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PRACTICE BRIDGE

Utilizing ecosystem services to support restorative marine economies

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A restorative economy is a melding of environmental restoration and business activities, with interactions and feedbacks that contribute positively to society through enhancing multiple social, cultural, environmental, and financial well-beings. Ecosystem services, which can be used to document and quantify the benefits of healthy functioning ecosystems, are likely to be crucial to the success of restorative economies in the scoping and planning phases, and as metrics of success while projects are underway. Describing and quantifying whole "bundles of benefits" delivered by healthy intact ecosystems will help to draw attention to the value of conservation and restoration. Restorative economies focused on single "tradable" services such as carbon sequestration may be problematic in the marine environment given that our oceans are "commons" without clear definitions of ownership. In this article, we focus on the role of ecosystem services in restorative marine economies, with examples from Aotearoa New Zealand where indigenous cultural values and rights are at the forefront of marine conservation and restoration. To reduce investment risk and secure financing for restorative economies, better quantification of ecosystem services and the development of multiple well-beings frameworks (encompassing social, ecological, cultural, and financial benefits to communities) will likely be required. This will also promote effective communication and monitoring of the multiple benefits obtained from restored ecosystems, which will ultimately serve to sustain and expand restorative economy endeavors.

Keywords: Ecological restoration, Bundles of benefits, Multiple well-beings, Natural capital, Circular economy

Introduction

Governmental and nongovernmental organizations, philanthropic and impact investors, and community-scale ecological entrepreneurs are increasingly interested in restorative economies. The definition of restorative economies continues to evolve, but the idea centers on combining business activities with environmental restoration, aiming to foster new investments and business opportunities that reverse environmental degradation instead of ignoring or contributing to it (Hewitt et al., 2018). In *The Ecology of Commerce*, Hawken (1993) states that the "restorative economy tries to create a market in which every transaction feeds the integrity of the commons, as opposed to what we know today, when consumption causes degradation and harm." As such, restorative economies are supposed to be decoupled from, rather than dependent on, the consumption of finite resources. Further, a truly restorative economy will enhance natural renewable resources and contribute positively to the commons, instead of depleting nonrenewable resources and creating waste. Restorative economies may seek to mitigate societal challenges such as climate change, or ecosystem degradation resulting from resource extraction, by sustainably managing or restoring key ecosystem components. An emphasis of restorative economies is nature-based solutions (Cohen-Shacham et al., 2016; Cohen-Shacham et al., 2019) that generate multiple well-beings (i.e., the social, environmental, cultural, and economic factors that contribute to human health, life satisfaction, and happiness). Nature-based solutions are "actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (International Union for Conservation of Nature, 2020).

The oceans cover most of the planet and support a huge range of human activities and societal benefits. Nevertheless, the oceans are also increasingly under threat, becoming warmer and acidified due to anthropogenic carbon absorption and beset by various assaults associated with resource extraction. Restoring marine ecosystems is one of the United Nation's Sustainable Development Goals (Goal 14). In recent history, the largest contributors to marine economies worldwide have been directly extractive or indirectly extractive due to dependence on nonrenewable

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Table 1. Facilitatory role of ecosystem services in the design and execution of restorative economy projects

Project Phase	Role of Ecosystem Services
Project scoping (1. Aspirations of people)	Decide what the restoration goals are by determining: a. What ecosystem services have been lost or degraded (as the presence of habitats can indicate restoration potential)? b. Which ecosystem services best link to the values and aspirations of people? c. Which species/habitats best deliver the desired ecosystem services? d. What ecosystem services are marketable and how can ecosystem services be "bundled"?
Project planning (2. Achieving goals)	Decide scale (and thus budget) for restoration by estimating: a. How much habitat needs to be restored to achieve goals? b. Net changes in ecosystem services delivery (what will be replaced?)
Project execution and completion (3. Measuring success)	Demonstrate/assess project success at various stages by: a. Quantifying net change (improvement) in the desired ecosystem services b. Quantifying net change in other attendant ecosystem services (broader picture)
Monitoring natural capital and social feedbacks (4. Evaluating and monitoring)	Monitor ecosystem well-being and delivery of ecosystem services by: a. Regular mapping of restored ecosystem/habitat b. Regular monitoring of restored ecosystem properties (e.g., species density, ecosystem biodiversity, etc.) c. Communication of nonmarketable ecosystem services delivery that can build positive social feedbacks and promote restorative economy perpetuity d. Monitoring of social, cultural, and financial outcomes

resources (e.g., fossil fuels). For example, mining (extraction of seafloor minerals, oil, and gas) and fisheries (removal of fish and invertebrate biomass) collectively contribute US$2.5 trillion to the world's economy (Food and Agriculture Organization of the United Nations, 2016). Maritime shipping previously accounted for approximately 50% of the global fuel oil demand and burned 3.5 million barrels of high sulfur "bunker" fuel per day (Billing et al., 2018). Changes by the International Maritime Organization in 2020 led to shifts to low sulfur fuel oils, and in 2023 a net-zero emissions target for 2050 was set, but the industry continues to be a major contributor to global carbon emissions.

The transformation of mining, fishing, and shipping into marine restorative economies will not happen overnight, simply due to the sheer scale of these industries. At the local level, however, partnerships between businesses, communities, philanthropists, and governmental and nongovernmental agencies are increasingly willing to explore new restorative economy initiatives that address environmental degradation and simultaneously foster improvement in multiple socioeconomic and sociocultural arenas. Yet, in order to sustain and grow these small-scale initiatives, a clearer understanding of the full range of benefits provided by restorative economies is required, as investors—even those who do not necessarily want a financial payoff—want to maximize returns on investment. Methods and tools for evaluating performance in economic, environmental, social, and cultural terms are therefore critical to advancing marine restorative economies (Blignaut et al., 2013).

