations in their countries (Cisneros-Montemayor *et al.*, 2016), and traditional diets have been noted for a variety of health benefits in Indigenous communities including the reduction of diabetes and heart disease, and an increase in micronutrient intake (Kuhnlein and Receveur, 1996; Mailer and Hale, 2015; Receveur *et al.*, 1997). In addition to physical health, traditional foods also support emotional, psychological, and spiritual health in Indigenous communities (Donatuto *et al.*, 2011; Lynn *et al.*, 2013).

In contrast to local Indigenous harvest and consumption, seafood is also a highly traded commodity in the global food system (Bellmann *et al.*, 2016). However, despite large contributions to the global food system, the importance of the nutritional and food security contributions of small-scale fisheries are under acknowledged in food and fisheries policies (Bennett *et al.*, 2021). Small-scale fisheries provide livelihoods for over 60 million people, with high geographic and socioeconomic heterogeneity (FAO *et al.*, 2023). These highly diverse fisheries feed roughly 1 billion people, a large portion of which are in the Global South, however, the focus on profits and exports typical of globalization has trade-offs with the nutritional benefits derived by locals diminished when seafood is exported (Hicks *et al.*, 2022; Short *et al.*, 2021). This tradeoff exacerbates inequities in global seafood value chains, especially for lower-income countries (Hicks *et al.*, 2022). Investments in fundamental structural shifts, such as changing property rights, that recognize small-scale fisheries and aquaculture actors' unique roles and needs may address these inequities (Short *et al.*, 2021).

Gender is also an underrecognized factor in assessing the benefits of fisheries, partially due to the fact that women are overrepresented in sectors that are rarely represented in fisheries statistics, such as informal and unpaid activities like subsistence fishing (FAO *et al.*, 2022). Nearly half of the blue food system workforce are women (FAO, 2021), yet they remain frequently excluded from decision making, and land and resource tenure (Barclay *et al.*, 2022; Mangubhai and Lawless, 2021); 55% of production-related policies have no reference to gender (Hicks *et al.*, 2022). However, when gender equality is greater, seafood tends to be more affordable and economically accessible (Hicks *et al.*, 2022). Women, particularly those who are pregnant or of childbearing age, also disproportionately benefit from the nutrients found in seafood (Spidalieri, 2020; FAO, 2014).

Like many ecosystem services, the food and livelihood benefits provided by coastal and estuarine ecosystems are vulnerable to the impacts of climate change (Free *et al.*, 2019; Tigchelaar *et al.*, 2021), threatening food security and sovereignty which are central to the resilience of social-ecological systems (Pinstrup-Andersen, 2009). Policy objectives that preserve the benefits of seafood to livelihoods and economies, while reducing the greenhouse gas footprint of dietary systems, can help support the contributions of blue foods to global food systems under a changing climate (Crona *et al.*, 2023). Meeting these objectives may require accounting for the perspectives and voices of those within the system as management responds to the impacts of climate change. Trust in institutions and a feeling of being able to influence decision-making are components of adaptive capacity (Barnes *et al.*, 2020), but many commercial fishers report feeling like they lack a voice in management (Nelson *et al.*, 2023; Runnebaum *et al.*, 2023), and marine protected areas, a conservation tool often employed to restrict overfishing, have often been designed and implemented without considering the impacts on the livelihoods, food security, and needs of local communities, including Indigenous groups (Ban and Frid, 2018; Bennett *et al.*, 2017; Bennett and Dearden, 2014). Equitable adaptation necessitates a consideration of communities' concerns (Matin *et al.*, 2018), and considerations of justice in adaptation are particularly important in fisheries systems with participants with diverse perspectives (Harper *et al.*, 2023). Equitable adaptation planning can be supported by improved ecosystem service assessments and conservation policies that better account for the food and livelihood benefits derived from coastal and estuarine systems by local communities.

Materials

In addition to fish for human consumption, harvested raw materials from a variety of estuarine and coastal ecosystems provide significant benefits to communities around the world. Raw materials are substances derived from ecosystems that are used in construction, clothing, and ornamental purposes (e.g. wood, peat, fibres, waxes, paper, resins, dyes, pearls, shells, coral branches), as well as live organisms used for decoration (i.e. ornamental plants, birds, fish in households and public spaces), company (e.g. pets), transport, and labour (including herding, searching, guidance, and guarding (Díaz *et al.*, 2018)). For instance, the export of shells and jewellery from giant clams, conch shells, coral, and pearls make up a substantial portion of fisheries on tropical coral reefs (Dewsbury *et al.*, 2016).

In the Pacific Islands, coastal communities rely on the use of coastal and mangrove species for firewood, construction and boat building materials, woodcarving, and medicines (Thaman, 2002) and Indigenous communities have used seagrasses (specifically *Enhalus acoroides*) in necklace making and stuffing pillows. Fishers also use seagrasses as fishing lures and nets as well as baskets for catching shrimp (Lauer and Aswani, 2010). In West Africa, mangrove trees and leaves provide wood for construction (houses, boats, farm tools, fishing gear), firewood and charcoal (for cooking, fish smoking, heating the brine to manufacture salt), drinks and alcohol, and traditional medicine (Cormier-Salem, 2017). In East Africa, the roots of seagrasses are used as a remedy against stings from rays and fish, for pain relief, wounds, and stomach problems. Seagrasses are also used as organic fertilizer and are reported as beneficial for the growth of coconut trees (De La Torre-Castro and Rönnbäck, 2004).

Among temperate communities, beaches and dunes provide sand that has been mined for centuries for extraction of minerals such silica and feldspar for glass and ceramic production (Barbier *et al.*, 2011). Indigenous communities in North America have used salt marsh reeds for a diversity of products including musical instruments, baskets, arrow shafts, and cigarette casings (Gedan *et al.*, 2009). Seagrasses are harvested and used as fertilizer in Tanzania, Portugal, and Australia, and have also been used for embroidery, erosion prevention, and mulch-use for home gardening (Dewsbury *et al.*, 2016). In the Chesapeake Bay, USA, seagrasses derived from by-catch or beach-cast are used to keep crabs moist during transportation (Barbier *et al.*, 2011).

Food and raw material provisioning have been assessed using a diverse set of valuation methods (Himes-Cornell *et al.*, 2018b). For raw materials that generate a market output (e.g., wood, fertilizer), price is often the metric used to reflect the value. However, some raw materials do not have market outputs, and therefore no observable prices. The failure to measure the value of these non-market services can lead to benefits being underpriced or excluded from ecosystem service estimates (Himes-Cornell *et al.*, 2018b). Moreover, the value of material benefits from ecosystems can be very context specific and can change greatly from one community or context to another depending on how the ecosystem is used and the unique ecological, economic, and social context (Himes-Cornell *et al.*, 2018a). Some material services provided by estuarine and coastal ecosystems have been poorly addressed (i.e., medicinal resources) or entirely absent (i.e., ornamental resources) in the literature, most likely due to limited data availability and the difficulty of valuing these services with economic methods (Himes-Cornell *et al.*, 2018b).

Purposive sampling approaches have been used to assign value to materials from estuarine and coastal ecosystems without a clear economic output (Queiroz *et al.*, 2017). For example, researchers in Brazil identified the portion of the population that worked directly with mangroves and could potentially benefit directly or indirectly from associated ecosystem services. They then used a variety of survey-based approaches, literature review, and focus groups to identify, characterize, and value the material benefits of mangroves (Queiroz *et al.*, 2017). Other recent studies have conducted semi-structured questionnaire-based individual interviews, focus group discussions, and key informant interviews to value ecosystem services in resource-dependent communities (Islam *et al.*, 2020). The goal of collecting self-reported data from interviews and questionnaires is to gain a holistic understanding of how services are utilized by local communities. Strategically choosing study areas to conduct these interviews can help differentiate the resource availability, level of dependency on ecosystem services, access to resource extraction, and the socio-demographic situation of individual communities (Islam *et al.*, 2020).

The use of self-reported data from interviews and questionnaires can also assist researchers in recognitional and procedural equity concerns by including marginalized communities in the valuation process. Some initiatives may have largely ignored social considerations (e.g., equitable access, sharing of the resources and benefits, and compliance of labor laws and human rights) which causes disadvantaged coastal communities to become further marginalized (Islam *et al.*, 2020). By consulting and representing individual communities, studies can identify the provisioning services (e.g., food, medicine, fodder, and timber) that are linked to the employment and income of local communities and ensure that they are represented in decision making (Islam *et al.*, 2020).

It is also important to consider who the recipients are for these ecosystem services and whether these benefits are transferred to local populations, tourists, poor or vulnerable communities or affluent sectors of the population (Himes-Cornell *et al.*, 2018b). Data availability is another concern, as some habitats and regions have had very little research conducted to estimate the value of common raw materials. For example, the benefits of raw material services from seagrass and saltmarsh ecosystems are poorly studied in comparison to mangroves and coral reefs (Barbier *et al.*, 2011; Dewsbury *et al.*, 2016; Himes-Cornell *et al.*, 2018b).

Energy

Estuaries and coasts have played important roles in energy systems for a long time and more recently are recognized increasingly for their importance in decarbonizing energy systems (Ocean Policy Committee, 2023; Stuchtey *et al.*, 2020). Renewable energy technologies, including wind farms, wave energy devices, tidal turbines, ocean thermal energy conversion, and salinity gradients can generate low carbon energy by drawing on physical processes in these ecosystems. Wind power, currently the most commercially viable among these technologies, is driven by temperature differences between the land and ocean. Many locations suitable for utility-scale offshore wind projects are spatially proximate to coastal cities with high population densities, reducing the need for long distance energy transmission from where the electricity is generated to where it is consumed (Kempton *et al.*, 2005).

Wave and tidal energy systems harness the ocean's kinetic energy using wave energy conversion devices and tidal turbines. Wave and tidal energy systems generate more constant and predictable energy with less visual impact than wind turbines, but costs per unit of energy generated are considerably higher. In addition to providing sites for renewable energy, coastal waters can provide cooling and heat exchange for industrial facilities. Ocean thermal energy conversion technologies use thermal heat engines to generate electricity based on the temperature differences between the warm surface layers of tropical and subtropical ocean and cold layers deep in the ocean. Salinity gradient technologies convert the chemical pressure differential of seawater as compared to freshwater, generating electricity based on ionic concentration differences (Kilcher *et al.*, 2021).

