Received: 24 February 2020 | Accepted: 19 March 2020
DOI: 10.1111/conl.12716

Conservation Letters
A journal of the Society for Conservation Biology
Open Access
WILEY

REVIEW

Integrating oceans into climate policy: Any green new deal needs a splash of blue

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Abstract
Recent warnings from scientists suggest there is limited time to enact policies to avert wide-ranging ecological and social damage from climate change. In the United States, discussions about comprehensive national policies to avert climate change have begun, with "Green New Deal" proposals and climate plans put forth by members of Congress and presidential candidates. Oceans are largely absent or separate from these nascent policy proposals. Here, we highlight a policy framework to develop terrestrial and ocean-integrated policies that can complement and enhance terrestrial-focused initiatives focused on four specific sectors: 1) energy; 2) transportation; 3) food security; and 4) habitat restoration. Given political friction and constrained budgets, an integrated policy framework offers greater potential to achieve a portfolio of

mitigation and adaptation goals in a cost-effective manner, beyond what could be realized with marine or terrestrial policy solutions alone.

KEYWORDS
aquaculture, blue economy, climate, Green New Deal, oceans, offshore wind, policy integration, restoration, sustainable transportation, Teal Deal

1 | INTRODUCTION

Scientific consensus is clear that bold, coordinated policies are needed to avert present and escalating climate crises. In the United States (U.S.), there is renewed attention to policies that align climate change mitigation and adaptation with economic investments and social equity, often referred to as a Green New Deal. While no detailed policy has been proposed, nascent policy descriptions, articulated primarily in the context of 2020 presidential elections, focus largely on investment in terrestrial strategies. Recent international reports (IPCC 2019; Hoegh-Guldberg et al. 2019) have begun to explore the importance of oceans in addressing climate change, signifying an important shift from viewing oceans as climate change aggressors (e.g., sea level rise) or victims (e.g., coral reef decline) to recognize oceans as an integral part of climate solutions. The foundation for this shift is well-established; a rich body of ocean science has demonstrated the critical roles that oceans play in climate mitigation, adaptation, resilience (Galland, Harrould-Kolieb, & Herr 2012), and sustainable economic development (Neumann, Ott, & Kenchington 2017). Yet high-level policy documents do not provide a blueprint to what changes can be made in the short-term to affect meaningful action towards an integrated terrestrial-ocean framework for climate resilience and adaptation. Here, we articulate the ecological, social and economic potential of investing in integrated terrestrial-ocean climate solutions and identify the specific steps needed to promote more comprehensive and integrated climate policies that leverage contemporary ocean science.

2 | REFRAMING POLICIES TO ADDRESS CLIMATE CHANGE

Recent national (U.S. HR 109, UK Climate Change Act) and subnational (Washington S.B. 5116, Oregon H.B. 2020, City of Los Angeles) policy proposals to tackle climate change have focused primarily on four policy areas - renewable energy generation, fuel efficiency in transportation systems, food security, and habitat restoration to increase carbon storage - all of which have proven capacity to achieve climate goals and promote economic growth. The oceans, however, are largely absent or separate from these proposals, despite recent discourse in environmental news media and increasing global attention to narratives of the blue economy.[1] The concept of a Blue New Deal, raised in a televised town hall on climate change with U.S. presidential candidates in September 2019, has received considerably less policy attention. Given the important role that oceans play in regulating climate, and the magnitude of the challenge of addressing climate change, a policy path that integrates both terrestrial and ocean solutions, which we refer to here as a Teal Deal, can catalyze cost-effective investments in carbon mitigation, sustainable food systems, and ecosystem restoration. Investing in oceans can strategically complement terrestrial mitigation efforts as part of climate policies to reduce carbon and other greenhouse gas (GHG) emissions while catalyzing economic development and social progress.

Expanding climate policy frameworks to integrate ocean-based solutions has robust theoretical support. In any policy context, portfolio theory (Markowitz 1952) suggests that by diversifying the potential solution set, risk is reduced and returns on investment increased. In this case, the goal is to identify combinations of terrestrial and marine investments that hedge against risks and maximize societal benefits from climate policies. Given both expected and unanticipated consequences of climate change, a portfolio approach increases flexibility and enables decision-makers to use policies that are sufficiently nimble to adapt to rapid changes. The U.S. Fourth National Climate Assessment specifically flags the importance of planning for uncertain risks from climate change, stating that "risks to interdependent systems" require a multisectoral approach (USGCRP 2018). In this context, a portfolio approach means shifting proposed climate change policies from a Green or Blue New Deal to a Teal Deal, one that combines terrestrial and ocean-based climate solutions. A Teal Deal is likely to hold greater potential for achieving climate regulation goals while also building resilience to risks, generating co-benefits from increased economic development and human well-being, and supporting valuable ecosystem services.