Here, we outline marine ecosystem services and their potential contributions to marine restorative economies, discussing restoration scale, motivations, and successes using examples from Aotearoa New Zealand. Aotearoa New Zealand has a relatively short history of human habitation, with the first human presence estimated to be approximately 700 years ago (Bunbury et al., 2022) and European colonization (and associated intensification of impacts on the marine environment) in the last 200 years. As human populations have expanded to what they are today (approximately 5 million; Stats NZ, 2024), extractive resource use, fishing, and sediment and nutrient runoff from land-use practices have contributed to the widespread degradation of marine ecosystems and attendant ecosystem services. In many places, degradation and loss of ecosystem services have occurred within living memory and have prompted a wave of community-driven restorations. We propose the use of a multiple well-beings framework (i.e., one that encompasses the social, economic, environmental, and cultural goals of a community) as a tool to support marine restorative economies. Such a framework will utilize bundling of marketable and nonmarketable ecosystem services to allow holistic quantification of the benefits delivered by restored ecosystems, which can be used as a guide through the design, execution, and monitoring stages of restorative economy projects (**Table 1**).

Ecosystem services for restorative economies

Ecosystem services is a term for conceptualizing and communicating the ways in which Earth's biodiversity and natural ecosystems benefit humans (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005; de Groot, 2010). The goal of ecosystem services is to engender a broader understanding of the benefits of healthy functioning ecosystems, and what humankind is losing when we overharvest, fragment, pollute, and disturb natural areas. Natural capital refers to the stock of natural assets from which ecosystem services are derived. When ecosystems are degraded, so too is their natural capital and thus their ability to provide ecosystem services. Restorative economies aim to build up natural capital, not just to pre-degraded levels, but further to where emergent properties and benefits (e.g., resilience) accrue. Thus, there are synergies between ecosystem services and restorative economies, with ecosystem services likely being useful as a basis for understanding and quantifying the benefits of restoration activities in ways that are palpable to society. Ecosystem services may thus be useful in attracting restorative economies investors and for measuring restorative economies outcomes and successes at various timepoints after initiation. Economic valuation of ecosystem services can help to drive ecosystem restoration and restorative economies (Iftekhar et al., 2017) and can help initiate or give momentum to restoration or conservation projects. The ecosystem services provided by marine systems are vital to include in coastal management and planning as the benefits provided to people are immense (Barbier et al., 2011); however, more scientific studies that demonstrate the socioeconomic benefits of coastal restoration are needed (Bayraktarov et al., 2020).

Ecosystem services provided by marine ecosystems are generally divided into 4 main classes: habitat and supporting services (e.g., nutrient regeneration, habitat provision, primary production, sediment formation, biodiversity), regulating services (e.g., carbon sequestration, storm protection, water filtration), provisioning services (e.g., food, materials), and cultural services (e.g., recreation, tourism, spiritual values) (Beaumont et al., 2007; Forest Trends, 2010; Townsend et al., 2018; Geange et al., 2019). The delivery of these ecosystem services is highly dependent on the state of the ecosystem involved, along with peripheral but interconnected elements that contribute to the state of the ecosystem. For example, the food provision ecosystem services of wild-caught fish depend on overall ecosystem health and stability, the availability of prey species in lower trophic levels, as well as seafloor nursery habitats, larval dispersal, and ecosystem primary productivity. A fishery is sustained only if these many different components are in a functioning state. The quantity, quality, and constancy of ecosystem services delivered will likely be lesser in degraded ecosystems, relative to healthy ones. Additionally, healthy and biodiverse ecosystems can enhance emergent ecosystem properties, such as ecological resilience and resistance to disturbance (Townsend et al., 2018), which help to maintain constancy in ecosystem service delivery over time despite inevitable challenges. In a world of increasing anthropogenic stressors and climate change impacts, such “insurance” ecosystem services are of paramount importance for environmental sustainability.

The ecosystem services concept, a way of defining “Nature’s Contributions to People” (Díaz et al., 2015), aims to holistically account for values including intrinsic and sociocultural values such as indigenous and local knowledge, and relational values such as sense of place, sacredness, and identity (Christie et al., 2019). Like ecological values, relational values can be highly context and scale dependent. The delivery of ecosystem services is dependent on the human demand for ecosystem services provided by an ecosystem. For example, mangrove forests can provide a storm wave buffer, but the ecosystem service of storm protection only exists if there are people living in the area. One of the problems with environmental degradation is that peoples’ activities and reliance on ecosystems change and in turn their values associated with them. From an indigenous perspective, this can result in a loss of intergenerational knowledge and cultural practices associated with an environment. If degradation is significant enough or if loss values occurred a long time ago, it may be difficult to demonstrate nature’s benefits to people. Restoring ecosystems, however, should not be solely for the sake of people, and removing this anthropocentric viewpoint may facilitate more impactful approaches to restoration.

Ecosystem services can be used to assess and communicate the link between healthy marine ecosystems (i.e., natural capital) and the multiple benefits and well-beings for people. Successful restorative economy projects will create a positive feedback loop that enhances the well-being of people and ecosystems through building natural capital and increasing the provision of ecosystem services (**Figure 1**).