Common metrics used by developers when determining if and where to site renewable energy technologies include anticipated costs in relation to revenue over the project lifecycle (i.e., planning, construction, operations, maintenance, and decommissioning). The planning phase generally includes environmental impact assessment. Marine renewable energy and offshore wind can have environmental impacts on wildlife, their habitats and their migration routes (Boehlert and Gill, 2010; Copping *et al.*, 2020; Goodale, 2018). Moving cool, nutrient dense water from the depths of the ocean to higher in the water column may change water quality and impact ecosystem processes. Also, warm water must be treated with chlorine to maintain the efficiency of the heat exchanger, which can impact water quality. Ongoing research is being conducted to better understand the impacts of underwater noise during construction and operations of these technologies, as well as changes in water quality and impacts on benthic ecosystems over the lifespan of the projects. Much of the research on potential negative effects of marine renewable energy has focused on environmental impacts (Copping *et al.*, 2020). More research is needed to understand how the influence of marine renewable energy on estuarine and coastal ecosystems may in turn affect ecosystem services and the coastal communities that depend upon them (Picchi *et al.*, 2019; Trifonova *et al.*, 2022). Moreover, renewable energy generation in coastal and estuarine ecosystems can have positive benefits for remote coastal and island communities that may otherwise rely on costly imported energy resources and be easily cut off from external sources of energy as a result of extreme events and natural hazards (Kilcher, 2019).

Development decisions also account for anticipated energy generation, generally measured in megawatts (MW), and terms of power purchase agreements (PPAs), which are contracts between developers and utilities that stipulate the amount of electricity that will be sold and its price. Offshore wind projects tend to have higher upfront costs than land-based wind projects, but these costs can be partly offset by the more consistent and stronger winds at sea than on land (Musial and Ram, 2010). Site selection is based on physical parameters subject to social and environmental considerations. Optimal project sites for commercial developments have feasible grid connection costs and a high potential for energy generation, i.e., strong consistent wind, waves, currents, tides, temperature gradients or salinity gradients.

These developments entail negotiating trade-offs while working through considerations of procedural, distributional, and recognitional justice. In general, developers must earn and maintain a social licence to operate, which requires some degree of procedural justice in the form of public engagement with affected groups in determining if and where the project is sited and explicitly addressing some dimensions of distributional and recognitional justice. In the United States, a consequence of considering the distribution of aesthetic impacts has been the prioritisation of federal waters for offshore wind projects rather than state waters. Federal waters are further from shore so generally more expensive for building and maintaining offshore wind projects, but the aesthetic impacts are reduced and winds are generally stronger and more consistent.

Distributional justice can also mean that developers provide private and/or public benefits. Private benefits can compensate individuals whose livelihoods are disrupted, which may include security jobs during construction for fishers whose fishing grounds are displaced by the renewable energy development (Withouck *et al.*, 2023). Public benefits can be custom-tailored community benefits such as the developer subsidising internet cables bundled with electrical cables to an island community as part of an offshore wind development (Klain *et al.*, 2015) or annually donating to a conservation fund (Rudolph *et al.*, 2018). Recognitional justice relates to questions of who or which groups are "acknowledged, ignored or misrepresented in consultations or impact assessment" (Withouck *et al.*, 2023). Much progress remains to better address recognitional justice in marine renewable energy planning, particularly related to Indigenous groups whose concerns can be co-opted and/or sidelined by other interest groups (Bacchiocchi *et al.*, 2022).

A just transition away from reliance on fossil fuel includes developing renewable energy in estuariane and coastal ecosystems in ways that meaningfully engage potentially impacted parties in determining if and where specific projects are developed. Recognizing the rights, interests, and perspectives of diverse and affected groups can ensure fair processes and outcomes. Inclusive efforts are needed to co-develop an understanding of what constitutes an equitable distribution of benefits and burdens associated with proposed and implemented renewable energy projects.

Regulating Services

The second category of benefits that we explore in this chapter is regulating services. Regulating services include resilience and purification benefits provided by ecosystem processes, such as water filtration, climate mitigation, and flood risk reduction (IPBES, 2019; Millennium Ecosystem Assessment, 2005). In the following section we discuss three subcategories of regulating services flowing from estuarine and coastal ecosystems: 1) Climate, 2) Coastal water quality), and 3) Coastal hazard regulation.

Regulation of climate

Coastal blue carbon is the carbon taken up and stored by coastal wetlands, specifically mangroves, tidal marshes, and seagrass beds. These coastal wetlands are some of the most productive ecosystems on the planet. They are very efficient at sequestering and storing carbon, mostly in their soils, and have done so for hundreds to thousands of years. For mangroves some of the carbon is also stored in the tree biomass (Mcleod *et al.*, 2011). As a result, there has been growing interest in blue carbon ecosystems as opportunities for natural climate mitigation. Nature-based solutions involve restoring degraded coastal wetlands or protecting threatened ecosystems that store and sequester carbon to avoid greenhouse gas emissions (Fargione *et al.*, 2018; Howard *et al.*, 2023, 2017). The potential for blue carbon is substantial; a recent estimate suggests that restoration of coastal blue carbon ecosystems could result in offsetting ~3% of global emissions (Macreadie *et al.*, 2021). These ecosystems also provide a suite of additional ecosystem benefits including climate adaptation benefits such as flood and erosion risk reduction (Arkema *et al.*, 2013; Guannel *et al.*, 2016; Sutton-Grier *et al.*, 2015), water quality improvements, recreation opportunities, key habitat for recreational and commercial fish species, including subsistence fisheries (Jones *et al.*, 2022; McKenzie *et al.*, 2021), and important habitat for many wildlife species (Vegh *et al.*, 2018). Therefore, restoring or protecting the climate mitigation benefit (the carbon storage) comes with the "triple win" benefits of protecting these other ecosystem services simultaneously and providing climate adaptation and conservation benefits (Arkema *et al.*, 2023; Sutton-Grier and Moore, 2016).

When it comes to measuring the climate change impacts of an action on ecosystems and people, one of the most common ways is to use the social cost of greenhouse gases (SC-GHG; Interagency Working Group on Social Cost of Greenhouse Gases, 2021). This rather technical measurement assigns a monetary value to the net harm to society of emitting a metric ton of a greenhouse gas (either carbon dioxide, methane, or nitrous oxide) in a given year. By reversing this logic, therefore, the SC-GHG also reflects the societal net benefit of *reducing* emissions of a greenhouse gas by a metric ton. It is important to recognize that the SC-GHG ideally encompasses the monetary value of all climate change impacts, both negative and positive. This includes, but is not limited to, impacts to human health, changes in net agricultural productivity, property damage from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of other ecosystem services (Interagency Working Group on Social Cost of Greenhouse Gases, 2021). However, because of data and modeling limitations, particularly when trying to predict climate change impacts decades into the future, it is virtually impossible to fully represent all of the harms from climate change. As a result, estimates of the SC-GHG likely underestimate the full climate change impacts. Nevertheless, the SC-GHG estimates remain the best metrics available for valuing changes in greenhouse gases (Interagency Working Group on Social Cost of Greenhouse Gases, 2021) and can be used to calculate the value to society of restoring coastal wetlands for carbon sequestration, or of avoiding emissions when a threatened coastal wetland is protected.

While the beneficiaries of some ecosystem services, such as flood risk reduction or water quality benefits, may be very local and geographically constrained (Mandle *et al.*, 2015b), the evaluation of climate mitigation and who benefits from the carbon sequestration and storage in any ecosystem, including coastal wetlands, must be considered differently. Most greenhouse gases are globally well-mixed because they remain in the atmosphere for long periods of time (EPA, 2022). Therefore, benefits of sequestering and storing carbon can be felt by everyone around the world and emissions of greenhouse gases impact all people and economies (Pendleton *et al.*, 2012), although these climate impacts are not distributed equally (Bennett *et al.*, 2023). The interest in implementing nature-based climate solutions around the world (Griscom *et al.*, 2017), including in the United States (Fargione *et al.*, 2018), is driven partly because these approaches can have global impact in terms of their climate mitigation benefits, while providing any number of additional benefits to local communities (Vegh *et al.*, 2018). However, there remain scientific and technical challenges to implementing blue carbon projects. These include developing improved financial approaches and accounting tools to incorporate the co-benefits coastal wetlands provide, developing *low cost* technological solutions for measuring blue carbon sequestration, and resolving knowledge gaps regarding blue carbon cycles including methane emissions from different types of wetlands (**Fig. 3**) (Macreadie *et al.*, 2022).

Social, legal, and cultural considerations also need to be addressed to realize blue-carbon offset projects over the long-term (Herr *et al.*, 2019). Broad engagement in the design, development, and execution of projects is one critical element for successfully implementing climate mitigation or adaptation actions (Palinkas *et al.*, 2022; Wylie *et al.*, 2016) because local communities are often both the user and steward of many coastal blue carbon projects (Pricillia *et al.*, 2021). Other considerations to support the long-term success of blue carbon projects include: sustaining livelihoods and income; inclusive governance (which means improving policy and legal arrangements to ensure equitable sharing of benefits); improving stewardship by incorporating Indigenous knowledge and values; clarifying property rights; simplifying carbon accounting and verification methodologies to lower barriers to entry (Dencer-Brown *et al.*, 2022; Macreadie *et al.*, 2022); and enhancing local capacity and awareness (Pricillia *et al.*, 2021). In some cases, blue carbon projects can generate local jobs to provide livelihoods for nearby communities, including women who may have few other job opportunities (Palinkas *et al.*, 2022; Wylie *et al.*, 2016). Despite the focus here on carbon storage and carbon markets, markets or payments for carbon benefits may not be the best choice for all communities. There may be options that are more financially beneficial or viable that are not carbon finance, such as sustainable shrimp labeling and pricing (see Vietnam example in (Palinkas *et al.*, 2022; Wylie *et al.*, 2016)). Co-development of projects with local populations is critical for ensuring that both environmental benefits and community benefits are aligned in project plans and implementation.

Lastly, a procedural justice approach based on fair social processes in decision making (Tyler and Lind, 2001), is also important to consider in blue carbon projects both to meet equity concerns and to design more sustainable conservation outcomes. For example, in some blue carbon projects, this could involve commercial, recreational, and subsistence fishers included in discussions about required amounts of mangrove cover in fishing areas and the area of mud flat managed to support local fishing practices. Or it could mean that subsistence use of mangrove wood for charcoal is considered and replacement sources of charcoal are part of the design of mangrove restoration projects. Broad community involvement is key, acknowledging that parts of a community, especially the most marginalized, need explicit recognition and financial support to participate in the process (Dencer-Brown *et al.*, 2022) and to realize equitable and sustainable conservation outcomes (**Fig. 3**).

