frontiers in Marine Science

POLICY AND PRACTICE REVIEWS
published: 09 June 2021
doi: 10.3389/fmars.2021.671837

Evolving Perspectives of Stewardship in the Seafood Industry

Robert Blasiak[1,2], Alice Dauriach[1,3], Jean-Baptiste Jouffray[1], Carl Folke[1,3,4], Henrik Österblom[1], Jan Bebbington[5], Frida Bengtsson[1], Amar Causevic[6], Bas Geerts[7], Wenche Grønbrekk[8], Patrik J. G. Henriksson[1,4,9], Sofia Käll[3], Duncan Leadbitter[10], Darian McBain[11,12], Guillermo Ortuño Crespo[1], Helen Packer[13], Isao Sakaguchi[14], Lisen Schultz[1], Elizabeth R. Selig[15], Max Troell[1,4], José Villalón[16], Colette C. C. Wabnitz[15,17], Emmy Wassénius[1,3], Reg A. Watson[18], Nobuyuki Yagi[2] and Beatrice Crona[1,3]*

[1] Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, [2] Graduate School of Agricultural and Life Sciences, The University of Tokyo, Tokyo, Japan, [3] The Global Economic Dynamics and the Biosphere Program, Royal Swedish Academy of Sciences, Stockholm, Sweden, [4] Beijer Institute of Ecological Economics, The Royal Swedish Academy of Science, Stockholm, Sweden, [5] Pentland Centre for Sustainability in Business, Lancaster University, Lancaster, United Kingdom, [6] Stockholm Environment Institute, Stockholm, Sweden, [7] Cefetra Group BV, Rotterdam, Netherlands, [8] Cermaq Group AS, Oslo, Norway, [9] WorldFish, Bayan Lepas, Malaysia, [10] Australian National Centre for Ocean Resources and Security, University of Wollongong, Wollongong, NSW, Australia, [11] Integrated Sustainability Analysis, School of Physics, University of Sydney, Camperdown, NSW, Australia, [12] Thai Union, Samutsakorn, Thailand, [13] World Benchmarking Alliance, Amsterdam, Netherlands, [14] Faculty of Law, Gakushuin University, Toshima-ku, Japan, [15] Stanford Center for Ocean Solutions, Stanford University, Stanford, CA, United States, [16] Nutreco, Amersfoort, Netherlands, [17] Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada, [18] Institute for Marine and Antarctic Studies, University of Tasmania, Battery Point, TAS, Australia

OPEN ACCESS

Edited by:
Rowan Trebilco,
Centre for Marine Socioecology, Australia

Reviewed by:
Carolyn J. Lundquist,
National Institute of Water and Atmospheric Research (NIWA), New Zealand
Bianca Haas,
University of Tasmania, Australia

***Correspondence:**
Robert Blasiak
robert.blasiak@su.se

Specialty section:
This article was submitted to Marine Conservation and Sustainability, a section of the journal Frontiers in Marine Science

Received: 24 February 2021
Accepted: 13 May 2021
Published: 09 June 2021

Citation:
Blasiak R, Dauriach A, Jouffray J-B, Folke C, Österblom H, Bebbington J, Bengtsson F, Causevic A, Geerts B, Grønbrekk W, Henriksson PJG, Käll S, Leadbitter D, McBain D, Crespo GO, Packer H, Sakaguchi I, Schultz L, Selig ER, Troell M, Villalón J, Wabnitz CCC, Wassénius E, Watson RA, Yagi N and Crona B (2021) Evolving Perspectives of Stewardship in the Seafood Industry. Front. Mar. Sci. 8:671837. doi: 10.3389/fmars.2021.671837

Humanity has never benefited more from the ocean as a source of food, livelihoods, and well-being, yet on a global scale this has been accompanied by trajectories of degradation and persistent inequity. Awareness of this has spurred policymakers to develop an expanding network of ocean governance instruments, catalyzed civil society pressure on the public and private sector, and motivated engagement by the general public as consumers and constituents. Among local communities, diverse examples of stewardship have rested on the foundation of care, knowledge and agency. But does an analog for stewardship exist in the context of globally active multinational corporations? Here, we consider the seafood industry and its efforts to navigate this new reality through private governance. We examine paradigmatic events in the history of the sustainable seafood movement, from seafood boycotts in the 1970s through to the emergence of certification measures, benchmarks, and diverse voluntary environmental programs. We note four dimensions of stewardship in which efforts by actors within the seafood industry have aligned with theoretical concepts of stewardship, which we describe as (1) moving beyond compliance, (2) taking a systems perspective, (3) living with uncertainty, and (4) understanding humans as embedded elements of the biosphere. In conclusion, we identify emerging stewardship challenges for the seafood industry and suggest the urgent need to embrace a broader notion of ocean stewardship that extends beyond seafood.

Keywords: private governance, corporate biosphere stewardship, voluntary environmental programs, seafood boycotts, Marine Stewardship Council, keystone actors, ocean governance, systems perspective

INTRODUCTION

In 1951, Rachel Carson, a marine biologist and the most famous conservationist of her day, wrote in "The Sea Around Us" that: *"man cannot control or change the ocean as, in his brief tenancy of earth, he has subdued and plundered the continents"* (Carson, 1951). But in the following decades, global catch volumes from marine fisheries stagnated despite growing fishing effort and capacity, sea surface temperatures steadily increased, marine heatwaves of increasing intensity and duration became an annual event, and hundreds of millions of tons of plastic entered the ocean (Jambeck et al., 2015; Bell et al., 2017; IPCC, 2019; FAO, 2020; Holbrook et al., 2020). In May 2019, nearly 70 years after Carson's book was published, one of the most prominent voices in today's marine science community, Jane Lubchenco, delivered her verdict to a room of her colleagues: *"The ocean is not too big to fail, nor is it too big to fix. It is too big to ignore"* (WMO, 2019).

In this paper, we consider a concept and an industry that, when combined, have the potential to transform humanity's relationship with the ocean: stewardship and the seafood industry. In its simplest sense, stewardship describes "action in pursuit of sustainability" (West et al., 2018). In the context of seafood, this translates into an approach to governance that goes beyond merely complying with regulations and aiming for environmentally sustainable sourcing for a particular commodity, to also incorporate a dimension of care and ethical consideration (Bennett et al., 2018; West et al., 2018), consider the broader social-ecological system in which a particular activity is conducted, and ensure that these activities are responsible by focusing on human rights and equity across different groups and generations (Chapin et al., 2010; Folke et al., 2016, 2019).

Stewardship of the natural resources on which humans depend is not a matter of altruism. It is anchored in a growing realization that transforming how we govern the planet is a necessity for a prosperous and equitable society (Chapin et al., 2009, 2010; Folke et al., 2016). This is particularly clear in the case of global seafood production. Seafood is a key source of protein for billions and the largest employer among ocean-based industries, sustaining livelihoods and households around the world (FAO, 2020). The future of marine capture fisheries rests entirely on the existence of healthy fish populations and their supporting ecosystems, and while certain forms of marine aquaculture have become somewhat decoupled from the ocean through the use of land-based facilities and a reduced dependence on wild-caught fish for feed (Cottrell et al., 2020), they remain fully dependent on a functioning biosphere, including a healthy and unpolluted ocean environment (Folke and Kautsky, 1992; Troell et al., 2014; Farmery et al., 2020; Cottrell et al., 2021).

Drawing on a transdisciplinary team, we consider an emerging reality in which an increasingly consolidated and globalized seafood industry has become disproportionately important for the future of the ocean and the life it contains. While a rich diversity of local examples of stewardship have arisen through the close interactions between communities and the landscapes and seascapes that surround them, could a global analog emerge within the context of the seafood industry? This paper reviews the historical development of private seafood governance and describes four core dimensions of stewardship that are evident to varying degrees over the past 50 years: (1) moving beyond compliance, (2) taking a systems perspective, (3) living with uncertainty, and (4) understanding humans as embedded elements of the biosphere. We conclude by considering several emerging trends within the seafood industry as well as prospects for a more robust embrace of ocean stewardship.

STEWARDSHIP AS A MULTIFACETED MOVING TARGET

The origin of the concept of stewardship in the Anglo-Saxon world can be traced back to the Abrahamic religions, in which humans are called upon to act as stewards of the Earth (Welchman, 2012; Al-Jayyousi, 2018) and has a legacy going back to the Middle Ages. Yet concepts of stewardship are evident in a rich diversity of local settings around the world: Japan has long traditions of landscape (*satoyama*) and seascape (*satoumi*) stewardship, Hawaii's traditional *ahupua'a* were governed through the *kapu* system of taboos, and further examples of stewardship practices of indigenous peoples have been described in Indonesia (*talun-kebun*), South Korea (*maeulsoop)*, New Zealand (*kaitiakitanga*), the Philippines (*muyong*), and elsewhere (Soemarwato et al., 1985; Johannes, 1992; Berkes et al., 1995; CBD, 2011; Kahui and Richards, 2014; McMillan and Prosper, 2016; Ban et al., 2019; Lee et al., 2019; Friedlander and Gaymer, 2020). While inherently diverse and challenging to generalize, such examples illustrate a recognition of the value of nature and the communities' relationship with it, or of humans as an integral element of their respective landscapes and seascapes, often noting the necessity of harmony between humans and nature (Folke et al., 2016).

Stewardship entails action by a specific entity or group, who will act as a steward, and be an agent of change. There is a long research tradition showing the significant role of individuals characterized as stewards of practice in traditional ecological knowledge systems and societies, emphasizing the institutional, cultural and ethical dimension of such stewardship (Gadgil et al., 1993; Hviding, 1996; Buchmann and Nabhan, 1997; Berkes et al., 2000). By the 1990s, interest groups and grassroots conservation organizations had secularized the concept of stewardship, and governments of several English-speaking countries followed their example by setting up "stewardship programs" to support private landholders in their conservation efforts (Welchman, 2012), while local stewardship associations gained attention for their efforts to manage freshwater resources, landscapes, seascapes, and urban ecosystems (Van Dyke, 1996; Olsson and Folke, 2001; Barthel et al., 2005; Andersson et al., 2014; Plieninger et al., 2015).

But is stewardship limited to local action by local actors? Current conceptualizations of stewardship focus on a mix of three potent dimensions: care, knowledge, and agency (West et al., 2018). More specifically, *care* encompasses notions of responsibility and attachment that drive stewardship, *knowledge* covers the understanding and information that shapes stewardship action, and *agency* implies the capacity to take action as stewards (Emirbayer and Mische, 1998; Chawla, 2009; Nassauer, 2011; Burkitt, 2016; Peçanha Enqvist et al., 2018). In the context of the Anthropocene, powerful corporate and

government actors are exercising agency over vast portions of the biosphere, but if such actions are not informed by knowledge of local systems and shaped by care, the outcome can be degradation rather than stewardship. The interconnected nature of the Anthropocene has spurred scholarship on the cross-scale dimensions of stewardship and its significance for human wellbeing, resulting in conceptualizations of biosphere stewardship, planetary stewardship, and Earth stewardship (Chapin et al., 2011; Steffen et al., 2011; Folke et al., 2016). Among other things, these framings share a recognition that humanity can never fully distance itself from natural variability and the corresponding need for humility when seeking to navigate the complexity of living and thriving on a finite planet.

One defining characteristic of the Anthropocene is the emergence of a small number of increasingly consolidated transnational corporations of fundamental importance for humanity's impacts on the biosphere (Folke et al., 2019; Nyström et al., 2019). A sense of urgency about global inequity and rapid environmental degradation have led some to question whether corporations can themselves act as stewards by engaging in a form of "corporate biosphere stewardship" (Folke et al., 2019; Österblom et al., 2020b). This framing depends on a fundamental realization by corporations that their future viability is entirely dependent on a functioning biosphere. Corporate biosphere stewardship identifies the potential contribution of business, industry and "enlightened entrepreneurs" to sustainable and responsible development, through private governance mechanisms that extend beyond compliance with regulations and applicable laws (Worrell and Appleby, 2000; Folke et al., 2019). A growing body of research focuses on the conditions under which corporate logic, often driven by short-term vision and incentives, could embrace, or would want to embrace, corporate biosphere stewardship (Bebbington et al., 2019; Folke et al., 2020; Etzion, 2020), and the limitations of this corporate logic (Schneider, 2020).

Recognizing that the notion of corporate biosphere stewardship draws on a diversity of historical and emerging stewardship concepts and that traditional governance approaches have yielded mixed results in achieving sustainable seafood production (Crespo et al., 2019; FAO, 2020; Hilborn et al., 2020), in the next section, we narrow our focus to private governance within the seafood industry (**Box 1**). By considering the range of voluntary initiatives, self-regulation and free market mechanisms associated with the seafood industry, we seek to understand the extent to which dimensions of stewardship are becoming evident within the industry and whether the industry is taking a proactive role toward becoming stewards.

BOX 1 | The global importance of small-scale fisheries.
Seafood production is global and diverse in nature, and while the focus of this paper is on the seafood industry, industrial fishing only accounts for around 50% of global capture fisheries production (FAO, 2020). The other half takes place in small-scale fisheries, which employ over 90% of the world's fishers and fish workers, and provide livelihoods for some 120 million people, primarily in low-income countries (Kelleher et al., 2012; Teh and Sumaila, 2013; FAO, 2015; Teh et al., 2020). Small-scale fisheries are also characterized by diversity, with many shaped by locally developed management practices such as community fisheries co-management (Sen and Raakjaer Nielsen, 1996), locally managed marine areas in the Pacific (Metai, 2018), *caletas* in Chile (Castilla et al., 1998), and *utaki* in Okinawa (Sugimoto, 2016). While the study of how stewardship manifests in these settings provides insights into the role of knowledge, customs and management structures, the link between stewardship and environmental sustainability in small-scale fisheries remains ambiguous (McConney et al., 2019; Björkvik, 2020). A further layer of ambiguity is the blurring of lines between small-scale fisheries and industrial fisheries from a market perspective. Although most of the landings from small-scale fisheries are for local human consumption (Kelleher et al., 2012), they are not limited to subsistence, but are increasingly connected to regional markets as well as global supply chains through international trade (FAO, 2020). As a result, industrial fishing and global trade can often drive local dynamics and influence sustainability in some small-scale fisheries (Crona et al., 2015).

FROM SUSTAINABLE SEAFOOD TO STEWARDSHIP

Building on the rich literature describing the "sustainable seafood movement" of the past 50 years, we focus on three main themes: (1) the emergence of seafood boycotts and reactive stewardship; (2) the transition from boycotts to buycotts and the importance of certification schemes; and (3) the growing use of voluntary environmental programs as a precompetitive platform for cooperating on sustainability challenges. Each section relies on paradigmatic examples of new developments in private governance within the seafood industry rather than cataloging all associated activities (see Jacquet et al., 2010a for a comprehensive list).

Boycotts and Reactive Stewardship

The labeling of dolphin-safe tuna in the United States is often pointed to as an early sign of emerging notions of ocean stewardship (Sutton and Wimpee, 2009; Roheim et al., 2018). In 1988, video footage of dolphins dying as a result of purse-seine tuna fishery operations was secretly filmed by the Earth Island Institute (an NGO focused on environmental issues) and subsequently nationally televised, sparking intense media attention and an outpouring of public concern (Teisl et al., 2002). At the time, canned tuna was the most-consumed type of seafood in the United States, and consumer boycotts followed, along with pop-culture references. The 1989 film Lethal Weapon 2, for instance, includes a scene in which Danny Glover's children attack him for eating a tuna fish sandwich "Daddy, you can't eat tuna!" His wife proceeds to explain that they are boycotting tuna because the nets kill dolphins. Retailers reacted to the shift in public opinion, and by mid-1990, the three largest tuna canneries in the United States announced a dolphin-safe label (Teisl et al., 2002), a crisis response as public opinion pushed companies to look beyond target species and explicitly address harm to the broader system. This collective private governance step was soon followed by public policy: the label gained extra credibility with the 1990 passage of the Dolphin Protection Consumer Information Act, codifying minimum standards for the label as well as requiring observers on all vessels in the Eastern Tropical Pacific tuna fishery. Civil society pressure subsided, and canned tuna remains one of the most-consumed seafood in the United States[1].

[1]Dolphin-safe labeling standards and associated practices continue to be the subject of disagreements and legal cases, addressed most recently in a 2019 dispute

The labeling of dolphin-safe tuna (**Figure 1A**) was of paradigmatic importance for the sustainable seafood movement that was to emerge over the coming decades, demonstrating how NGO-advocacy could rapidly shape public opinion, and then lead to consumer pressure, industry response, and ultimately government action (Roheim et al., 2018; Boström et al., 2019; Bush and Roheim, 2019). As with many of the later examples of successful boycotts, a number of important enabling conditions were in place prior to the advocacy campaign. First, dolphins already enjoyed the status of a charismatic species within the United States; second, a considerable body of scientific evidence on dolphin mortality in purse seine tuna fisheries existed; third, several pieces of legislation had already been enacted by the United States government that provided fertile ground for further action. Consider the state of the Eastern Tropical Pacific tuna fishery three decades before the dolphin bycatch footage was broadcast: purse-seiners intentionally targeted dolphins due to awareness of their tendency to join aggregations of yellowfin tuna and scientific surveys estimated that from the 1960s onward, some 100,000 dolphins were dying annually as bycatch, with marine scientists warning that the dolphin populations were at risk (Hyde, 1979). The Marine Mammal Protection Act was passed in 1972, and a 1975 amendment pushed the tuna fleet to already start implementing preventive measures to reduce dolphin mortality, and required observers on vessels (Teisl et al., 2002). While the mobilization of consumer pressure in the 1980s certainly catalyzed action in this instance, the successful introduction of the dolphin-safe label and bycatch reductions benefited from existing legislation and scientific surveys.

