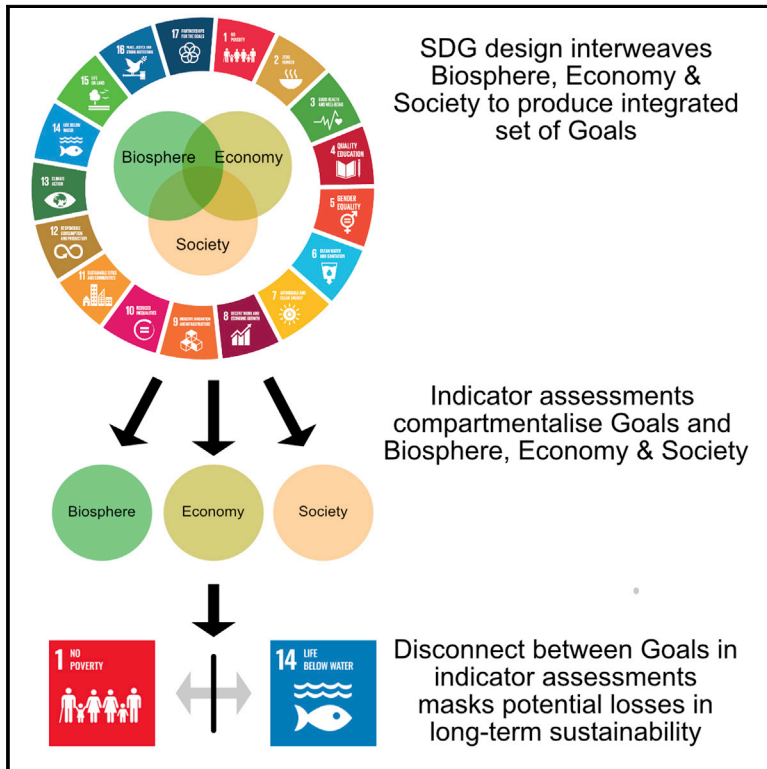


One Earth

To Achieve a Sustainable Blue Future, Progress Assessments Must Include Interdependencies between the Sustainable Development Goals

Graphical Abstract



Authors

Kirsty L. Nash, Jessica L. Blythe, Christopher Cvitanovic, ..., Gretta T. Pecl, Reg A. Watson, Julia L. Blanchard

Correspondence

nashkirsty@gmail.com

In Brief

Considerable effort is being put into tracking progress toward the Sustainable Development Goals via indicator assessments. The design of these assessments has the potential to undermine human well-being and the health of the environment by masking interdependencies among the goals. We present an extension to the current assessment protocol to help provide decision makers with the information they need to understand these interdependencies and their impact on actions implemented to achieve sustainability.

Highlights

- The Sustainable Development Goals link society, the economy, and the biosphere
- Indicator assessments of progress toward the SDGs do not account for these links
- Thus, progress assessments mask important trade-offs and synergies among the goals
- This oversight risks reducing society's capacity to achieve sustainability



To Achieve a Sustainable Blue Future, Progress Assessments Must Include Interdependencies between the Sustainable Development Goals

Kirsty L. Nash,^{1,2,9,10,*} Jessica L. Blythe,³ Christopher Cvitanovic,^{1,4,5} Elizabeth A. Fulton,^{1,4} Benjamin S. Halpern,^{6,7} E.J. Milner-Gulland,⁸ Prue F.E. Addison,⁸ Gretta T. Pecl,^{1,2} Reg A. Watson,^{1,2} and Julia L. Blanchard^{1,2}

¹Centre for Marine Socioecology, University of Tasmania, Private Bag 129, Hobart, TAS 7001, Australia

²Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, TAS 7001, Australia

³Environmental Sustainability Research Centre, Brock University, St. Catharines, ON L2S 3A1, Canada

⁴CSIRO, Oceans and Atmosphere, Castray Esplanade, Battery Point, TAS 7004, Australia

⁵Australian National Centre for the Public Awareness of Science, Australian National University, Canberra, ACT 0200, Australia

⁶National Centre for Ecological Analysis and Synthesis, University of California, Santa Barbara, 735 State Street, Santa Barbara, CA 93101-5504, USA

⁷Bren School of Environmental Science & Management, University of California, Santa Barbara, Santa Barbara, CA 93101, USA

⁸Interdisciplinary Centre for Conservation Science, Department of Zoology, University of Oxford, Oxford OX1 3PS, UK

⁹Twitter: @NasherK

¹⁰Lead Contact

*Correspondence: nashkirsty@gmail.com

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SCIENCE FOR SOCIETY The Sustainable Development Goals (SDGs) focus on providing society with a sustainable future. Progress toward the goals is being tracked by a series of indicators. These indicators show progress toward individual goals and targets but do not show how success or failure in relation to one goal might affect success or failure in another area. We show how interactions between the oceans and human poverty, hunger, and gender equity are hidden by indicator assessments and how this undermines the capacity of governments and organizations to maximize long-term moves toward sustainability. These findings are important for decision makers who work in the public and private sectors and wish to avoid unforeseen outcomes when implementing sustainability initiatives. Here, we suggest extensions to the current assessment framework to help counteract the identified issues, providing a research agenda for scientists working in all fields of sustainability science.

SUMMARY

The Sustainable Development Goals (SDGs) were designed to address interactions between the economy, society, and the biosphere. However, indicators used for assessing progress toward the goals do not account for these interactions. To understand the potential implications of this compartmentalized assessment framework, we explore progress evaluations toward SDG 14 (Life below Water) and intersecting social goals presented in submissions to the UN High-Level Political Forum. We show that there is a disconnect between the apparent progress shown by indicators and long-term sustainability; for example, short-term gains in reducing hunger or poverty might be undermined by poor ocean health, particularly in countries dependent on fisheries or developing their blue economy. We suggest an extension to existing indicator assessments to inte-

grate scenarios and social-ecological modeling. This approach would ensure that decision makers are provided with knowledge fundamental to directing actions to attain SDGs while minimizing unintended outcomes due to interactions among goals.