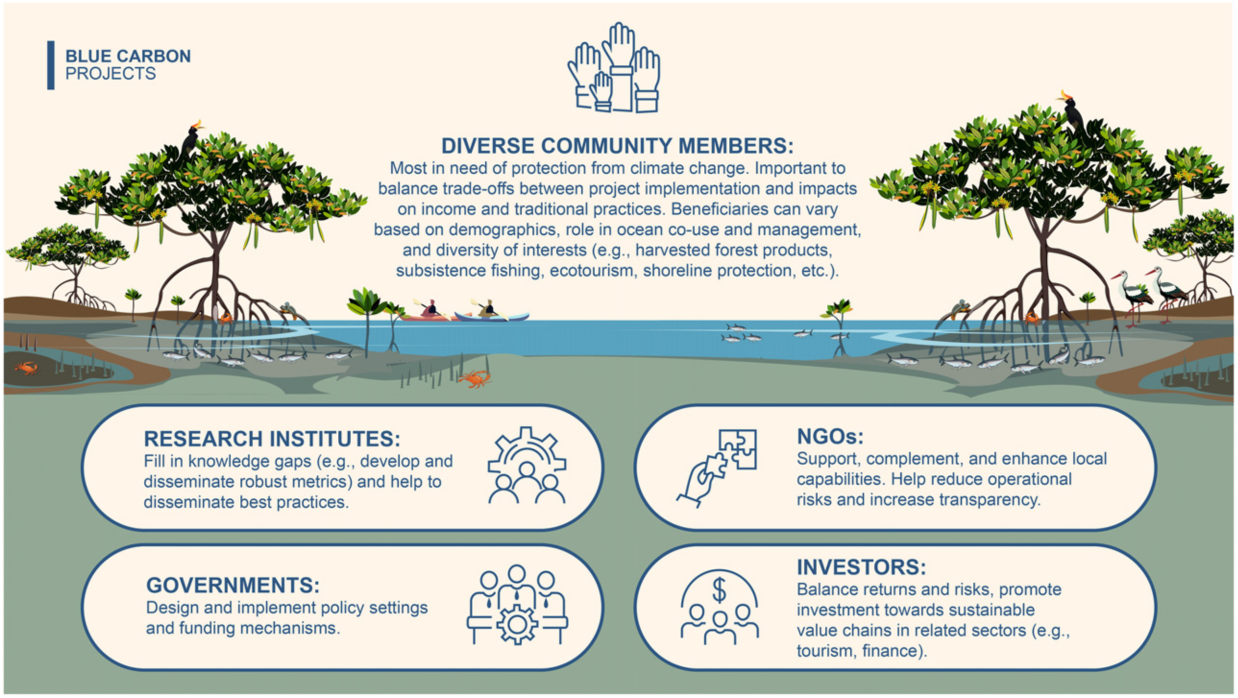

Fig. 3 Key actors and their roles in implementing blue carbon projects in estuarine and coastal ecosystems, with a focus on communities as beneficiaries (Dencer-Brown, 2022).

Regulation of coastal water quality

Estuarine and coastal ecosystems influence water quality in a number of different ways and through a variety of mechanisms. Species of coastal vegetation and invertebrates improve water quality by direct removal or inactivation of contaminants in the water column (Klohmann and Padilla-Gamiño, 2022), removal of nutrients (Zhao *et al.*, 2019), buffering acidification (Jiang *et al.*, 2020), sequestering heavy metals (Wang *et al.*, 2019), attenuating sedimentation (Horstman *et al.*, 2015), and serving as a sink for larger anthropogenic pollutants such as plastic (Martin *et al.*, 2020). Major mechanisms of physical, chemical, and microbial regulation within coastal ecosystems include production of phytochemicals, filtration by bivalves, sedimentation, competition from symbiotic organisms, and changes to physicochemical conditions (Klohmann and Padilla-Gamiño, 2022). Regulation of water quality by coastal ecosystems provides socioeconomic benefits through reduced disease burden in humans and marine organisms, improved quality of provisioning services, and increased capacity for services such as tourism, carbon sequestration, and coastal protection (Keeler *et al.*, 2012).

Quantifying benefits of coastal water quality to human health and productivity range from measurements of field-based indicators to global cost reduction analyses. Direct measurement of water quality parameters in the presence and absence of an estuarine or coastal ecosystem are often used to determine filtration capacity. A number of pollutants have been proposed as indicators of anthropogenic contamination (Lim *et al.*, 2017). Isotopic nitrogen is a more general indicator of anthropogenic contamination, and eutrophication caused by nutrient overloading is directly related to ecosystem decline (Sankoh *et al.*, 2022). The bacterial genus *Enterococcus* remains the primary indicator of wastewater pollution in seawater, although it does not directly reflect concentrations of disease-causing organisms (He and Jiang, 2005). Governmental standards for coastal water quality safety tend to rely on thresholds for allowable concentrations of *Enterococcus* or other specific indicators. Economic valuation can be used to quantify improvements to water quality provided by coastal ecosystems, though economic approaches tend to underestimate the global scale as they rarely consider benefits of improved water quality to other ecosystem services (Keeler *et al.*, 2012).

Regulation of water quality can directly benefit human health at both local and global scales. For example, vegetated coastal ecosystems perform waste treatment services valued at an average of $10,224 ha/yr (Gaylard *et al.*, 2020). Mangrove forests have been used as a water filtration method in regions where wastewater treatment options are limited (Ouyang and Guo, 2016), with reductions in disease-causing organisms preventing human-associated illness (Keeler *et al.*, 2012). Seagrass ecosystems have been estimated to prevent as much as 24 million cases of gastroenteritis per year, globally (Ascioti *et al.*, 2022). In addition to reducing the disease burden to local coastal communities, improved water quality allows ecosystems to function and provide other services. For example, the presence of seagrass ecosystems is associated with reduced levels of disease affecting reef corals (Lamb *et al.*, 2018), which are foundation ecosystems that function to regulate, provision, and support both local and global services. Disaggregating local and global benefits and ensuring that the capacity of coastal ecosystems to regulate water quality is not threatened can help promote equitable maintenance of this service.

Both upstream processes and use of seawater contribute to a community's reliance on coastal ecosystems for regulation of water quality (Keeler *et al.*, 2012). In many coastal communities, direct contact with seawater occurs through recreation, although contact may additionally occur through activities of daily life. Local communities and recreationalists are willing to pay for policies and infrastructure upgrades that improve coastal water quality (Hatton MacDonald *et al.*, 2015; Peng and Oleson, 2017). In low income countries, literacy and political rights are related to air and water quality metrics (Torras and Boyce, 1998). However, public perception must be considered, as sociopolitical aspects such as subjective perceptions of water quality can be more important to local communities than widely used metrics (Artell *et al.*, 2013; Gunko *et al.*, 2022). The relative contribution of coastal ecosystems to regulation of water quality depends on regional management, including wastewater treatment and land use (Keeler *et al.*, 2012). For example, regulation of water quality could be important in coastal regions adjacent to agriculture, a known contributor of harmful microorganisms, chemical contaminants, and nutrients (Xie *et al.*, 2019). Community reliance on, and contact with, seawater is a consideration when evaluating the importance of regulation of water quality to human health.

Regulation of water quality by coastal ecosystems may be threatened when other services are prioritized without considering the importance of improved water quality for supporting these services. For example, seagrass beds may be manually removed adjacent to tourist sites (Daby, 2003). However, intact coastal ecosystems improve water clarity, which is a priority for tourists (Anfuso *et al.*, 2018). Trade-offs in maintaining water quality services must be balanced with utilizing the benefits of these services. Improved water quality is not a terminal service; instead, it reduces contaminants in coastal ecosystems that can otherwise have downstream impacts that affect the efficacy of other services (**Fig. 4**) (Keeler *et al.*, 2012). For instance, harmful algal blooms affect not only water quality but air quality as well, as toxins from these blooms can be aerosolized and transported inland (Lim *et al.*, 2023).

Decision-making surrounding regulation of coastal water quality may consider a wide array of factors, many of which have yet to be established. Informed management includes evaluation of the local contaminants of concern, characterization of the role of coastal ecosystems in regulating these contaminants, consideration of the capacity for the ecosystem to withstand the pollution, and risk of exposure or loss of function within ecosystems. In many cases, one or more of these components remain unknown, and community participation in decision-making could help fill in the gaps. Procedural equity in regulation of water quality benefits from collaboration between communities (to understand the local uses of and exposure to coastal ecosystems), wastewater practitioners, policy-makers and scientists. Similarly, community perspectives can inform conversations to promote recognitional equity. Local knowledge of illness and barriers to wellness is essential to healthcare decision-making (Kim *et al.*, 2013), and a similar framework may be applied to encourage human and ecosystem health more broadly.

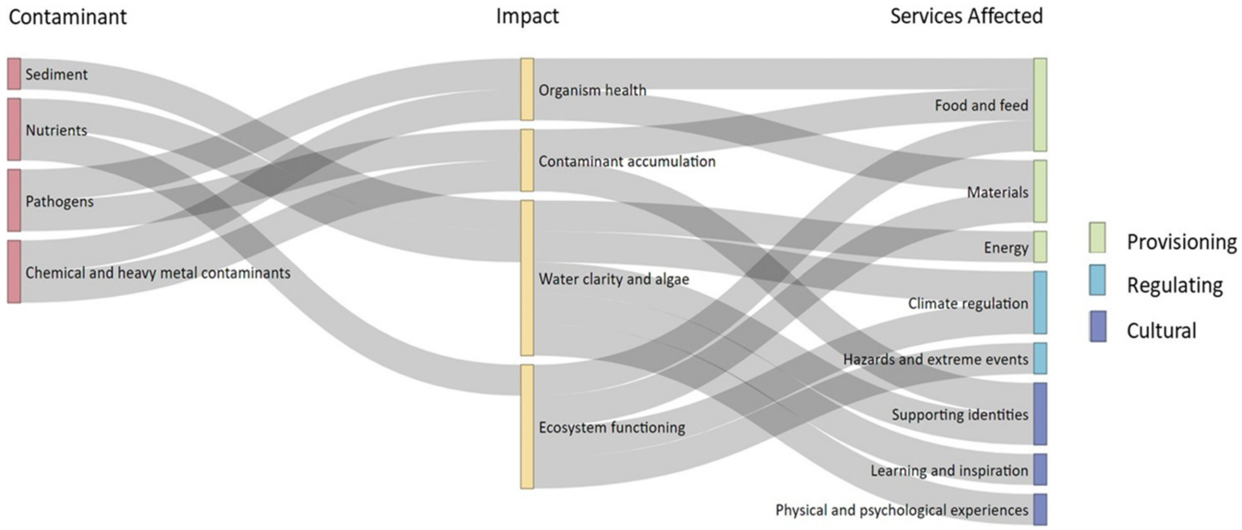

Fig. 4 Water filtration is not a terminal service and instead supports other services. Flowchart shows primary contaminants reduced by water filtration services, major impacts of contaminants, and services affected by impacts. Grey lines highlight primary interactions, though other interactions also occur.