Some NGOs have continued to tweak the recipe of consumer pressure and mobilization of popular culture to push for more sustainable management of ocean resources. In 1997, for instance, the "Give Swordfish a Break" campaign was launched by a trio of NGOs: SeaWeb, the Natural Resources Defense Council and the Wildlife Conservation Society (**Figure 1B**). Celebrity chefs were recruited as allies to spread the message, and Sutton and Wimpee (2009) trace how a combination of social marketing and strategic communications were leveraged to spread the message of taking Atlantic swordfish (*Xiphias gladius*) off the menu. As with dolphin-safe tuna, the eventual success of the campaign relied on the existence of both strong science and a well-defined governance system. Annual assessments had shown a 68% drop in catch from 1960 and 1996, with average size dropping from 266 to 90 pounds (Sugarman, 1999). Managing swordfish is also a challenge: as highly migratory fish, they migrate annually thousands of miles up and down the Eastern and Western coasts of the Atlantic Ocean, crossing multiple international boundaries (NOAA, 2019). In 1969, the International Commission for the Conservation of Atlantic Tunas (ICCAT) was established with the mandate to manage a number of species, including swordfish, with contracting states meeting annually to set quotas. While NGOs emphasize that the depletion of stocks points to a willful refusal by ICCAT contracting parties to set quotas based on scientific evidence (Pew Charitable Trusts, 2017), the regulatory framework nevertheless provided a platform for the introduction of a recovery plan for swordfish in 2000, along with a closure of 28,000 square kilometers of the Atlantic to swordfishing (Sutton and Wimpee, 2009). Following these twin actions, the campaign ended and today North Atlantic swordfish population levels are considered to be above management targets (NOAA, 2019).

A rich catalog of additional NGO-driven seafood boycotts exists (Jacquet et al., 2010a) with notable examples including a 2004 campaign by Greenpeace aimed at drawing attention to the discarding of bycatch and the sourcing of species on the IUCN Red List by supermarket chains in the United Kingdom (Greenpeace, 2005; Bush and Roheim, 2019). Among other things, Greenpeace's "Recipe for Disaster" campaign entailed dumping bycatch at the entrances to retailers in the United Kingdom (**Figure 1C**; Greenwood, 2019). Retailers responded rapidly by announcing changes to their seafood sourcing policies, including to only source sustainable seafood (Greenpeace, 2005; Bush and Roheim, 2019). As before,

settlement by the World Trade Organization (https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds381_e.htm"\T1\textbackslashl"bkmk381abrw2).

FIGURE 1 | Seafood boycott milestones. **(A)** Dolphin-safe tuna labels; **(B)** poster for "Give Swordfish a Break" campaign; **(C)** bycatch deposited outside a Tesco supermarket in the United Kingdom during Greenpeace's "Recipe for Disaster" campaign (Photograph from John Cobb, reproduced with permission from Greenpeace image database https://bit.ly/3sof9gc).

the advocacy campaign resulted in a reactive step toward stewardship as corporations took voluntary measures to address non-target species (bycatch) and endangered species. But as Bush and Roheim argue (Bush and Roheim, 2019), this response also marked a shift from boycotts like "Give Swordfish a Chance" arguing against the consumption of a seafood product to "buycotts," which promoted consumption of (sustainable) seafood.

From Boycotts to Buycotts: Stewardship Through Certification and Labeling

The 1990s were a momentous time for the seafood industry, and marine issues began to rapidly grow in prominence within the conservation community (Sutton and Wimpee, 2009). This growth can be attributed not only to recent seafood advocacy successes such as those described in section "Boycotts and Reactive Stewardship" (for a comprehensive list of subsequent market-based initiatives, see Jacquet et al., 2010a), but also to the impact that conservation organizations had on mobilizing support for the 1986 moratorium on commercial whaling under the International Whaling Commission (Mulvaney, 1996; Betsill and Corell, 2001) and a 1992 moratorium on high seas driftnet fishing (UN, 1989). Spurred by these wins, and building on the high-profile collapse of major fisheries and a growing public awareness about the risks of overexploitation, major NGOs like the World Wildlife Fund (WWF) and National Audubon Society increasingly turned their focus to the ocean, with new funding streams from philanthropic organizations, most prominently the David and Lucile Packard Foundation and the Pew Charitable Trusts (Sutton and Wimpee, 2009).

In 1996, WWF and the Unilever Corporation kickstarted a process that would explicitly push stewardship up the seafood industry's agenda. As one of the world's largest retailers of seafood products, and with recent fishery collapses as well as economic losses due to "Mad Cow" disease all in recent memory, Unilever was looking for a way to ensure that consumers would have no reservations purchasing their seafood products (Sutton and Wimpee, 2009; Jacquet et al., 2010b). It was well aware of the Forest Stewardship Council (FSC), a market-based certification mechanism established in 1993 to promote sustainable forestry management (Gale and Haward, 2011), and this served as a model for the Marine Stewardship Council (MSC), launched through a partnership between WWF and Unilever, with the purpose of certifying sustainable fisheries and their products (Ponte, 2012). Such a high-profile union of civil society and the private sector was unprecedented in the seafood industry, and the notion of corporations contributing to sustainability was still relatively novel; the World Business Council on Sustainable Development, for instance, had just been founded in 1990 (Sutton and Wimpee, 2009).

The birth of the MSC was not an easy one, with its early years marked by a struggle to gain credibility with the market and NGOs, and skepticism from governments (Gulbrandsen, 2014). Yet an innovative approach seemed more crucial than ever. In 1995, the Food and Agriculture Organization (FAO) of the United Nations had published its Code of Conduct for Responsible Fisheries, a set of international best practices and standards, but it was voluntary and non-binding, leaving many concerned about its long-term impact (Pitcher et al., 2009; Sutton and Wimpee, 2009). Likewise, an implementing agreement to UNCLOS, the "Fish Stocks Agreement"[2], was adopted by governments in 1995 with the purpose of devolving management of straddling and highly migratory fish stocks like tuna and swordfish to a network of regional fisheries management organizations (RFMOs), but the results have been uneven and a frequent target of criticism from civil society organizations and others (Cullis-Suzuki and Pauly, 2010). If the MSC could leverage consumers to demand sustainable seafood products, could corporations fix what governments had struggled to achieve? (Roheim et al., 2018).

In contrast to seafood boycotts, which often would focus on a single fishery, or even a single undesirable aspect of that fishery (e.g., bycatch, illegal activity, wasteful resource usage), certifications cover a suite of different factors. In the case of MSC certification, fisheries need to meet three primary criteria: (1) Fishing must be at a level that ensures it can continue indefinitely and the fish population can remain productive and healthy; (2) Fishing activity must be managed carefully so that other species and habitats within the ecosystem remain healthy; (3) Fisheries must comply with relevant laws and be able to adapt to changing environmental circumstances (MSC, 2019b). Although the MSC has become the most prominent certifier of fishery products over the past 20 years, it has been under near-constant criticism for just as long. Many of these criticisms are of particular interest for this research, as they imply an evolving and continuously expanding suite of factors that "stewardship" entails (**Table 1**). The steps taken by the MSC to respond to these external calls are equally interesting, as they demonstrate the dynamic approach needed by bodies seeking to certify stewardship or act as credible stewards themselves. Broadly speaking, for MSC certification, this has meant expanding beyond an original focus on identifying individual fisheries characterized by sustainable management practices, to gradually encompass additional factors related to human rights, as well as ecosystem-based management, more aligned with a systems perspective and its inherent uncertainty.

The growth of MSC to become the globally dominant certification standard for capture fisheries can be attributed not only to the strategic partnership of WWF and Unilever, but to an array of other familiar actors as well. From 1997, when MSC was founded as an NGO until 2004, it certified a total of six fisheries, totaling around 500,000 tons of annual production (less than 1% of global fisheries catch at the time; FAO, 2020), and straddled the line between bankruptcy and solvency (Sutton and Wimpee, 2009; Jacquet et al., 2010b). Then, as now, MSC was heavily reliant on philanthropic foundations for its survival (including the Packard Foundation), who sought return on their support by commissioning external evaluations of the MSC; these resulted in recommendations to strengthen monitoring, enforcement and communication efforts (Sutton and Wimpee, 2009). The trajectory of the MSC changed in 2006, when Walmart pledged to only sell MSC-certified fish

[2]Formally, the United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea (UNCLOS) of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

TABLE 1 | Stewardship as a moving target.

Topic	Arguments	Responses
Social standards Labor abuses/modern slavery Human rights Equity	Stewardship implies not only environmental factors, but should encompass social responsibility as well (Kittinger et al., 2017; Nakamura et al., 2018).	"As of August 2018, as part of the MSC assessment process, fisheries and off-shore supply chains will be required to provide a self-disclosure document that reports on measures, policies and practices in place to ensure absence of forced and child labor." (MSC, 2019a). In August 2018, the MSC deemed that any fisheries in which forced labor violations had been the focus of prosecution would be ineligible for certification for a period of 2 years (MSC, 2019b).
Specifying sustainability Precautionary principle Broader ecosystem impact Invasive species.	Fisheries targeting species for which very little is known about life cycles, spawning rates, impact of fishing pressure, etc. should not be certified until scientific basis exists to demonstrate sustainability (Jacquet et al., 2010b; Froese and Proelss, 2012; Bailey et al., 2018). While some fishing practices with substantial negative ecological impacts have been banned (e.g., dynamite fishing), others (e.g., high-impact bottom trawling) (Jacquet et al., 2010b); broader ecosystem impacts beyond the target fishery (e.g., bycatch) are not adequately captured (Jacquet and Pauly, 2007). Russian Barents Red King Crab, a purposefully introduced invasive species, has received MSC certification (Kourantidou and Kaiser, 2019). Certification of longline Atlantic Bluefin Tuna fishery in July 2020 although stocks have not recovered fully, and certification is conditional on stock reaching sustainable status by 2025 (MSC, 2020a; WWF, 2020).	MSC standard review 2019 expands beyond earlier efforts to specify sustainability by also including focus on ecosystem performance indicators and their consistent application (MSC, 2020b).
Exclusivity *De facto* exclusion of small-scale fisheries	Costs of certification exceed potential benefits for small-scale fisheries (Jacquet and Pauly, 2007; Foley and McCay, 2014; Nyiawung et al., 2021).	The MSC established an "In-transition to MSC program" and a "Global Accessibility Program" (MSC, 2021b,d). The MSC set up the Transition Assistance Fund (up to GBP 50,000) to support small-scale fisheries and fisheries in the Global South on their pathway to sustainability as part of the Ocean Stewardship Fund (MSC, 2021f). Other funds/programs managed by the MSC to support small-scale fisheries/fisheries in the global south include the Fish for Good Project (MSC, 2021a) (Indonesia, Mexico, and South Africa) and Capacity Building Programs (MSC, 2021c).
Credibility Lack of representation from developing world Financial conflicts of interest Mechanisms to challenge certifications	To ensure credibility, stewardship schemes should have representative governance, and conflicts of interest should be declared or eliminated; challenges to granted certifications based on concerns about stock sustainability should be considered by scientific experts (Jacquet et al., 2010b; Christian et al., 2013).	In 2010, none of MSCs 13 board members were from the developing world (Jacquet et al., 2010b); in 2021, one was (MSC, 2019c).
Other ethical issues Shark-finning Ghost gear Endangered species Animal welfare	Stewardship implies not just managing the target stock sustainably, but ensuring that other ethical issues be addressed, including animal welfare (Browman et al., 2019), steps to prevent loss of fishing gear (Carr and Harris, 1997), etc.	MSC standard review 2019 included focus on requirements associated with shark-finning, endangered, threatened or protected species, and ghost gear (MSC, 2019a).

Selected examples of recent actions by the Marine Stewardship Council to address expanding notions of what stewardship entails.

by 2010 within its North American market (Jacquet et al., 2010b). Shortly after the announcement, Walmart took two key steps: first, it convened a meeting to bridge the divide between two disparate communities, inviting representatives of seafood suppliers and civil society organizations focused on marine conservation; second, the Walton Family Foundation awarded the MSC the largest grant it had ever received to speed up its assessment and certification processes (Sutton and Wimpee, 2009). The expanding budget of MSC and the market pressure to certify more fisheries have remained a concern for some, who worry that MSC may become increasingly liberal in certifying fisheries that are not truly sustainable, or which are characterized by fishing practices that result in lasting ecosystem degradation (Jacquet et al., 2010b; Bush and Roheim, 2019; Schiller and Bailey, 2021; **Table 1**). Nevertheless, by early 2021, over 18,000 products were being sold bearing the MSC label, accounting for over 17% of marine fisheries catch (MSC, 2020b). It is noteworthy that Walmart's pledge to only sell MSC-certified fish by 2010 remains unmet, yet its 2006 announcement added weight to the fledgling initiative, catalyzed other retailers, and coincided with an inflection point in the growth of MSC-certified fisheries (**Figure 2**).

An aquaculture analog to the MSC was launched in 2010 following a series of global multi-stakeholder aquaculture dialogues organized by the WWF. The resulting Aquaculture Stewardship Council (ASC) now includes over 2,200 stakeholders

from across industry, academia and governments, who have collaborated to develop the industry standards for farmed salmon, shrimp, tilapia, pangasius, trout, bivalves, abalone, seriola, cobia, and tropical marine fish like groupers and barramundi. The ASC represents the aquaculture industry's leading certification scheme, with over 1.83 million metric tons of independently certified farmed seafood in 2020 (Vince and Haward, 2017). Volumes of MSC- and ASC-certified seafood are noteworthy in the context of overall production (**Figure 3**), with MSC expanding to cover a growing proportion of global production volumes that have remained fairly static over the past 30 years. By contrast, aquaculture production has been anything but static, expanding from 58 million tones to 85 million tones since 2010, meaning that despite the rapid growth of ASC-certified volumes, this remains only 2% of global production today (FAO, 2021). While MSC and ASC are perhaps the most prominent seafood certifications in a global sense, a plethora of national, local and other certifications, ratings, and ecolabels also exist – well over 100 by one count (Blasiak et al., 2017a). The diversity of certification criteria renders calculations of what percentage of fisheries or aquaculture production are under some form of certification challenging, while the varying levels of rigor means comparisons or aggregates would be easily misinterpreted (Jonell et al., 2013, 2016; Leadbitter and Benguerel, 2014; **Table 2**).

The decision by both the MSC and ASC to make "stewardship" an explicit aspect of their identity and branding makes their emergence and uptake a key element in the narrative of stewardship in the seafood industry. They also give some insight into initial efforts to define stewardship on a global level, while grounding it in regional or local metrics – looking for instance at individual fisheries rather than whole species, relying on audits on the ground, and exploring mechanisms to bring small-scale fisheries and local communities into a large-scale, global certification body (**Table 1**).

Voluntary Environmental Programs as Engines of Precompetitive Collaboration

While the founding of the MSC may have heralded a turning point at which sustainability became a key element of corporate strategies throughout the seafood industry, various constellations of "voluntary environmental programs" (VEPs) began to form in the subsequent years. Although diverse in nature, VEPs share a number of common characteristics largely in line with theoretical concepts of sustainability stewardship (Mathevet et al., 2018) and the importance of "enlightened entrepreneurs" in the corporate world (Welchman, 2012). Most fundamentally, VEPs recognize that (1) commercial activities can result in negative impacts on the environment and society; (2) government regulations are a frequent mechanism used to oblige companies to internalize these costs; and (3) in the case of weak or inconsistent governance and regulatory frameworks, these costs are externalized and can result in environmental degradation and negative social impacts (Prakash and Potoski, 2007; Blasiak et al., 2018a). With over 150 coastal states around the world engaged in fishing and other ocean-based industries, considerable variation exists not only in governance and regulatory frameworks (**Box 2**), but also in the capacity to monitor and enforce national or international regulations (Pretlove and Blasiak, 2018). Illegal fishing activities, for instance, have tended to aggregate in marine areas characterized by weak governance (Österblom et al., 2010). Likewise, the speed of global corporate activity often outpaces the development of appropriate regulatory frameworks, ultimately resulting in negative social and ecological impacts (Berkes et al., 2006; Österblom et al., 2010; Blasiak, 2015; Eriksson et al., 2015). In the best case, VEPs can tighten or eliminate governance gaps, and can foster more desirable social and environmental outcomes by bringing together actors who voluntarily take actions that exceed the minimum requirements of governmental regulations (Prakash and Potoski, 2007; Österblom et al., 2017a; Oceana Europe, 2021).

FIGURE 2 | Growth in number of fisheries MSC-certified or in assessment. In January 2006, the world's largest retailer, Walmart, announced its (unmet) pledge to only sell MSC-certified fish by 2010.