INTRODUCTION

The Sustainable Development Goals (SDGs), launched in 2015, articulate a negotiated international strategy to support environmental and human well-being.^{1,2} The SDGs recognize three interlinked pillars of sustainability: society, the economy, and the biosphere (the global ecological system). The SDGs are composed of 17 goals split into 169 targets. Primary targets (designated by numbers) communicate desirable outcomes, whereas secondary targets (designated by letters) express means of implementing the goals.¹ The three pillars of sustainability are incorporated into this structure in two forms. First, some goals place a greater emphasis on a particular pillar, for



example, the biosphere (e.g., SDG 14: Life below Water), society (e.g., SDG 1: No Poverty), or the economy (e.g., SDG 8: Decent Work and Economic Growth). Second, and perhaps more important considering the necessarily integrated nature of sustainability, the goals and targets were structured to interweave components of these three pillars.^{3–5} For example, target 1.4 clearly integrates economic, societal, and biosphere components: “by 2030, ensure that all men and women, particularly the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership, and control over land and other forms of property, inheritance, natural resources, appropriate new technology, and financial services including microfinance.”

Effective policy development, resourcing, and implementation at the local, national, and international levels are central to society’s capacity to meet the SDGs.⁶ Consequently, decision makers are now tasked with directing actions that progress toward attainment of the SDGs while minimizing adverse outcomes. To achieve the desired outcomes, decision makers must understand the feedbacks and interactions between society, the economy, and the biosphere, prompting research efforts to understand how synergies and trade-offs influence our ability to achieve the 2030 Agenda.^{3,7–9} The emergence of literature on interactions among the goals is a welcome step;^{3,8,10,11} however, these trade-offs and synergies are not a core component of the SDG evaluation protocol. Indicators have been developed for each target by the Inter-agency and Expert Group on SDG Indicators, a group made up of participants from UN member states. The feedback that decision makers receive on progress toward achieving the 2030 Agenda is based on assessments that use one, or occasionally a few, of these indicators to evaluate goal and target attainment.^{12,13} The current indicator approach does not provide an understanding of *why* targets are on track or unfulfilled^{14,15} or to which factors change can be attributed, lacks clear measures of performance relative to targets, and does not evaluate how interdependence of the three pillars of sustainability might affect goal and target attainment. This oversight risks implementation of palliative policy responses that act to address short-term gains in localized geographies or populations rather than support the long-term sustainability of human activities.

Here, we explore whether ignoring within- and among-target interactions risks prioritizing short-term attainment of the SDGs to the detriment of long-term, sustained achievement of these outcomes. We examine the role that the marine environment plays in supporting social and economic goals and targets. We focus on the marine environment for four reasons:

- (1) There are real challenges associated with understanding human impacts on the oceans and society’s capacity to meet SDG 14 (Life below Water). For example, monitoring ocean state and function is extremely difficult, as ongoing debates about fish-stock status have shown, even for places with high monitoring and analytical capacity.^{16,17} Furthermore, the large-scale and numerous effects of climate change on ocean ecosystems present a moving target for those tasked with addressing SDG 14.¹⁸
- (2) A low level of prioritization is being placed on SDG 14. This goal is consistently considered the least-important SDG

by government leaders responsible for developing actions to support the 2030 Agenda.^{19,20} These perspectives are mirrored by sustainability professionals, non-governmental organizations, development and donor organizations, and the private sector, resulting in a lack of urgency related to improving ocean health.^{19,21,22} Furthermore, the oceans have received limited focus in conceptual frameworks that informed the development of the SDGs, such as planetary boundaries.²³ This low level of prioritization is understandable in some instances. For example, landlocked countries, which have insufficient capital (monetary or human) to meet all the SDGs, might view SDG 14 as peripheral to their planning for the 2030 Agenda despite the indirect benefits that the oceans afford to these countries.

- (3) There is wide-scale enthusiasm for the expanding role and projected growth of the blue economy, which is doubling in size per decade and is already equivalent to the seventh-largest economy on the planet.^{24,25} If society is to realize the anticipated expansion of benefits gained from the oceans across multiple sectors, a healthy ocean is necessary and will have implications for the fulfilment of the SDGs more generally.
- (4) Research that makes trade-offs and interactions among the SDGs explicit can open up space for dialogues and exploration of scenarios where the interests of multiple groups are acknowledged and shared. Interpretation of the blue-economy concept is contested and varies from a focus on business development (including resource extraction) to the ocean as a provider of natural capital and livelihoods.^{26,27} These contrasting perspectives exemplify the various framings of sustainability issues that must be acknowledged in any discussion of synergies and trade-offs in the SDGs, providing fertile ground for such research.

In delivering our analysis on the interdependencies between the SDGs with respect to the ocean, we first evaluate the likelihood that sustainability targets for the oceans will be achieved by the specified dates or 2030. We then examine the intersections among social goals and SDG 14 through the lens of the indicators used for assessing progress toward goal attainment. To illustrate the breadth of interdependencies, risks, and opportunities, we draw on three examples—SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 5 (Gender Equity)—and their respective links to the oceans.

RESULTS AND DISCUSSION

Likely Attainment of SDG 14 (Life below Water) and Its Constituent Targets

We evaluated progress toward the targets in SDG 14 by using stakeholder submissions and indicator assessments provided to the annual High-Level Political Forum (HLPF) and thematic reviews arising from the HLPF.^{12,13,28,29} The evidence provided in these submissions (Table S1) suggests that only 2% of countries are likely to achieve SDG 14 by 2030 (Table 1).¹³ As a result of the inherent problems associated with forecasting future trends in the context of interacting social, biophysical, and

Table 1. Global Status of Targets within SDG 14 (Life below Water)