Filtration is considered a local benefit (Keeler *et al.*, 2012), but buoyant, persistent substrates such as plastic can serve as transoceanic rafts for microorganisms and other pollutants (Bowley *et al.*, 2021). Even in the absence of exogenous surfaces, neither seawater nor the harvested organisms remain in the same place over time, migrating through the global fishery trade, ballast water, and oceanic gyres. Thus, regulation of water quality is relevant both to local exposure and in the context of regional to global ecosystem services. Understanding regulation of water quality as an intermediate service on which other services rely can help to provide a generalizable framework. However, quantification of value and translation into management decisions will remain difficult, especially when considering the needs of both upstream communities and downstream communities (Delevaux *et al.*, 2023; Wakwella *et al.*, 2023).

Regulation of hazards and extreme events

Estuarine and coastal ecosystems are widely recognized for their value in buffering cities and communities from devastating hazards such as storms and flooding (Narayan *et al.*, 2016). Field observations in the aftermath of hurricanes, complex modeling studies informed by insurance industry best practices, and the local knowledge of coastal communities have all contributed to rapidly expanding literature on the coastal protection benefits of ecosystems (Arkema *et al.*, 2017; Narayan *et al.*, 2017; Smith *et al.*, 2020). Coupled with the known environmental harms caused by traditional shoreline hardening (Gittman *et al.*, 2016), this broader appreciation for the shoreline protection benefits of marshes, mangroves, dunes, coral reefs, and other coastal and estuarine ecosystems has also led to rapidly growing investment and implementation. Given the constant and potentially worsening catastrophic risks posed along coastlines and will climate change, the equity implications of mitigating hazards and disasters is of paramount importance.

In many ways, understanding how the risks of coastal hazards and benefits of coastal habitats are distributed across society parallels the "distribution of bads and goods" conversations that have been the central to environmental sociology and environmental justice for decades (Hobson, 2004). A distributional equity model for coastal risk reduction largely focuses on ensuring that the risks and impacts of coastal hazards are fairly distributed across individuals and groups, and that systemically marginalized groups are not disproportionately at risk. Coastlines with high residential development are a good example of the need to consider procedural equity as waterfront residents, who are often wealthier than average, make coastal protection decisions that influence the risk and resources for nearby inland residents. Historically, these private landowners have disproportionately armored their shorelines with bulkheads and revetments leading to dramatic declines in natural habitats like marsh (Scyphers *et al.*, 2015). Surveys of waterfront and inland residents have shown that major hurricanes are similarly concerning for both groups, and armored shorelines do not translate to lowered concerns among waterfront residents (Scyphers *et al.*, 2019). Arkema and colleagues (2013) illustrated these trade-offs through a study that explored how coastal habitats protect people and property. They found that prioritizing investments based upon the economic value of coastal properties could come at the expense of highly vulnerable populations. Specifically, their study shows how the distribution of coastal habitats can protect a high proportion of low-income families relative to the total population in one geography but more elderly and higher property values in another. However, the implications extend beyond just distributional equity by recognizing key groups of residents typically not considered in cost-benefit driven models of decision-making. Overcoming these inequities would require procedural justice.

Investment in ecosystem restoration is not the only strategy for mitigating coastal risk and may not always be the most equitable. Migration away from the coast is increasingly discussed as a necessary pathway to climate adaption; however, major equity considerations remain. For instance, a study of migration following Hurricane Sandy showed that economic constraints on relocation can lead to people fleeing areas of high hazard vulnerability only to move to areas of higher social vulnerability (McGhee *et al.*, 2020). While many studies have measured the flood risk perceptions and preferences of residents, fewer have approached these studies from an equity perspective. One such study focused on inland flooding in the UK and Ireland finding that in a community with a long history of flooding, procedural justice was important for predicting individual willingness to adapt (Adger *et al.*, 2016). The study also found that perceptions of fairness were an effective measure of perceived equity.

Globally, funding for infrastructure typically has historically dwarfed funding for ecosystem restoration (McCreless and Beck 2016). However, coastal habitats are increasingly considered as infrastructure for coastal protection and stormwater management, opening up new pathways for fudning restoration and resilience projects. In the United States, federal funding to restore coastal ecosystems for risk reduction include the Federal Emergency Management Agency (FEMA)'s Building Resilient Infrastructure and Communities (BRIC), the National Oceanographic and Atmospheric Administration (NOAA)'s Coastal Resilience Grants, to name a few. However, historically, some of the major funding sources focused on coastal resilience have required matching funds by the applicant. These types of funding models exist to help extend or multiply the investment, but they tend to favor wealthier communities and could deepen inequities. Furthermore, many highly vulnerable communities are under-resourced and lack the capacity to apply for and manage grants (Taylor and Blondell, 2023).

Cultural Services

The third category of benefits that we explore in this chapter is cultural services. Cultural services comprise non-material benefits that contribute to advancement of social systems, including how ecosystems play a role in local, national, and global cultures, the building of knowledge and the spreading of ideas, creativity born from interactions with nature, and recreation (IPBES, 2019; Millennium Ecosystem Assessment, 2005). In the following section we discuss three subcategories of cultural services flowing from estuarine and coastal ecosystems: 1) Physical and psychological experiences, 2) Learning and inspiration, and 3) Supporting identities.

Physical and psychological experiences

Estuarine and coastal ecosystems offer opportunities for recreation, leisure, tourism, aesthetic enjoyment, and bolstering physical and mental health (Depledge and Bird, 2009; Garrett *et al.*, 2023). Coral reefs, kelp forests, seagrasses, saltmarshes, mangroves, beaches, sandflats, and other shoreline and subtidal environments support a diversity of activities including snorkelling, diving, fishing, boating, walking, wildlife viewing, and relaxing (Arkema *et al.*, 2021; Lucrezi and du Plessis, 2022; McKenzie *et al.*, 2021; Spalding *et al.*, 2017; Spalding and Parrett, 2019). In turn these ocean-inspired experiences can generate numerous health outcomes including stress reduction, improved mood, greater physical activity, and enhanced connection to coastal systems and wellbeing (White *et al.*, 2020). The benefits of blue spaces may pertain especially to those living in close proximity to the ocean (Bell *et al.*, 2015). For example, one longitudinal study found that the same people reported better general and mental health in the years they were living < 5 km from the coast versus when they were living inland (White *et al.*, 2013b). The benefits of time spent in nature also accrue beyond those who experience direct contact with coastal and estuarine environments. The global coastal and ocean tourism industry is valued at $390 billion and supports millions of jobs, especially in lower-income countries (OECD, 2016). The public health sector is also showing greater interest in blue spaces. For example, nature-prescription programs have emerged to address the growing burden of mental health, chronic disease, and increases in sedentary life-styles. Although the literature on the efficacy of nature prescriptions is sparse and the focus has largely been on green spaces (Britton *et al.*, 2020; Kondo *et al.*, 2020), new programs such as Europe's Blue Health aim to advance approaches for mapping and quantifying the potential benefits to public health and well-being from blue spaces (Grellier *et al.*, 2017).

Physical and psychological experiences generated by coastal and estuarine ecosystems have traditionally been quantified in self-reported metrics based on surveys and interviews. Surveys are particularly effective for understanding how people are spending time in and near ocean environments and their self-reported health outcomes (Cracknell *et al.*, 2016; Garrett *et al.*, 2023; Grellier *et al.*, 2017). However, surveys and interviews are costly and time intensive; they tend to provide intermittent information at particular locations or across very large areas with little spatial resolution. With the advent of hand-held devices and social media, researchers have turned to new technologies to address these challenges and limitations (Grellier *et al.*, 2017; Spalding *et al.*, 2017; Wood *et al.*, 2013).

Over the past decade an increasing number of studies have shown that the relative distribution of photos, tweets, and other geotagged social-media data generally aligns well with the relative distribution of visitors to all kinds of destinations (Wood *et al.*, 2020, 2013), including estuarine and coastal ecosystems (Arkema *et al.*, 2021). These studies and others leveraging data from online resources, such as travel sites, reveal the importance of access and amenities in addition to ecosystem attractors and enable wide-spread tracking of visitation to locations typically not visited by surveyors (Arkema *et al.*, 2021; Spalding *et al.*, 2017; Spalding and Parrett, 2019). Technology and innovation have also led to new approaches for measuring the physical and mental health benefits of time spent in nature (Bratman *et al.*, 2015). In one study, ecologists and medical professionals that tracked physiological outcomes (e.g., blood pressure) as well as psychological reactions from exposure to blue spaces found that viewing more fish in aquaria led to greater reductions in heart rate and increases in self-reported mood (Cracknell *et al.*, 2016). Another study developed an iPhone app that contacted people over several days to ask how they were feeling, tagging their responses to their geolocations. Results found that people were happiest in marine or coastal settings (MacKerron and Mourato, 2013).

While the last decade has seen an explosion in research on relationships between physical and psychological health and time spent in nature, much of this work focuses on the biophysical elements that drive wellbeing (Bratman *et al.*, 2019; Garrett *et al.*, 2023; Remme *et al.*, 2021; White *et al.*, 2020). Understanding distributional benefits and impacts of nature exposure is still in its infancy, especially for coastal and estuarine systems. The vast majority of research comes from the United States and Europe with more limited studies in other countries (Garrett *et al.*, 2019; White *et al.*, 2020). In many higher-income countries, homes close to inland and coastal waters, especially those with blue space views, tend to be more expensive (Jim and Chen, 2009; Luttik, 2000; Gibbons *et al.*, 2014). Access to nature thus varies among demographic groups, with lower-income, Black and Brown neighbourhoods frequently farther away from natural spaces. This is particularly important because the benefits of blue space on health and well-being tend to be stronger for people living in poor regions (Wheeler *et al.*, 2012) or lower-income households (Garret *et al.*, 2019b). Moreover, ocean-based activities such as SCUBA diving or fly fishing tend to be among the most expensive leisure activities and often less accessible to Black, Indigenous, and people of colour. Lodging in waterfront hotels and with sea views commands higher prices (Lange and Schaefer, 2001) and increasing travel distance to blue space is associated with lower mental wellbeing outcomes (Garret *et al.*, 2023). Blue space views from home may also be important to older adults with poorer mobility (Coleman and Kearns, 2015).