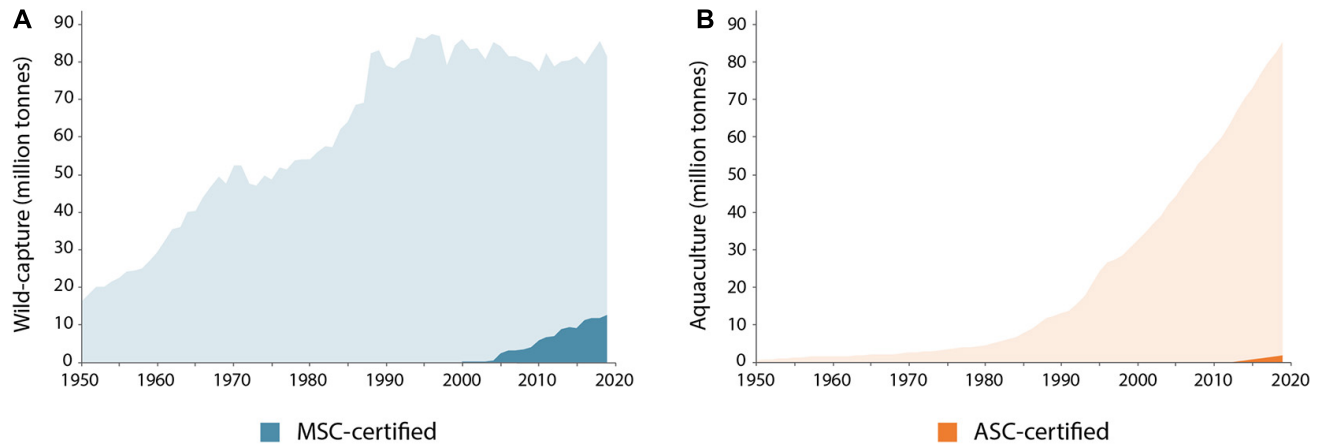

FIGURE 3 | Global production and eco-certifications. Volumes of **(A)** wild-capture marine fisheries and **(B)** aquaculture production and corresponding share of MSC-certified and ASC-certified production, respectively. Global production data are from the FAO FishStatJ 4.01.0. MSC- and ASC-certified volumes were provided by MSC and ASC, respectively.

TABLE 2 | Proliferation of tools and certification schemes within the sustainable seafood movement.

Tool	Purpose	First one	Number to date	Associated risks
Recommendation lists/ratings	Give consumers advice on how to make responsible purchases	1998 (Safina, 1998)	200+ (Roheim, 2009; Bush and Roheim, 2019)	Conflicting recommendations leading to confusion among consumers, market saturation of lists.
Seafood certification schemes and ecolabels	Credible assurance for consumers that products meet criteria of sustainability, fairness or responsibility	1990s (Bush and Roheim, 2019)	129 (SeafoodSource, 2019)	Challenge for retailers seeking to judge which certifications meet their own sourcing needs, reputational risk if violations are found, conflicting requirements that lead to confusion, and the difficulty of rewarding performance rather than just disclosure. Confusion among consumers (Jonell et al., 2013, 2016).

The Coalition of Legal Toothfish Operators (COLTO), founded in 2003, is exemplary of the potential for VEPs to foster sustainable fisheries and solve a series of problems that national governments were struggling to address. Patagonian toothfish (*Dissostichus eleginoides*) are a long-lived fish (often living for over 50 years) generally found in deep waters of the Indian Ocean, South Georgia and Patagonian shelf (Collins et al., 2010). Creatively rebranded as "Chilean seabass," Patagonian toothfish supports a valuable fishery, which expanded rapidly in the early 1990s to reach peak levels of annual reported catch that exceeded 40,000 tons in 1995. Yet catches were substantially higher due to the prevalence of highly lucrative illegal, unregulated and unreported (IUU) fishing, estimated at 35,000 tons (with a value of USD 150 million) in 1997 (**Figure 4**; Österblom and Bodin, 2012; Pala, 2015). Illegal toothfish operations were depleting toothfish stocks so rapidly that the future of legal fisheries was also at risk – illegal operations also relied on deep-sea longlines that were catching so many seabirds that the stocks of multiple albatross species (*Diomedidae*) and white-chinned petrels (*Procellaria aequinoctialis*) were likely on the verge of collapse (Nel et al., 2002; Österblom and Bodin, 2012). By the early 2000s, retailers were halting sales of Chilean seabass, and over 1,000 chefs had agreed to "Take a Pass on Sea Bass," a campaign launched by the National Environmental Trust in the style of the previous dolphin-safe tuna and "Give Swordfish a Break" efforts (Wu, 2006).

Legal toothfish operations were in a particularly challenging position due to the depletion of stocks by illegal operators and the increasingly negative perceptions of retailers and consumers about toothfish. They noted that the rapid increase in illegal fishing was outpacing the slow response from governments (Österblom and Folke, 2013). While the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), with its 26 members and 10 acceding states, aims to conserve life in the Antarctic, combatting illegal fishing is a sensitive issue as some of the member states have been involved as flag states or port states for vessels engaged in these activities (Österblom et al., 2010). An informal "shadow network" of actors, however, began to emerge in the mid-1990s through engagement between a Norwegian NGO and industry actors seeking a more rapid response to illegal activity – the outcome was the International Southern Ocean Longline Fisheries Information Clearinghouse (ISOFISH), an organization dedicated to eliminating illegal toothfish operations, and explicitly connecting industry players and civil society actors (Österblom and Folke, 2013). Unbound by the formalities and sensitivities that face governments when engaging through CCAMLR, ISOFISH was able to exert considerable social and political pressure with reports detailing vessels engaged in illegal activities, their ports of call, and efforts to obscure their purpose through reflagging (Österblom and Folke, 2013). The reports were welcomed by CCAMLR, spurring the introduction of a range of formal and informal

BOX 2 | Examples of international governance and processes relevant to the seafood industry.

While the focus in this manuscript is primarily on private governance mechanisms associated with sustainable seafood and stewardship, there has been a concurrent expansion of relevant public policies, regulatory frameworks and negotiations. Several key international examples are highlighted here:

The **United Nations Convention on the Law of the Sea (UNCLOS)**, frequently referred to as the Constitution of the Ocean (signed in 1982; entered into force in 1994) describes the rights and responsibilities of states with regard to their use of the ocean. Among other things, it grants states broad autonomy in decisions on the management and use of the ocean and marine resources within their respective exclusive economic zones (generally extending 200 nautical miles from their coastlines). An implementing agreement to UNCLOS, the UN Fish Stocks Agreement (signed in 1995; entered into force in 2001) addresses the conservation and management of straddling and highly migratory fish stocks.

The **Food and Agriculture Organization** is a specialized agency of the United Nations (founded in 1945; currently 197-member states) that has developed multiple voluntary frameworks of fundamental relevance for fisheries and aquaculture activities. These include a Code of Conduct for Responsible Fisheries (1995), International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (1999), Voluntary Guidelines for Flag State Performance (2014), Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (2015), and Voluntary Guidelines for Catch Documentation Schemes (2017).

The **Port State Measures Agreement** entered into force in 2016 as an international legally binding instrument aimed at preventing, deterring and eliminating illegal, unreported and unregulated (IUU) fishing. It applies to fishing vessels seeking entry into any port outside of the nation where they are flagged, and seeks to be a cost-effective solution to reducing IUU fishing, which is estimated to account for USD 10–23 billion in annual production (Agnew et al., 2009).

World Trade Organization Negotiations on Fisheries Subsidies have been ongoing since 2001 with the aim, among other things, to eliminate certain forms of fisheries subsidies that are contributing to overcapacity and overfishing, an aim also codified within Sustainable Development Goal 14.6.

Negotiations on the conservation and sustainable use of **Biodiversity in Areas Beyond National Jurisdiction** have been ongoing in different iterations since a 2005 UN General Assembly Resolution (68/70) to initiate a working group on the topic in recognition of gaps in the governance framework for the nearly two-thirds of the ocean that is beyond national jurisdiction. As of early 2021, negotiations have entered the final stage of an intergovernmental conference centered around a "package" of four issues: (1) marine genetic resources, including questions on the sharing of benefits; (2) measures such as area-based management tools, including marine protected areas; (3) environmental impact assessments; and (4) capacity-building and the transfer of marine technology (Tiller et al., 2019).

compliance mechanisms that reduced illegal fishing by over 90% within years (Österblom and Bodin, 2012; **Figure 4**). As a result of these successes, ISOFISH formally disbanded in 1999, among other things to avoid potential legal liability from companies that ISOFISH had implicated in illegal activity (Österblom and Folke, 2013). Illegal toothfish operations in the Southern Ocean, however, experienced an upsurge in 2002, creating alarm among legal toothfish operators. The shadow networks that had formed as a result of collaboration under ISOFISH was reanimated and formalized with the establishment of COLTO in 2003.

Aware of the existential threat to the legal toothfish operations, COLTO members invested USD 2 million to self-fund investigations into illegal fishing activities; a series of high-profile reports were broadcast on national television in Australia, and dramatic pursuits of vessels engaged in illegal operations helped to build further awareness among the general public and politicians (Masters, 2002; Österblom and Folke, 2013). Since the drama of the early 2000s, COLTO has entered a relatively more dormant state in which it maintains the networks necessary for rapid response to illegal activity, and activates them as needed (Petersson, 2019). COLTO's activities have now expanded to focus not only on eliminating illegal activity, but also to embrace a broader stewardship role by focusing on reducing seabird bycatch, whale depredation on toothfish longline fisheries, and science communication (COLTO, 2020). The final vessels engaged in illegal toothfish operations are being systematically eliminated; by 2010, there were just a handful of vessels left on the list of repeat offenders, and their ranks continue to thin – in 2016, one was blown up by Indonesian authorities, while another was chased all the way to the coast of Liberia, where it was apprehended in 2018 (Pala, 2015; Anthony and Pullar-Strecker, 2016; Sea Shepherd, 2018). With illegal catches almost entirely eliminated (**Figure 4**), the membership of COLTO now represents around 77% of the world's toothfish catch, 51% of which also enjoys MSC certification (COLTO, 2020, 2021).

The number of VEPs operating in the ocean space has grown in recent years. For instance, the International Seafood Sustainability Foundation (ISSF), launched in 2009, facilitates "science-based initiatives for the long-term conservation and sustainable use of global tuna stocks, reducing bycatch and promoting tuna ecosystem health" (ISSF, 2020), conducts third-part monitoring and has publicly sanctioned members who did not comply with agreed standards. A key VEP within the marine ingredients space is MarinTrust (formerly IFFO RS), established in 2001 with the aim of ensuring a responsible supply of fish meal and fish oil, and whose members currently produce over 50% of the world's supply of both (MarinTrust, 2020).

Two of the most recent additions to the family of seafood VEPs are the Global Salmon Initiative (GSI; established in 2012) and the Seafood Business for Ocean Stewardship initiative (SeaBOS; established in 2016). Both seek to embed and capitalize on stewardship ideals at the executive level and encourage precompetitive collaboration by bringing together competing companies to solve shared problems that cannot be addressed in isolation and which would not result in competitive advantage for any one company. A noteworthy area of overlap between the GSI and SeaBOS is a focus on appropriate use of antimicrobials, driven in part by concerns related to the increased frequency and spread of antimicrobial resistance (Wernli et al., 2017), which threatens to generate negative public perceptions of the aquaculture industry and to potentially undermine production in parts of the world (Watts et al., 2017; Henriksson et al., 2018). It is a global challenge that transcends the capacity of any single company to address (similar to climate change), rendering it an attractive focus for precompetitive collaboration (Folke et al., 2019). While the GSI focuses on salmon (and its members produce 40% of the world's farmed salmon), the SeaBOS

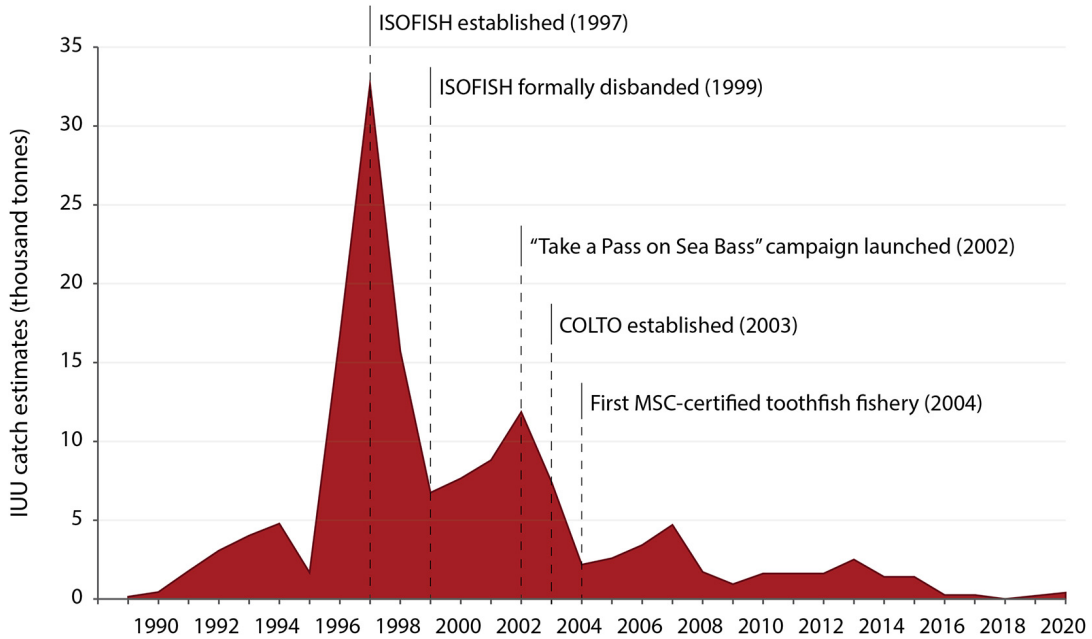

FIGURE 4 | IUU catch estimates for toothfish. Volumes of both Patagonian toothfish (*Dissostichus eleginoides*) and Antarctic toothfish (*Dissostichus mawsoni*) are aggregated. Data are from CCAMLR (until 2010) and COLTO (since 2011, based on market price and surveillance data). Key stages in the elimination of illegal catches are also highlighted.

initiative includes ten of the world's largest seafood companies, encompassing wild capture fisheries, aquaculture, and feeds production, with time-bound goals focused on addressing social, ethical and ecological issues that afflict the industry's reputation and future viability, including illegal fishing, labor abuses, ocean plastic pollution and antimicrobial resistance. The initiative is the result of a science-industry collaboration to understand the potential of "keystone actors" within the seafood industry to achieve transformative change toward ocean stewardship (**Box 3**; Österblom, 2017; Österblom et al., 2017b, 2020a).

The long-term credibility and effectiveness of VEPs is linked in particular to two key factors: the existence of clear sanctioning mechanisms, and the standards for membership (Potoski and Prakash, 2013). For instance, weak membership standards coupled with an absence of sanctioning mechanisms, will likely result in free-riding by some members, leading to a loss of credibility for the VEP, limited environmental impact, and few branding benefits for members. Conversely, high membership standards and strong sanctioning mechanisms could result in a credible VEP without free-riding, but could also entail substantial expense for members (Prakash and Potoski, 2007). Certain VEPs, like SeaBOS and GSI, have small and exclusive memberships, resulting in a further dimension of soft power in which dynamics of peer pressure take on added importance, potentially serving as stronger motivation for members to position themselves as leaders in their industry.

Acknowledging that many corporations have embraced corporate social responsibility to eliminate negative environmental and social outcomes from their operations, and that these positive steps seldom penetrate throughout entire supply chains (Thorlakson et al., 2018), VEPs are also faced with the challenge of effectively monitoring, understanding and communicating their impact (**Box 4**). Optimally, VEPs are able to demonstrate to public officials the benefits and incentives of engaging in more effective management and stewardship of ocean resources (Sutton and Wimpee, 2009). As such VEPs often become actively engaged in seeking to influence governance and regulation, recognizing the positive synergies that can emerge from promoting enabling and cooperative public policy approaches. Indeed, as Sutton and Wimpee emphasize:

> *"one of the leading challenges for the sustainable seafood movement will be to move beyond commitments to change seafood sourcing policies [···] to directly influence fishery management itself [since] market-based approaches can never supplant or replace effective public policy, nor should they be expected to do so."* (Sutton and Wimpee, 2009)

BOX 3 | Keystone actors in the seafood industry.

The seafood industry is characterized by increasing levels of consolidation, with 13 companies controlling 11–16% of global catch, and responsible for 38% of the seafood industry's revenues (Österblom et al., 2015). Dubbing these 13 giants as "keystone actors" within the seafood industry, the authors make reference to the ecological principle of keystone species, which are disproportionately important for the structure and functioning of their respective ecosystems (Österblom, 2017).

Four characteristics of keystone actors: (a) dominate global production revenues and volumes within a particular sector, (b) control globally relevant segments of production, (c) connect ecosystems globally through subsidiaries, and (d) influence global governance processes and institutions (Österblom et al., 2015).

BOX 4 | Measuring and ranking stewardship.
While certification schemes and ecolabels can be considered VEPs due to their voluntary nature, benchmarks and indices occupy similar but distinct territory, providing independent assessments of performance. In both instances, their legitimacy is tied to their methodologies, ranking metrics and transparency.

The **Seafood Stewardship Index (SSI)** is a benchmark under the umbrella of the World Benchmarking Alliance, seeking to measure the performance of the world's 30 largest seafood companies in relation to the Sustainable Development Goals. Inspired by the keystone actors approach (**Box 3**), the index is conceived as a way to accelerate movement toward a sustainable seafood industry. Rankings are calculated based on a set of 60 indicators across five measurement areas: governance and management of stewardship practices, stewardship of the supply chain, ecosystems, human rights and working conditions, and local communities. In the first iteration of the SSI, published in 2019, overall findings included that two-thirds of companies in scope did not have specific mechanisms in place to reduce IUU risks in supply chains, and only 20% of companies had remediation mechanisms in place to address human rights abuses.