Goal or Target		Likelihood of Meeting Goal or Target	Evidence Used for Assessing the Likelihood of Achieving Goal or Target
14	life underwater: conserve and sustainably use the oceans, seas, and marine resources for sustainable development	will not be met	SDSN: only 2% of countries are currently on track to meeting SDG 14 by 2030
14.1	by 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution	uncertain	CBD: “lagging behind” Aichi 2020 timeline TR: potential to meet 2025 timeline is uncertain, but the current state of coastal waters is deteriorating
14.2	by 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	will not be met	CBD: “lagging behind” Aichi 2020 timeline TR: status unclear
14.3	minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	will not be met	CBD: “lagging behind” 2020 timeline TR: significant efforts needed to achieve this target by 2030 are currently lacking
14.4	by 2020, effectively (1) regulate harvesting, (2) end overfishing; illegal, unreported, and unregulated fishing; and destructive fishing practices, (3) and implement science-based management plans in order to restore fish stocks in the shortest time feasible, at least to levels that can produce a maximum sustainable yield as determined by their biological characteristics	will not be met	CBD: “lagging behind” 2020 timeline TR: wild fishery production is relatively stable (2006–2015), but over 30% of marine fish stocks are overfished, and this percentage has been rising since the 1970s
14.5	by 2020, conserve at least 10% of coastal and marine areas, consistent with national and international law and based on the best available scientific information	uncertain	TR: coastal waters are on track (13.2% up to 200 nm), but very little of the open ocean is protected (0.25% of area outside national jurisdictions)
14.6	by 2020, prohibit certain forms of fishery subsidies that contribute to overcapacity and overfishing; eliminate subsidies that contribute to illegal, unreported, and unregulated fishing; and refrain from introducing new such subsidies by recognizing that appropriate and effective special and differential treatment for developing and least-developed countries should be an integral part of the World Trade Organization’s fishery-subsidy negotiation	uncertain	CBD: “lagging behind” 2020 timeline WTO: the 2017 WTO Ministerial Decision on Fisheries Subsidies was an agreement among members to agree on a fishery subsidy by the end of 2019; negotiations to reach this are ongoing at this time
14.7	by 2030, increase the economic benefits to Small Island Developing States and least-developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture, and tourism	uncertain	CBD: “lagging behind” 2020 timeline TR: potential to meet 2030 timeline is uncertain

Status is based on evidence provided in submissions to the High-Level Political Forum (HLPF): SDSN, 2018 submission by the Sustainable Development Solutions Network; CBD, 2018 submission by the Convention on Biological Diversity; TR, 2017 HLPF thematic review;^{13,28,29} WTO, 2019 report from the World Trade Organization.³⁰

economic dynamics, there are uncertainties around these predictions. Nevertheless, these findings are supported by independent, private-sector research indicating that no country with sufficient data to make an assessment is currently on track to attain SDG 14 by 2030.³¹ Similarly, the trajectories and status of the individual targets under SDG 14 are of considerable concern: five of the seven targets will not be met, and the remaining two are unlikely to be met by 2030 or in the prescribed time periods (Table 1).

However, bright spots with respect to SDG 14 include the focus on ocean conservation in Palau and the efforts made to remove fishery subsidies that contribute to overcapacity and overfishing within the World Trade Organization (target 14.6). Nonetheless, the predominantly discouraging trajectories (Table 1) are likely to be compounded by the large-scale and increasing impacts of climate change on ocean ecosystems.¹⁸ As a result, substantial effort will be required not only to counteract ecosystem decline in the marine environment but also to improve ocean health to the level required to meet SDG 14.^{23,32,33} The challenges associated with improving marine health and the low prioritization and funding that decision makers in the public and private sectors are giving to SDG 14 suggest that this effort might not be made.^{19–22}

Tracking Synergies and Trade-offs between Ocean Health, Society, and the Economy

Poor environmental health, such as discussed above in relation to the oceans and SDG 14, has broad-scale implications. The biosphere is central to many of the social and economic goals and the targets within them: 34 of the 91 social and economic primary targets are identified by the UN as being directly reliant on the biosphere.³⁴ Thus, ecosystem degradation has the potential to trigger a decline in society's capacity to meet other targets that are reliant on the health of the biosphere;³⁵ for example, pollution might affect water security and health despite initiatives focused on improving access to water sources.

These interactions between the biosphere, society, and the economy are increasingly recognized. For example, an evaluation by Singh et al.,⁸ who assessed links between SDG 14 and the remaining SDGs, found that SDG 14 targets are connected to the attainment of all other goals. 35% of the links between SDG 14 targets and other targets are synergistic, whereas fewer than 1% represent trade-offs. Moreover, in 37% of these synergies, SDG 14 targets act as necessary pre-conditions for particular social or economic targets under other goals.⁸ For example, target 14.4 ("by 2020, effectively regulate harvesting and end overfishing, illegal, unreported, and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics") is a prerequisite for achieving SDG 2.4 ("by 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality").⁸ It should be noted that some of these synergies and pre-conditions are context

dependent;⁸ nevertheless, ocean health is fundamental to many social and economic goals.³⁶

Despite this recognition of the interactions between the biosphere, society, and the economy in the SDGs, the feedback that decision makers receive on progress toward achieving the 2030 Agenda is based on assessments that use one indicator, or occasionally a few, to evaluate the attainment of individual goals and targets.^{12,13} These indicators do not provide an understanding of *why* targets are on track or unfulfilled.^{14,15} Achieving the target (or not) is a long way down the causal chain from the actions or interventions that have been put in place to support attainment, and the indicators do not evaluate how interdependence of the three pillars of sustainability might affect goal and target attainment in the short or long term. As a result, within the existing indicator framework, attainment of many social and economic goals and their constituent targets requires that decision makers have a sound understanding of the relationships both within and among targets so they can direct action that ensures that successful outcomes in relation to specific targets are not constrained by poor outcomes for other targets. Where understanding of causal pathways is lacking, the result could be palliative policies that lead to short-term target attainment but risk the loss of these gains over time. Indeed, such policies are analogous to medical interventions that treat symptoms rather than the root cause. This could result in trade-offs and costs associated with other SDGs and underpins considerable potential to overlook important demographic or geographic differences in outcomes. Furthermore, there is the danger that outcomes might be ephemeral in nature and lead to the pursuit of transitory effects rather than fundamental change. To illustrate the potential risks and missed opportunities associated with a lack of understanding regarding the causal links among and within the SDGs in the context of the indicator assessments, we provide examples of the intersection between SDG 14 and three social goals.

Example 1

SDG 1 aims to "end poverty in all its forms everywhere." Poverty has multiple dimensions ranging from disempowerment to insufficient income and institutional maltreatment.³⁷ Thus, eradicating poverty will require a multi-faceted approach driven by a range of different actors. One such facet relates to government-funded initiatives; a healthy economy is central to governments' capacity to fund poverty-eradication programs or provide basic services and will influence success in meeting SDG targets that focus on government-level interventions (e.g., 1.2, 1.A, and 1.B). A healthy economy is reliant in part on industries that are strong and, perhaps more critically, exhibit sustainable practices, e.g., industries that are based on fair work practices and do not exacerbate economic inequality.