The benefits of healthy marine ecosystems (or restored ecosystems) are often not obvious to the general public and communicating the full range of benefits of restoration to stakeholders or investors is likely to be critical ahead of restorative economy project initiation. Ecosystem services are a way of translating and generalizing the multiple benefits received (Rullens et al., 2019). Effectively communicating such benefits requires site-, species-, and ecosystem-specific ecological and social knowledge of a potential restoration endeavor, and we argue that ecosystem services quantification and mapping are crucial for increasing the utility of the concept (Townsend et al., 2018; Townsend and Lohrer, 2019; Lohrer et al., 2020; Rullens et al., 2022). Monetization may be possible following quantification for some ecosystem services, but certainly not for all, especially those that are not marketable. Regardless, demonstrating the outcomes of restoration, sometimes relative to a goal or “reference” ecosystem (i.e., one in a non-degraded or desirable ecological state) is critical. Metrics of restoration success can be used to quantify outcomes, and although delivery of ecosystem services is not commonly used to measure restoration success (Ruiz-Jaen and Mitchell Aide, 2005), ecosystem services can be used as effective metrics to conduct cost–benefit analyses before, during, and after restoration (Kimball et al., 2015) (**Table 1**).

Combining business activities with environmental restoration is predicted to provide multiple social benefits at

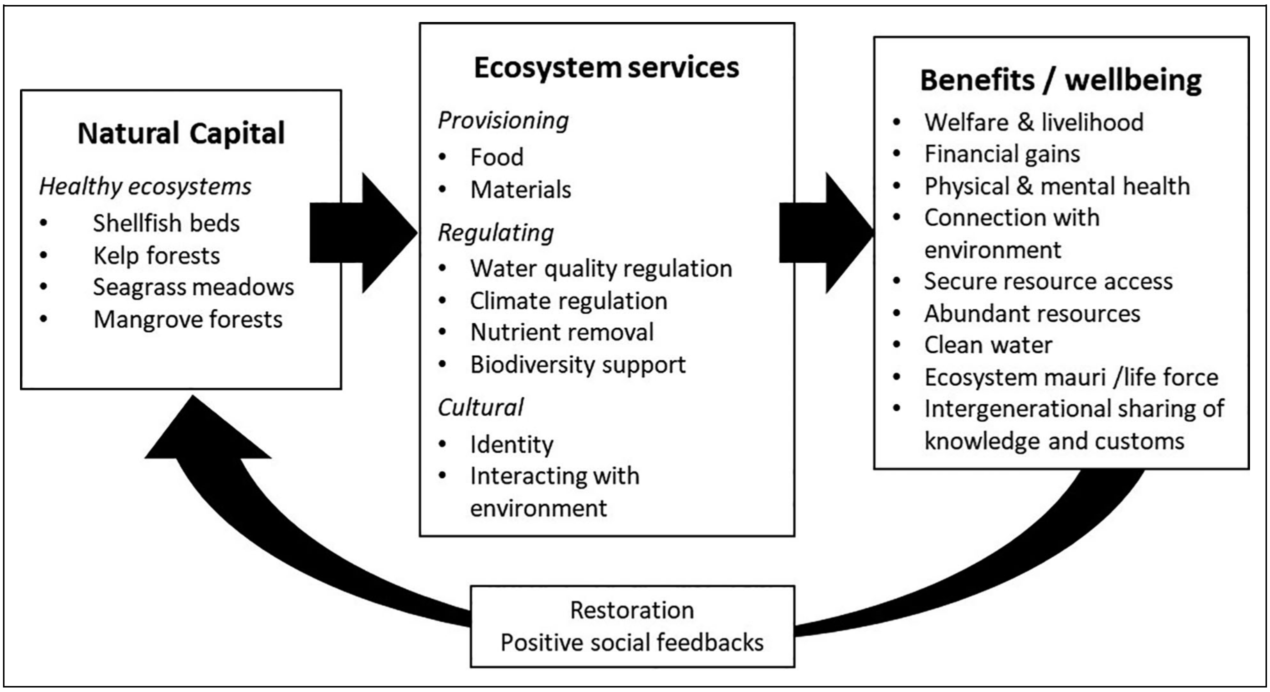

Figure 1. Ecosystem services bridge the gap between healthy ecosystems and benefits received. Restoration provides positive social feedback that enhance ecosystems and in turn ecosystem service provision.

the local level by enriching lives through community involvement, contributing to the commons, reviving collective environmental guardianship, and restoring culturally significant ecosystems (Science Task Force for the UN Decade on Ecosystem Restoration, 2021). These benefits are particularly important in areas with indigenous communities, where cultural values, indigenous world views, traditional ecological knowledge, and concepts of reciprocity in human–environment interactions are essential for community-wide buy-in to projects (Wehi and Lord, 2017). In Aotearoa New Zealand, Te Ao Māori (the Māori worldview) frames all things including humans as interconnected through whakapapa (genealogy, kinship ties). Human relationships with the environment are reciprocal through these kinship ties between the physical and metaphysical world, and goals and aspirations for environmental protection and restoration are intergenerational, aiming for the best possible outcomes regardless of time or cost (Morgan and Manuel, 2020; Walker et al., 2021). This contrasts with a more "transactional" type of restoration that may be motivated by improved public relations (i.e., a clean green image) or as an offset for pollution or degradation associated with the core business. Often, the benefits of the latter will be sought in the fastest possible time frame with minimum expenditure.