In addition to variation in who benefits most from time spent in estuarine and coastal ecosystems, the knowledge, norms, and values of people vary with respect to natural environments and this in turn influences the physical and psychological benefits they experience. For instance, studies from urban settings show that inequities in access and utilisation of open spaces can be driven by perceived threats and safety concerns as well as income and other demographic factors (Cohen *et al.*, 2016; Sefcik *et al.*, 2019; Smardon, 1988). Similar patterns have been found for estuarine and coastal systems, where perceived safety is a key predictor in mental health outcomes from time spent in blue spaces (Garret *et al.*, 2023). Communities' perceptions and relationships with the ocean are also influenced by their cultural heritage, which may simultaneously celebrate the beauty of coastal ecosystems and recognize historical trauma. For example, Bahamian artist Antonius Roberts explores the ocean as a medium for healing and as a memorial of triumph, hope, and determination. His sculptures depict figures of women created from twelve trees overlooking one of the first landing places for slaves brought to The Bahamas (**Fig. 5**). Cultural differences in perceptions of estuarine and coastal ecosystems may also relate to experiences with ecosystem services and disservices. For example, mangroves and saltmarshes provide a wide range of benefits to people, including food resources, climate mitigation, and wave attenuation. However, perceptions of wetlands can be negative, stemming from their odour, a sense of danger, and actual or perceived relationships with disease (Friess *et al.*, 2020). Whether subgroups of people experience physical and psychological benefits of time spent recreating in wetlands will depend on the balance of these negative and positive interactions and the influence of historical viewpoints (Friess, 2016).

Incorporating the varied elements of recognitional equity in the management of coastal and estuarine ecosystems involves bolstering procedural equity. The tourism industry is increasingly involved in innovative mechanisms for investing in nature that involve bringing together new actors. For example, hotel owners along the Mesoamerican Reef have joined The Nature Conservancy, Swiss Re, and the Mexican government, in a program to insure 100 miles of coastline through funding for coral reef restoration in the event of a large hurricane (Einhorn *et al.*, 2020; Reguero *et al.*, 2020). In other places in the Caribbean, sustainable development planning has incorporated community voices to understand local perspectives for the future of tourism

Fig. 5 Sacred space at Clifton Cay in The Bahamas. Art installation by Antonio Roberts. Photograph taken by Mike Druckenbrad (2022).

and recreation in estuarine and coastal systems (see Bahamas case study below). Different pathways for tourism development can have implications for what types of investments are made in amenities for beaches and parks, who benefits from different types of job opportunities (e.g., low-wage service positions vs. higher-wage skilled positions), and ecosystem health (Arkema *et al.*, 2021, 2015). Transdisciplinary approaches have helped to advance more inclusive sustainable development planning; however, power dynamics, structural barriers, and historical legacies consistently challenge the involvement of marginalized groups (Arkema and Ruckelshaus, 2017; Chan *et al.*, 2017; Loos *et al.*, 2023; Wyatt *et al.*, 2021).

Quantifying and monitoring the beneficiaries of physical and psychological experiences in coastal and estuarine systems is particularly important for understanding potential outcomes of interventions designed to facilitate and reap the societal and economic benefits of time spent in nature. For example, investments in large-scale coastal tourism may provide easier access to beautiful places for more people, but produce local jobs with lower paying wages for disadvantaged communities. Similarly, infrastructure development is important for facilitating increased access for certain groups, such as disabled populations or lower-income populations that lack equipment, time, and expertise to access remote locations. How can we balance this need with potential degradation of ecosystems? New technologies have the potential to bring massive amounts of data to bear on these difficult problems, but these approaches have their drawbacks, including potential privacy considerations for the visitors themselves (Ghermandi *et al.*, 2023).

Learning and inspiration

Typically, assessments of cultural ecosystem services focus on recreation and scenic beauty, with less attention to the importance of land and seascapes for fostering spiritual values, cultural identity and heritage, and social cohesion (Chan *et al.*, 2016; Gould *et al.*, 2015; Klain *et al.*, 2014; Chan *et al.*, 2012; Gould *et al.*, 2015). To address these limitations, Pascua and colleagues (2017) expanded the traditional framework for cultural ecosystem services developed through the Millennium Ecosystem Assessment to incorporate place-based and indigenous knowledge systems. They employ a case study from Hawai'i to strengthen the knowledge base of learning and inspiration benefits from estuarine and coastal environments. Educational values are captured through traditional and formal knowledge systems (*'Ike* in Hawaiian) and include experimental and action-based learning and learning through observation.

A key benefit of estuarine and coastal ecosystems is the opportunity for learning place-based practices by actually doing them (*Ma ka hana ka 'ike*). Examples from Hawai'i include gathering salt from natural pools and making salt in raised ponds, as well as gathering and preparing seasonally abundant seaweed varieties. Another benefit is the opportunity for diverse (formal and informal) learning (*Hālau 'Ike*), such as scientific research, experiential, *'āina-based* (land-based) education, and learning from elders. Estuarine and coastal ecosystems in Hawai'i (such as wetlands, estuaries, anchialine pools, and coastal springs) are a living classroom for diverse formal and informal learning, including *'āina-based*, cultural, historical, and scientific learning; knowledge sharing; learning family histories; and shared knowledge of place names and events. These land and seascapes provide opportunities to share traditional values and knowledge for youth education, tourism, and intergenerational learning (Gibson *et al*., 2023).

Relational approaches to science and knowledge are an important part of Indigenous ways of knowing and "Native science" often focuses on connections, cycles, and nature as a teacher (Gould *et al.*, 2018; Cajete, 1994). However, society has long perceived Indigenous knowledge as "the other" and opposite to western scientific knowledge that is thought to be quantitative, factual, objective, and analytical. This dichotomy leads to perceptions of inequality, rather than discussion of individual strengths. A growing body of research emphasises the need for "two-eyed" seeing, which involves "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of mainstream knowledges and ways of knowing, and to use both these eyes together, for the benefit of all" (Bartlett *et al.*, 2012). This is in contrast to the idea that Indigenous knowledge should be "incorporated" or "subsumed" into western science (Reid *et al.*, 2021).

Another challenge related to distributional and procedural equity is gender equality in marine education. The UN's Decade of Ocean Science for Sustainable Development has committed to providing equal opportunities for women and men to contribute to the research and innovation needed to reverse declining ocean health. Equity in estuarine and coastal learning globally can be improved by collecting baseline data disaggregated by gender to monitor and evaluate progress and policies that value women's participation in scientific research, especially in leadership positions. Gender equality is about more than just increasing the number of women and girls in ocean science. It is also about transforming organizations and cultures to reduce implicit bias and creating a more inclusive environment to support "Ocean Literacy." McKinley and colleagues (2023) draw on existing research, parallel concepts, (e.g., marine citizenship and ocean connectedness), and public perceptions to propose ten dimensions of ocean literacy they argue will help ocean-based learning and inspiration encompass diverse knowledges, values, and experiences (**Fig. 6**).

Supporting Identities

Coastal and estuarine ecosystems support and shape diverse identities around the world. Identity encompasses the traits, beliefs and values that make an individual or group distinct from others. Identity refers to an internal sense of self and external perception of how others may see an individual or group (Buckingham, 2008). Personal, cultural, national, gender, sexual, social, ethnic and religious dimensions of identity vary in their relevance to coasts and estuaries. Landscapes and seascapes can provide a "sense of place, purpose, belonging, rootedness or connectedness, associated with different entities of the living world (e.g., cultural and heritage landscapes; sounds, scents, and sights associated with childhood experiences; iconic animals, trees, or flowers)" (IPBES, 2019). For example, several coastal indigenous peoples in the Pacific Northwest (e.g., Kwakwaka'wakw First Nation) refer to

Fig. 6 Ten dimensions of ocean literacy to support the goals of the UN's Ocean Decade (based on graphical abstract in McKinley *et al.*, 2023).

themselves as salmon people (Gerwing and McDaniels, 2006). Their identities are interwoven with a cultural keystone species (Garibaldi and Turner, 2004) that they rely on not only materially but also as an integral part of their identity. Depictions of how coastal and estuarine ecosystems support identities abound in popular films and books such as Moana, Where the Crawdads Sing, and The Old Man and The Sea.

When navigating social-ecological change, understanding the relationships linking coasts and estuaries to identities of diverse, potentially impacted groups and individuals is crucial for working towards recognitional and contextual equity. Natural resource conflicts can pit community members with strongly rooted identities against others with different, strongly rooted identities. In an ocean context, a fisher's identity may be inextricably linked to their livelihood, so they perceive their identity as threatened when they are excluded (or anticipate being excluded) from a growing area of the ocean due to marine protected areas, aquaculture and/or offshore wind project development (Martin *et al.*, 2016). Alternatively, for example, engineers employed by offshore wind developers may derive a sense of identity from believing they are helping to address the climate crisis. Just processes and outcomes, may stem from effectively negotiating responses to these issues often rooted in conflicting notions of identity.

Identity also stems from spiritual and religious values closely tied with estuarine and coastal ecosystems. For example, Native Hawaiian ceremonial rituals and cultural protocol are captured through the spiritual beliefs and practices (*Ho'omana/Mauli Ola*) that allow people to interact with the *mana*, or spiritual force of a landscape, such as the perpetuation and use of *oli* (chants), *hula* (dances), and *pule* (prayers) of/for place (Pascua *et al.*, 2017). Another spiritual value is the existence of, appropriate access to, and understanding of place-specific practices associated with storied landscapes (*wahi pana*), such as birth place (*one hānau*), family burial sites (*kulaiwi*), and gathering/harvesting sites. The presence and recognition of familial guardians or ancestors as kin (*'Aumakua*) illustrates how spiritual values are interwoven with marine environments. Turtle (*honu*) or shark (*manō*) are cared for by, and take care of, specific families. There is also the ability to detect and observe environmental signs or species (*Hō'ailona*) that signal the cycles of another plant or animal species (bioindicators) and the presence of place-based Hawaiian names that describe the environment (*I ka 'ōlelo nō ke ola, i ka 'ōlelo nō ka make*), such as specific reef system that serve as a nursery ground or places for elders to collect *limu* (seaweed or algae). These examples demonstrate that spirituality can be a phenomenon tightly intertwined with ecosystems and grounded in relationships (Chan *et al.*, 2016; Gould *et al.*, 2020).

In addition to the strong ties between identity and estuarine and coastal ecosystems, individual and community identities are multidimensional. The multidimensional nature of identity makes this subcategory of estuarine and coastal benefits complicated and inherently difficult to assess, especially with a western science approach. Yet, if time and resources are invested towards a better understanding of identity, it has the potential to not only underpin but to also foster common ground when working towards procedural, distributional, and recognitional justice.