Here, we present a blueprint for action in four specific sectors—renewable energy, transportation, food security, and habitat restoration—elaborating on ocean-based approaches

[1] MongaBay March 13, 2019; Grist July 15,2019; Data for Progress September 3, 2019; The Hill September 9, 2019.

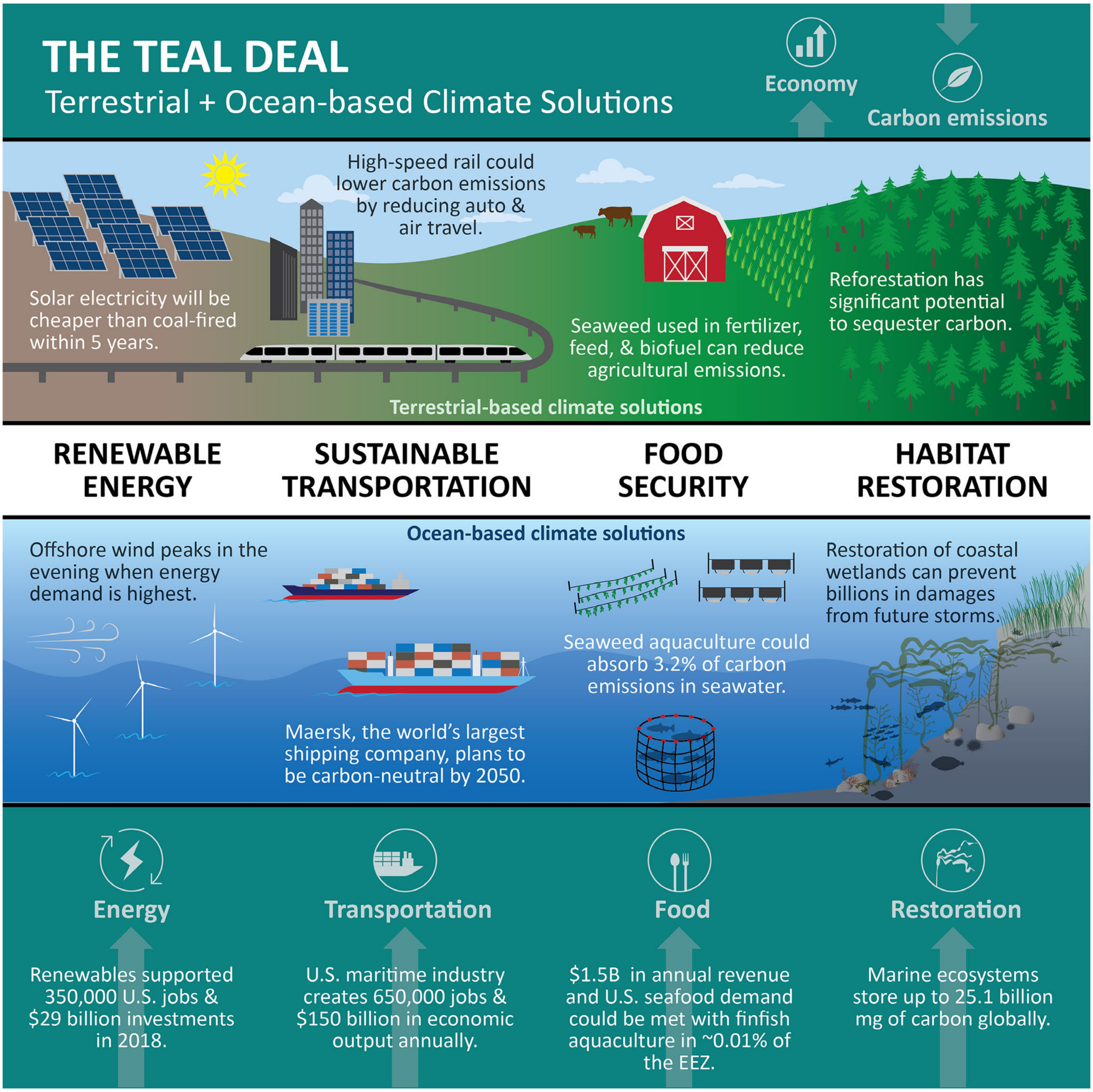

FIGURE 1 The Teal Deal: Integrating Oceans into Terrestrial Climate Solutions. Each proposed terrestrial-based climate solution in nascent Green New Deal proposals has an ocean-based analog. Expanding the portfolio of policy options increases probability of achieving international climate agreement targets. In the bottom panel, the Energy statistics are from the American Wind Energy Association, the ***Transportation*** statistics are from the American Maritime Partnership, the ***Food*** statistics from NOAA and the ***Restoration*** statistics from Howard et al. (2017)