Globally the potential of marine restorative economies is huge, especially in countries where indigenous communities are at the forefront of conservation and have the governmental support to drive projects. Opportunities for marine restorative economies in Aotearoa New Zealand have the ability to be very successful with wide-ranging uptake and benefits due to proactive indigenous communities and a population that in general is culturally very connected with the sea (75% of the population residing within 10 km of the coast; LEARNZ, 2021). The provision of food is commonly the foremost ecosystem service that people identify in the marine environment (Barbier, 2017). However, in Aotearoa New Zealand, it goes much further; New Zealanders and especially Māori are intricately associated with the ocean, and the ability to collect and provide kaimoana (seafood) is extremely valuable in a cultural context. For example, kaimoana is used to manaaki (care for, provide hospitality to) guests on the marae (a communal meeting place), and the inability to provide traditional kai (food) during cultural gatherings may be considered as shameful or a loss of mana (prestige, power, or status) (e.g., Tipa et al., 2010). A loss of signature kaimoana species may be associated with a loss of local identity, and an inability to harvest is associated with an inability to pass on mātauranga (traditional Māori knowledge) (Dick et al., 2012; Ministry for the Environment and Stats NZ, 2021). Māori often allude to an energy, mauri, that binds and animates all things in the physical world, and spiritual connections derived from whakapapa between humans and nature are fundamental in Te Ao Māori (Harmsworth and Awatere, 2013). These types of cultural ecosystem services are difficult to quantify, as essentially they are priceless, but their importance must be considered as an element of any multiple well-beings metric that is developed.

1. Motivations for restoration linked to aspirations

In recent times, due to international commitments to mitigate climate change impacts (e.g., the Paris Agreement), many ecosystem restoration projects have focused on carbon sequestration as a means for countries or companies to achieve goals of carbon neutrality (e.g., Corporate Social

Responsibility) (Torabi and Bekessy, 2015). Initiatives to change land management practices to those that store carbon or reduce greenhouse gas concentrations ("Carbon farming") are being encouraged in many countries. For example, in Aotearoa New Zealand, large areas of relatively low-productivity farmland are being converted to forestry incentivized by an Emissions Trading Scheme (New Zealand Government, 2023), and government-incentivized changes to agricultural practices are occurring throughout the European Union (McDonald et al., 2021). In a terrestrial context, carbon sequestration by certain species of trees (especially those that are commercially produced) is something that can be quantified and assigned monetary value. Moreover, if forests can be milled, there are financial gains in addition to carbon credits making planting of carbon sequestering forests worthwhile for investors. However, milling removes the long-term sequestration of the stock, in effect defeating the purpose of restoration for the sake of carbon sequestration.

Restorative economies focused on a single ecosystem service such as carbon sequestration may be more challenging in the marine environment as it is not "owned" (with exceptions including coastal wetlands or licensed aquaculture areas) and therefore benefits or credits are not tradable. In many countries, the marine environment is a government-owned "common," unlike on land where ownership (and therefore financial benefits) of carbon credits, for example, is more clear-cut. Furthermore, at a local or regional level, benefits of carbon sequestration are not observable (or socially valued) to the extent that other ecosystem services are. Seaweed aquaculture has been touted as a restorative economy initiative that produces multiple ecosystem services financed through global carbon markets (e.g., Greenwave.org). It should be noted, however, that the ecosystem services and their values obtained through aquaculture-based restorative economies may be much different to those of restored natural ecosystems. Furthermore, the carbon sequestration role of seaweeds is unresolved as there is currently no evidence of long-term sequestration (Froehlich et al., 2019; Gallagher et al., 2022; Ross et al., 2022).

Blue carbon strategies can provide a way to finance marine ecosystem restoration and conservation where the main motivations are to obtain or enhance ecosystem services that are locally more tangible than carbon sequestration such as cultural benefits, enhancing food provision, biodiversity, and water quality. The National Oceanic and Atmospheric Administration (NOAA) in the United States has developed strategies to leverage blue carbon for coastal conservation (Sutton-Grier and Moore, 2016), and blue carbon strategies combining climate change mitigation and coastal restoration of retired sugar cane wetlands have been used in Queensland, Australia (Hagger et al., 2022a). Such governmental policy-driven initiatives will pave the way for community- through to regional-scale restorative economy projects, but the existence of such initiatives will vary by country and may not eventuate for under-resourced developing nations for some time. Although there are many benefits to using blue carbon strategies to finance restorative economies, this may wrongly emphasize the value of carbon sequestration as greater than other ecosystem services (i.e., the co-benefits) (Canning et al., 2021). Bundling of ecosystem services can help generate more income, gain benefits of less tradable ecosystem services, and obtain maximum overall benefits to society (Banerjee et al., 2013; Torabi and Bekessy, 2015). Bundling ecosystem services can also help to ensure that the multiple well-beings and co-benefits obtained from restorations are quantified and communicated (Aronson et al., 2010).

Restoration of vegetated marine habitats (seagrass, mangroves, saltmarsh) can have wide-ranging benefits including climate change mitigation, protection against sea level rise and storm wave erosion, biodiversity enhancement, and fisheries enhancement. Coastal vegetated habitats are valuable for carbon sequestration and burial, a significant sink in the global carbon cycle (Fourqurean et al., 2012; Duarte et al., 2013). Carbon burial rates, relative to terrestrial vegetation (approximately 5 g C m^{-2} y^{-1}), are very high in seagrass beds (approximately 140 g C m^{-2} y^{-1}) (Mcleod et al., 2011; Duarte et al., 2013) and restoration of such habitats has been shown to be an appropriate climate change mitigation strategy (Irving et al., 2011). However, this is species and context dependent. For example, in Aotearoa New Zealand, seagrass carbon stocks may be little more than those of unvegetated marine sediments (Bulmer et al., 2020).