The **FAIRR Protein Producer Index** brings together both livestock and aquaculture/fisheries under the umbrella of "protein production," generating an investor benchmark of environmental, social and governance performance. The index is built around a set of nine risk factors, including waste and pollution, governance, working conditions, and antibiotics. Members of the Index include banks and investment groups, with a total of USD 27 trillion in assets under management as of January 2021.

The **Global Sustainable Seafood Initiative (GSSI)** was developed with the aim of addressing the proliferation of certification schemes and standards and associated confusion among retailers about their qualities (**Table 2**). Acting as a type of "benchmark of benchmarks," the GSSI benchmarking tool directly derives its 186 "essential components" from relevant FAO codes (Code of Conduct for Responsible Fisheries, Ecolabelling Guidelines (for fisheries or aquaculture) and Technical Guidelines for Aquaculture Certification for aquaculture) and is applied across the range of aquaculture and fisheries products. As of February 2021, nine certification schemes had received GSSI recognition.

DIMENSIONS OF STEWARDSHIP

The concept of stewardship implies the existence of stewards. Stewards are taking on this role because they have a strong incentive to do so: because they use, exploit, or enjoy some part of the biosphere. But considering that the uptake of such terms is still largely unfamiliar to an industry accustomed to the framing of corporate social responsibility, to what extent has the seafood industry taken on a stewardship role? As described in the paradigmatic examples in Section "From Sustainable Seafood to Stewardship," simple cause-effect storylines are largely absent from the seafood industry. While stewardship is associated with aspiration and responsibility, many such actions have clearly pragmatic qualities, in the sense that they are driven by a desire to protect reputation and maintain sales. Through reflecting on the theoretical notions of stewardship in Section "Stewardship as a Multifaceted Moving Target" and the historical narrative of Section "From Sustainable Seafood to Stewardship," we note four broad dimensions of stewardship in which efforts by actors within the seafood industry have aligned to varying degrees with theoretical concepts of stewardship.

Moving Beyond Compliance

A key distinction between sustainability and stewardship is that the latter entails notions of care, knowledge and agency. Evidence for stewardship within the seafood industry would therefore include proactive steps to move beyond compliance with governmental regulations to becoming a positive force in sustainability transitions (Österblom, 2017; Folke et al., 2019; Jouffray et al., 2019). While the operational changes implemented by seafood companies in response to public pressure and NGO campaigns seem more reactive than proactive, the growing universe of VEPs provides some evidence for movement toward stewardship. One such example is provided by COLTO (see Section "Voluntary Environmental Programs as Engines of Precompetitive Collaboration") and the capacity for legal operators in the toothfish industry to engage with a diverse range of actors, as well as each other, to virtually eliminate illegal operations from toothfish fisheries. Elsewhere, the Association of Responsible Krill Harvesting Companies (ARK) established a series of voluntary spatial closures in the fishery that have been adhered by all members with 100% compliance since 2018 (ARK, 2019, 2020). When the GSI was established in 2013, there were no salmon farms certified by the ASC. Members committed to 100% certification by 2020, and while the target was not reached, the quotient grew from 0 to 65% in less than 7 years (Global Salmon Initiative, 2020a). Common to all cases is a clear reputational gain for participating companies and the associated VEPs as well as a more explicit attention to sustainable operations, although the extent to which this has translated into price premiums or positive environmental impacts is often unclear. In the absence of associated public policy measures, a failure to capture and communicate positive environmental impacts and economic incentives may weaken the durability of such private governance approaches.

Taking a Systems Perspective

A systems perspective recognizes that the target species in focus are part of a broader ecosystem, with species interactions that are critical for ecosystem functioning and a healthy ocean (Häyhä and Franzese, 2014; Yletyinen et al., 2016). Nowhere is this systems perspective more evident, perhaps, than in voluntary commitments by the aquaculture industry and associated VEPs to reduce the use of fish ingredients in aquaculture feed. Rapid growth of the aquaculture sector since the 1980s has been accompanied by a rising demand for aquaculture feeds and a recognition of finite limits on fish ingredients. Most of the fish that are reduced for use in feed play important roles in their ecosystems and are themselves food-quality (Pikitch et al., 2014), raising questions in the context of a planetary diet about their conversion for use as aquaculture feed rather than for direct human consumption (Troell et al., 2014; Cashion et al., 2017; Froehlich et al., 2018; FAO, 2020; Tacon, 2020). Moreover, key fish populations such as the Peruvian anchoveta are particularly prone to fluctuations in El Niño years, making over-reliance on such fisheries a risk (Hernández-Santoro et al., 2019; Siple et al., 2019; Szuwalski et al., 2019). Elsewhere, feed companies have called on governments to follow scientific guidance on the management of pelagic fish populations in the northeastern Atlantic and reduce fishing pressure and quotas accordingly (Korban, 2020). One key factor in the context of aquaculture

feed production is the potential future role of mesopelagic fish as a source of feed for the growing aquaculture sector. Even though there is uncertainty on the global biomass of mesopelagic fishes, their role as biological carbon pumps is thought to have important implications for climate regulation, and the ecological impacts of harvesting them for aquaculture feed are unknown (Cavan et al., 2019; Hidalgo and Browman, 2019; Olsen et al., 2020). The aquaculture and feeds segments of the seafood industry have also taken substantial steps toward investing in research and development of feed alternatives like algae oil, genetically modified canola that contains high levels of omega-3 fatty acids, methane fermentation, and increased use of fisheries by-products (Cao et al., 2015; Pieja et al., 2017; Blasiak et al., 2018b; Cottrell et al., 2020; Naylor et al., 2021). The emergence of some of these feed alternatives creates challenging choices though, as GMOs remain controversial and agriculture is the leading cause of biodiversity loss on the planet (Brondizio et al., 2019). Additional signs of a shift from a single-minded focus on target species include the range of voluntary commitments to eliminate bycatch and non-target species (particularly marine megafauna and other charismatic species) from capture fisheries operations. Efforts to reduce the risk of farmed salmon (or their associated diseases and parasites) impacting wild salmon populations fall under this umbrella as well – representing significant steps by the industry closely linked to consumer pressure, NGO advocacy, and major reputational risks (Global Salmon Initiative, 2020b).

Living With Uncertainty

Stewardship has been associated with actions demonstrating recognition that natural variability can never be fully controlled for, and therefore approaches to living with uncertainty are needed (Folke et al., 2005). Precautionary approaches and efforts to quantify uncertainty are gradually being incorporated into traditional management plans for capture fisheries and aquaculture production, but are by no means the norm (Privitera-Johnson and Punt, 2020). One example from salmon fisheries is the focus on a portfolio approach, whereby attention is paid to maintaining sub-populations and their associated genetic diversity to hedge against unexpected variation and change (Schindler et al., 2010; Blasiak et al., 2020). Many of the private governance approaches detailed above contain similar elements, including a focus on ecosystem-based management (e.g., MSC), and benchmarking progress toward risk-based management of capture fisheries (e.g., SSI) (see Section "From Boycotts to Buycotts: Stewardship Through Certification and Labeling" and **Table 2**). Companies can also be proactive in supporting scientific approaches to the development of models and scenarios focused on better predicting the future ocean, particularly by mainstreaming transparency throughout their operations and by sharing data. The 76 signatories (UN Global Compact, 2020b) to the UN Global Compact's Sustainable Ocean Principles, for instance, have committed to "share relevant scientific data to support research on and mapping of relevance to the ocean," and the associated UN Global Compact Action Platform for Sustainable Ocean Business entered into an agreement in late 2020 with the Intergovernmental Oceanographic Commission of UNESCO to formalize a commitment to science-industry collaboration within the context of the UN Decade of Ocean Science for Sustainable Development (UNESCO, 2020).

Understanding Humans as Embedded Elements of the Biosphere

A theoretical element of stewardship that is more challenging to identify within the seafood industry is a clear recognition of human society as part of nature (Dasmann, 1976; Gadgil et al., 2021) and acknowledging that human well-being is dependent on biosphere health (Folke et al., 2016; Österblom et al., 2017a). Language in line with this thinking can be found throughout industry sustainability reports, yet how this is reflected in operations is less obvious. One area in which the worlds of seafood production and human well-being explicitly connect is in the context of antimicrobials use in aquaculture operations. The increased frequency and spread of antimicrobial resistance is a looming global health challenge (Wernli et al., 2017) (see section "Voluntary Environmental Programs as Engines of Precompetitive Collaboration"), and has been linked to overuse and misuse in the agrifood industry, leading the World Health Organization (WHO) to publish a list of Critically Important Antimicrobials for Human Health (World Health Organization, 2019). Yet the WHO designation has not halted the use of these antimicrobials in the aquaculture industry (Henriksson et al., 2015). Members of the GSI have committed to report annually on their use of antibiotics, but the Norwegian salmon sector is something of an outlier in the industry, with large investments in research and development and distributions of vaccines to salmon in the Northern Hemisphere, dramatically cutting rates of antibiotics use in these farms (World Health Organization, 2015). Salmon farms in other parts of the world face different pathogens for which vaccines do not exist, and ultimately salmon is only one among a multitude of other aquaculture species, which have drawn far less investment in the development of vaccines and non-medicinal methods for addressing pathogens and parasites (FAO, 2020; Tacon, 2020). Overall, there is little transparency with regards to antibiotic use within the aquaculture industry, and the detection of antimicrobial residues and resistant bacteria in seafood suggests a globally prevalent and poorly quantified problem that is contributing to a future health crisis (Watts et al., 2017; Troell et al., 2019a). Transparent and responsible use of antibiotics within the aquaculture industry is just one of a suite of emerging and future stewardship challenges that the seafood industry has struggled to address to date (Schar et al., 2020), but which are garnering growing international concern and attention, and are detailed in the following section.

A FUTURE OF PERSISTENT AND EMERGING STEWARDSHIP CHALLENGES

Perceptions of stewardship have expanded since the 1980s to encompass a growing range of issues, with more likely to follow

as novel challenges become apparent within the seafood industry. While some of these issues are not new to the industry, they have certainly gained new prominence and attention in recent years.

Labor Abuse

In recent years, social responsibility and social justice have gained prominence in the sustainable seafood dialogue (Kittinger et al., 2017; Lewis et al., 2017; Duong, 2018; Nakamura et al., 2018; Teh et al., 2019), not least due to high-profile Pulitzer Prize-winning stories by the Associated Press in 2015 on slavery in Southeast Asian fisheries (Geller, 2016). Yet the linkage between social justice and seafood sustainability has not always been obvious. One analysis of several hundred popular media articles published from 2003–2013 dealing with sustainable seafood found that almost none were linking social issues with seafood sustainability (Van Holt et al., 2018). Among experts informing seafood certification processes, initial hesitation also existed due to the normative aspects of social justice and the lack of universally accepted external reference points for some social issues such as what constitutes fair pay or underage labor (Blasiak et al., 2017a). Within the past 3 years, however, MSC, ASC, GSSI, the SSI and others have taken initial steps to explicitly consider elements of social justice in their activities (GSSI, 2018; MSC, 2019d; Wilhelm et al., 2020). A rapidly growing suite of electronic monitoring, traceability and artificial intelligence applications has also emerged in recent years and is being leveraged to identify and address labor abuse in the seafood industry (Dunn et al., 2018; Kroodsma et al., 2018; McDonald et al., 2021). Jim Leape, a board member of MSC, put it simply at the 2019 World Economic Forum in Davos: "If your seafood is caught by slaves, it doesn't matter if it's sustainable." (FOA, 2019). Among the suite of social and environmental challenges that VEPs and certification schemes strive to address, companies have proven particularly open to interventions addressing working conditions, perhaps due to associated concerns about reputational risk (Thorlakson et al., 2018). Yet while the SSI found in 2019 that 22 of the 30 largest seafood companies have human rights commitments in place, only 6 of these had corresponding remediation processes (World Benchmarking Alliance, 2019).

Ocean Plastic Pollution

In recent years, ocean plastic pollution has become front-page news in the international media, with a 2018 episode of the BBC Blue Planet II series on plastic pollution garnering over 10 million viewers in its first broadcast (Ruddick, 2017). A growing body of scientific work has cataloged the growth of ocean plastic pollution, but often relies on local sampling coupled with global extrapolations (Eriksen et al., 2014; Jambeck et al., 2015; Barrett et al., 2020). Recent studies have also found that many particles and fibers found in ocean water are organic in nature or cannot be conclusively categorized as microplastics (Martinelli et al., 2020; Suaria et al., 2020), suggesting the need for greater scientific clarity in sampling and analysis of ocean plastics. Sampling of seafood has found that microplastics are ubiquitous, yet are found at levels far below contamination thresholds, even in filter-feeding species such as oysters (Lusher et al., 2017). Land-based sources far exceed the seafood industry in terms of their contribution to ocean plastic pollution, but abandoned, lost and discarded fishing gear (ALDFG) is a significant contributor, which seafood industry actors are seeking to address, most prominently perhaps through the Global Ghost Gear Initiative (Worm et al., 2017). A correlation between ALDFG and IUU fishing activities is thought to exist, due to the greater likelihood of illegal operations being undertaken at night and under extreme weather conditions, making retrieval of damaged or lost gear less likely (Macfadyen et al., 2009). Labeling of gear and appropriate port state measures may help to reduce levels of ALDFG (Macfadyen et al., 2009). While much focus has been placed on reducing the flow of plastic into the ocean and on removing macroplastics that are already polluting it, effective methods for cleaning up microplastic and nanoplastic particles have proven elusive. The impacts of this pollution on the functioning of marine systems and how these are changing in response to this influx of new materials is also poorly understood, but the widespread presence of enzymes that can degrade plastics in ocean waters, and their greater densities in deep water, suggest that microbes in the ocean may already be rapidly evolving to capitalize on the presence of ocean plastic pollution, and providing a source of carbon to associated microbial communities (Alam et al., 2020).

Sustainable Aquaculture Expansion

The aquaculture industry is at a crossroads, and several decades of rapid growth coupled with a simplified narrative of endless ocean space for expanding aquaculture production have sometimes obscured an array of limiting factors (Troell et al., 2017; Couture et al., 2021). The industry's future contribution to food provision and sustainable development outcomes is inherently tied to the development of effective climate change adaptation efforts (Barange et al., 2018), increased innovation aimed at developing sustainable feed resources and improved biosecurity and disease treatment (Troell et al., 2014, 2017), as well as governance mechanisms that support equitable development opportunities (Brugere et al., 2021).

Expansion of fed aquaculture may involve intensification and extension of freshwater pond systems, and/or extension of more technologically advanced systems, such as recirculating aquaculture systems (RAS) and offshore farming systems. While the latter two categories can have reduced impacts on local ecosystems, their success will depend in part on price of final products, technological innovations, sustainable energy, careful spatial planning, strong governance, and development of sustainable feed resources. With responsibly managed oceanic forage fisheries already at maximum sustainable yields, and more being utilized for food, fish-based ingredients are increasingly being replaced with plant-based ingredients (e.g., soy, wheat, canola oil), and much is currently being done to develop novel feed resources (e.g., insects and single-celled organisms utilizing various by-products) (Cottrell et al., 2020). Genes from marine algae have also been inserted into genetically modified canola crops, resulting in production of high levels of polyunsaturated omega-3 fatty acids that otherwise are absent from the crop (Napier et al., 2019). These GMO crops as well as algae oils represent two new alternatives to fish meal and fish oil, that

could have special importance for aquaculture feeds (Cashion et al., 2017; Cottrell et al., 2020). All of these alternatives carry economic, environmental, nutritional, and ethical considerations (Pelletier et al., 2018), and intense efforts are underway to develop appropriate benchmark and certification criteria for aquaculture and feeds production and corresponding carbon footprints (Amundsen and Osmundsen, 2020; Osmundsen et al., 2020; Naylor et al., 2021).

Expansion of extractive aquaculture is different as its production is not tied to food-grade resources as feed inputs or land use. If strategically placed, it can generate valuable ecosystem services such as coastal protection and mitigation of eutrophication (Buck et al., 2017). Seaweeds are already used as human foods and may play an increasingly important role, but this depends on addressing challenges such as palatability and digestibility (Cherry et al., 2019). Their potential role as animal feed may also be large and is presently being heavily researched. Addition of certain red seaweeds to ruminant feed reduces methane emissions, which have accounted for about 20% of climate change in the 20th century (Pachauri et al., 2014; Kinley et al., 2020). Industrial-scale cultivation of red seaweeds may come with a drawback as they also produce a secondary metabolite called bromoform, known for its potent ozone-depleting properties (Carpenter and Liss, 2000; Blasiak et al., 2020). A broader systems perspective on the implications of this and other alternative feed resources is urgently needed – perhaps transcending the need for seafood stewardship and moving the ambition to "food systems stewardship" (Farmery et al., 2021). Seaweed farming is also researched for its ability to take up carbon and how this function could become an additional tool for mitigating climate change. However, the narrative surrounding this potential is built on beliefs more than science, so its potential still needs to be evaluated (Naylor et al., 2021).

Social Norms of Animal Welfare and Consumption

While the narrative suggested in this manuscript arguably starts with animal welfare, namely the bycatch of dolphins in tuna fisheries, the ethical and emotional inner compass of animal-rights advocates and the general public continues to change. Research underscoring sentience and the ability to feel pain within marine species targeted by seafood producers has led, among other things, to recent calls to ban octopus aquaculture and electric pulse fishing (Browman et al., 2019; Jacquet et al., 2019). At the same time, while aquaculture has rapidly expanded to include at least 408 species (FAO, 2020), specialized welfare information is only available for 84 of these (Franks et al., 2021), pointing to a vast gray area at the core of seafood production. Yet perceptions of animal welfare are not universal, and represent a dynamic and evolving aspect of what constitutes sustainable and ethical seafood.