that are analogous to familiar terrestrial strategies. We highlight opportunities in each sector for action and policies to address climate impacts in the near-term. This integrated approach expands the solution set in the portfolio of strategies to meet global targets for reducing and mitigating carbon emissions, adapting to the impacts of future climate change, and supporting sustainable and equitable economies (Figure 1).

3 | EXPANDING THE CLIMATE SOLUTION SET

3.1 | Offshore renewable energy

The ocean's winds, waves and currents represent a massive source of clean energy that can reduce GHG emissions, meet electricity demand, and spur new economic growth.

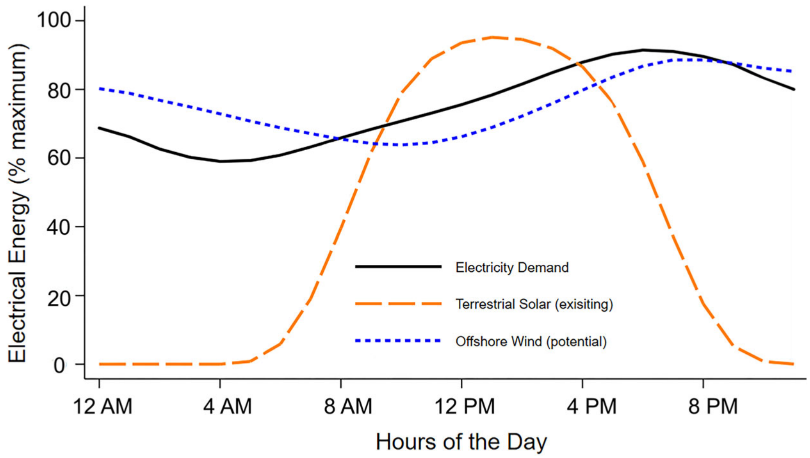

FIGURE 2 Contributions of Offshore Wind to California's Energy Portfolio. The three lines are individually scaled relative to a maximum annual value to focus on the timing of energy production and demand. Offshore wind energy could provide significant power to the grid when California's electricity demand peaks in the evening. This relationship demonstrates the complementary nature of pairing terrestrial solar and offshore wind in a renewable energy portfolio as the latter has potential to fill supply gaps when solar production is low. Data displayed are from Wang et al. (2019)

Offshore winds blow harder and more consistently than on land, enabling marine wind farms to produce more electricity than their terrestrial counterparts. Estimates suggest the potential to harness more than 100 GW of untapped offshore wind resources in U.S. Federal waters (Menaquale 2015). Furthermore, wind strength peaks in the afternoon and evening, when available renewable energy from solar declines but daily electricity demand is at its highest (Wang et al. 2019; Figure 2). Marine renewable energy is also amidst a step-change with the development of new hydrokinetic (wave, current) technology and the incipient engineering of deep-water floating wind turbines capable of powering over 15,000 homes each (e.g., Pacific Marine Energy Center, General Electric). Deep-water, floating turbines provide an opportunity to increase energy production, while avoiding many of the environmental and socioeconomic impacts associated with fixed-bottom turbines closer to shore. European countries demonstrate this economic potential, where the construction and operation of offshore wind farms generated nearly 18.5 GW clean power in 2018 and supported as many as 130,000 full-time equivalent jobs/year (Kahouli & Martin 2018) in the fields of engineering, manufacturing, and transportation.

Targets for renewable energy are more likely to be successful if they include both terrestrial and marine energy sources that produce external benefits, allowing states to pursue flexible energy portfolios that maximize regional net benefits (Okioga, Wu, Sirelli, & Hendren 2018). While 29 U.S. states have Renewable Portfolio Standards (RPS) for electricity generation, significant infrastructure investments renewable energy production ($23 to $194 billion by 2050) has disincentivized widespread RPS development (e.g., only 9 states require >50% renewable energy production, Wiser et al. 2017). RPS programs produce many societal benefits, including those to human health from improved air quality and the conservation of water resources. For example, over the full life cycle (manufacturing through decommissioning) of wind energy production, water use is significantly less compared to all other electricity generating technologies, including solar (Meldrum, Nettles-Anderson, Heath, & Macknick 2013). Economic policies at the national and state level that reward local communities and utilities for supporting renewable energy could help mitigate community objections to energy development and offset costs of investments to facilitate the transition to renewables.