Restoring vegetated marine habitats such as seagrass beds can reduce land-derived nutrients and improve water quality and turbidity (Aoki et al., 2020; Orth et al., 2020). Nutrient removal by seagrass beds is highly variable, dependent on species as well as environmental factors (La Nafie et al., 2014; Sandoval-Gil et al., 2015), and can be negatively affected by stressors such as turbidity (Bulmer et al., 2018; Drylie et al., 2018). Although successful restoration attempts will need to consider the species- and site-specific nature of this ecosystem service, reliable values for ecosystem services quantification may be difficult to obtain. Negative effects of nutrient loading may not manifest themselves if suspended fine sediment concentrations are high, because suspended fine sediment occludes light (and both light and nutrients are required to stimulate nuisance macroalgal outbreaks and the onset of eutrophication symptoms). Initiatives that reduce sediment loading may relieve sediment-associated impacts, but unexpected indirect effects (i.e., nuisance macroalgal outbreaks) may begin to emerge.

From an indigenous or local perspective, motivations for restoration may focus on returning an ecosystem to a state where lost ecosystem services that benefit local and indigenous people can be reestablished. Goals can be guided by oral history of cultural and indigenous values, and inclusion of local indigenous knowledge such as mapping of culturally important sites can greatly complement and/or be used as reference maps for restoration (Wehi and Lord, 2017). The Mussel Management Action Plan developed for Ōhiwa Harbour in Aotearoa New Zealand's North Island was codeveloped by iwi (Māori tribe) and Government partners to restore populations of a culturally and ecologically important species; Kūtai, Green Lipped mussels, *Perna canaliculus* (Paul-Burke et al., 2018). This project involved an integration of indigenous knowledge systems (use of customary principles, interviews, identification of historical mussel distributions, and culturally important sites) with western science (quantitative surveys, mapping, etc.), and although it did not directly employ an ecosystem services approach it provides a clear demonstration of the multiple co-benefits obtained by such restoration projects. These included revitalizing intergenerational practices and obligations of kaitiakitanga (an active guardianship or stewardship of the natural world; Marsden and Henare, 1992; Roberts et al., 1995), strengthening of community relationships, enrichment of lives of those involved, and showcasing community capability through collaboration and relationships. Furthermore, this work shows that indigenous knowledge can be positioned and used with equal weighting as more normative biophysical data for restoration projects (Paul-Burke et al., 2018). The potential for restorative economies to complement projects like this in Aotearoa New Zealand and globally is substantial but ways to measure the human benefits are less clear.

2. Achieving goals by quantifying and evaluating ecosystem services

Assessing and quantifying ecosystem services are essential elements of restorative economies; however, current metrics of ecosystem service delivery are lacking in terms of scale, context dependency, and valuing intrinsic things such as biodiversity or cultural values. Ecosystem service matrix approaches have been developed to try to quantify ecosystem services provided in different habitats or ecosystems (Burkhard et al., 2009; Burkhard et al., 2014; Jacobs et al., 2015; Geange et al., 2019). Although this is useful for communicating the potential range of ecosystem services that are being delivered in a given area (e.g., a marine protected area), it is essentially a presence–absence approach. In other words, if a kelp or seagrass habitat is present, it is assumed the ecosystem services associated with that habitat are delivered. Ecosystem services tools need to evolve beyond this to something that acknowledges scale (how much habitat area is required for a service to be delivered in appreciable quantities) as well as interactions and trade-offs between ecosystem services (Townsend et al., 2018; Rullens et al., 2019; Lohrer et al., 2020). Matrix approaches have been combined with mapping of habitat quality and quantity to document changes in ecosystem services delivery through time although these approaches require further development (Geange et al., 2019). In addition to scale, the quality of an ecosystem (i.e., how pristine or healthy it is) can determine its ability to deliver ecosystem services. A degraded ecosystem may provide the same types of ecosystem services as a pristine ecosystem; however, the efficiency and "amount" of that service delivered may be different. For example, all else being equal, a degraded shellfish bed with a low density of small individuals will not provide the same quantity of water filtration ecosystem service per area as a healthy bed with a high density of large individuals.

Deciding restoration scale

We do not know the minimum scales at which the benefits of ecosystem services begin to accrue, and scales of accrual will vary for different ecosystem services. Yet this is imperative to plan a successful restoration, especially if economic values are to be assigned. For restoration success, scale is important because having larger numbers of individuals across larger areas reduces risks associated with high environmental variability, and larger restored populations are more self-perpetuating and thus self-sustaining (van Katwijk et al., 2016). The benefits of some ecosystem services may only occur if a restoration is greater than a certain size, or if a certain number of years have passed since restoration. For example, mangroves can take decades to mature compared with 1 or 2 years for saltmarsh and seagrass, and the rate of benefit accrual will differ by ecosystem (Stewart-Sinclair et al., 2021). For some services, timescale may not be important, but for others, especially where economic investment and returns are important, these need to be at least defined to get stakeholder buy-in. This is another benefit of using ecosystem services bundles, they can encompass variations in ecosystem service scale and uncertainty.