In nations where marine industries such as tourism represent a large share of gross domestic product (GDP), a healthy economy will be reliant on the oceans.^{35,38} A 2018 indicator assessment of current trajectories toward SDG 1 by the UN Sustainable Development Solutions Network (SDSN) showed that 109 out of 193 countries are on track to meet SDG 1 and its component targets by 2030.¹³ To understand whether this assessment overestimates the long-term capacity of countries to end poverty, we compared the economic reliance of 15 small island nations on a healthy marine environment (percentage of GDP contributed by

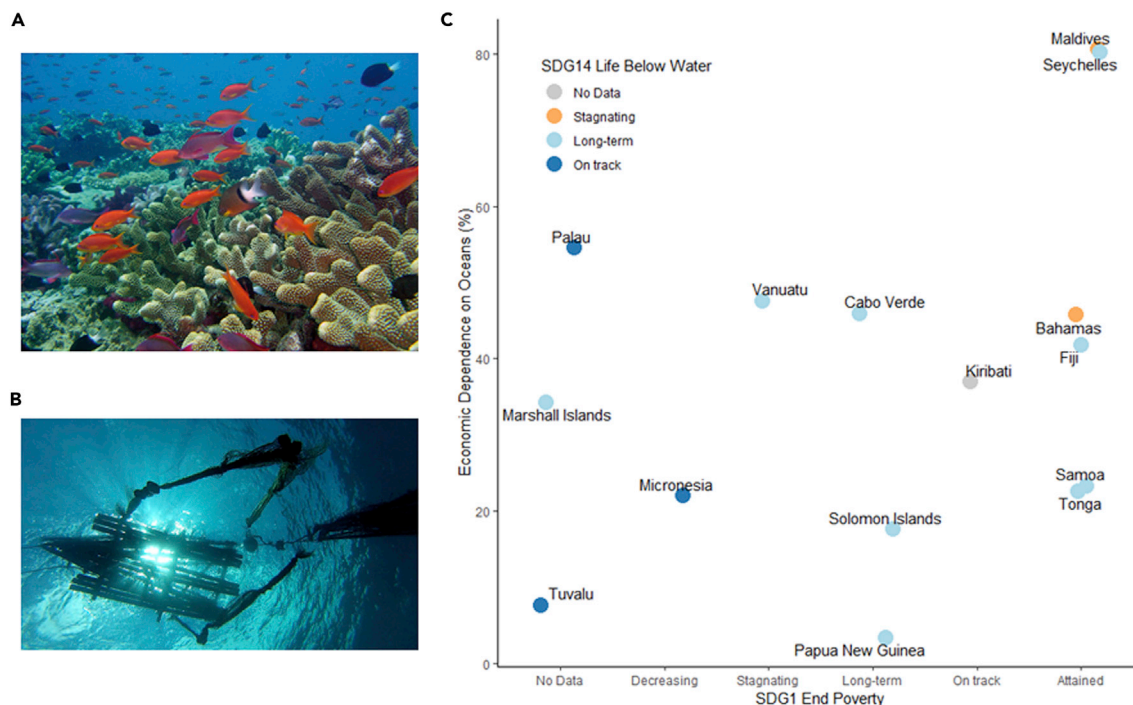


Figure 1. Exploration of Potential Consequences of Overlooking SDG 14 (Life below Water) for Meeting SDG 1 (End Poverty)

(A) Coral reef in Fiji (photo: WorldFish CC BY-NC-ND 2.0). Marine-based tourism such as diving is an important source of economic revenue in many island nations.

(B) Fish-aggregating device in the Solomon Islands (photo: WorldFish CC BY-NC-ND 2.0). Fisheries are an important source of economic revenue in many island nations.

(C) Relationship between the trajectory of progress toward SDG 1 (End Poverty) (achievement by 2030; x axis), economic dependence on the oceans (y axis), and the trajectory of progress toward SDG 14 (shading of points) for a series of small island nations. Sensitivity to low marine ecosystem health and services is represented by the economic dependence on the oceans, which we estimated as the percentage of GDP from tourism and fisheries (Table S2). We chose example countries where data were available and marine-based tourism predominates. Classification of progress toward goals was sourced from the 2018 SDSN indicator dashboard, which reports on progress toward all SDGs:¹³ decreasing, trajectory is negative such that the country is moving further away from goal attainment over time; stagnating, trajectory is horizontal or shallowly positive such that the country will not attain the goal by 2030; long term, trajectory is positive but the country is unlikely to attain the goal by 2030; on track, trajectory is positive and the country is likely to attain the goal by 2030; attained, the country has already achieved the goal.

fisheries and tourism; Table S2) with progress toward SDGs 1 and 14 (Figure 1; Table S1).

According to indicator assessments by the SDSN,¹³ a number of these island nations are on track to meet SDG 1 or have already attained it (Figure 1C). However, for countries with a high economic dependence on healthy oceans, indicator assessments showing significant progress toward attainment of SDG 1 might be misleading in the long term. This ambiguity arises because, although nations might have marine ecosystems characterized by a level of degradation that does not currently affect industry, in light of the tight coupling between fisheries, tourism, and the ecosystem state³⁹ and ongoing climate impacts exacerbating marine degradation,¹⁸ it is unlikely that nations will be able to trade off these industries against ocean health in the long term.⁴⁰

The Maldives and Bahamas provide examples of nations that are highly dependent on fisheries and tourism (80% and 46% of the GDP, respectively). As a result, although the indicator assessment by the SDSN shows that these countries have already attained SDG 1, the current poor state of their marine ecosystem and the unlikely attainment of SDG 14 by 2030¹³ raise

serious concerns regarding the capacity of either country to maintain a classification of “no poverty” in the long term. Two solutions present themselves: either the countries shift rapidly away from their ocean dependence (difficult given the nations’ geographies and the central importance of ocean-based livelihoods^{27,41}), or they invest in ocean health. Concerns might also be raised for countries that have a significant dependence on marine systems, such as Kiribati (37% of the GDP), but where there are currently insufficient data to inform progress toward meeting SDG 14. Consequently, although the risk that environmental degradation might counteract progress toward SDG 1 is potentially significant, these risks are not highlighted by this indicator-based approach.

Our analysis (Figure 1) also highlights potential opportunities for improving progress toward ending poverty. For example, countries such as the Federated States of Micronesia are moving away from meeting SDG 1 but are on track to meet SDG 14 and currently have low economic dependence on fishing and tourism, suggesting the potential to leverage their environmental stewardship to attract tourist dollars that governments could potentially use to address local poverty. Such opportunities are

not clear when the indicators used for assessing progress toward individual goals and targets are viewed in isolation, as is the case in the current formal progress-assessment framework.