Growing a marine renewable energy industry in the U.S. will also require a rigorous and transparent legal framework regulating the permitting of projects. Disjointed regulatory mechanisms and a lack of consistent federal policy present significant obstacles to renewable energy entrepreneurs, companies and investors (Schumacher 2019). Offshore energy development in the U.S. currently intersects nine different domestic policies, including the Coastal Zone Management Act (CZMA), the National Environmental Policy Act, the Submerged Lands Act, and the Marine Mammal Protection Act, as well as national, regional, and local regulatory mechanisms (Wright et al. 2016; Schumacher 2019), creating bureaucratic obstacles. Analysis of policies in Japan, New Zealand, Europe and elsewhere highlight the importance of consolidated and comprehensive legal frameworks to reduce the planning uncertainties for developers (Schumacher 2019). Strengthening the coordinating capacity and operational efficiency of the U.S. Bureau of Ocean Energy Management (BOEM) to issue permits for offshore energy development projects, in coordination with relevant federal agencies and affected state and local governments, could reduce uncertainties and streamline the expansion of marine renewable energy development.

Finally, a proactive approach to spatial planning for offshore renewable energy could facilitate its sustainable development. Resolving the trade-offs between potential negative impacts on the local scale with carbon emissions benefits at the national and global scales is a pervasive challenge in developing strategies for climate change mitigation (Dolšak & Prakash 2018). New policy frameworks designed to include science-based spatial planning could help prioritize siting emerging offshore energy developments in locations that minimize local environmental impacts and satisfy a diverse suite of marine management and socio-economic objectives (White, Halpern, & Kappel 2012; Lester, Gentry, Kappel, White, & Gaines 2018). Marine spatial planning has recently gained some political traction in the U.S. (e.g., by Northeast and Mid-Atlantic regional planning bodies). A national authority to proactively direct scientific marine spatial planning for guiding energy investment, rather than reactively responding to applications for development in a piecemeal fashion, could reduce risk in the permitting process and the environmental and economic impacts from development and expedite a transition to sustainable renewable energy in the U.S. continental shelf.

3.2 | Sustainable transportation

Over 80% of global merchandise is transported by sea, and maritime transportation contributes approximately 3% to total annual anthropogenic GHG emissions (Bouman, Lindstad, Rialland, & Strømman 2017), greater than twice the emissions from air travel. Marine transport has a comparative advantage over road and air transport in terms of sustainability potential, due to high carrying capacity and low fuel consumption of ships as a function of weight and distance traveled. Growth in world trade is predicted to increase emissions 150–250% by 2050 (Bouman et al. 2017), suggesting that measures to promote and improve maritime transportation sustainability are critical; yet, these are largely absent in international emission reduction efforts, such as the Kyoto Protocol or Paris Climate Agreement. Recent reviews suggest that maritime transportation emissions can be reduced by more than 75% using a combination of currently available technologies, such as modification of hull designs, switching to liquid natural gas, biofuels and wind power, or optimizing ship speed and capacity (Bouman et al. 2017). Cariou, Parola, and Notteboom (2019) found that the shipping sector has already achieved CO_2 reductions of 33% since 2007, mostly from more efficient operations and travel routes. The ongoing loss of sea ice in the Arctic is also opening more efficient shipping routes between North American and Europe (Stevenson et al. 2019). Improvements to industry standards, such as the Energy Efficiency Design Index (EEDI) from the International Maritime Organization (IMO), are encouraging shifts towards greater fuel efficiency and reduced emissions by limiting the sulfur content in vessel fuel (Van, Ramirez, Rainey, Ristovski, & Brown 2019). Additionally, the IMO has established an objective to reduce fuel emissions by 50% by 2050, relative to 2008 levels. However, without specific incremental targets or regulatory mandates, there is concern that this goal may not be met (Monios 2020).

Market-based mechanisms (MBMs) to reduce CO_2 emissions, such as emission trading schemes and bunker fuel levies, have been considered by the IMO but have gotten little traction (Bergqvist & Monios 2019; Monios 2020). There are also examples of industry leading carbon reduction efforts: Maersk, the world's largest container ship and supply vessel operator, committed to net zero carbon emissions by 2050, with carbon neutral vessels commercially viable by 2030. In some cases, local, national and international jurisdictions are stepping in to establish strict targets and standards where the IMO and industry have not. For example, the EU has stated that it will regulate shipping within the EU Emissions Trading System if the IMO does not adopt MBMs by 2021. Additionally, fuel content limits and ship emission regulations have been introduced by the U.S. State of California, the U.S. Environmental Protection Agency and the EU.