Case Studies

In the following section we explore trade-offs and beneficiaries of a suite of ecosystem services using three case studies that consider equity to inform different estuarine and coastal management contexts: 1) Sustainable development planning in The Bahamas, 2) Renewable energy transitions in island and remote communities, and 3) Wetland mitigation in the United States.

Sustainable Development Planning in The Bahamas

The Bahamian archipelago is made up of more than 700 islands and cayes. Mangroves, corals, sand flats, beaches, and hundreds of blue holes support a vibrant tourism sector that accounts for 60% of the country's GDP (Bahamas Ministry of Tourism 2019). The estuarine and coastal ecosystems of The Bahamas also help to reduce the risk of coastal hazards by buffering low-lying islands from storms and to support livelihoods by providing habitat for the lucrative spiny lobster and domestic conch fisheries (Arkema *et al*., 2019; Silver *et al*., 2019). Despite this wealth of natural resources, the islands of The Bahamas face a host of challenges. For example, the largest island in the country, Andros, depends upon an extensive system of sand flats and wetlands to support its sport-fishing industry. However, this same terrain, characterized by waterways and creeks, combined with limited finacial resources, makes development of transportation infrastructure and travel to business centers difficult. Ad hoc development also risks the health of sensitive estuarine and coastal ecosystems and the benefits they provide to local communities. Andros, like the rest of The Bahamas, is threatened increasingly by storms and sea-level rise, with recent hurricanes such as Matthew destroying homes and businesses. A highly invasive tree species, *Casuarina equisetifolia*, appears to exacerbate coastal hazards and ecological degradation by eroding shorelines and competing with native plants (Wyatt *et al*., 2021).

To address these challenges, the government of The Bahamas decided to create a Sustainable Development Master Plan for Andros. The overarching goal was to design a plan that would harness the island's wealth of natural assets without sacrificing the very ecosystems that underlie its economy and ensure the well-being of its citizens. Spearheaded by the Office of the Prime Minister beginning in 2015, this island-wide roadmap was part of The Bahamas national development planning process entitled "Vision 2040". The Office of the Prime Minister sought to use the Vision 2040 process to implement the international Sustainable Development Goals (SDGs) through the pillars of governance, human capital, the environment, and the economy. The Master Plan was to focus on the island's four districts—North Andros, Central Andros, Mangrove Cay, and South Andros (The Government of The Bahamas, 2017). With support from the Biodiversity and Ecosystem Services Program at the Inter-American Development Bank, the planning effort involved collaboration among local government councils, natural resource and economic development ministries, several non-governmental organizations (e.g., The Nature Conservancy), universities (University of The Bahamas, Natural Capital Project at Stanford University), and consulting firms (i.e., SEV consulting).

While fostering equity was not an explicit goal of the Master Plan, the design of the plan involved three main streams of work that relate to the three dimensions of equity discussed in this chapter: 1) participatory planning process, 2) scenario design, and 3) assessment of ecosystem services. The participatory planning process incorporated several elements that can help bolster procedural equity. First, the process engaged a wide variety of community members with different perspectives about the future of Andros, including students, government officials, and local leaders in the fishing, hospitality, and agricultural sectors. Second, the process was designed to be iterative and offer multiple opportunities for participation tailored to the different needs of different populations. For instance, community members in each of the four districts of Andros were engaged during six different periods within the two-year planning process. Third, a variety of approaches were used to engage community members. These included more than 30 gatherings (attended by more than 500 people) in the form of open sessions, town meetings, additional one-on-one visits to homes and businesses, and participatory mapping exercises. In parallel, 13 government agencies were engaged on many occasions. This participatory process generated a list of diverse ocean and coastal activities and ecosystems to consider in the master plan, multiple perspectives about the future of Andros, and a set of shared societal benefits of estuarine and coastal ecosystems with which to evaluate alternative options for development (Arkema and Ruckelshaus, 2017; Wyatt *et al*., 2021).

The second main element of the master planning process was the design of four alternative scenarios for development (**Table 2**). The scenarios each describe how Andros might look given a particular suite of development and investment decisions. Scenarios play an important role in sharing information, illustrating a variety of different ideas about potential pathways for the future, comparing and evaluating options, and building consensus for a plan. To create alternative scenarios for Andros, the Government of The Bahamas and its partners gathered information from the community engagement and participatory mapping exercises. The team grouped the range of desired outcomes and recommendations into four future storylines which were also represented by detailed spatial data that translated each storyline into different maps of a future Andros (**Table 2**). The four scenarios reflect the strong differences among some community members in their desires for the future of their island and aimed to give voice to perspectives that may not typically be reflected in development planning, such as the desire from some settlements to avoid any new investment in infrastructure (Wyatt *et al*., 2021).

Table 2 Four alternative development scenarios designed through participatory and quantitative approaches to inform the Andros Master Plan in The Bahamas.

Scenario	*Description*	*Example activities*
Business-as-Usual Scenario (BAU)	Represents future similar to the current conditions at the time of the planning process (2015).	Little investment in new infrastructure, educational opportunities, or other development programs.
Conservation Scenario	Gives priority to ecosystem health and protection of habitats and species rather than near-term economic development.	For example, this scenario includes the ratification of a National Park for the Andros barrier reef, but no new coastal development.
Sustainable Prosperity Scenario	Blends human development and conservation goals by investing in critical infrastructure and education to achieve a nature-based economy that can be sustained over time.	Example activities include daily ferries from Nassau, small and mid-sized Bahamian owned businesses (e.g., hotels, processing factories for local goods), community agriculture, and mangrove restoration as both a natural means of shoreline protection from storms and a habitat for lobster.
Intensive Development Scenario	Gives priority to major economic development rather than ecosystem health and protection of habitats and species.	Example activities include construction of a cruise ship port in North Andros, large, energy intensive resorts and luxury housing developments, expanded mining activities, and seawalls along the entire east coast of the island.

The third element of the Master Planning process was an assessment of the benefits of estuarine and coastal ecosystems on Andros under the four future development scenarios (**Fig. 7**). The planning team applied a suite of ecosystem service models that estimate change in societal benefits with the potential change in ecosystems that may result from interventions related to human activities and infrastructure development. These models have been tested and applied around the world to elucidate the potential outcomes of a variety of decisions including sustainable development planning, climate adaptation, and coastal and marine spatial planning, and can be tailored to shed light on distributional effects (Ruckelshaus *et al.*, 2015). In the case of The Bahamas, using 2015 as a baseline and projecting 25 years in the future to 2040, the ecosystem service analysis estimated that the Sustainable Prosperity scenario would reduce the coastal and estuarine habitat at high risk of degradation from human activities by more than 30% relative to the Business-as-Usual scenario and to a tenth of the area at high risk under Intensive Development (Ruckelshaus *et al.*, 2020; The Government of The Bahamas, 2017; Wyatt *et al.*, 2021).

Safeguarding ecosystems under the Sustainable Prosperity and Conservation scenarios would increase the export value of lobster catch provided by estuarine and coastal ecosystems around Andros by almost 50% from US$14 million (in BAU) to US$20 million. In contrast, Intensive Development would decrease the country-wide catch by 13% and reduce export value to US$10 million annually due to degradation of nursery habitats in and around Andros (Arkema *et al.*, 2019). Estuarine and coastal ecosystems are also important for coastal risk reduction on Andros, with more than 60% of the populated north and east coasts currently buffered by coral reefs, seagrass, mangroves, wetlands, and terrestrial coppice forest. Under the Sustainable Prosperity scenario, 85 km of coastline would be buffered by estuarine and coastal ecosystems, thus shielding over 750 people and US$5.8 million in income that would otherwise be highly vulnerable to flooding and erosion without the risk reduction capabilities of ecosystems. These numbers are a relatively small improvement over the coastal resilience provided by estuarine and coastal ecosystems under a Business-as-Usual scenario. But the Intensive Development scenario would more than triple the number of people at risk from flooding and erosion, due to ecosystem degradation and increases in coastal population and infrastructure (Arkema *et al.*, 2017; Ruckelshaus *et al.*, 2020; Silver *et al.*, 2019).

Finally, the Sustainable Prosperity scenario would increase tourism expenditures in all four districts (**Fig. 8**). Total expenditures from tourism would increase by more than 35% in Mangrove Cay and North Andros and by about 10% and 20% in South and Central Andros, respectively. In contrast, the Intensive Development scenario would concentrate tourism in the North and South districts (expenditures are predicted to be 30% and 25% more than the BAU scenario) but cost Central Andros and Mangrove Cay US$15 million and US$3.5 million, respectively. Thus, the Sustainable Prosperity scenario lays out a vision and approach for bolstering tourism-based livelihoods throughout the island while the Intensive Development scenario further exacerbates the unequal distribution of wealth (Arkema *et al.*, 2021; Ruckelshaus *et al.*, 2020).

Results indicated the Sustainable Prosperity scenario would produce a similar delivery of fishery and coastal protection services compared to the Conservation scenario, a higher delivery of services than the BAU scenario, and lower the risk of coastal, marine, and freshwater degradation relative to Intensive Development. Importantly, using an ecosystem services approach and participatory mapping showed that community members on Andros were less interested in large new development projects that could pose severe risk to ecosystems. Instead, they wanted investments in degraded infrastructure like roads or processing plants within existing settlements that would allow them to better access – and safeguard – the island's natural resources. These results were then used to lay out a vision for Andros in the island's Sustainable Development Master Plan. Androsians, local institutions, and non-governmental organizations reported that the plan is useful for communicating what Bahamians want for the future of Andros, especially when international corporations proposed development projects that may not be aligned with local interests. The results