Understanding the regionally and locally specific social norms related to seafood consumption, and how they change over time, will be fundamental not only to the future of animal welfare discussions but also the future population status of species such as sharks, tunas and eels. In some cases, changes in social norms can be quite rapid, including in the case of diets (Nyborg et al., 2016), with social pressure, convenience, and the sheer enjoyment of sharing meals leading people to adopt the same diet as their peers (Nyborg et al., 2016). Celebrity activism in China focused on shark fin soup, for instance, has spurred new regulations and led to a drop in domestic consumption, although demand continues to grow in nearby markets such as Indonesia and Vietnam (Jeffreys, 2016; Knott, 2018), where seafood consumption has grown in recent years alongside rising incomes and increased urbanization (Troell et al., 2019b). In Japan, eel is traditionally consumed on the Day of the Ox holiday, and despite the species being listed as endangered and celebrity chefs seeking to introduce freshwater fish as eel substitutes, demand remains strong (Hunt, 2017; Jiji Press, 2020; IUCN, 2021; MAFF, 2021).

Growing awareness of climate change and the footprint of food production has also driven changes in social norms (Nyborg et al., 2016; Folke et al., 2021). Seafood has been identified as a more "climate-friendly" and healthy substitute for meat due to generally lower carbon emissions, and corresponding branding campaigns are aimed at promoting more consumption of certain types of seafood (Naylor et al., 2021). If social norms shift accordingly toward increasingly replacing meat with fish in diets, this would have substantial ramifications for both meat and seafood production and associated environmental footprints at the local and global scale (Troell et al., 2019b).

TOWARD OCEAN STEWARDSHIP

"The decade to 2030 is one that will define a century [. . .] and the ocean, our most important global common, is key to achieving these goals" according to a 2019 report from the United Nations Global Compact (UNGC) Action Platform for Sustainable Ocean Business – a VEP of ocean-based businesses committed to adopting sustainable policies. But who can achieve this, and how can they do it? The report answers this as well: *"We need industry and corporations to come forward and step up as stewards of sustainable ocean practice"* and 1 year later, the platform announced its 10-year action plan under the title "Ocean Stewardship 2030" (UN Global Compact, 2020a). These are increasingly familiar notions: the ocean standing at a pivotal moment, the need for urgent action, and a call for stewardship (**Box 5**).

It has long been recognized that both fisheries and aquaculture depend on the support of healthy and resilient ecosystems (Folke and Kautsky, 1989; Holmlund and Hammer, 1999). What is becoming clear is that marine ecosystems are not only influenced by human actions, but that our actions now dominate the way marine ecosystems operate and function (Worm and Paine, 2016; Jouffray et al., 2020). These impacts range from serial depletion of marine fish populations, to the emergence and accelerating growth of multiple ocean industries, all the way to human-induced climate change altering marine food-webs, ecosystems, oxygen levels, and ocean acidification (Eriksson et al., 2015; Rocha et al., 2015; Blasiak et al., 2017b; Limburg et al., 2020). The tightly intertwined world and the rising awareness that human wellbeing and development are embedded within and dependent on a healthy ocean and a resilient biosphere (Folke et al., 2016, 2021) shift the focus from managing ocean

BOX 5 | New forums for shaping ocean policy and action.
Several high profile multi-stakeholder efforts to influence and shape ocean policy have emerged in recent years, signaling an eagerness for approaches that extend beyond the formal structure of international governance processes (**Box 2**).

The Economist's **World Ocean Initiative** was launched in 2012 and convenes an annual World Ocean Summit. The Initiative is focused around three cross-cutting levers of change, namely finance, governance, and innovation, and seeks to mobilize new partnership and insights into how to achieve a sustainable ocean economy. More than 5,000 attendees from over 100 countries were expected for the 2021 Summit, with 130 speakers focused on six action tracks: aquaculture, energy, plastics, fishing, shipping and tourism.

The **Friends of Ocean Action** was launched following the first UN conference dedicated to Sustainable Development Goal 14 (Life Below Water) and is co-chaired by the UN Secretary General's Special Envoy for the Ocean and the Deputy Prime Minister of Sweden. The Friends of Ocean Action is a coalition of over 50 prominent "ocean leaders" from governments, philanthropies, civil society and academia, convened by the World Economic Forum and seeking to "fast-track solutions to the most pressing challenges facing the ocean." The coalition's work is focused around 11 action tracks, including "Sustainable ocean production" and "Ending illegal, unreported and unregulated fishing".

In late 2018, the **High Level Panel for a Sustainable Ocean Economy** was launched with 14 heads of state and the UN Secretary-General's Special Envoy for the Ocean. Informed by a 2-year scientific process involving over 250 experts and resulting in 16 scientific syntheses ("Blue Papers"), the Panel members committed, among other things, to protect 30% of marine habitats by 2030, and to reduce carbon emissions and ocean plastics, while also addressing illegal fishing and labor abuse in supply chains. Crucially, all 14 heads of state committed in late 2020 to sustainably manage 100% of the ocean area under their national jurisdiction by 2025, although announcements several weeks later by one of the states to initiate seabed mining and expand offshore oil extraction raise questions about shared conceptualizations of sustainable management or stewardship (Adomaitis, 2021a,b; Österblom and Blasiak, 2021).

resources and ecosystems to governing marine social-ecological systems (Österblom et al., 2017a). This also entails a fundamental emphasis on equity and equitable distribution of resources rather than simply increasing production to meet global nutrition goals in isolation from the rest of the sustainable development agenda (Farmery et al., 2021). The increasing attention in science, practice and policy on stewardship is a reflection of this shift in perspective (World Benchmarking Alliance, 2019; UN Global Compact, 2020a; Folke et al., 2021; MSC, 2021e; WWF, 2021).

Many examples exist of community-level stewardship of natural resources, where people's connection to their surrounding landscapes and seascapes breeds care and has resulted in unique cultural practices and resource management (Chakraborty et al., 2020). But we asked at the start of this paper whether an analogous form of stewardship might be emerging in the seafood industry at a global level. Certainly stewardship is in the long-term self-interest of communities and corporations alike, but that self-interest takes highly different forms: to sustain livelihoods and well-being on one hand, and to sustain the viability and profitability of industry on the other. But in the context of an increasingly consolidated and globally connected seafood industry, what evidence is there of the transformative potential of evolving shared concepts of stewardship and a commitment by companies to act as stewards?

Prominent efforts by the Marine Stewardship Council, the Seafood Stewardship Index and other initiatives have been met with vigorous criticism and engagement. This reaction suggests not only a skepticism about current notions of stewardship by the seafood industry, but also an optimism and energy dedicated to ensuring that seafood companies embrace a role as stewards of the ocean. It also underscores the notion of stewardship as a moving target, a dynamic term that encompasses a growing range of aspirations and ideals, but which is still being translated into practice. The list of criteria that are considered evidence of stewardship has continuously grown over the past decades, and while bright spots of progress are evident within the industry, on a global scale even the most basic elements of sustainable fisheries management and elimination of bycatch remain distant targets. The extent to which individual seafood companies, and the industry overall, can achieve these fundamentals while also responding to the growing suite of stewardship aspirations will shape the future of seafood production.

The energy that has been driving the notion of stewardship can be traced back to a diversity of sources. NGOs and other civil society groups kickstarted change by mobilizing consumer awareness and pressure. Philanthropic foundations have played a key and recurring role in promoting a growing suite of market-based efforts to steer the seafood industry toward embracing an ever-wider range of environmental and social issues. And the companies that comprise the seafood industry have increasingly entered into VEPs to engage in pre-competitive collaboration to address challenges within the seafood industry or specific segments of it.

While the focus of this manuscript has been on actions by the seafood industry, it is clear that its actions are, in fact, reactions. Reactions to drivers as diverse as consumer pressure, government regulation, a changing climate, and collapse of fish populations. A more proactive approach might seem to be a clearer indicator of stewardship, but we note in this manuscript that movement toward stewardship has been dependent on a complex interplay of different actors, and there is limited capacity for NGO campaigns, market mechanisms or voluntary environmental programs to enable systemic change in isolation, and even leadership by companies can falter in the absence of clear political leadership and associated actions. The High Level Panel for a Sustainable Ocean Economy (**Box 5**) represents the most recent initiative by governments to institutionalize ocean stewardship, including with a commitment by the participating 14 heads of state to sustainable manage their respective exclusive economic zones by 2025, announced in December of 2020 (Lubchenco et al., 2020). Action by these countries could provide a powerful and paradigmatic counterexample to recent disappointments such as the global community's failure to achieve any of the 20 Aichi Targets under the Convention on Biological Diversity by 2020 (Greenfield, 2020). The extent to which governments follow through on such bold commitments, and are held accountable if they fail, remain a central question of relevance for the ocean stewardship challenge (Anon, 2020).

As the concept of stewardship within the seafood industry matures, it may also provide a useful touchpoint for the suite

of other ocean-based industries (Virdin et al., 2021). Perhaps more than any other major ocean-based industry, the seafood industry – and capture fisheries in particular – are reliant on ocean health and functioning ecosystems, with degradation of both constituting an existential threat. Yet all ocean-based industries depend to some extent on stable and predictable conditions, and the simultaneous growth of these industries as well as their interactions sets the stage for developing a shared and ambitious vision of "ocean stewardship."

Much of this manuscript has tended toward the optimistic: introducing the possibilities and promise inherent to an industry showing initial signs of moving beyond short-term operational priorities to exploring the dimensions of stewardship. But a bitter reality of swift degradation of the biosphere cannot be ignored (Halpern et al., 2008; Crespo et al., 2019; Duarte et al., 2020; Pacoureau et al., 2021). The urgency of slowing and reversing current trajectories is omnipresent, as illustrated by a growing proportion of overfished stocks, a 70% loss of global shark and ray populations in 50 years, the rapid spread of antimicrobial resistance, and a dozen more grim statistics (Wernli et al., 2017; FAO, 2020; Lau et al., 2020; Pacoureau et al., 2021). The future of the ocean and humanity's relationship with it may rest on efforts to translate stewardship from an aspirational notion to a pillar of standard operating procedure anchored in supportive public policy.

AUTHOR CONTRIBUTIONS

RB and AD conceptualized and primarily drafted the manuscript. All authors contributed to the writing of the article and approved the submitted version.

FUNDING

RB, J-BJ, ES, JB, CW, HÖ, and BC received funding from the Walton Family Foundation (2018-1371), The David and Lucile Packard Foundation (2019-68336), and The Gordon and Betty Moore Foundation (GBMF5668.02). RB was also supported by the Swedish Research Council Formas (2020-01048). PH is funded by FORMAS's Inequality and the Biosphere project (2020-00454) and SeaWin project (2016-00227) and CGIAR Research Programs on Fish Agri-Food Systems (FISH) led by WorldFish. CF is supported from the Beijer Foundation and the Marianne and Marcus Wallenberg Foundation. AC is funded by the Stockholm Environment Institute's BiH ESAP 2030 + project, which is supported by the Swedish Embassy in Bosnia and Herzegovina. SK was supported by the Swedish Research Council Formas (2016-00375). AD, SK, EW, BC, and CF were supported by the Global Economic Dynamics and the Biosphere Program of the Royal Swedish Academy of Sciences, funded by the Family Erling-Persson Foundation. MT acknowledges the SEAWIN project funded by Formas (2016-00227). The Pew Fellows Program in Marine Conservation Grant Number A-01984. RB, J-BJ, and CW received additional support by the Ocean Risk and Resilience Action Alliance through the Government of Canada. NY received funds from the Nippon Foundation (UTokyo Future Society Initiative Fund) and Japan Society for the Promotion of Science (Kakenhi grant number 16H02565).

ACKNOWLEDGMENTS

We would like to thank participants in the workshop 'Developing an evidence-based framework for what a comprehensive Ocean Stewardship should comprise' which was convened on June 14-15, 2018 by the Stockholm Resilience Centre at Stockholm University in collaboration with the Global Economic Dynamics and the Biosphere programme of the Royal Swedish Academy of Sciences, and with intellectual input from the Seafood Stewardship Index (Index Initiative), including several co-authors as well as D. Belhabib, R. Beukers, C. Hicks, and L. Urlings. We would like to express our appreciation to S. Russell, M. Berger, E. Hazen, J. Jacquet, K. Reid, R. Arangio, and other colleagues, whose insights helped to shape this manuscript.

REFERENCES

Adomaitis, N. (2021a). *Norway Awards oil and Gas Exploration Rights to 30 Firms*. London: Reuters.

Adomaitis, N. (2021b). *Norway Eyes Sea Change in Deep Dive for Metals Instead of Oil*. London: Reuters.

Agnew, D. J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J. R., et al. (2009). Estimating the worldwide extent of illegal fishing. *PLoS One* 4:e4570. doi: 10.1371/journal.pone.0004570

Alam, I., Aalismail, N., Martin, C., Kamau, A., Guzmán-Vega, F. J., Jamil, T., et al. (2020). Rapid evolution of plastic-degrading enzymes prevalent in the global ocean. *bioRxiv* [Preprint]. doi: 10.1101/2020.09.07.285692

Al-Jayyousi, O. (2018). *How Islam Can Represent A Model For Environmental Stewardship*. Nairobi: UN Environ.

Amundsen, V. S., and Osmundsen, T. C. (2020). Becoming certified, becoming sustainable? Improvements from aquaculture certification schemes as experienced by those certified. *Mar. Policy* 119:104097. doi: 10.1016/j.marpol.2020.104097

Andersson, E., Barthel, S., Borgström, S., Colding, J., Elmqvist, T., Folke, C., et al. (2014). Reconnecting cities to the biosphere: stewardship of green infrastructure and urban ecosystem services. *Ambio* 43, 445–453. doi: 10.1007/s13280-014-0506-y

Anon (2020). World leaders are waking up to the ocean's role in a healthy planet. *Nature* 588, 7–8. doi: 10.1038/d41586-020-03301-5

Anthony, J., and Pullar-Strecker, T. (2016). *Toothfish Poaching Vessel Viking Blown up by Indonesian Authorities | Stuff.co.nz*. Available online at: https://www.stuff.co.nz/business/industries/78044632/toothfish-poaching-vessel-blown-up-by-indonesian-authorities (accessed August 25, 2020).

ARK (2019). *ARK'S Commitment Review Panel 2019*. Margate: ARK.

ARK (2020). *Report From the Expert Panel on the Evaluation of the VRZs During the 2018/19 Fishing Season*. Margate: ARK.

Bailey, M., Packer, H., Schiller, L., Tlusty, M., and Swartz, W. (2018). The role of corporate social responsibility in creating a Seussian world of seafood sustainability. *Fish Fish.* 19, 782–790. doi: 10.1111/faf.12289

Ban, N., Wilson, E., and Neasloss, D. (2019). Strong historical and ongoing indigenous marine governance in the northeast Pacific Ocean: a case study of the Kitasoo/Xai'xais First Nation. *Ecol. Soc.* 24:10. doi: 10.5751/ES-11091-240410

Barange, M., Bahri, T., Beveridge, M. C., Cochrane, K. L., Funge-Smith, S., and Poulain, F. (2018). *Impacts of Climate Change on Fisheries and Aquaculture:*

Synthesis of Current Knowledge, Adaptation and Mitigation Options. Prais: FAO.

Barrett, J., Chase, Z., Zhang, J., Holl, M. M. B., Willis, K., Williams, A., et al. (2020). Microplastic pollution in deep-sea sediments from the great australian bight. *Front. Mar. Sci.* 7:576170. doi: 10.3389/fmars.2020.576170

Barthel, S., Colding, J., Elmqvist, T., and Folke, C. (2005). History and local management of a biodiversity-rich, urban cultural landscape. *Ecol. Soc.* 10:27.

Bebbington, J., Österblom, H., Crona, B., Jouffray, J.-B., Larrinaga, C., Russell, S., et al. (2019). Accounting and accountability in the Anthropocene. *Account. Audit. Account. J.* 33, 152–177. doi: 10.1108/AAAJ-11-2018-3745

Bell, J. D., Watson, R. A., and Ye, Y. (2017). Global fishing capacity and fishing effort from 1950 to 2012. *Fish Fish.* 18, 489–505. doi: 10.1111/faf.12187

Bennett, N. J., Whitty, T. S., Finkbeiner, E., Pittman, J., Bassett, H., Gelcich, S., et al. (2018). Environmental stewardship: a conceptual review and analytical framework. *Environ. Manag.* 61, 597–614. doi: 10.1007/s00267-017-0993-2

Berkes, F., Colding, J., and Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecol. Appl.* 10, 1251–1262. doi: 10.2307/2641280

Berkes, F., Folke, C., and Gadgil, M. (1995). "Traditional ecological knowledge, biodiversity, resilience and sustainability," in *Biodiversity Conservation: Problems and Policies Ecology, Economy & Environment*, eds C. A. Perrings, K.-G. Mäler, C. Folke, C. S. Holling, and B.-O. Jansson (Dordrecht: Springer Netherlands), 281–299. doi: 10.1007/978-94-011-0277-3_15

Berkes, F., Hughes, T. P., Steneck, R. S., Wilson, J. A., Bellwood, D. R., Crona, B., et al. (2006). Globalization, roving bandits, and marine resources. *Science* 311, 1557–1558. doi: 10.1126/science.1122804

Betsill, M. M., and Corell, E. (2001). NGO influence in international environmental negotiations: a framework for analysis. *Glob. Environ. Polit.* 1, 65–85. doi: 10.1162/152638001317146372

Björkvik, E. (2020). *Stewardship in Swedish Baltic Small-Scale Fisheries: A Study on the Social-Ecological Dynamics of Local Resource use*. Stockholm: Stockholm University.