Port-based incentives are another mechanism that is accelerating adoption of emission-reducing technologies and improving local air quality. Key actions taken by ports include using shore-based electricity ('cold ironing') to reduce emissions while ships are at berth (Winkel, Weddige, Johnsen, Hoen, & Papaefthimiou 2016; Innes & Monios 2018), using electricity to power handling equipment (Wilmsmeier & Spengler 2016), requiring slow vessel speeds or use of liquefied natural gas while in the port area (Winnes, Styhre, & Fridell 2015) and incentivizing rail and barge transport rather than roads from ports (Gonzalez-Aregall, Bergqvist, & Monios 2018). A voluntary Vessel Speed Reduction Program (VSP) in the ports of Los Angeles and Long Beach in California discounts dockage fees to ocean-going vessels that slow their speeds as they approach or depart the port, reducing CO_2 equivalent emissions by 26,000 tons in 2008 (ITF 2018). Many other ports also reduce fees based on indices that assess the environmental performance of individual vessels, such as the Environmental Ship Index (ESI) or the GHG Emissions Rating used by RightShip. Expanding and coordinating environmentally differentiated fees across U.S. ports would increase incentives to reduce GHG emissions (ITF 2018).

Commercial marine transportation remains the most energy-efficient and cost-effective method of transporting goods and people globally. While it is currently not possible to fully decarbonize the shipping sector using available technology (Psaraftis 2019), there are many changes, including vessel modification (Lindstad, Asbjørnslett, & Strømman 2012), fuel-switching, and port-based programs (Winnes et al. 2015), that can reduce emissions. Given the distributed and global nature of maritime transportation sector operations, policies, and regulations, concrete actions at the national and port level are likely to play a critical role in pushing emissions reductions in the near future. While progress has started (e.g., The Sustainable Shipping Initiative), more action is needed to strengthen and incentivize stronger commitments with specific and measurable targets, incentives, and policies.

3.3 | Food security

Marine fisheries remain one of the most sustainable sources of protein for human consumption and have a lower total carbon footprint than many terrestrial food sources (Hilborn, Banobi, Hall, Pucylowki, & Walsworth 2018; Parker et al. 2018), despite challenges with overexploitation (Worm et al. 2009). Climate change is predicted to result in size and distribution shifts in marine resources, a phenomenon which has already been observed in some regions (Dubik et al 2019), with potential for socioeconomic impacts and increased inequity in capture fisheries (Rogers et al. 2019). When faced with shifting fish stocks, fishing communities have three main alternatives: follow the fish; transfer fishing effort to a new species; or find an alternative livelihood. The first two options may lead to increased costs and GHG emissions as fleets widen their search areas and increase effort. The third option is often not feasible, due to cultural considerations, the sunk costs of gear investments, and a lack of viable alternatives. The second option may be the most attractive, but faces complications due to regulatory and market considerations. Developing policies that allow for more timely management responses to shifting stocks (Lewison et al. 2015), as well as commercial investment in marketing new species, can help to encourage a switch (Pinsky & Fogarty 2012). The negative climate impacts could also be offset by fixing maladaptive economic incentives and improving transboundary management efforts (Gaines et al. 2018). Fisheries management reforms that allow harvest levels and permit allocation to change in-step with spatial variation in biomass and productivity could help buffer against longer-term changes in stock dynamics, increasing sustainability. Such reforms are not possible without improvements in data availability and assessment information, highlighting the value of continued attention to evaluating stock status and basing harvest recommendations on sound science (Hilborn et al. 2020).

Shifting stock distributions change incentives across jurisdictional governance structures, suggesting an opportunity to negotiate now to avoid conflict later. It is particularly important to consider how sustainable harvest levels may shift and trade policies can be modified to allow for food and economic requirements in impoverished nations. These considerations may point toward exploitation levels higher than normally recommended in areas where migrating species spend less time in a changing ocean, or tempered harvest responses in regions where these species are expected to spend more time and which may emerge as vibrant fisheries in coming decades (e.g., Hazen et al. 2013). Despite potential opportunities for adaptation in wild capture fisheries, reductions in carbon emissions through technological and efficiency improvements remain necessary – in fisheries as in other industries – to compensate for the negative impacts of climate change on fisheries and associated food security (Cheung et al. 2009).