It should be noted that drivers of poverty vary in time and space, influencing the experience of poverty, such that the real-world impact of any economic benefits derived from a healthy ocean will be specific to context and demographic groups. As a result, increases in government spending on reducing poverty might address targets such as 1.A (which aims to “ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions”) but will not necessarily move nations toward all of the targets within SDG 1.

Example 2

SDG 2 aims to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture.” Hunger is more than simply ensuring a minimum caloric intake. Food security relates to the availability, access, use, and sustainability of nutritious food. For example, SDG 2.2 aims to, “by 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons.” Fish are high in bioavailable micronutrients and are thus essential to addressing the nutrient deficiencies that cause stunting and wasting and undermine the health of pregnant and lactating women and their children.^{42,43} Therefore, in nations where fisheries currently represent a large proportion of the diet, reducing food insecurity will be reliant on maintaining fish stocks and the aquatic systems they inhabit.^{35,38}

A 2018 indicator assessment of current trajectories toward SDG 2 by the SDSN showed that only 6 out of 193 countries are on track to meet SDG 2 and its component targets by 2030, but a further 124 countries are likely to meet SDG 2 over the longer term.¹³ To understand whether this assessment overestimates the long-term capacity of countries to achieve zero hunger, we quantified the reliance on fish for food at the national level (with data sourced from Blanchard et al.⁴⁴) and compared this with the likely attainment of SDG 14 (with data sourced from Sachs et al.;¹³ Table S1). We used the proportion of animal protein from fisheries to represent the contribution of fish to reducing hunger. It should be noted that this provides an estimate only of the potential nutrition derived from fish as a result of variability in nutritional value among species.⁴⁵

Few countries have attained or are on track to attain SDG 2 by 2030 according to the SDSN assessment.¹³ However, for those nations that are on track, more than 20% of their animal protein comes from fisheries, and their marine ecosystems are currently in a poor state in that progress toward SDG 14 has stagnated (Figure 2).¹³ In Japan, for example, fish represent 39% of animal protein consumed. Thus, although the indicator assessment for SDG 2 suggests that Japan has already attained zero hunger, the poor state of progress toward SDG 14 brings into question Japan’s capacity to maintain zero hunger in the

long term unless there is a concerted move away from fish as a source of food or targeted investment and actions supporting the health of marine ecosystems. Although some might point to trade as a solution in such cases, this just pushes the problem somewhere else, potentially risking SDG attainment in that location and undermining inter-regional sustainability.^{46,47} 67% of countries are likely to meet SDG 2 in the longer term. However, for countries with a high dependence on fisheries for food security and little progress toward meeting SDG 14—such as the Maldives, Sierra Leone, and Cambodia—even an indicator-based assessment stating long-term attainment of SDG 2 could be misleading. Indicator-based progress shown toward the attainment of SDG2 could, in fact, hide the potentially devastating consequences of poor ocean health on human hunger.

Example 3

SDG 5 aims to “achieve gender equality and empower all women and girls.” The previous two examples explore the risk of missing causal links among and within SDGs at a national level when progress is based on the current indicator framework. However, this problem is further compounded when there is a need to understand the distribution of winners and losers in relation to sustainable development initiatives at the sub-national scale. A key instance is the designation of marine protected areas (MPAs) as per target 14.5, which aims to, “by 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.” Marine parks, particularly long-established MPAs, can have positive impacts on the food security of local communities.⁴⁸ However, such positive outcomes are far from universal, and designation of no-take areas can marginalize certain demographics.^{48,49} For example, in some areas women contribute significantly to household nutrition through regular gleaning activities, often for sessile invertebrate species in estuaries and inter-tidal areas^{50–52} (Figures 3A and 3B). Yet, MPA design and management often excludes women (among others) from the decision-making process and overlooks these important subsistence fisheries.^{53,54} This oversight can have serious implications for a country’s capacity to achieve targets within SDG 5 (Gender Equality), particularly 5.A, which aims to “undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws.” Furthermore, there are potential knock-on effects for the nutrition of women and children, who might be particularly vulnerable to the loss of seafood-derived micronutrients⁵¹ (SDG 2).

The interactions between SDG 14.5 and SDG 5.A can be illustrated in Palau. The nation’s GDP growth is supported by fisheries and tourism, both of which rely on the marine environment. As a result, the government has been very proactive in conserving their marine ecosystems. Today, over 40% of coastal habitats in Palau are under protection or management, attracting increasing numbers of high-end tourists. And in 2020, a no-take national marine sanctuary that covers 80% of the exclusive economic zone will come into effect. The remaining 20% will be open to a domestic, pelagic fishery in the hope that this will support food security in this fish-reliant nation and will help reduce pressure on near-shore waters.³⁹ As a result, Palau is on track to

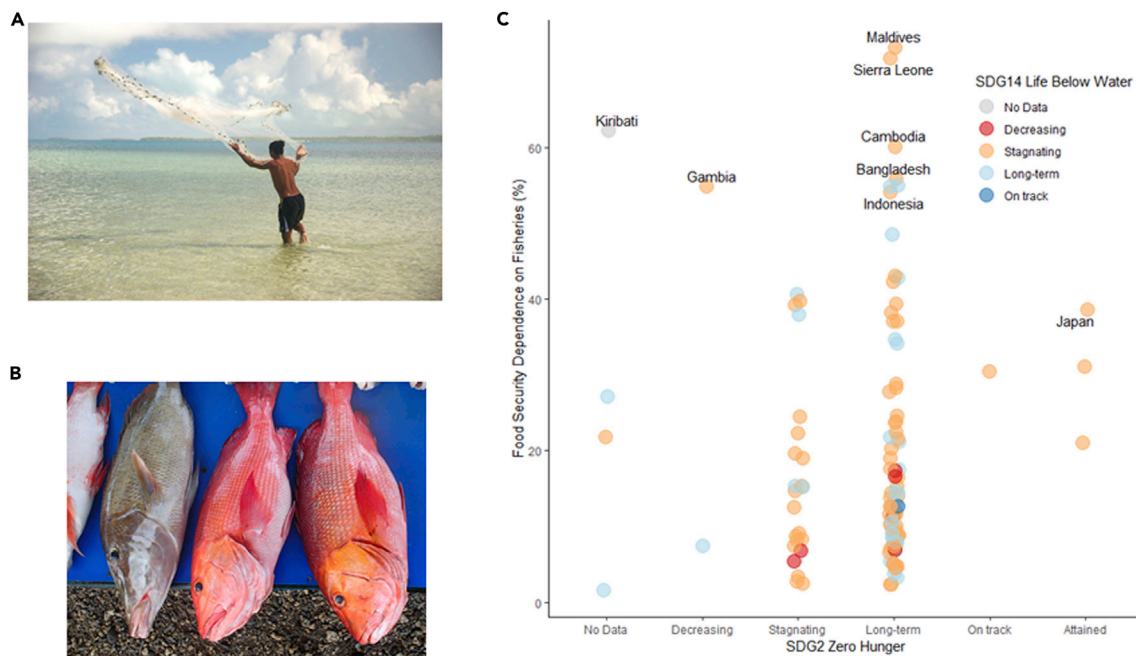


Figure 2. Exploration of Potential Consequences of Overlooking SDG 14 (Life below Water) for Meeting SDG 2 (Zero Hunger)

(A) Fisherman in Kiribati (photo: WorldFish CC BY-NC-ND 2.0).