Define what success will look like

For a restoration project to be successful, there first needs to be a definition of what success is (i.e., what ecosystem services will be provided or enhanced and in what quantities). To support restorative economies, effective reporting and robust metrics of restoration outcomes are required, especially for social and economic benefits, as these often resonate the most with people and will therefore have the greatest positive feedbacks. Unfortunately, the outcomes and lessons learned from restorations are not frequently reported, especially if a project is unsuccessful (Bayraktarov et al., 2020). Furthermore, marine ecosystem restoration outcomes have been largely defined by ecological rather than social or economic outcomes, and coastal restoration studies have been mostly motivated by ecological questions rather than for the purpose of enhancing biodiversity, ecosystem services, or social benefits (Bayraktarov et al., 2020). Increased reporting of restoration outcomes, including failures, will encourage and aid future restoration successes (Duarte et al., 2020), and restoration success must include indicators of socioeconomic sustainability (Lovelock and Brown, 2019). Employing an ecosystem services approach from the outset that plans, guides, and monitors has the potential to greatly enhance new and existing restoration projects (**Table 1**). Focusing metrics and monitoring on a predetermined ecosystem services "success bundle" will help to constrain costs for managers, which can be an impediment to using a bundles approach.

Using ecosystem services provision as a measure of restoration success will require knowledge of the background level of that ecosystem's services prior to restoration. For example, the amount of carbon a restored shellfish bed sequesters must be quantified, but carbon sequestration must also be quantified in the habitat type that was replaced. In other words, the benefits derived are linked to the *net* change in ecosystem services delivery. If the net change is small or insignificant (or negative), then the use of that ecosystem service as a measure of success may not be relevant in that context. Restoration also needs to be put into the context of why the ecosystem or habitat was lost, as the ecosystem services delivered by the non-restored ecosystem may be of greater value to the local community than the restored ecosystem. Mangrove deforestation is widespread throughout Southeast Asia mainly because of agriculture and shrimp aquaculture development (Barbier and Cox, 2003; Hagger et al., 2022b). Many mangrove restoration projects have occurred in the region but with numerous failures because the political, social, and economic drivers of initial deforestation were not adequately addressed (Brown et al., 2014; Thompson, 2018; Lovelock and Brown, 2019).

Habitat mapping is a useful tool for ecosystem services quantification and for restorative economies may provide many benefits throughout different stages of restoration (**Table 1**). Before restorative economies projects are undertaken, a scoping of potential sites will be needed as well as determining what services were historically provided at the site. This may require interviews with kaumātua (Māori elders) to understand the provisioning of cultural ecosystem services. Maps and quantification of the habitats present (and historically present or lost), their quality, and ecosystem services they deliver will provide imperative baseline data for restorations. Monitoring is an important part of restorations (Eger et al., 2022) and comparisons to mapped benchmarks will enable measurement of the benefits and improvements obtained through restoration, especially if they are to be monetized. Mapping also allows measurement of changes in the spatial extent of an ecosystem and can be combined with metrics or ratings of the quality of the ecosystem (such as shellfish size and density) that can be tracked through time. Maps can also be used for communicating qualitative information that relates to the delivery of cultural ecosystem services such as the locations of historical indigenous food gathering sites, or knowledge of a species' historical range (Wehi and Lord, 2017).

Shellfish restoration

Shellfish beds are known to provide the ecosystem services of enhancing water quality through filtration, which removes contaminants and reduces turbidity (Dame and Prins, 1997; Grant et al., 2007; Rullens et al., 2019). The delivery of this service will be highly dependent on the size of the shellfish bed, the species, the size, condition, and density of individuals comprising the bed, as well as seasonal and environmental conditions that influence animal behavior. The effect that a small shellfish bed has on the water quality of the wider ecosystem may not be substantial; however, this does not mean that this ecosystem service or the shellfish bed is not valuable, and if scaled up through restoration can have the potential to make a large impact on whole ecosystems (e.g., oyster restoration in Chesapeake Bay; Bruce et al., 2021).

The role of shellfish in the carbon cycle is complicated and still up for debate (Miller et al., 2009; Waldbusser et al., 2011), and it is important not to oversimplify or rely on faulty assumptions. For example, shellfish grow a shell of calcium carbonate so are assumed to sequester carbon, with shellfish beds thus acting as a carbon sink. However, carbon dioxide is actually released during the synthesis of calcium carbonate (i.e., shellfish are a carbon source), so for a shellfish bed or reef to be a net carbon sink, rates of carbon burial (including from the filtration, repackaging, and biodeposition of water column organic carbon) need to offset this (Ware et al., 1992; Fodrie et al., 2017). Furthermore, quantification of carbon cycling in shellfish beds is hard to generalize and is likely to vary significantly among species and locations (Sea et al., 2022).

Coastal vegetation

Carbon sequestration by coastal vegetation is a similar story, with seagrass, for example, contributing to the amelioration of this major global problem (Irving et al., 2011). Seagrass meadows worldwide are collectively a significant carbon sink, though there is a need for quantification of greenhouse gas emissions from these ecosystems in addition to carbon burial rates (i.e., both sources and sinks must be quantified, with *net* carbon flux being the critical factor). Scale matters, however. The carbon sequestered by an individual seagrass meadow is infinitesimally small relative to global carbon emissions. Thus, the value of this particular seagrass ecosystem service may not resonate with people interacting with their local estuary. Yet locals may value seagrass for its role in estuarine habitat provision, biodiversity enhancement, and support of upper trophic levels (including the fish and invertebrates that they harvest commercially, recreationally, and for cultural purposes). These are examples of where the use of bundles of ecosystem services (Raudsepp-Hearne et al., 2010; Rullens et al., 2019) may be important because they communicate the multiple benefits provided by particular species and habitats.