Aquaculture, the world's fastest growing form of food production, also holds potential for significant growth (FAO 2018). Aquaculture production of lower trophic level species (e.g., shellfish) produces less CO_2 per kilogram of protein than most forms of terrestrial meat production (Froehlich, Runge, Gentry, Gaines, & Halpern 2018). Seaweed aquaculture also has enormous potential as a food source globally; recent studies have found macroalgae to be an excellent source of dietary fiber, protein, and a variety of micronutrients (Cherry, O'Hara, Magee, McSorley, & Allsopp 2019). Seaweed aquaculture has the potential to mitigate about 1,500 tons CO_2 km^{-2} $year^{-1}$ (Duarte, Wu, Xiao, Bruhn, & Krause-Jensen 2017). There are interacting benefits of growing seaweeds that extend beyond carbon drawdown from the atmosphere, linking terrestrial and ocean-based climate solutions to increased food security (Figure 1). For example, nitrogen, phosphorus, and mineral-rich seaweeds can be used for fertilizer and soil enhancement for terrestrial agriculture (Roberts, Paul, Dworjanyn, Bird, & de Nys 2015). These same limited and agriculturally valuable nutrients are often problematic drivers of eutrophication at high concentrations in coastal waters, and culturing marine algae can significantly mitigate eutrophication by removing these excess nutrients (Seghetta, Tørring, Bruhn, & Thomsen 2016), connecting food security to habitat restoration. Seaweed production also links terrestrial-ocean climate solutions by increasing sustainability of livestock operations. The addition of small amounts of seaweed to livestock diets significantly reduces production of ruminal methane (Maia, Fonseca, Oliveira, Mendonça, & Cabrita 2016). Seaweeds can be cultivated as a sustainable alternative biofuel (relative to bioethanol) (Alvarado-Morales et al. 2013), and do not compete with agriculture for fertilizer and other scarce resources (Duarte et al. 2017).

To ensure the long-term social and ecological sustainability of seaweed aquaculture, stakeholders can develop practices that include both wild and farmed populations. It is important to define ecosystem and management boundaries and assess ecosystem services and environmental carrying capacity (Grebe, Byron, Gelais, Kotowicz, & Olson 2019). This will enhance productivity and help prevent habitat degradation and associated biodiversity loss. The development and use of ecological infrastructure will help to reduce impacts on other marine fauna associated with seaweed farms (e.g., mammal entanglement). Building diverse seed banks and developing cultivation strategies for different species will assist in the protection and maintenance of genetic diversity of wild and farmed seaweeds (Grebe et al. 2019). In a social context, it is important to develop and share best management practices for the harvesting, management, cultivation and processing of seaweed to reduce economic and ecological risk (Rebours et al. 2014; Friedman et al. 2020). Quantifying seaweed resilience to global climate change will help to identify resistant species/genotypes and ensure that farmed species can contribute to food security despite a changing climate. The potential for seaweed farming to act as a meaningful carbon offset depends upon the fate of the cultured biomass: whether it will be exported to the deep sea or respired during other uses. In either application, seaweed farming can provide localized positive effects through mitigation of ocean acidification, hypoxia, or eutrophication (Froehlich, Afflerbach, Frazier, & Halpern 2019). Properly executed aquaculture, paired with sustainable capture fisheries, has the potential to increase food security, sequester CO_2, decrease the carbon footprint of protein sources, and stimulate economic activity in both coastal and inland communities (Froehlich et al. 2018; Gaines et al. 2018).

3.4 | Habitat restoration

Investment in habitat restoration and nature-based infrastructure in both ocean and terrestrial systems will be a key component of any transformative climate policy. A primary mitigation benefit from both terrestrial and marine restoration is carbon storage. Recent work suggests that reforestation of a billion hectares of land to sequester carbon could mitigate 25 percent of global emissions (Bastin et al. 2019). Coastal habitats, like mangroves, tidal wetlands, kelp forests, and seagrasses currently store up to 25.1 billion metric tons of carbon (Howard et al. 2017) and are able to store three time more carbon per unit area than terrestrial habitats (Taillardat, Friess, & Lupascu 2018). This suggests that coastal habitat restoration offers promise to help meet carbon mitigation goals, significantly enhancing carbon storage and reducing total atmospheric carbon (Pendleton et al. 2012; Lovelock et al. 2017).