(B) Fish for sale in the Solomon Islands (photo: WorldFish CC BY-NC-ND 2.0). Fisheries are an important source of food in many countries.

(C) Relationship between the trajectory of progress toward SDG 2 (Zero Hunger) (achievement by 2030; x axis), food-security dependence on the oceans (y axis), and the trajectory of progress toward SDG 14 (shading of points). Each point represents a country; only select countries are named. Sensitivity to low marine ecosystem health and services is represented by the dependence of food security on the oceans according to estimates of the percentage of animal protein in human diets sourced from fish. These data were sourced from Blanchard et al.⁴⁴ Categories of progress toward goals were sourced from the 2018 SDSN indicator dashboard, which reports on progress toward all SDGs:¹³ decreasing, trajectory is negative such that the country is moving further away from goal attainment over time; stagnating, trajectory is horizontal or shallowly positive such that the country will not attain the goal by 2030; long term, trajectory is positive but the country is unlikely to attain the goal by 2030; on track, trajectory is positive and the country is likely to attain the goal by 2030; attained, the country has already achieved the goal.

meet SDG 14.5.⁵⁵ These efforts are laudable and will assist in the conservation of fish stocks and the marine environment on which the Palauan economy relies. However, they account for neither the reduced access that these initiatives will cause for women participating in reef gleaning rather than pelagic fishing^{52,56} nor the reliance on coastal fisheries for household nutrition.⁵⁷ Furthermore, in some areas fishing permits for local citizens are being considered to reduce fishing pressure from external sources, but these schemes do not allow permits to be held by spouses born in other regions.⁵⁸ Currently, there is insufficient information available to establish progress toward SDG 5 as a whole or 5.A specifically in Palau according to indicator assessments.^{13,55} But, even with sufficient data, the indicators that have been defined for SDG 5.A (Figure 3C) focus on land use and make no mention of fisheries or seafood and as such will not be informative in relation to potential trade-offs between achieving target 14.5 and gender equality.

Our three examples suggest that interdependencies between the oceans and human well-being are being underemphasized in indicator-based progress assessments as countries try to meet the SDGs by 2030, meaning that appropriate actions might not be being operationalized. This oversight potentially has more pernicious implications. For example, after significant effort is put into achieving specific targets, a reversal could sour the

appetite for further action (“how will we know that this time it is enough?”) or even the overall concept (“it is all too complicated and overwhelming”). This is particularly the case if potential changes in dependencies and their associated feedbacks are not well understood.

Using Suites of Indicators to Understand Cause-and-Effect Relationships

With the growth of the blue economy, marine nations will be presented with multiple future pathways. To make informed decisions about which future is more “desirable,” it is important that decision makers explore the connections between society, the economy, and the biosphere and how these are (or are not) reflected in evaluations of progress toward the SDGs. Specifically, decision makers working to achieve the SDGs must understand (1) how indicator-based progress assessments reflect the full suite of outcomes from their actions (Examples 1, 2, and 3), (2) that some near-term actions might actually preclude future actions and block attainment of the desired goals in the long term (Examples 1 and 2), and (3) how the resultant benefits and deficits are distributed among different societal and demographic groups (Example 3). This understanding will help support the attainment of desired outcomes while

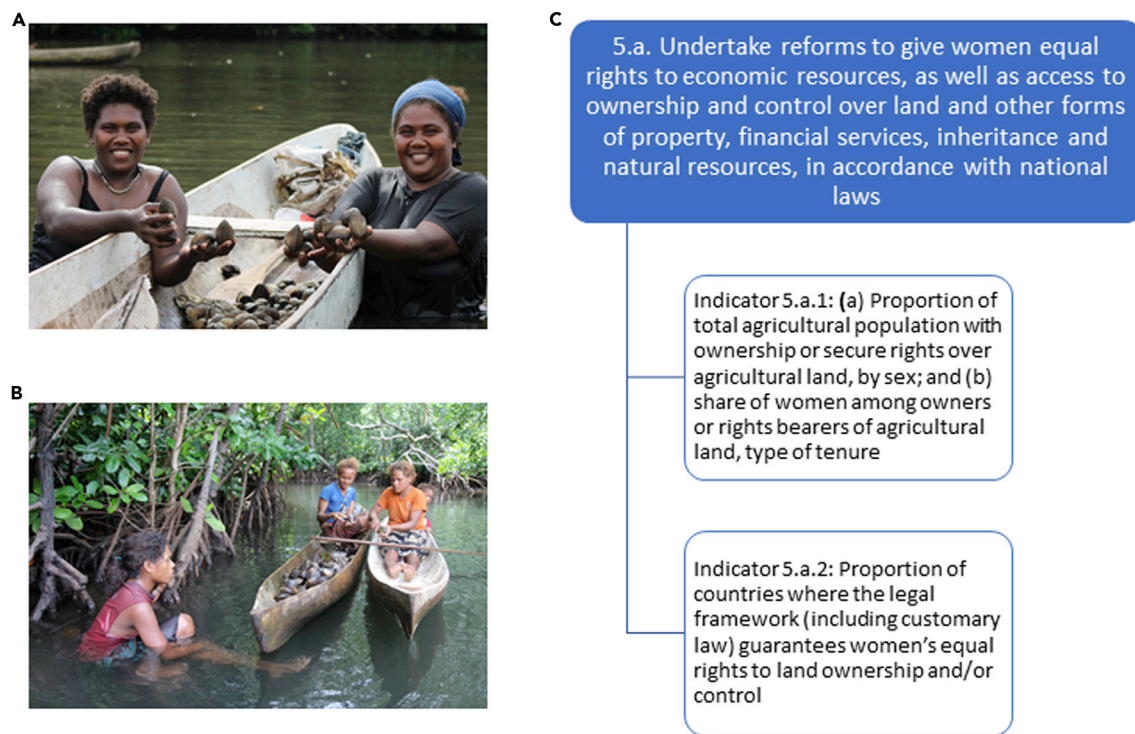


Figure 3. Interaction between SDG 14 (Life below Water) and SDG 5 (Gender Equality)

(A) Women fishing for arc clams in the Solomon Islands (photo: WorldFish CC BY-NC-ND 2.0).