Mangroves provide shoreline protection, a service valued at over US$65 billion per year globally (Menéndez et al., 2020); however, much of the research in this area is based in tropical regions. In many instances, location and species-specific quantification of ecosystem services metrics have not been quantified, such as shoreline protection by mangrove forests in Aotearoa New Zealand. Additional factors such as the depth and width of the forest, the size and age of the trees, and the location of human settlements are likely to influence the effectiveness and value of ecosystem services like shoreline protection at a local scale (Barbier, 2016; del Valle et al., 2020).

Some ecosystem services can be measured through costs avoided and may be used to incentivize restorative economies. For example, the shoreline protection ecosystem service of a healthy mangrove forest can be evaluated through the avoided costs of hard engineering solutions like seawall construction. Additionally, the co-benefits obtained through a nature-based solution may be much greater than a human-engineered one; however, negative perceptions of the effectiveness of these or of the ecosystems themselves may influence local support for that type of solution (Stewart-Sinclair et al., 2020). Furthermore, the timescales for the benefits to be realized may be much greater for ecosystem-based defenses than for conventional coastal engineering. Restoration for ecosystem-based coastal defense may be a more ecologically and financially sustainable alternative to conventional coastal engineering (Temmerman et al., 2013) and may present a different avenue for facilitating investment in restorative economies.

Understand potential trade-offs

Despite the many intrinsic ecosystem services associated with coastal plants such as mangroves and seagrass, negative social perceptions of these ecosystems may interfere with restoration initiatives and buy-in. Seagrass recolonization of beaches in Aotearoa New Zealand (e.g., Snell's Beach; T Drylie, personal communication, 22/11/2022), where it has not been seen for decades, is sometimes perceived by locals as an unwanted species even though it may represent a positive ecosystem response to improving environmental conditions. This is because seagrass can affect amenity values, such as the texture of the sediment underfoot, the "weediness" of the water while swimming, and the "cleanliness" of the beaches where seagrass detritus accumulates. Tropical mangrove forests are comprised of multiple species, some of which remain submerged throughout the tidal cycle; tropical mangroves collectively support diverse communities of marine species as well as terrestrial mammals, reptiles, birds, and insects. In contrast, temperate New Zealand mangrove "forests" are comprised of a single species (*Avicennia marina*), have a low and simple canopy (small, short trees), and have an upper intertidal distribution (submerged briefly at high tide only). Thus, the appetite for mangrove restoration may be much less depending on local culture and perceptions of their value. Similarly, New Zealand seagrass (*Zostera muelleri*) is mostly intertidal and short-bladed relative to northern hemisphere species (e.g., *Zostera marina, Thalassia testudinum, Syringodium filiforme*) that provide food and habitat for large fauna like turtles, manatees, and commercially important species such as blue crabs (*Callinectes sapidus*). Such differences in ecosystem attributes contribute to large regional differences in the cultural and social perceptions of ecosystems manifesting differences in enthusiasm and motivation for restoration.

There can be feedbacks and interactions that can have negative effects; ecosystem services such as food provision that involve the extraction of natural capital have the potential to reduce other ecosystem services (Rullens et al., 2019). For example, harvesting shellfish from a restored bed removes the animals that are providing other services such as water filtration and may therefore reduce the overall ecosystem service value of the habitat. Protecting biodiversity and enhancing fisheries are examples of conflicts or trade-offs in restoration motivations, which may come about due to differences in the agendas of different groups of people (Hicks et al., 2015). Such considerations need to be acknowledged and clarified at the outset to ensure long-term success of a restoration effort. Moreover, a coastal area may be recognized and valued as a productive fishing ground, without recognition of its dependence on supporting ecosystem services that occur in other distant but connected ecosystems. Estuaries provide many ecosystem services that support adjacent coastal ecosystems and fisheries through the provision of habitat for juvenile fish (Parsons et al., 2014; Lohrer et al., 2018), and fueling food webs through primary productivity and supply of nutrients (Savage et al., 2012; Douglas et al., 2022). Yet this service can be largely unrecognized by the stakeholders who benefit. This is an example of where the benefits (i.e., supporting ecosystem services) of healthy ecosystems occur in a separate place to where they are generated (Townsend et al., 2018).

3 & 4. A multiple well-beings framework for measuring success and evaluating impact

Measuring the success of nature-based solutions and restoration efforts can be extremely difficult, as successes and benefits may be diverse, sparsely distributed, and not observable for many years. Much more ecosystem-specific research is needed on the costs and benefits of restorations in the marine environment especially in the context of potential barriers to success, which are highly ecosystem-, place-, and context-dependent (Stewart-Sinclair et al., 2020). There is a general lack of quantification and evidence of sociocultural and socioeconomic benefits of restoration in the literature (Wortley et al., 2013), and we emphasize that the success of marine restorative economies hinges on progress in this area. Many ecosystem services are nonmarketable, difficult to appraise, and as a consequence are often underestimated or omitted from ecosystem valuations (Turner et al., 2010). Long-term benefits and stakeholder buy-in will be enhanced if restoration efforts take a holistic and bioregional perspective (de Groot et al., 2013). In a review of shellfish restoration studies, most focused on ecological outcomes rather than social outcomes; the latter are harder to measure but are known to be of profound importance (Toone et al., 2021). Positive social outcomes are likely to have strong positive feedbacks to ecosystem well-being (ecological outcomes) and promote successive restorations (i.e., a snowball effect that occurs following successful projects) (**Figure 1**) (Toone et al., 2021). This emphasizes how measuring "social success" of restoration projects, although difficult, is extremely important and will start with effectively communicating and promoting the social and cultural co-benefits obtained. Communication fosters connection and excitement with projects and can help promote future restoration opportunities and funding (Fitzsimons et al., 2020).