International policy mechanisms to store carbon in terrestrial ecosystems, such as Reducing Emissions through Decreased Deforestation (REDD+), are also expanding to include coastal and marine habitats, such as mangrove forests. The Blue Carbon Initiative has developed a similar framework to implement blue carbon-based restoration efforts with current field-tests in five countries. In the U.S., current laws, including the Clean Water Act and the CZMA, clearly recognize the value of blue carbon but it remains underused relative to its potential (Sutton-Grier, Moore, Wiley, & Edwards 2014). Despite a lack of momentum nationally, coastal municipalities (e.g., Tampa Bay, FL; Snohomish, WA) are evaluating blue carbon potential of habitats (Radabaugh et al. 2018; Crooks et al. 2014). The private sector is also involved, using blue carbon as a means to offset carbon footprints (e.g., Conservation International). This suggests that market forces and public sentiment offer additional vehicles beyond top-down policy to advance coastal blue carbon initiatives.

Coastal and marine habitat restoration provide pathways to adapt to climate change by increasing flood and erosion protection and mitigating storm impacts (Cheong et al. 2013). Such investments limit the vulnerability of coastal populations to extreme weather events and help reduce the burden of billions of dollars in disaster aid and liabilities borne by taxpayers each year (Arkema et al. 2013). Recently, flood reduction benefits of \$625 million were attributed to tidal wetlands for a single storm event in the U.S. Mid-Atlantic (Narayan et al. 2017).

There is precedent for large investments in coastal habitat restoration that supports employment (~126,000 workers) and economic output (~\$9.5 billion annually) in diverse sectors of the economy (BenDor, Lester, Livengood, Davis, & Yonavjak 2015). Through the American Recovery and Reinvestment Act (ARRA) of 2009, the U.S. government invested \$167 million in coastal restoration projects, including living shorelines, oyster reef restoration, and hydrologic reconnections. An on-going federal effort to protect coastal communities in the U.S. is beach nourishment, with \$7.5 billion in spending to date on projects covering over 950 miles of coastline, according to NOAA's National Beach Nourishment Database. This suggests the funds and the political will exist to invest massively in coastal adaptation through restoration. Yet, beach nourishment rarely restores beach and dune habitat to natural conditions and provides only a temporary buffer from rising seas and storms. Managing a nature-based system for one service, e.g., storm protection, ignores potential ancillary impacts that could lead to investments that are ultimately a net cost to society (Dundas 2017). To move forward requires a shift in thinking about the role of coastal habitat restoration in a modern economy and a commitment to new funding to support endeavors that produce long-term broad societal benefits.

The dynamic nature of marine social–ecological systems is likely to affect restoration and its ability to address the impacts of climate change (Ingeman, Samhouri, & Stier 2019). Past restoration efforts have primarily focused on turning back the clock by reconstructing a system to its previous natural state, with limited success (Lotze, Coll, Magera, Ward-Paige, & Airoldi 2011). The ocean, and coastal economies tied to it, are changing rapidly due to globalization and climate change, suggesting that setting benchmarks for restoration based on the past might not be achievable, desirable, or economically feasible. An expanded perspective on recovery that includes the dynamic nature of ocean systems and embraces the need to tie restoration to socio-economic values (e.g., Lewis, Dundas, Kling, Lew, & Hacker 2019) is more likely to produce a set of reasonable restoration targets that effectively garner long-term social, economic and political support and encourage accountability (De Groot et al. 2013).

3.5 | Ocean climate solutions provide benefits to inland communities and economies

These four examples illustrate the significant potential of pairing terrestrial and ocean-based solutions to reduce GHG emissions and support climate resilience and adaptation while providing important co-benefits in pollution reduction, stimulating economic development and global trade, increasing food security, and reducing climate hazards. Importantly, investing in terrestrial-ocean strategies can generate benefits for both coastal and inland communities. For example, GE has manufacturing facilities for wind energy technology located throughout the country, including North Dakota, Arkansas, and other inland U.S. states. Products from aquaculture are distributed to non-coastal regions and, when used as inputs for fertilizers, support terrestrial food production while reducing total agricultural emissions. The flow of global goods that support the U.S. national economy relies heavily on marine transportation, and reducing fuel use in this sector has the potential to decrease the costs of commercial goods worldwide. The companies contracted under the ARRA for coastal restoration directly and indirectly employed people from both coastal and inland regions, generating an estimated 17 jobs per $1 million spent (Edwards, Sutton-Grier, & Coyle 2013). In addition to these economic benefits, improved climate change mitigation through integrated policies will benefit inland regions that are considered at risk to extreme weather events, such as drought (Strzepek, Yohe, Neumann, & Boehlert 2010) and that may be potential destinations for sea-level rise induced migration flows (Robinson, Dilkina, & Moreno-Cruz 2020).