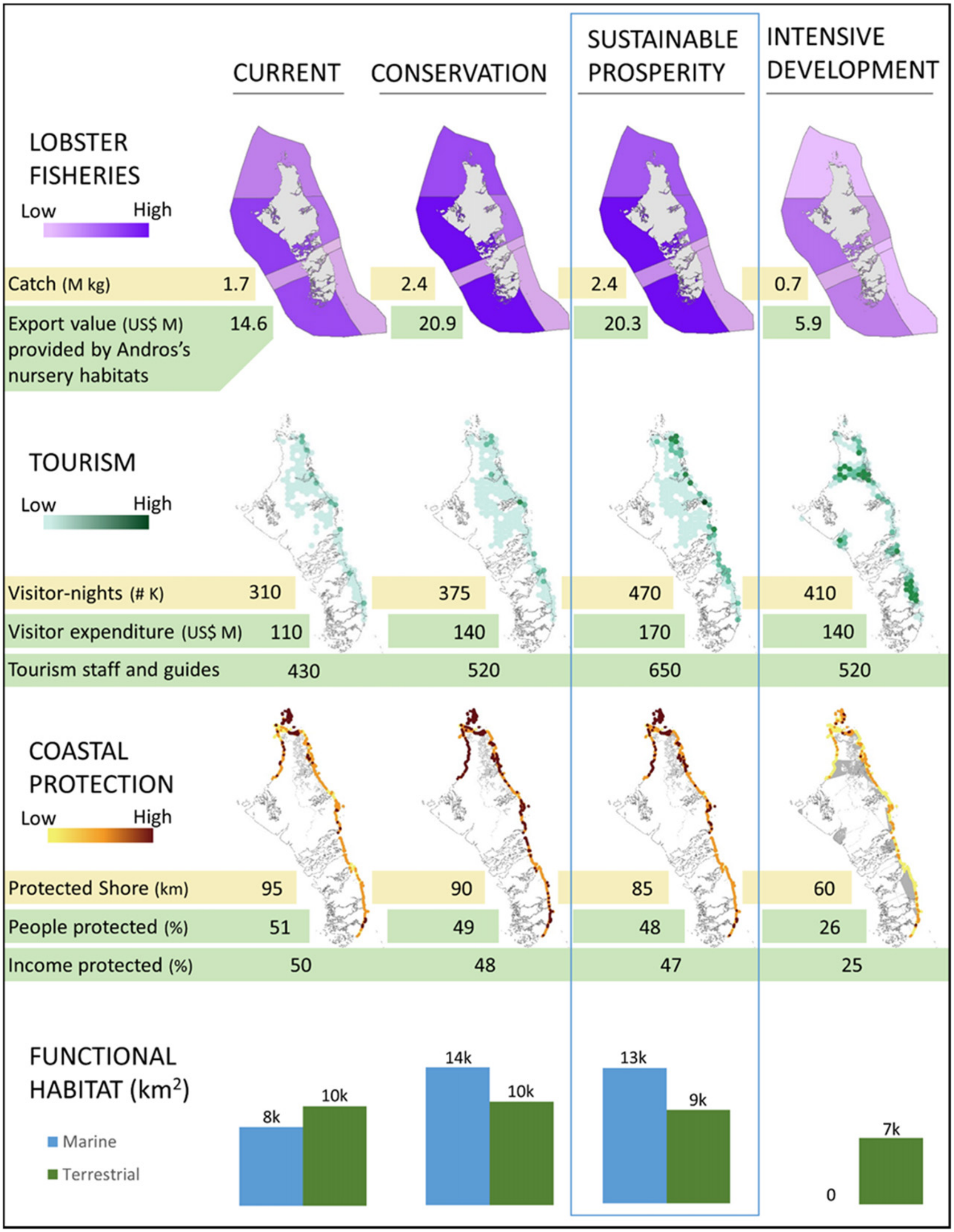

Fig. 7 Summary of future scenario analyses included in the Sustainable Development Master Plan for Andros, The Bahamas. Changes in three ecosystem services and habitats underpinning the services (i.e., mangroves, coral reefs, and seagrasses) were modeled under current conditions and three future development scenarios co-developed with stakeholders. Services are quantified using biophysical, economic, and demographic metrics defined by the government and communities to facilitate uptake in decision-making (**Fig. 2** in Ruckelshaus *et al.*, 2020).

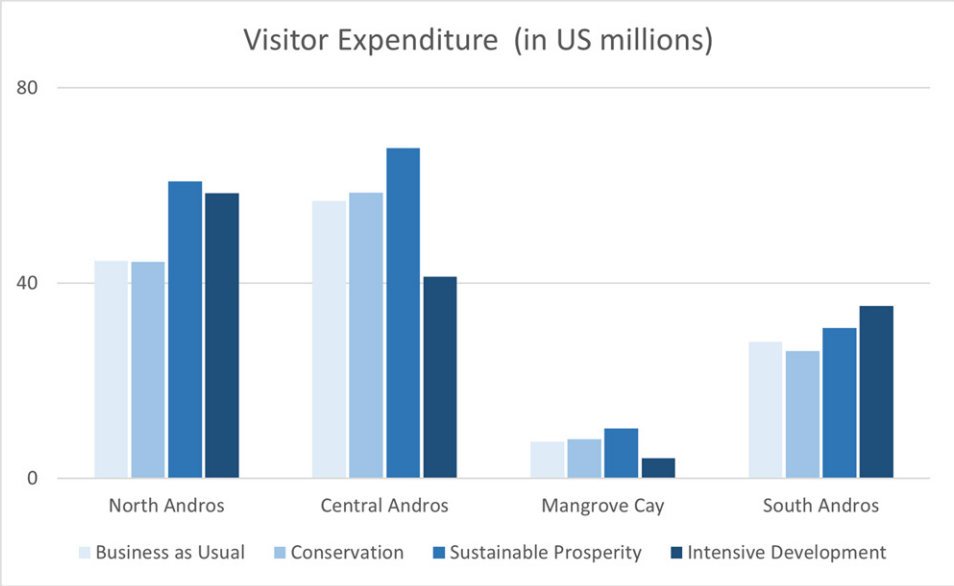

Fig. 8 Annual visitor expenditures for the four districts on the island under the four future development scenarios.

of this analysis and the Andros Plan also helped to inspire investments in estuarine and coastal ecosystems for coastal risk reduction. Following a series of storms, the Government of The Bahamas secured a loan from the Inter-American Development Bank for coastal management of which $3 USD million was specifically designated for mangrove protection and restoration (Lemay *et al.*, 2017; Silver *et al.*, 2019).

Renewable Energy Transitions in Island and Remote Coastal Communities

Remote coastal and island communities are often on the front lines of a changing climate and aging energy infrastructure. Building, operating, and maintaining energy infrastructure in coastal areas presents unique challenges and this can lead to high costs for electricity, fuels, and other essential energy sources. Moreover, the combination of rising sea levels and more intense and frequent storms puts these communities and their energy infrastructure at increasing risk from natural hazards. In addition, as described throughout this chapter, the well-being of remote shoreline communities is often closely tied to the health of estuarine and coastal ecosystems, thus any energy development will need to consider interactions with the natural environment. Moreover, many island and coastal communities lack access to reliable energy resources in part due to the historical legacies that have confined them to remote locations and/or past infrastructure projects that have led to environmental degradation and social injustice. To address these challenges in the United States, many island and remote coastal communities are exploring renewable energy solutions that will support the triple bottom line goals of sustainable development: economic growth, environmental health, and social equity. Yet, small coastal communities often face limited resources and capacity to tackle complex energy and resilience issues.

To support community-driven energy transitions in coastal regions, and to better understand relationships between energy, communities, and ecosystems, the United States Department of Energy (DOE) has embarked on the Energy Transitions Initiative Partnership Project. The goal of the program is to support island and remote communities seeking to transform their energy systems and increase energy resilience. The program is unique for two main reasons. First, it is technology agnostic, which means that it is funded by a cross section of DOE offices, including the wind, solar, and waterpower technology offices. Second, the program is community-driven because local entities and populations apply into the program rather than being approached by developers or government agencies wanting to implement a project. While the energy transitions project is not designed explicitly to address issues of equity in coastal social-ecological systems, several aspects of the program reflect the dimensions of equity explored in this chapter.

For example, the self-selection of communities into the program helps to foster procedural equity. Applications for the energy transitions project articulate communities' visions and values for the future and their goals for support from DOE. The program is designed to involve collaboration between community leaders, researchers from national laboratories, and community-based non-governmental organizations in the region. Collaborators aim for a transdisciplinary research approach in which partnering organizations work together to understand and co-develop innovations in the science needed to inform real-world challenges at the interface of energy, environment, equity, and climate resilience. The energy transitions project provides an early example of the shift in science and practice in the energy sector towards a greater emphasis on procedural equity. Traditionally focused on technology development, the renewable energy sector is now realizing the power of a transdisciplinary research approach for reimagining energy development. This is leading to a suite of community-based programs and the development of tools to build the capacity of DOE and the national laboratories to better meet coastal community needs and vision for renewable energy.

Similarly, the technology agnostic aspect of the energy transitions project relates to recognitional equity by putting decisions about which technologies to embrace in the hands of the communities rather than developers or the federal government. Some communities have strong cultural aversion to certain technologies that have degraded their traditional landscapes and seascapes. For example, Indigenous communities may articulate an energy sovereignty goal, rather than a renewable energy goal because of the impact of large scale hydropower on coastal watersheds and fisheries.

Any energy development in estuarine and coastal systems may lead to trade-offs with other ecosystem services. For example, ocean thermal energy conversion (OTEC)–which leverages temperature differentials in tropical areas–not only generates electricity by bringing colder deeper waters to the surface, but it also supplies quantities of cold, desalinated water as a by-product. This cold freshwater can be used for air conditioning, refrigeration, and drinking. However, to truly fulfill a vision for climate and energy resilience, development of coastal OTEC facilities may consider the role of coastal habitats in helping to reduce the risk of communities and infrastructure to coastal hazards. Coastal OTEC pipes need to be laid from the onshore facilities to offshore areas with the proper depth and temperature gradient. Such development could impact the coral reefs, mangrove forests, wetlands, and dunes that help to attenuate waves, reduce storm surge, and stabilize sediments. By carefully siting OTEC facilities and storage capabilities inland from these natural buffers, and running pipes around, rather than through ecosystems, energy facilities can benefit from nature-based reductions in flooding and erosion and support coastal community safety.

While still in its infancy, the literature on potential interactions between renewable energy and ecosystem services is growing (Picchi *et al.*, 2019; Trifonova *et al.*, 2022). The advancement of tools and approaches for understanding relationships between renewable energy technologies, estuarine and coastal ecosystems, and communities is an important step towards the equitable distribution of benefits of energy and other estuarine and coastal ecosystem services for remote coastal and island populations.