Successful communication of ecosystem service delivery is at the heart of the successful "Revive Our Gulf" mussel restoration initiative in northern Aotearoa New Zealand. The Hauraki Gulf was historically home to dense beds of Green-lipped mussels, Kūtai, *Perna canaliculus*, that were lost to overfishing and have failed to recover

(Paul, 2012). This huge loss of ecosystem services provision by one species alongside ecosystem degradation has been widely recognized in recent years prompting restoration of mussel beds to enhance ecosystem health. Revive Our Gulf, a collaboration of indigenous groups, scientists, and nongovernment organizations, is driving mussel reef restoration and research in The Hauraki Gulf (Revive Our Gulf, 2022). Successful communication of the impact that water filtration by mussel beds can have, in addition to other ecosystem services (healthier ecosystems, increased biodiversity, nitrogen removal), is at the core of this expanding project, which has a growing list of funders and supporters. Although not quantified or specifically designed in an ecosystem services context, this project provides a demonstration of "social success"; it has fostered important relationships and stakeholder buy-in through partnerships with Māori, community, and industry groups. Restorations are more successful if local communities are involved, as they are often economically dependent on and committed to a place (Schultz et al., 2022). This underscores the potential value in identifying and quantifying the multiple social and ecological benefits of a restoration (i.e., bundles of ecosystem services), and the importance of including site-specific local indigenous knowledge and cultural values through partnerships (Aronson et al., 2010).

Development of a multiple well-beings, or multi-ecosystem services, metric may prove useful for quantitatively predicting the success of restoration efforts before implementation to gauge the potential enhancement effect before investment, and for measuring the success or impact of restoration afterward. This may employ the use of bundles of ecosystem services, which have successfully been used to describe the ecosystem services associated with wild shellfish beds in Aotearoa New Zealand (Rullens et al., 2019). Describing and quantifying whole "bundles of benefits" delivered by healthy intact ecosystems will help to draw attention to the value of conserving and restoring ecosystems. This may then be used to leverage compensation for protecting and restoring ecosystems such as Payments for Ecosystem Services (PES) schemes. The key to PES is that "the payment causes the benefit to occur where it would not have otherwise" (Forest Trends, 2010), thus the seller has to ensure that ecosystem services are continually delivered. This may occur through maintaining, restoring, or enhancing ecological structures and functions (Forest Trends, 2010).

PES schemes have been set up worldwide to support mostly conservation objectives, but also ecosystem restoration (Farley et al., 2010). These schemes have been successful although have drawbacks including difficulty in accounting for changes in ecosystem services delivery through time (i.e., to assess monetary value), and a tendency to favor certain ecosystem services such as carbon sequestration (where there are established markets and trading schemes) at the expense of others like biodiversity (which have intrinsic existence value but are difficult to value in direct dollar terms) (Bullock et al., 2011). Furthermore, PES-funded restoration projects may be swayed by financial markets detracting from local social or cultural ecosystem values. There may be large temporal lags in the benefits seen from restoration efforts and this may not be compatible with ever-changing financial entities such as carbon markets. In terrestrial ecosystems, the "sellers" in PES schemes are typically landowners, but in the marine environment (especially in Aotearoa New Zealand), a lack of legal ownership adds a level of complexity to developing such projects. To make PES fair and objective, there needs to be more robust quantification of ecosystem services as well as comprehensive and accurate assignment of monetary value. Bundling ecosystem services for projects may help to maximize benefits and reduce risks (Forest Trends, 2010), but this is difficult when some services are monetizable and others not, although we stress that ecosystem services can be valuable even if not monetizable. Ensuring perpetuity of the conserved ecosystem is necessary for successful PES schemes, otherwise there is no incentive to collect dividends only up until a time where the benefits of ecosystem services and PES are outweighed by the monetary value of resource extraction or other activity that contributes to ecosystem degradation. PES schemes in the marine environment work where a management action can facilitate or increase delivery of a service such as shoreline stabilization, fish nursery habitats, biodiversity conservation, and coastal water quality and pollution filtration (Forest Trends, 2010).

Beyond monetization, a restorative economy approach can facilitate marine restoration by including, assessing, and communicating the benefits of many types of ecosystem services. Development of project-specific goals for ecosystem services delivery for a restoration will provide the first steps to bundling monetizable and non-monetizable ecosystem services.

Conclusion

As anthropogenic impacts on natural ecosystems increase so too does the need and desire to mitigate or reverse degradation. In the marine environment, restorative economies have huge potential to contribute but to date have been largely restricted to certain ecosystem types or geographic locations (e.g., tropical mangrove forests, and oyster reefs in the United States). This is because successful restoration initiatives commonly draw on learnings from similar projects (i.e., focused on the same species, similar habitats, or within the same region) (Toone et al., 2021). Securing financial backing requires that restoration projects are proven and underpinned by robust science that can quantify ecosystem services delivery, but this is difficult due to the location- and ecosystem-specific nature of ecosystem services delivery. Moving forward, we recommend that projects employ a multiple well-beings framework that encompasses social, ecological, cultural, and financial benefits, which can be defined through the use of bundles of ecosystem services. Creating restorative economies underpinned by an ecosystem services bundles approach provides a new avenue for marine ecosystem restoration that promotes effective communication and monitoring of the multiple benefits obtained and allows valuations beyond monetization, which will ultimately determine the success of restorative economies endeavors.

Data accessibility statement

No data were generated or used for this article.

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Competing interests

The authors declare no conflict of interest.

Author contributions

Contributed to conception and design: EJD, AML.

Wrote the first article draft: EJD, AML.

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