4 | MOVING TOWARD TERRESTRIAL-OCEAN INTEGRATED CLIMATE POLICIES

Integrating ocean and terrestrial solutions into a comprehensive climate change policy will require commitment from multiple governance levels (state, national, and international), the public, as well as private sector innovation and investment. Some governmental entities have begun to recognize the essential nature of the ocean in climate mitigation and adaptation, paving the way for integrating oceans into future climate policies. For instance, the state of California recently launched the Ocean-Climate Contribution initiative, which shifts the focus of climate mitigation and adaptation to include both land and oceans. The Ocean-Climate Action Agenda also debuted at the 2018 Global Climate Action Summit with a set of goals that focus heavily on ocean-climate connections, such as increasing the area of wetlands, reducing emissions from ocean industries, and mobilizing international ocean-climate finance.

Internationally, there have been several ocean-integrated climate change frameworks developed. In 2018, the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), building on outcomes from the 2017 UN Ocean Conference, adopted the Ocean Pathway, a framework that aims to expand ocean-focused considerations in the UNFCCC process and catalyze action in priority areas impacting or impacted by ocean and climate change. By establishing SDG 14: Life Below Water, as an element of the 2030 Sustainable Development Agenda, and calling for the Decade of Ocean Science for Sustainable Development (2021–2030), the UN has firmly cemented the role of oceans on the global sustainable development platform. Another international effort, The High Level Panel for a Sustainable Ocean Economy representing 14 countries, has committed to catalyzing bold, pragmatic solutions for ocean health with particular focus on oceans as solutions to climate change (Hoegh-Guldberg et al. 2019). The challenge now is to assimilate this global aggregation of climate science and calls for action into an integrated and comprehensive U.S. domestic approach to designing and implementing climate policy.

5 | A PATH FORWARD

A terrestrial-ocean integrated climate policy is part of a larger changing narrative about oceans and the recognition of their untapped potential for climate regulation, mitigation and adaptation. The contribution of the blue economy to global prosperity recently topped $2.5 trillion (USD) annually (Hoegh-Guldberg et al. 2015), not including the value of important non-market ecosystem services the oceans provide, with tremendous potential for growth across both market and non-market sectors.

Investing in integrated climate solutions has the potential to provide needed economic stimulus and empowerment to vulnerable communities, who often contribute the least to climate change yet bear the brunt of its consequences (Cohen et al. 2019). A critical next step will be to develop viable financing mechanisms, across multiple scales of governance and institutions, to fund and incentivize the implementation of terrestrial-ocean integrated solutions to mitigate climate change. Economists have long suggested the use of market-based mechanisms (MBMs) to reduce GHG emissions, which can also raise the needed capital for other climate mitigation and welfare-improving policy investments. Other promising opportunities include intentional financing mechanisms and incentives schemes that benefit private sector companies capable of actualizing ocean-integrated solutions as well as philanthropic impact investing (e.g., Österblom, Jouffray, Folke, & Rockström 2017). To be successful in the long-term, funding strategies that are cognizant of social inclusivity and equity can contribute to policy sustainability.

International agreements have set ambitious targets to avert catastrophic climate change, and integrating ocean and terrestrial solutions provides an opportunity to develop policies to meet these targets and move toward a more sustainable and equitable economy. Incentivizing the necessary growth in terrestrial and ocean integrated climate solutions will not be easy and will likely require large-scale investments in infrastructure combined with market-based and regulatory mechanisms to align individual, corporate, and societal incentives with an integrated climate policy portfolio that is robust to the ever-shifting political winds in the U.S.

ACKNOWLEDGMENTS

This article developed from a COMPASS science communication workshop in 2019. S. Kim provided assistance with Figure 1. J. Phillips, K. McLeod, E. Robichaux, S. Aylesworth, L. Suatoni, G. Taraska, and M. Goldstein provided feedback on this manuscript. S.J.D., A.S.L., R.L.L. co-led project administration. S.J.D., A.S.L., R.L.L., C.W., and A.N.D. led individual section drafts and revisions. All authors contributed to content. The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the authors and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

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How to cite this article: Dundas SJ, Levine AS, Lewison RL, et al. Integrating oceans into climate policy: Any green new deal needs a splash of blue. *Conservation Letters*. 2020;e12716. https://doi.org/10.1111/conl.12716