Blasiak, R. (2015). Balloon effects reshaping global fisheries. *Mar. Policy* 57, 18–20. doi: 10.1016/j.marpol.2015.03.013

Blasiak, R., Bebbington, J., and Jouffray, J.-B. (2018a). *Voluntary Environmental Programs: The Amersfoort Dialogue, Background Brief 2*. Available online at: https://seabos.org/wp-content/uploads/2018/06/Brief2-Voluntary-Environmental-Programs.pdf (accessed February 22, 2021).

Blasiak, R., Jouffray, J.-B., Wabnitz, C. C. C., Sundström, E., and Österblom, H. (2018b). Corporate control and global governance of marine genetic resources. *Sci. Adv.* 4:eaar5237. doi: 10.1126/sciadv.aar5237

Blasiak, R., Hsiang-Wen Huang, J., Ishihara, H., Kelling, I., Lieng, S., Lindoff, H., et al. (2017a). Promoting diversity and inclusiveness in seafood certification and ecolabelling: prospects for Asia. *Mar. Policy* 85, 42–47. doi: 10.1016/j.marpol.2017.08.011

Blasiak, R., Spijkers, J., Tokunaga, K., Pittman, J., Yagi, N., and Österblom, H. (2017b). Climate change and marine fisheries: least developed countries top global index of vulnerability. *PLoS One* 12:e0179632. doi: 10.1371/journal.pone.0179632

Blasiak, R., Wynberg, R., Grorud-Colvert, K., Thambisetty, S., Bandarra, N. M., Canário, A. V. M., et al. (2020). The ocean genome and future prospects for conservation and equity. *Nat. Sustain.* 3, 588–596. doi: 10.1038/s41893-020-0522-9

Boström, M., Micheletti, M., and Oosterveer, P. (2019). *The Oxford Handbook of Political Consumerism*. Oxford: Oxford University Press.

Brondizio, E. S., Settele, J., Díaz, S., and Ngo, H. T. (2019). *Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn: IPBES Secr.

Browman, H. I., Cooke, S. J., Cowx, I. G., Derbyshire, S. W. G., Kasumyan, A., Key, B., et al. (2019). Welfare of aquatic animals: where things are, where they are going, and what it means for research, aquaculture, recreational angling, and commercial fishing. *ICES J. Mar. Sci.* 76, 82–92. doi: 10.1093/icesjms/fsy067

Brugere, C., Troell, M., and Eriksson, H. (2021). More than fish: policy coherence and benefit sharing as necessary conditions for equitable aquaculture development. *Mar. Policy* 123:104271. doi: 10.1016/j.marpol.2020.104271

Buchmann, S. L., and Nabhan, G. P. (1997). *The Forgotten Pollinators*. Washington, DC: Island Press.

Buck, B. H., Nevejan, N., Wille, M., Chambers, M. D., and Chopin, T. (2017). "Offshore and multi-use aquaculture with extractive species: seaweeds and bivalves," in *Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene*, eds B. H. Buck and R. Langan (Cham: Springer International Publishing), 23–69. doi: 10.1007/978-3-319-51159-7_2

Burkitt, I. (2016). Relational agency: relational sociology, agency and interaction. *Eur. J. Soc. Theory* 19, 322–339. doi: 10.1177/1368431015591426

Bush, S., and Roheim, C. (2019). "The shifting politics of sustainable seafood consumption," in *The Oxford Handbook of Political Consumerism*, eds M. Boström, M. Micheletti, and P. Oosterveer (Oxford: Oxford University Press).

Cao, L., Naylor, R., Henriksson, P., Leadbitter, D., Metian, M., Troell, M., et al. (2015). China's aquaculture and the world's wild fisheries. *Science* 347, 133–135. doi: 10.1126/science.1260149

Carpenter, L. J., and Liss, P. S. (2000). On temperate sources of bromoform and other reactive organic bromine gases. *J. Geophys. Res. Atmospheres* 105, 20539–20547. doi: 10.1029/2000JD900242

Carr, H. A., and Harris, J. (1997). "Ghost-fishing gear: have fishing practices during the past few years reduced the impact?," in *Marine Debris: Sources, Impacts, and Solutions* Springer Series on Environmental Management, eds J. M. Coe and D. B. Rogers (New York, NY: Springer), 141–151. doi: 10.1007/978-1-4613-8486-1_11

Carson, R. (1951). *The Sea Around Us*. Oxford: Oxford University Press.

Cashion, T., Manach, F. L., Zeller, D., and Pauly, D. (2017). Most fish destined for fishmeal production are food-grade fish. *Fish Fish.* 18, 837–844. doi: 10.1111/faf.12209

Castilla, J. C., Manriquez, P., Alvarado, J., Rosson, A., Pino, C., Espoz, C., et al. (1998). Artisanal" Caletas" as units of production and co-managers of benthic invertebrates in Chile. *Can. Spec. Publ. Fish. Aquat. Sci.* 125, 407–413.

Cavan, E. L., Laurenceau-Cornec, E. C., Bressac, M., and Boyd, P. W. (2019). Exploring the ecology of the mesopelagic biological pump. *Prog. Oceanogr.* 176:102125. doi: 10.1016/j.pocean.2019.102125

CBD (2011). *Biological and Cultural Diversity in Coastal Communities, Exploring the Potential of Satoumi for Implementing the Ecosystem Approach in the Japanese Archipelago*. Montreal: Convention on Biological Diversity.

Chakraborty, S., Gasparatos, A., and Blasiak, R. (2020). Multiple values for the management and sustainable use of coastal and marine ecosystem services. *Ecosyst. Serv.* 41:101047. doi: 10.1016/j.ecoser.2019.101047

Chapin, F. S., Carpenter, S. R., Kofinas, G. P., Folke, C., Abel, N., Clark, W. C., et al. (2010). Ecosystem stewardship: sustainability strategies for a rapidly changing planet. *Trends Ecol. Evol.* 25, 241–249. doi: 10.1016/j.tree.2009.10.008

Chapin, F. S., Kofinas, G. P., and Folke, C. (2009). *Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World*. Berlin: Springer Science & Business Media.

Chapin, F. S., Power, M. E., Pickett, S. T. A., Freitag, A., Reynolds, J. A., Jackson, R. B., et al. (2011). Earth Stewardship: science for action to sustain the human-earth system. *Ecosphere* 2:art89. doi: 10.1890/ES11-00166.1

Chawla, L. (2009). Growing up green: becoming an agent of care for the natural world. *J. Dev. Process.* 4, 6–23.

Cherry, P., O'Hara, C., Magee, P. J., McSorley, E. M., and Allsopp, P. J. (2019). Risks and benefits of consuming edible seaweeds. *Nutr. Rev.* 77, 307–329. doi: 10.1093/nutrit/nuy066

Christian, C., Ainley, D., Bailey, M., Dayton, P., Hocevar, J., LeVine, M., et al. (2013). A review of formal objections to Marine Stewardship Council fisheries certifications. *Biol. Conserv.* 161, 10–17. doi: 10.1016/j.biocon.2013.01.002

Collins, M. A., Brickle, P., Brown, J., and Belchier, M. (2010). "Chapter four - the patagonian toothfish: biology, ecology and fishery," in *Advances in Marine Biology*, ed. M. Lesser (Cambridge, MA: Academic Press), 227–300. doi: 10.1016/B978-0-12-381015-1.00004-6

COLTO (2020). *COLTO: Background. Coalit. Leg. Toothfish Oper. - Support. Sustain. Toothfish Chil. Seabass Fish*. Available online at: https://www.colto.org/about-us/background/ (accessed October 8, 2020).

COLTO (2021). *All Toothfish Fisheries | Coalition of Legal Toothfish Operators - Supporting sustainable toothfish (Chilean Seabass) Fisheries*. Available online at: https://www.colto.org/toothfish-fisheries/all-toothfish-fisheries/ (accessed February 9, 2021).

Cottrell, R. S., Blanchard, J. L., Halpern, B. S., Metian, M., and Froehlich, H. E. (2020). Global adoption of novel aquaculture feeds could substantially reduce forage fish demand by 2030. *Nat. Food* 1, 301–308. doi: 10.1038/s43016-020-0078-x

Cottrell, R. S., Metian, M., Froehlich, H. E., Blanchard, J. L., Jacobsen, N. S., McIntyre, P. B., et al. (2021). Time to rethink trophic levels in aquaculture policy. *Rev. Aquac.* 13, 1583–1593. doi: 10.1111/raq.12535

Couture, J. L., Froehlich, H. E., Buck, B. H., Jeffery, K. R., Krause, G., Morris, J. A. Jr., et al. (2021). Scenario analysis can guide aquaculture planning to meet sustainable future production goals. *ICES J. Mar. Sci.* fsab012. doi: 10.1093/icesjms/fsab012

Crespo, G. O., Dunn, D. C., Gianni, M., Gjerde, K., Wright, G., and Halpin, P. N. (2019). High-seas fish biodiversity is slipping through the governance net. *Nat. Ecol. Evol.* 3, 1273–1276. doi: 10.1038/s41559-019-0981-4

Crona, B. I., Van Holt, T., Petersson, M., Daw, T. M., and Buchary, E. (2015). Using social–ecological syndromes to understand impacts of international seafood trade on small-scale fisheries. *Glob. Environ. Change* 35, 162–175. doi: 10.1016/j.gloenvcha.2015.07.006

Cullis-Suzuki, S., and Pauly, D. (2010). Failing the high seas: a global evaluation of regional fisheries management organizations. *Mar. Policy* 34, 1036–1042. doi: 10.1016/j.marpol.2010.03.002

Dasmann, R. (1976). Future primitive: ecosystem people versus biosphere people. *Coevol. Q.* 11, 26–31.

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.-P., et al. (2020). Rebuilding marine life. *Nature* 580, 39–51. doi: 10.1038/s41586-020-2146-7

Dunn, D. C., Jablonicky, C., Crespo, G. O., McCauley, D. J., Kroodsma, D. A., Boerder, K., et al. (2018). Empowering high seas governance with satellite vessel tracking data. *Fish Fish.* 19, 729–739. doi: 10.1111/faf.12285

Duong, T. (2018). The True Cost of "Cheap" seafood: an analysis of environmental and human exploitation in the seafood industry. *Hastings Environ. Law J.* 24:279.

Emirbayer, M., and Mische, A. (1998). What is agency? *Am. J. Sociol.* 103, 962–1023. doi: 10.1086/231294

Eriksen, M., Lebreton, L. C. M., Carson, H. S., Thiel, M., Moore, C. J., Borerro, J. C., et al. (2014). Plastic pollution in the World's oceans: more than 5 trillion plastic pieces Weighing over 250,000 Tons Afloat at Sea. *PLoS One* 9:e111913. doi: 10.1371/journal.pone.0111913

Eriksson, H., Österblom, H., Crona, B., Troell, M., Andrew, N., Wilen, J., et al. (2015). Contagious exploitation of marine resources. *Front. Ecol. Environ.* 13:435–440. doi: 10.1890/140312

Etzion, D. (2020). Corporate engagement with the natural environment. *Nat. Ecol. Evol.* 4:493. doi: 10.1038/s41559-020-1142-5

FAO (2020). *The State of World Fisheries and Aquaculture*. New York, NY: United Nations.

FAO (2021). *Fisheries and Aquaculture Software. FishStatJ-Softw. Fish. Stat. Time Ser*. Rome: FAO Fish.

FAO (2015). *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication: Summary*. Rome: International Collective in Support of Fishworkers.

Farmery, A. K., Alexander, K. A., Anderson, K., Blanchard, J. L., Carter, C. G., Evans, K., et al. (2020). Food for all: designing sustainable and secure future seafood systems. *Authorea* [Preprint]. doi: 10.22541/au.160322471.16891119/v1

Farmery, A. K., Allison, E. H., Andrew, N. L., Troell, M., Voyer, M., Campbell, B., et al. (2021). Blind spots in visions of a "blue economy" could undermine the ocean's contribution to eliminating hunger and malnutrition. *One Earth* 4, 28–38. doi: 10.1016/j.oneear.2020.12.002

FOA (2019). *Ocean Programme at Davos: World Economic Forum Annual Meeting 2019*. Available online at: http://www3.weforum.org/docs/WEF_FOA_Ocean_Day.pdf (accessed February 22, 2021).

Foley, P., and McCay, B. (2014). Certifying the commons: eco-certification, privatization, and collective action. *Ecol. Soc.* 19, 28. doi: 10.5751/ES-06459-190228

Folke, C., Biggs, R., Norström, A. V., Reyers, B., and Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. *Ecol. Soc.* 21:41.

Folke, C., Hahn, T., Olsson, P., and Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.* 30, 441–473. doi: 10.1146/annurev.energy.30.050504.144511

Folke, C., and Kautsky, N. (1989). Role of ecosystems for a sustainable development of aquaculture. *AMBIO* 18, 234–243.

Folke, C., and Kautsky, N. (1992). Aquaculture with its environment: prospects for sustainability. *Ocean Coast. Manag.* 17, 5–24. doi: 10.1016/0964-5691(92)90059-T

Folke, C., Österblom, H., Jouffray, J.-B., Lambin, E. F., Adger, W. N., Scheffer, M., et al. (2019). Transnational corporations and the challenge of biosphere stewardship. *Nat. Ecol. Evol.* 3, 1396–1403. doi: 10.1038/s41559-019-0978-z

Folke, C., Österblom, H., Jouffray, J. B., Lambin, E. F., Adger, W. N., Scheffer, M., et al. (2020). An invitation for more research on transnational corporations and the biosphere. *Nat. Ecol. Evol.* 4, 494–494. doi: 10.1038/s41559-020-1145-2

Folke, C., Polasky, S., Rockström, J., Galaz, V., Westley, F., Lamont, M., et al. (2021). Our future in the Anthropocene biosphere. *Ambio* 50, 834–869. doi: 10.1007/s13280-021-01544-8

Franks, B., Ewell, C., and Jacquet, J. (2021). Animal welfare risks of global aquaculture. *Sci. Adv.* 7:eabg0677. doi: 10.1126/sciadv.abg0677

Friedlander, A. M., and Gaymer, C. F. (2020). Progress, opportunities and challenges for marine conservation in the Pacific Islands. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 31, 221–231. doi: 10.1002/aqc.3464

Froehlich, H. E., Jacobsen, N. S., Essington, T. E., Clavelle, T., and Halpern, B. S. (2018). Avoiding the ecological limits of forage fish for fed aquaculture. *Nat. Sustain.* 1, 298–303. doi: 10.1038/s41893-018-0077-1

Froese, R., and Proelss, A. (2012). Evaluation and legal assessment of certified seafood. *Mar. Policy* 36, 1284–1289. doi: 10.1016/j.marpol.2012.03.017

Gadgil, M., Berkes, F., and Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio* 22, 151–156.

Gadgil, M., Berkes, F., and Folke, C. (2021). Indigenous knowledge: from local to global. *Ambio* 50, 967–969. doi: 10.1007/s13280-020-01478-7

Gale, F., and Haward, M. (2011). *Global Commodity Governance: State Responses to Sustainable Forest and Fisheries Certification*. London: Palgrave Macmillan UK, doi: 10.1057/9780230304697

Geller, A. (2016). *How 4 AP Reporters got the Story "Seafood From Slaves."*. New York, NY: AP NEWS.

Global Salmon Initiative (2020a). *ASC Certification*. Boston, MA: Global Salmon Initiative.

Global Salmon Initiative. (2020b). *Sustainability Report*. Boston, MA: Global Salmon Initiative.

Greenfield, P. (2020). *World fails to Meet a Single Target to Stop Destruction of Nature – UN Report*. London: The Guardian.

Greenpeace. (2005). *A Recipe for Disaster: Supermarkets' Insatiable Appetite for Seafood*. Amsterdam: Greenpeace.

Greenwood, M. (2019). *Seafood Supply Chains: Governance, Power and Regulation*. London: Routledge.

GSSI (2018). *GSSI-SSCI Collaboration*. Nashua, NH: GSSI.

Gulbrandsen, L. H. (2014). Dynamic governance interactions: evolutionary effects of state responses to non-state certification programs. *Regul. Gov.* 8, 74–92. doi: 10.1111/rego.12005

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., et al. (2008). A global map of human impact on marine ecosystems. *Science* 319, 948–952. doi: 10.1126/science.1149345

Häyhä, T., and Franzese, P. P. (2014). Ecosystem services assessment: a review under an ecological-economic and systems perspective. *Ecol. Model.* 289, 124–132. doi: 10.1016/j.ecolmodel.2014.07.002

Henriksson, P. J. G., Rico, A., Troell, M., Klinger, D. H., Buschmann, A. H., Saksida, S., et al. (2018). Unpacking factors influencing antimicrobial use in global aquaculture and their implication for management: a review from a systems perspective. *Sustain. Sci.* 13, 1105–1120. doi: 10.1007/s11625-017-0511-8

Henriksson, P. J. G., Troell, M., and Rico, A. (2015). Antimicrobial use in aquaculture: Some complementing facts. *Proc. Natl. Acad. Sci. U.S.A.* 112:E3317. doi: 10.1073/pnas.1508952112

Hernández-Santoro, C., Landaeta, M. F., and Pizarro, J. C. (2019). Effect of ENSO on the distribution and concentration of catches and reproductive activity

of anchovy Engraulis ringens in northern Chile. *Fish. Oceanogr* 28, 241–255. doi: 10.1111/fog.12405

Hidalgo, M., and Browman, H. I. (2019). Developing the knowledge base needed to sustainably manage mesopelagic resources. *ICES J. Mar. Sci.* 76, 609–615. doi: 10.1093/icesjms/fsz067

Hilborn, R., Amoroso, R. O., Anderson, C. M., Baum, J. K., Branch, T. A., Costello, C., et al. (2020). Effective fisheries management instrumental in improving fish stock status. *Proc. Natl. Acad. Sci. U.S.A.* 117, 2218–2224. doi: 10.1073/pnas.1909726116

Holbrook, N. J., Sen Gupta, A., Oliver, E. C. J., Hobday, A. J., Benthuysen, J. A., Scannell, H. A., et al. (2020). Keeping pace with marine heatwaves. *Nat. Rev. Earth Environ.* 1, 482–493. doi: 10.1038/s43017-020-0068-4

Holmlund, C. M., and Hammer, M. (1999). Ecosystem services generated by fish populations. *Ecol. Econ.* 29, 253–268. doi: 10.1016/S0921-8009(99)00015-4

Hunt, J. (2017). *Japan Copes With the Disappearing Eel*. New York, NY: New Yorker.