(B) Women removing shells from mangroves in the Solomon Islands (photo: WorldFish CC BY-NC-ND 2.0).

(C) Target 5.A and the two indicators used for assessing progress toward target 5.A. Neither of these indicators mentions fisheries; instead, they focus on land-use and agriculture.

minimizing unintended consequences and costs to other objectives or social groups.

The current indicator frameworks do not provide a clear roadmap for decision makers and stakeholders tasked with maximizing human well-being. Few indicators have been tested for understanding their relative strengths and weaknesses in the context of achieving sustainability across the suite of SDGs. For example, it might be possible to designate 10% of the oceans as no-take MPAs, but if the protected areas are all high-seas locations away from threatening or extractive activities (termed “residual reserves”),⁵⁹ this would clearly not be delivering on the goal’s actual intent to reduce human pressures, conserve important ecosystems, and support livelihoods and food security. This would require a suite of management actions that focus on habitats within coastal and shelf ecosystems, as well as climate change more broadly.⁶⁰ Furthermore, by definition, indicators provide a snapshot of the situation. Decades of research highlight that single indices cannot easily or universally capture the many aspects of ecosystem structure or function that must be included if we are to accurately track the state of the biosphere.^{61,62} The same is true of other complex systems, including human societies—indicators aggregated to the national level do not reflect the distribution of gains and losses within countries or among demographic groups or the contexts in which gains or losses are made.

Consequently, decision makers are faced with a “black box,” whereby policies are put in place to influence the trajectory to-

ward a target but there is no explicit tracking of the connections between policy and outcome, making it difficult to identify why trajectories do not change or why they change in an unanticipated manner. Indicator versus expert assessment of progress toward SDG 1 (End Poverty) provides an example of this issue. As discussed above, a recent SDSN assessment of SDG 1 using a current indicator framework showed that 56% of countries are on track to meet SDG 1 and its component targets by 2030 (see [Experimental Procedures](#) and Sachs et al.¹³ for more information on this indicator assessment). In contrast, an elicitation of sustainability experts found that only 6% of participants thought headway toward ending poverty had been good or excellent to date, and 60% thought progress had been poor.²¹ Expert understanding of all the interacting factors that have an impact on reducing poverty at various scales, including the influence of biosphere health, might explain these inconsistent results. If society wants to achieve long-term sustainability and avoid unintended outcomes,⁶³ decision makers need to understand *why* targets are on track or unfulfilled and have a measure of performance regarding different actions.^{14,15} Thus, there is a need to build on the existing indicators to provide greater transparency regarding the interactions between society, the economy, and the biosphere.

Identifying cause-and-effect relationships ranging from policy drivers to human well-being will be extremely challenging because of the complex nature of social-ecological systems, cross-scale and non-linear relationships, and the historical

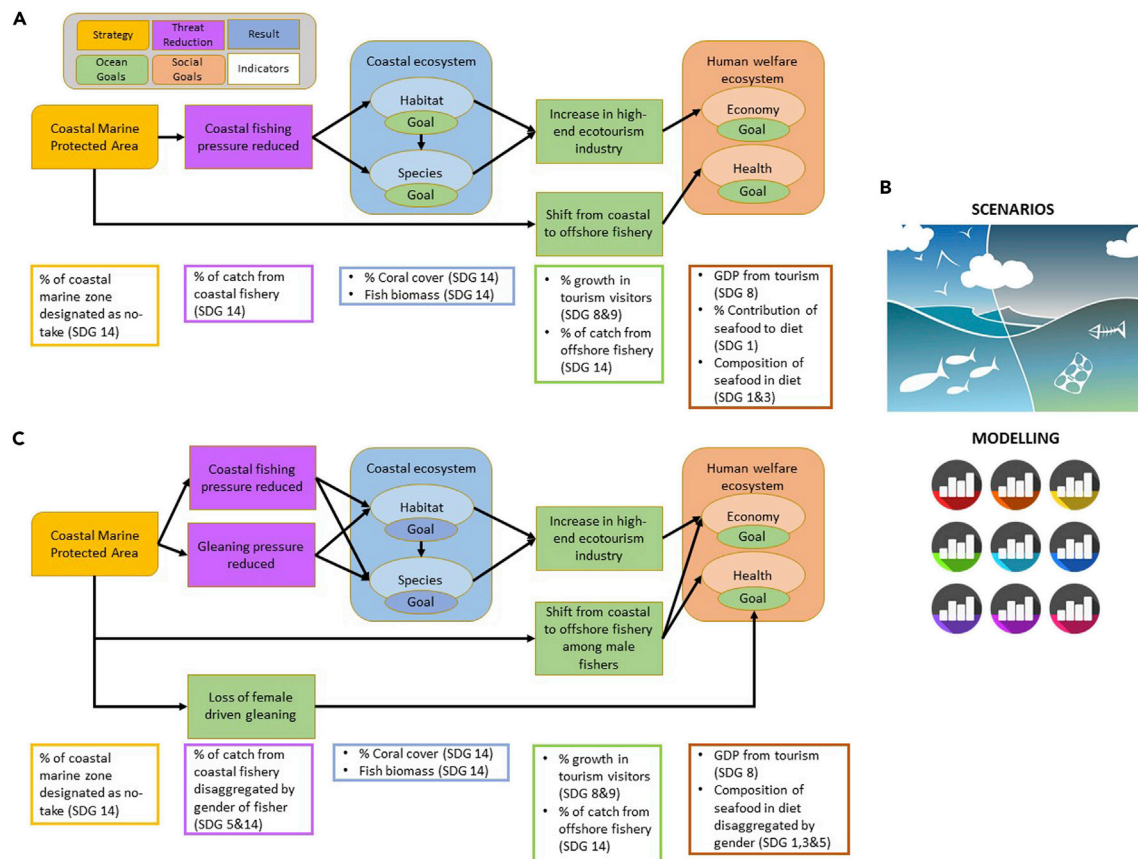


Figure 4. Result Chains Used for Visualizing Relationships between the Biosphere, Society, and the Economy

(A) Iteration 1 of a result chain in relation to existing efforts to protect the marine environment in Palau draws on expert knowledge, research, and monitoring information to populate the result chain.