Wetland Migration in the United States

In the United States, agriculture and urbanization have converted at least 53% of the country's original wetlands, including coastal and inland wetlands (Dahl, 1990; Fluet-Chouinard *et al.*, 2023) . The remaining coastal wetlands—estimated to be one of the most valuable ecosystems in the world—are now threatened by sea level rise (Costanza *et al.*, 2014, 1997; Nicholls and Cazenave, 2010). Wetlands could adapt to rising seas by vertical accretion (the building of elevation over time through sediment and organic matter deposition) and/or landward migration (gradually moving to higher elevations as seas rise in areas with gentle slopes) (Borchert *et al.*, 2018). Scientists continue to debate if wetlands will be able to keep up with sea level rise through vertical accretion (Coleman *et al.*, 2022; Törnqvist *et al.*, 2021). However, scientists project that large-scale wetland loss and retreat will occur at global warming levels above 1.5°C (Saintilan *et al.*, 2023). Under accelerated sea level rise, allowing wetland migration could maintain some saline wetlands, but at the expense of coastal freshwater wetlands, forests, agricultural lands, and other uplands (Osland *et al.*, 2022). Some of these coastal ecosystems and economically productive lands will be lost as they convert to saline wetlands. Nonethelesss, facilitating migration could preserve the ecosystem services that coastal wetlands afford United States coasts: protecting shorelines from flooding and erosion, improving water quality, sequestering carbon, as well as providing habitat for species and recreational open space for people (Barbier *et al.*, 2011; Costanza *et al.*, 2014; Sutton-Grier *et al.*, 2015). However, wetland migration will not be universally good for all communities and estuarine and coastal ecosystems. Wetland migration has important tradeoffs and synergies that need to be carefully considered in adaptation planning and natural resource management (Balderas Guzmán, in preparation).

Allowing wetland migration requires United States government agencies or conservation organizations to intentionally protect wetland migration corridors by removing physical barriers if needed (such as sea walls or levees) and setting aside these areas. To do so, they have many policy options at their disposal: land acquisitions, easements, restrictive covenants, future interest payments, land swaps, zoning or setbacks, transfer or purchase of development rights programs, and shoreline management policies (Field *et al.*, 2017; Spidalieri, 2020). The ideal policies to protect wetland migration corridors, such as land acquisitions and easements, can be expensive to implement at a large scale because of the cost of buying land, which in the United States is largely in private ownership (Spidalieri, 2020). Plus, governments and conservation organizations must pay the costs of acquiring land sooner than the benefits can be demonstrated since wetland migration takes time. Meanwhile, protected areas are also subject to ongoing maintenance and monitoring costs along with the potential loss of property tax revenue (Runting *et al.*, 2017; Spidalieri, 2020; Taylor and McAllister, 2014). Hence, choosing to protect wetland migration corridors will have opportunity costs and tradeoffs for institutions, especially those facing pressures to spend money on more immediate local needs. Urban communities also have the option to not build in planned growth areas that could be subject to future wetland migration (Enwright *et al.*, 2016).

Wetland migration can also have negative impacts on individual landowners. Wetlands encroaching on property can decrease property values or impact the commercial productivity of agricultural and forestry lands. As a result, some people do not want migrating wetlands on their property (Spidalieri, 2020). Wetland migration can cause water damage to property and saltwater intrusion that reduces crop yields, threatening farms, homes, and historic and cultural sites; and once landowners have wetlands on their property, their options for adaptation can be constrained due to wetland and endangered species protection laws and depreciating property values (Spidalieri, 2020; Van Dolah *et al.*, 2020). These impacts could be especially problematic for disadvantaged communities in both urban and rural areas whose adaptive capacity is already constrained.

Yet allowing wetland migration could be synergistic with other adaptation efforts. Since lands subject to wetland migration will be risky for human habitation, pairing the protection of wetland migration corridors with managed retreat could be a strategy to simultaneously move people to safer areas and preserve wetlands (Kaprielian, 2017; Spidalieri, 2020; Taylor and McAllister, 2014). While migrating wetlands often encroach on farmland and reduce productivity, modeling shows that in certain cases, fringing wetlands can protect farmland and groundwater from salinization (Guimond and Michael, 2021). And while coastal farmland may eventually be lost to migrating wetlands, research shows that in the meantime, farmers could transition to salt- and flood-tolerant crops such as the seashore mallow (*Kosteletzkya pentacarpos*)—a crop that is commercially viable, prepares the soil for migrating wetlands, and promotes wetland biodiversity (Voutsina *et al.*, 2015).

For coastal wetlands to migrate, other upland or upstream coastal ecosystems inhabiting those areas will be lost to migrating saline wetlands, particularly coastal forests and tidal freshwater wetlands (Borchert *et al.*, 2018; Gedan *et al.*, 2020; Mitchell *et al.*, 2020; Sklar *et al.*, 2021; Wen and Hughes, 2022). This tradeoff between coastal ecosystems will impact forest and freshwater wetland species and reduce the overall habitat diversity of coasts. Even if the total area of saline wetlands can be maintained by allowing migration, the habitat characteristics of wetlands may not stay the same as they migrate. Modeling studies of wetland edge morphology suggest that migrating wetlands may have edges whose evolving form could be harmful to certain species. For example, in Chesapeake Bay, ribbed mussels (*Geukensia demissa*) may not be able to adapt to the rapidly changing pace of wetland edges, and their reduction in numbers could have significant impacts on water quality (Isdell *et al.*, 2020). On the Atlantic coast of Maine, migrating wetlands could have simpler seaward edges that could be of lower habitat quality to mummichog fish (*Fundulus heteroclitus*), which depend on morphologically complex wetland edges and play an important role in the health of local fisheries (Torio and Chmura, 2015). These two examples show that decreases in particular wetland species could have cascading impacts. Landward edges (wetland-forest edges) may also be of lower habitat quality to certain avian species (Taillie and Moorman, 2019). Other modeling studies predict an expansion of low marsh habitat compared to high marsh, which would be detrimental to high marsh species (Valiela *et al.*, 2018). Maintaining as much saline wetland area as possible with migration is important but does not guarantee the preservation of all ecosystem functions and species. Ideally, natural resource managers should aim to preserve the full gradient of coastal ecosystems as well as employ restoration techniques to preserve the gradient of within-wetland habitats (high, mid, and low marsh areas) to the extent possible under sea level rise.

Given the potential for both tradeoffs and synergies with wetland migration, cross-sectoral, cross-scalar, and phased approaches to adaptation planning and natural resource management are needed. These tradeoffs and synergies show how a variety of actors (from governments to individual people to particular species) could be impacted at multiple spatial and temporal scales. Hence, linking together in a phased approach the protection of wetland migration corridors, human adaptation planning to sea level rise, and broader coastal ecosystem protection and restoration will maximize benefits and avoid unforeseen impacts. To support such policies, more research into the tradeoffs and synergies between human and ecosystem adaptation is needed to anticipate synergies and avoid maladaptation (Barreteau *et al.*, 2020; Burley *et al.*, 2012; Magnan *et al.*, 2016). Finally, community engagement will be a necessary component to cross-sectoral coastal policies. Crucially, decision-makers will need to balance the protection of critical and already scarce coastal wetlands with the needs of vulnerable coastal populations that face disproportionate risks to sea level rise and reduced adaptive capacity (Van Dolah *et al.*, 2020).

Conclusion

In recent years, the volume of estuarine and coastal science addressing multiple dimensions of equity has grown. Our chapter highlights advances in the knowledge base underlying three dimensions of equity–procedural, recognitional, and distributional –but also underscores the challenges of applying and implementing theory in practice. Even for distributional equity, which is arguably the most well-understood, there are opportunities for more consistent disaggregation of benefits from estuarine and coastal ecosystems among regions and demographic groups. Similarly, our general understanding of who benefits from different categories and subcategories of ecosystem services has improved. However, identifying specific actors, institutions, and individuals to engage in actual decision-making processes, at the relevant scales for governance, can be extremely challenging. Once these entities are identified, current approaches for incentivizing and realizing their participation are often not well-established, nor effective, and can be challenging from a capacity standpoint for smaller and under-resourced communities.

While progress has been made, all three dimensions would benefit from more work that elevates and incorporates different cultural norms and values into coastal and estuarine science and management practices (Loos *et al.*, 2023). A powerful aspect of ecosystem service approaches and tools is the quantification of benefits in multiple metrics that reveal unintended consequences of decisions and resonate with diverse interests. Yet, cultural benefits are very difficult to quantify and the idea that contributions of nature to human societies can be quantified is misaligned with some cultures' ways of knowing. While there is a desire among many scientists and practitioners to elevate Indigenous and other marginalized voices, real barriers exist. A shift in power dynamics that promotes Indigenous scholars and leaders and broadens the scope of traditional science-policy processes are a necessary and important step towards estuarine and coastal science and management that reflects the needs, cultures, and knowledge of coastal communities.

We find that research on social metrics, beneficiaries, and dimensions of equity is relatively mature for some subcategories of estuarine and coastal ecosystem services. For example, fisheries are critical for providing nutritional benefits in the form of protein, lipids and other compounds for many populations, with marginalized groups living in remote coastal areas especially dependent on food from marine environments. In contrast, understanding the dimensions of equity, beneficiaries, and trade-offs for newer coastal disciplines and sectors, such as marine-based renewable energy, is limited. Researchers are exploring what equitable access to new technology for energy generation in coastal systems looks like. This is a challenging undertaking when the technology is not well-understood nor are the pathways clear for how remote coastal communities, often dependent on ageing transmission infrastructure, may reap the benefits.

Finally, our case studies focus on three decision contexts that confront coastal communities: coastal planning to achieve triple bottom line goals of sustainable development, renewable energy transitions in remote coastal and island communities, and wetland mitigation related to climate adaptation. A limitation of our chapter is that these cases are all from the Americas; however, they describe trade-offs and beneficiaries common to estuarine and coastal systems around the world. Emerging from these case studies are patterns similar to those highlighted in the previous two sections. First, The Bahamas and wetland migration cases indicate that addressing distributional equity tends to be more well-established than procedural and recognitional equity. However, data availability and knowledge gaps in The Bahamas preclude disaggregation of benefits and costs by demographic groups and limit the study to distributional effects assessed by district. Second, The Bahamas case and the renewable energy case aim to foster participatory processes, yet in some respects Indigenous and marginalized voices are limited. Third, coastal planning and climate adaptation are more advanced in considering multiple benefits and trade-offs than the renewable energy case. There is an opportunity to advance renewable energy planning in estuarine and coastal ecosystems to move beyond its singular focus on energy outcomes to better understand how local energy resources and technology can be leveraged to realize community goals for ecological sustainability, social equity, and economic development.

In conclusion, equity, trade-offs, and beneficiaries are ripe areas for research at the boundary between fundamental and applied estuarine and coastal science. Advancing the knowledge base underpinning these elements of ecosystem service science not only requires more interdisciplinary scholarship, it also requires opportunities for scientists and coastal communities to co-develop and test theory in practice. Equitable access to, and management of, estuarine and coastal systems is still a long way off in many places. However, science that moves beyond problem identification towards developing innovative solutions, partnerships, and technologies, is an important part of equitable environmental and societal change.

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