Hviding, E. (1996). *Guardians of Marovo Lagoon: Practice, Place, and Politics in Maritime Melanesia*. Honolulu: University of Hawaii Press.

Hyde, L. (1979). Dolphin Conservation in the tuna industry: the United States'. Role in an International Problem. *San Diego Law Rev.* 16:665.

IPCC (2019). *The Ocean and Cryosphere in a Changing Climate A Special Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC.

ISSF (2020). *About | International Seafood Sustainability Foundation*. Available online at: https://iss-foundation.org/who-we-are/about/ (accessed October 8, 2020).

IUCN. (2021). *The IUCN Red List of Threatened Species*. Available online at: https://www.iucnredlist.org/en (accessed April 19, 2021).

Jacquet, J., Franks, B., Godfrey-Smith, P., and Sánchez-Suárez, W. (2019). The case against octopus farming. *Issues Sci. Technol.* 35, 37–44.

Jacquet, J., Hocevar, J., Lai, S., Majluf, P., Pelletier, N., Pitcher, T., et al. (2010a). Conserving wild fish in a sea of market-based efforts. *Oryx* 44, 45–56. doi: 10.1017/S0030605309990470

Jacquet, J., Pauly, D., Ainley, D., Holt, S., Dayton, P., and Jackson, J. (2010b). Seafood stewardship in crisis. *Nature* 467, 28–29. doi: 10.1038/467028a

Jacquet, J. L., and Pauly, D. (2007). The rise of seafood awareness campaigns in an era of collapsing fisheries. *Mar. Policy* 31, 308–313. doi: 10.1016/j.marpol.2006.09.003

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., et al. (2015). Plastic waste inputs from land into the ocean. *Science* 347, 768–771. doi: 10.1126/science.1260352

Jeffreys, E. (2016). Translocal celebrity activism: shark-protection campaigns in mainland China. *Environ. Commun.* 10, 763–776. doi: 10.1080/17524032.2016.1198822

Jiji Press (2020). *Japan Eel Sales Hitting Peak on Day of Ox*. Tokyo: Jiji Press. nippon.com.

Johannes, R. E. (1992). *Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia*. Berkeley: University of California Press.

Jonell, M., Crona, B., Brown, K., Rönnbäck, P., and Troell, M. (2016). Eco-labeled seafood: determinants for (Blue) green consumption. *Sustainability* 8:884. doi: 10.3390/su8090884

Jonell, M., Phillips, M., Rönnbäck, P., and Troell, M. (2013). Eco-certification of farmed seafood: will it make a difference? *Ambio* 42, 659–674. doi: 10.1007/s13280-013-0409-3

Jouffray, J.-B., Blasiak, R., Norström, A. V., Österblom, H., and Nyström, M. (2020). The blue acceleration: the trajectory of human expansion into the ocean. *One Earth* 2, 43–54. doi: 10.1016/j.oneear.2019.12.016

Jouffray, J. B., Crona, B., Wassénius, E., Bebbington, J., and Scholtens, B. (2019). Leverage points in the financial sector for seafood sustainability. *Sci. Adv.* 5:eaax3324. doi: 10.1126/sciadv.aax3324

Kahui, V., and Richards, A. C. (2014). Lessons from resource management by indigenous Maori in New Zealand: governing the ecosystems as a commons. *Ecol. Econ.* 102, 1–7. doi: 10.1016/j.ecolecon.2014.03.006

Kelleher, K., Westlund, L., Hoshino, E., Mills, D., Willmann, R., de Graaf, G., et al. (2012). *Hidden Harvest: The Global Contribution of Capture Fisheries*. Washington, DC: Worldbank.

Kinley, R. D., Martinez-Fernandez, G., Matthews, M. K., de Nys, R., Magnusson, M., and Tomkins, N. W. (2020). Mitigating the carbon footprint and improving productivity of ruminant livestock agriculture using a red seaweed. *J. Clean. Prod.* 259:120836. doi: 10.1016/j.jclepro.2020.120836

Kittinger, J. N., Teh, L. C. L., Allison, E. H., Bennett, N. J., Crowder, L. B., Finkbeiner, E. M., et al. (2017). Committing to socially responsible seafood. *Science* 356, 912–913. doi: 10.1126/science.aam9969

Knott, K. (2018). *Jackie Chan, Yao Ming back ad Campaign Against Illegal Wildlife Trade*. Hong Kong: South China Morning Post.

Korban, D. (2020). *Mowi, BioMar, Skretting, Cargill Call for Pre-Emptive Action on Troubled EU Fish Stocks*. Bergen: Intrafish.

Kourantidou, M., and Kaiser, B. A. (2019). Sustainable seafood certifications are inadequate to challenges of ecosystem change. *ICES J. Mar. Sci.* 76, 794–802. doi: 10.1093/icesjms/fsy198

Kroodsma, D. A., Mayorga, J., Hochberg, T., Miller, N. A., Boerder, K., Ferretti, F., et al. (2018). Tracking the global footprint of fisheries. *Science* 359, 904–908. doi: 10.1126/science.aao5646

Lau, W. W. Y., Shiran, Y., Bailey, R. M., Cook, E., Stuchtey, M. R., Koskella, J., et al. (2020). Evaluating scenarios toward zero plastic pollution. *Science* 369, 1455–1461. doi: 10.1126/science.aba9475

Leadbitter, D., and Benguerel, R. (2014). Sustainable Tuna – can the marketplace improve fishery management? *Bus. Strategy Environ.* 23, 417–432. doi: 10.1002/bse.1794

Lee, L. C., Reid, M., Jones, R., Winbourne, J., Rutherford, M., and Salomon, A. K. (2019). Drawing on indigenous governance and stewardship to build resilient coastal fisheries: people and abalone along Canada's northwest coast. *Mar. Policy* 109:103701. doi: 10.1016/j.marpol.2019.103701

Lewis, S. G., Alifano, A., Boyle, M., and Mangel, M. (2017). "Chapter 18 - human rights and the sustainability of fisheries," in *Conservation for the Anthropocene Ocean*, eds P. S. Levin and M. R. Poe (Cambridge, MA: Academic Press), 379–396. doi: 10.1016/B978-0-12-805375-1.00018-0

Limburg, K. E., Breitburg, D., Swaney, D. P., and Jacinto, G. (2020). Ocean deoxygenation: a primer. *One Earth* 2, 24–29. doi: 10.1016/j.oneear.2020.01.001

Lubchenco, J., Haugan, P. M., and Pangestu, M. E. (2020). Five priorities for a sustainable ocean economy. *Nature* 588, 30–32. doi: 10.1038/d41586-020-03303-3

Lusher, A., Hollman, P., and Mendoza-Hill, J. (2017). *Microplastics in Fisheries and Aquaculture Status of Knowledge on Their Occurrence and Implications for Aquatic Organisms and Food Safety*. Rome: Food & Agriculture Org.

Macfadyen, G., Huntington, T., and Cappell, R. (2009). *Abandoned, Lost or Otherwise Discarded Fishing gear*. Nairobi: United Nations Environment Programme.

MAFF (2021). *Information About Eels (ウナギに関する情報：水産庁). Minist. Agric. For. Fish. Jpn*. Available online at: https://www.jfa.maff.go.jp/j/saibai/unagi.html (accessed April 22, 2021).

MarinTrust (2020). *MarinTrust Programme (July 2019 - May 2020)*. London: MarinTrust.

Martinelli, J. C., Phan, S., Luscombe, C. K., and Padilla-Gamiño, J. L. (2020). Low incidence of microplastic contaminants in Pacific oysters (*Crassostrea gigas* Thunberg) from the Salish Sea. USA. *Sci. Total Environ.* 715:136826. doi: 10.1016/j.scitotenv.2020.136826

Masters, C. (2002). *The Toothfish Pirates. Four Corners Doc*. Ultimo: Australian Broadcasting Commission.

Mathevet, R., Bousquet, F., and Raymond, C. M. (2018). The concept of stewardship in sustainability science and conservation biology. *Biol. Conserv.* 217, 363–370. doi: 10.1016/j.biocon.2017.10.015

McConney, P., Pereira Medeiros, R., Pascual-Fernández, J. J., and Pena, M. (2019). "Stewardship and sustainable practices in small-scale fisheries," in *Transdisciplinarity for Small-Scale Fisheries Governance: Analysis and Practice MARE Publication Series*, eds R. Chuenpagdee and S. Jentoft (Cham: Springer International Publishing), 181–201. doi: 10.1007/978-3-319-94938-3_10

McDonald, G. G., Costello, C., Bone, J., Cabral, R. B., Farabee, V., Hochberg, T., et al. (2021). Satellites can reveal global extent of forced labor in the world's fishing fleet. *Proc. Natl. Acad. Sci. U.S.A.* 118:e2016238117. doi: 10.1073/pnas.2016238117

McMillan, L. J., and Prosper, K. (2016). Remobilizing netukulimk: indigenous cultural and spiritual connections with resource stewardship and fisheries management in Atlantic Canada. *Rev. Fish Biol. Fish.* 26, 629–647. doi: 10.1007/s11160-016-9433-2

Metai, T. (2018). *Through the Author's Eyes: Why are we Succeeding and Why Aren't we Succeeding in Managing our own Marine Resources in the South Pacific Region*. Available online at: https://escholarship.org/uc/item/3177d5tz (accessed April 18, 2021).

MSC (2019a). *Fisheries Standard Review (FSR): List of Topics Prioritized for Review*. Available online at: https://www.msc.org/docs/default-source/default-document-library/stakeholders/msc-fisheries-standard-review---list-of-topics-2019.pdf?sfvrsn=2a3b4a6e_4 (accessed February 22, 2021).

MSC (2019b). *Labour Requirements for Fisheries and Supply Chains*. Available online at: https://www.msc.org/media-centre/press-releases/msc-announces-changes-to-labour-reporting-objections-and-stakeholder-engagement.

MSC (2019c). *MSC Board Trustees*. Available online at: https://www.msc.org/about-the-msc/our-governance (accessed February 22, 2021).

MSC (2019d). *New Measures Introduced to Combat Forced and Child Labour in Seafood Businesses*. London: Marine Stewardship Council.

MSC (2020a). *Japanese Fishery Awarded First Ever MSC Certification for Bluefin Tuna*. Available online at: https://www.msc.org/media-centre/news-opinion/2020/07/30/japanese-fishery-first-ever-msc-certification-for-bluefin-tuna (accessed February 22, 2021).

MSC (2020b). *Our Collective Impact*. Available online at: https://www.msc.org/what-we-are-doing/our-collective-impact (accessed February 22, 2021).

MSC (2021a). *Fish for Good*. London: Marine Stewardship Council.

MSC (2021b). *Fishery Improvement Projects (FIPs)*. London: Marine Stewardship Council.

MSC (2021c). *MSC Capacity Building Program*. London: Marine Stewardship Council.

MSC (2021d). *MSC Global Accessibility Program*. London: Marine Stewardship Council.

MSC (2021e). *Ocean Stewardship Fund*. London: Marine Stewardship Council.

MSC (2021f). *Transition Assistance Fund Grant Available to Small-Scale Fisheries*. London: Marine Stewardship Council.

Mulvaney, K. (1996). The International whaling commission and the role of non-governmental organizations. *Georget. Int. Environ. Law Rev.* 9:347.

Nakamura, K., Bishop, L., Ward, T., Pramod, G., Thomson, D. C., Tungpuchayakul, P., et al. (2018). Seeing slavery in seafood supply chains. *Sci. Adv.* 4:e1701833. doi: 10.1126/sciadv.1701833

Napier, J. A., Olsen, R.-E., and Tocher, D. R. (2019). Update on GM canola crops as novel sources of omega-3 fish oils. *Plant Biotechnol. J.* 17, 703–705. doi: 10.1111/pbi.13045

Nassauer, J. I. (2011). Care and stewardship: from home to planet. *Landsc. Urban Plan.* 100, 321–323. doi: 10.1016/j.landurbplan.2011.02.022

Naylor, R. L., Hardy, R. W., Buschmann, A. H., Bush, S. R., Cao, L., Klinger, D. H., et al. (2021). A 20-year retrospective review of global aquaculture. *Nature* 591, 551–563. doi: 10.1038/s41586-021-03308-6

Nel, D. C., Ryan, P. G., and Watkins, B. P. (2002). Seabird mortality in the patagonian toothfish longline fishery around the Prince Edward Islands, 1996–2000. *Antarct. Sci.* 14, 151–161. doi: 10.1017/S0954102002000718

NOAA (2019). *North Atlantic Swordfish: About the Species*. Available online at: https://www.fisheries.noaa.gov/species/north-atlantic-swordfish (accessed February 22, 2021).

Nyborg, K., Anderies, J. M., Dannenberg, A., Lindahl, T., Schill, C., Schlüter, M., et al. (2016). Social norms as solutions. *Science* 354, 42–43. doi: 10.1126/science.aaf8317

Nyiawung, R. A., Raj, A., and Foley, P. (2021). Marine Stewardship Council sustainability certification in developing countries: certifiability and beyond in Kerala, India and The Gambia, West Africa. *Mar. Policy* 129:104526. doi: 10.1016/j.marpol.2021.104526

Nyström, M., Jouffray, J.-B., Norström, A. V., Crona, B., Søgaard Jørgensen, P., Carpenter, S. R., et al. (2019). Anatomy and resilience of the global production ecosystem. *Nature* 575, 98–108. doi: 10.1038/s41586-019-1712-3

Oceana Europe (2021). *Assisting ocean Stewardship Through Marine Insurance:The Insurance Industry's Statement Against Illegal, Unreported and Unregulated (IUU fishing) < Back to campaign page*. Madrid: Oceana Europe.

Olsen, R. E., Strand, E., Melle, W., Nørstebø, J. T., Lall, S. P., Ringø, E., et al. (2020). Can mesopelagic mixed layers be used as feed sources for salmon aquaculture? *Deep Sea Res. Part II Top. Stud. Oceanogr.* 180:104722. doi: 10.1016/j.dsr2.2019.104722

Olsson, P., and Folke, C. (2001). Local ecological knowledge and institutional dynamics for ecosystem management: a study of lake racken watershed. Sweden. *Ecosystems* 4, 85–104. doi: 10.1007/s100210000061

Osmundsen, T. C., Amundsen, V. S., Alexander, K. A., Asche, F., Bailey, J., Finstad, B., et al. (2020). The operationalisation of sustainability: sustainable aquaculture production as defined by certification schemes. *Glob. Environ. Change* 60:102025. doi: 10.1016/j.gloenvcha.2019.102025

Österblom, H. (2017). Reimagining ocean governance using the keystone species concept. *Nat. Ecol. Evol.* 1:133. doi: 10.1038/s41559-017-0133

Österblom, H., and Blasiak, R. (2021). Oil licences undermine Norway's ocean leadership. *Nature* 590:551. doi: 10.1038/d41586-021-00445-w

Österblom, H., and Bodin, O. (2012). Global cooperation among diverse organizations to reduce illegal fishing in the Southern Ocean. *Conserv. Biol. J. Soc. Conserv. Biol.* 26, 638–648. doi: 10.1111/j.1523-1739.2012.01850.x

Österblom, H., Crona, B. I., Folke, C., Nyström, M., and Troell, M. (2017a). Marine ecosystem science on an intertwined planet. *Ecosystems* 20, 54–61. doi: 10.1007/s10021-016-9998-6

Österblom, H., Jouffray, J.-B., Folke, C., and Rockström, J. (2017b). Emergence of a global science–business initiative for ocean stewardship. *Proc. Natl. Acad. Sci. U.S.A.* 114, 9038–9043. doi: 10.1073/pnas.1704453114

Österblom, H., Cvitanovic, C., van Putten, I., Addison, P., Blasiak, R., Jouffray, J.-B., et al. (2020a). Science-industry collaboration: sideways or highways to ocean sustainability? *One Earth* 3, 79–88. doi: 10.1016/j.oneear.2020.06.011

Österblom, H., Wabnitz, C. C. C., Tladi, D., Allison, E. H., Arnaud-Haond, S., Bebbington, J., et al. (2020b). *Towards Ocean Equity*. Washington, D.C.: World Resour. Inst.

Österblom, H., and Folke, C. (2013). Emergence of global adaptive governance for stewardship of regional marine resources. *Ecol. Soc.* 18:4. doi: 10.5751/ES-05373-180204

Österblom, H., Jouffray, J.-B., Folke, C., Crona, B., Troell, M., Merrie, A., et al. (2015). Transnational Corporations as 'Keystone Actors' in marine ecosystems. *PLoS One* 10:e0127533. doi: 10.1371/journal.pone.0127533

Österblom, H., Sumaila, U. R., Bodin, Ö, Sundberg, J. H., and Press, A. J. (2010). Adapting to regional enforcement: fishing down the governance index. *PLoS One* 5:e12832. doi: 10.1371/journal.pone.0012832

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., et al. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC.

Pacoureau, N., Rigby, C. L., Kyne, P. M., Sherley, R. B., Winker, H., Carlson, J. K., et al. (2021). Half a century of global decline in oceanic sharks and rays. *Nature* 589, 567–571. doi: 10.1038/s41586-020-03173-9

Pala, C. (2015). *The Hunt for the Last Chilean Sea Bass Poachers*. Available online at: https://foreignpolicy.com/2015/06/17/chilean-sea-bass-toothfish-thunder-sea-shepherd/ (accessed February 22, 2021).

Peçanha Enqvist, J., West, S., Masterson, V. A., Haider, L. J., Svedin, U., and Tengö, M. (2018). Stewardship as a boundary object for sustainability research: linking care, knowledge and agency. *Landsc. Urban Plan.* 179, 17–37. doi: 10.1016/j.landurbplan.2018.07.005

Pelletier, T. A., Carstens, B. C., Tank, D. C., Sullivan, J., and Espíndola, A. (2018). Predicting plant conservation priorities on a global scale. *Proc. Natl. Acad. Sci. U.S.A.* 115, 13027–13032. doi: 10.1073/pnas.1804098115

Petersson, M. T. (2019). Transnational partnerships' strategies in global fisheries governance. *Int. Groups Adv.* 8, 460–479. doi: 10.1057/s41309-019-00056-x

Pew Charitable Trusts (2017). *Following the Science Is Critical for Atlantic Fish Stocks*. Available online at: https://www.pewtrusts.org/en/research-and-analysis/data-visualizations/2017/following-the-science-is-critical-for-atlantic-fish-stocks (accessed February 22, 2021).

Pieja, A. J., Morse, M. C., and Cal, A. J. (2017). Methane to bioproducts: the future of the bioeconomy? *Curr. Opin. Chem. Biol.* 41, 123–131. doi: 10.1016/j.cbpa.2017.10.024

Pikitch, E. K., Rountos, K. J., Essington, T. E., Santora, C., Pauly, D., Watson, R., et al. (2014). The global contribution of forage fish to marine fisheries and ecosystems. *Fish Fish.* 15, 43–64. doi: 10.1111/faf.12004

Pitcher, T., Kalikoski, D., Pramod, G., and Short, K. (2009). Not honouring the code. *Nature* 457, 658–659. doi: 10.1038/457658a

Plieninger, T., Kizos, T., Bieling, C., Le Dû-Blayo, L., Budniok, M.-A., Bürgi, M., et al. (2015). Exploring ecosystem-change and society through a landscape lens: recent progress in European landscape research. *Ecol. Soc.* 20:5. doi: 10.5751/ES-07443-200205

Ponte, S. (2012). The marine stewardship council (MSC) and the making of a market for 'Sustainable Fish.'. *J. Agrar. Change* 12, 300–315. doi: 10.1111/j.1471-0366.2011.00345.x

Potoski, M., and Prakash, A. (2013). Green clubs: collective action and voluntary environmental programs. *Annu. Rev. Polit. Sci.* 16, 399–419. doi: 10.1146/annurev-polisci-032211-211224

Prakash, A., and Potoski, M. (2007). Collective action through voluntary environmental programs: a club theory perspective. *Policy Stud. J.* 35, 773–792. doi: 10.1111/j.1541-0072.2007.00247.x

Pretlove, B., and Blasiak, R. (2018). "Mapping ocean governance and regulations," in *Working paper for consultation for UN Global Compact Action Platform for Sustainable Ocean Business*, New York.

Privitera-Johnson, K. M., and Punt, A. E. (2020). A review of approaches to quantifying uncertainty in fisheries stock assessments. *Fish. Res.* 226:105503. doi: 10.1016/j.fishres.2020.105503

Rocha, J., Yletyinen, J., Biggs, R., Blenckner, T., and Peterson, G. (2015). Marine regime shifts: drivers and impacts on ecosystems services. *Philos. Trans. R. Soc. B Biol. Sci.* 370:20130273. doi: 10.1098/rstb.2013.0273

Roheim, C. A. (2009). An evaluation of sustainable seafood guides: implications for environmental groups and the seafood industry. *Mar. Resour. Econ.* 24, 301–310. doi: 10.1086/mre.24.3.42629657

Roheim, C. A., Bush, S. R., Asche, F., Sanchirico, J. N., and Uchida, H. (2018). Evolution and future of the sustainable seafood market. *Nat. Sustain.* 1, 392–398. doi: 10.1038/s41893-018-0115-z

Ruddick, G. (2017). *Blue Planet II is year's Most Watched British TV show*. London: The Guardian.

Safina, C. (1998). What'sa fish lover to eat? The Audubon guide to seafood. *Audubon* 100, 63–66.

Schar, D., Klein, E. Y., Laxminarayan, R., Gilbert, M., and Van Boeckel, T. P. (2020). Global trends in antimicrobial use in aquaculture. *Sci. Rep.* 10:21878. doi: 10.1038/s41598-020-78849-3

Schiller, L., and Bailey, M. (2021). Rapidly increasing eco-certification coverage transforming management of world's tuna fisheries. *Fish Fish.* 22, 592–604. doi: 10.1111/faf.12539

Schindler, D. E., Hilborn, R., Chasco, B., Boatright, C. P., Quinn, T. P., Rogers, L. A., et al. (2010). Population diversity and the portfolio effect in an exploited species. *Nature* 465, 609–612. doi: 10.1038/nature09060

Schneider, A. (2020). Bound to Fail? Exploring the systemic pathologies of CSR and their implications for CSR research. *Bus. Soc.* 59, 1303–1338. doi: 10.1177/0007650319856616

Sea Shepherd (2018). *Notorious Toothfish Poacher Arrested by Liberian Coast Guard with Sea Shepherd Assistance*. Available online at: https://www.seashepherdglobal.org/latest-news/toothfish-poacher-arrest/ (accessed February 22, 2021).

SeafoodSource (2019). *Seafood Certifications Guide*. Portland, ME: SeafoodSource.

Sen, S., and Raakjaer Nielsen, J. (1996). Fisheries co-management: a comparative analysis. *Mar. Policy* 20, 405–418. doi: 10.1016/0308-597X(96)00028-0

Siple, M. C., Essington, T. E., and Plagányi, ÉE. (2019). Forage fish fisheries management requires a tailored approach to balance trade-offs. *Fish Fish* 20, 110–124. doi: 10.1111/faf.12326

Soemarwato, O., Christanty, L., Henky, Herri, Y. H., Iskandar, J., Hadyana, et al. (1985). The talun-kebun: a man-made forest fitted to family needs. *Food Nutr. Bull.* 7, 1–4. doi: 10.1177/156482658500700314

Steffen, W., Persson, Å, Deutsch, L., Zalasiewicz, J., Williams, M., Richardson, K., et al. (2011). The anthropocene: from global change to planetary stewardship. *Ambio* 40, 739–761. doi: 10.1007/s13280-011-0185-x

Suaria, G., Achtypi, A., Perold, V., Lee, J. R., Pierucci, A., Bornman, T. G., et al. (2020). Microfibers in oceanic surface waters: a global characterization. *Sci. Adv.* 6:eaay8493. doi: 10.1126/sciadv.aay8493

Sugarman, C. (1999). *Saga of the Swordfish Campaign*. Washington, DC: The Washington Post.

Sugimoto, A. (2016). Fish as a 'bridge' connecting migrant fishers with the local community: findings from Okinawa. *Japan. Marit. Stud.* 15:5. doi: 10.1186/s40152-016-0046-0

Sutton, M., and Wimpee, L. (2009). "Towards sustainable seafood: the evolution of a conservation movement," in *SEAFOOD Ecolabelling*, eds T. Ward and B. Phillips (Hoboken, NJ: John Wiley & Sons, Ltd), 403–415. doi: 10.1002/9781444301380.ch20

Szuwalski, C. S., Britten, G. L., Licandeo, R., Amoroso, R. O., Hilborn, R., and Walters, C. (2019). Global forage fish recruitment dynamics: a comparison of methods, time-variation, and reverse causality. *Fish. Res.* 214, 56–64. doi: 10.1016/j.fishres.2019.01.007

Tacon, A. G. J. (2020). Trends in global aquaculture and aquafeed production: 2000–2017. *Rev. Fish. Sci. Aquac.* 28, 43–56. doi: 10.1080/23308249.2019.1649634

Teh, L. C. L., Caddell, R., Allison, E. H., Finkbeiner, E. M., Kittinger, J. N., Nakamura, K., et al. (2019). The role of human rights in implementing socially responsible seafood. *PLoS One* 14:e0210241. doi: 10.1371/journal.pone.0210241

Teh, L. C. L., and Sumaila, U. R. (2013). Contribution of marine fisheries to worldwide employment. *Fish Fish.* 14, 77–88. doi: 10.1111/j.1467-2979.2011.00450.x

Teh, L. C. L., Teh, L. S. L., Abe, K., Ishimura, G., and Roman, R. (2020). Small-scale fisheries in developed countries: looking beyond developing country narratives through Japan's perspective. *Mar. Policy* 122:104274. doi: 10.1016/j.marpol.2020.104274

Teisl, M. F., Roe, B., and Hicks, R. L. (2002). Can eco-labels tune a market? Evidence from Dolphin-Safe Labeling. *J. Environ. Econ. Manag.* 43, 339–359. doi: 10.1006/jeem.2000.1186

Thorlakson, T., de Zegher, J. F., and Lambin, E. F. (2018). Companies' contribution to sustainability through global supply chains. *Proc. Natl. Acad. Sci. U.S.A.* 115, 2072–2077. doi: 10.1073/pnas.1716695115

Tiller, R., De Santo, E., Mendenhall, E., and Nyman, E. (2019). The once and future treaty: towards a new regime for biodiversity in areas beyond national jurisdiction. *Mar. Policy* 99, 239–242. doi: 10.1016/j.marpol.2018.10.046

Troell, M., Henriksson, P. J. G., Jorgensen, P., Rico, A., Nyberg, T., Grells Fernandez, T., et al. (2019a). *Antibiotics in Aquaculture: The Phuket Dialogue, Background Brief 4*. Available online at: https://keystonedialogues.earth/wp-content/uploads/2019/12/Brief4-Antibiotics-in-Aquaculture.pdf (accessed February 22, 2021).

Troell, M., Jonell, M., and Crona, B. (2019b). *The Role of Seafood in Sustainable and Healthy Diets. The EAT-Lancet Commission report Through a Blue Lens*. Stockholm: The Beijer Institute.

Troell, M., Jonell, M., and Henriksson, P. J. G. (2017). Ocean space for seafood. *Nat. Ecol. Evol.* 1, 1224–1225. doi: 10.1038/s41559-017-0304-6

Troell, M., Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., et al. (2014). Does aquaculture add resilience to the global food system? *Proc. Natl. Acad. Sci. U.S.A.* 111, 13257–13263. doi: 10.1073/pnas.1404067111

UN (1989). *Resolution 44/225. Large-Scale Pelagic Driftnet Fishing and Its Impact on the Living Marine Resources of the World's Oceans and Seas*. New York, NY: UN.

UN Global Compact (2020a). *Ocean Stewardship 2030: Ten Ambitions and Recommendations for Growing Sustainable Ocean Business*. New York, NY: UN Global Compact.

UN Global Compact (2020b). *Sustainable Ocean Principles*. New York, NY: UN Global Compact.

UNESCO (2020). *New Agreement Between UN Bodies Aims to Advance Science-Based Sustainable Ocean Business into the Ocean Decade*. Paris: UNESCO.

Van Dyke, J. M. (1996). The rio principles and our responsibilities of ocean stewardship. *Ocean Coast. Manag.* 31, 1–23. doi: 10.1016/0964-5691(95)00071-2

Van Holt, T., Weisman, W., Käll, S., Crona, B., and Vergara, R. (2018). What does popular media have to tell us about the future of seafood? *Ann. N. Y. Acad. Sci.* 1421, 46–61. doi: 10.1111/nyas.13613

Vince, J., and Haward, M. (2017). Hybrid governance of aquaculture: opportunities and challenges. *J. Environ. Manage.* 201, 138–144. doi: 10.1016/j.jenvman.2017.06.039

Virdin, J., Vegh, T., Jouffray, J.-B., Blasiak, R., Mason, S., Österblom, H., et al. (2021). The Ocean 100: transnational corporations in the ocean economy. *Sci. Adv.* 7:eabc8041. doi: 10.1126/sciadv.abc8041

Watts, J. E. M., Schreier, H. J., Lanska, L., and Hale, M. S. (2017). The rising tide of antimicrobial resistance in aquaculture: sources, sinks and solutions. *Mar. Drugs* 15:158. doi: 10.3390/md15060158

Welchman, J. (2012). A defence of environmental stewardship. *Environ. Values* 21, 297–316. doi: 10.3197/096327112x13400390125975

Wernli, D., Jørgensen, P. S., Morel, C. M., Carroll, S., Harbarth, S., Levrat, N., et al. (2017). Mapping global policy discourse on antimicrobial resistance. *BMJ Glob. Health* 2:e000378. doi: 10.1136/bmjgh-2017-000378

West, S., Haider, L. J., Masterson, V., Enqvist, J. P., Svedin, U., and Tengö, M. (2018). Stewardship, care and relational values. *Curr. Opin. Environ. Sustain.* 35, 30–38. doi: 10.1016/j.cosust.2018.10.008

Wilhelm, M., Kadfak, A., Bhakoo, V., and Skattang, K. (2020). Private governance of human and labor rights in seafood supply chains – The case of the modern slavery crisis in Thailand. *Mar. Policy* 115:103833. doi: 10.1016/j.marpol.2020.103833

WMO (2019). *UN Decade of Ocean Science Gears up*. Available online at: https://public.wmo.int/en/media/news/un-decade-of-ocean-science-gears (accessed August 25, 2020).

World Benchmarking Alliance (2019). *Seafood Stewardship Index*. London: World Benchmarking Alliance.

World Health Organization (2015). *WHO | Vaccinating salmon: How Norway avoids antibiotics in fish Farming*. Geneva: WHO.

World Health Organization (2019). *Critically Important Antimicrobials for Human Medicine, 6th Revision*. Geneva: WHO.

Worm, B., Lotze, H. K., Jubinville, I., Wilcox, C., and Jambeck, J. (2017). Plastic as a persistent marine pollutant. *Annu. Rev. Environ. Resour.* 42, 1–26. doi: 10.1146/annurev-environ-102016-060700

Worm, B., and Paine, R. T. (2016). Humans as a hyperkeystone species. *Trends Ecol. Evol.* 31, 600–607. doi: 10.1016/j.tree.2016.05.008

Worrell, R., and Appleby, M. C. (2000). Stewardship of natural resources: definition, ethical and practical aspects. *J. Agric. Environ. Ethics* 12, 263–277. doi: 10.1023/A:1009534214698

Wu, C. (2006). *Sea Bass Returns, But There's a Catch*. Available online at: https://www.sfgate.com/news/article/Sea-bass-returns-but-there-s-a-catch-2465549.php (accessed February 22, 2021).

WWF (2020). *MSC Certification of Bluefin Tuna Fishery Before Stocks Have Recovered Sets Dangerous Precedent*. Available online at: https://wwf.panda.org/wwf_news/?364790/MSC-certification-of-bluefin-tuna-fishery-before-stocks-have-recovered-sets-dangerous-precedent (accessed February 22, 2021).

WWF (2021). *Ocean Stewardship: Moving From Words to Action in the Central Arctic Ocean*. Available online at: https://arcticwwf.org/newsroom/the-circle/sea-change-managing-the-arctic-ocean/ocean-stewardship-moving-from-words-to-action-in-the-central-arctic-ocean/ (accessed February 9, 2021).

Yletyinen, J., Bodin, Ö, Weigel, B., Nordström, M. C., Bonsdorff, E., and Blenckner, T. (2016). Regime shifts in marine communities: a complex systems perspective on food web dynamics. *Proc. R. Soc. B Biol. Sci.* 283:20152569. doi: 10.1098/rspb.2015.2569

Conflict of Interest: RB, AD, J-BJ, CF, HÖ, JB, FB, PH, SK, GC, LS, ES, MT, CW, and BC provide scientific support to companies in the seafood sector through the Seafood Business for Ocean Stewardship (SeaBOS) initiative (https://seabos.org/). The Stockholm Resilience Centre, Cermaq, and the University of Tokyo are members of the UN Global Compact Action Platform for Sustainable Ocean. Business. RB and DL are members of the expert review committee of the Seafood Stewardship Index. BG was employed by WWF (2000–2007), the ASC Foundation (2011–2017), and the World Benchmarking Alliance (2017–2019). DL is a member of the governing board of MarinTrust. HP leads the Seafood Stewardship Index at the World. Benchmarking Alliance. Thai Union, Cermaq, and Nutreco are members of the SeaBOS initiative. FB was employed by Greenpeace Nordic. (2007–2020). BG is employed by the company Cefetra Group BV. WG is employed by the company Cermaq Group AS. DM is employed by the company Thai Union. JV is employed by the company Nutreco.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.