(B) Addition of new information from research such as social-ecological modeling and narrative scenarios.

(C) Iteration 2 of a result chain in relation to Palau's efforts to protect the marine environment and its differential impacts on male and female fishers. Boxes showing potential indicators also detail the relevant SDGs that the indicators would be informing, highlighting the interdependencies among goals. See [Example 3](#) in the text for more detail.

context (path dependency).^{64–68} Nonetheless, such evidence is critical if society wants to maintain sustainability and human well-being beyond 2030. A research agenda focused on providing fundamental knowledge of these relationships is an extremely challenging but pressing need. A first step will be to explore relationships between society, the economy, and the biosphere. This will require an iterative process where theories of change are tested and updated. Social-ecological models exploring the behavior of complex systems and narrative-based scenario development are two powerful tools that can help support this testing process by allowing the integration of multiple knowledge systems (e.g., scientific, cultural, local, and experiential knowledge) and the exploration of different futures and how we might achieve these futures.^{14,69–73}

Results chains, *sensu* Salafsky and Margoluis,⁷⁴ provide a transparent approach for tracking these hypothesized relationships and iterations in our understanding (Figures 4A and 4B) and visually representing theories of change and the relationships between specific actions, the intermediate effects of these actions, and the ultimate desired outcomes.⁷⁵ Results chains can then be used for identifying suites of new or existing indica-

tors that can explicitly demonstrate the effect of actions (economic or political) on outcomes (as shown by potential indicators in Figure 4). Furthermore, the results-chain logic can be used for structuring the analysis and reporting of SDG indicators through the linking of indicators collected in assessment databases, permitting the formal exploration of SDG interactions, synergies, and trade-offs. Thus, we recommend that results chains be used at the national or sub-national scale so that countries can understand their interdependencies, as well as feedbacks within and between their indicators for the SDGs. Efforts to integrate result chains into existing SDG assessments would be facilitated by existing recognition in the international policy arena where this approach is already well understood. For example, it is a method employed by the World Bank and is the basis for how the World Health Organization assesses program performance.

Conclusions

The SDGs aim to balance ideals with practicalities and as such are defined through a set of tangible targets and indicators of progress. Such tangibility is essential for communication and reducing the onerous nature of expansive monitoring programs

but is at odds with the complex interacting sustainable development challenges we are facing. Specifically, the indicators mask interdependences among and within targets. Thus, understanding the contribution of each pillar of sustainability (society, the economy, and the biosphere) to the other pillars is likely to be difficult if not impossible. Where social or economic targets are underpinned by a healthy biosphere, apparently positive progress toward meeting these social and economic targets, as shown by simplistic indicators, could mask underlying declines in long-term sustainability for biosphere-dependent communities, compromising society's capacity to meet these targets in the long term. If the SDGs are to effectively support policy action that will lead to improved human well-being in the long term, it is critical that those tasked with achieving goals and their constituent targets be supported by assessments based on linked suites of indicators that answer both the how and the why of success or failure, as well as uncover the potential for short-term gains at the expense of long-term sustainability. Making these changes will be challenging, but the upcoming UN Decade of Ocean Science for Sustainable Development (2021–2030) provides a potential leverage point for focusing international energy and effort on building interactions between the oceans and society into SDG-focused initiatives and assessments.

EXPERIMENTAL PROCEDURES

Status of SDG 14 (Life below Water) and Its Constituent Targets

To understand the likelihood that sustainability targets for the oceans will be achieved by the specified dates or 2030, we assessed global progress toward SDG 14 and its constituent targets by using submissions to and summary reports from the 2017 and 2018 UN HLPF (Table 1). The HLPF, which meets annually, occurs under the auspices of the UN Economic and Social Council. Its responsibilities include giving “guidance and recommendations for sustainable development, [following] up and [reviewing] progress in the implementation of sustainable development commitments, [and enhancing] the integration of the three dimensions of sustainable development in a holistic and cross-sectoral manner at all levels” (p. 3).⁷⁶ Voluntary submissions to the HLPF from individual countries, intergovernmental bodies, and other stakeholders are used for developing a picture of progress toward the SDGs and developing thematic reviews of the status of each SDG.^{77,78}

We used the 2018 submission by the SDSN as evidence of the likelihood of meeting SDG 14. This network, which runs under the patronage of the UN Secretary General, brings together international scientific and technical expertise relating to sustainable development to provide annual reviews of the current status of SDGs. See Sachs et al.¹³ for full details on how status was assessed. We drew evidence of the status and progress of individual targets within SDG 14 from the 2017 thematic review and the 2018 submission by the Convention on Biological Diversity (CBD).^{28,29} Using this evidence, we defined three categories of progress and assigned the goal and each target into one of these categories according to the potential of attainment by 2030 or within the stipulated time period: (1) the goal or target “will not be met,” (2) it is “uncertain” whether the goal or target will be met, and (3) the goal or target “will be met” given current progress. The SDSN¹³ provided the status of SDG 14 according to the same classification scheme, and thus we used their classification directly. The CBD²⁸ provided information on how SDG targets were linked to corresponding Aichi targets (20 targets to support 5 strategic goals for conservation, sustainable use, and fair and equitable sharing of biodiversity). Where the Aichi targets were said to be “lagging behind” attainment and the thematic review provided a similar message,²⁹ we categorized the corresponding SDG target as “will not be met.” Where the Aichi targets were said to be “lagging behind” attainment and the thematic review provided a more equivocal message,²⁹ we categorized the correspond-

ing SDG target as “uncertain.” Where SDG targets were not explicitly discussed by the CBD²⁸ but progress was uncertain or poor according to the thematic review, we also categorized the target as “uncertain.”

Tracking Synergies and Trade-offs between Ocean Health, Society, and the Economy

To understand the relationship between the state of the oceans and social and economic goals, we explored quantitative examples of interactions:

- (1) The intersection between progress toward SDG 1 (End Poverty), SDG 14 (Life below Water), and an estimate of economic dependence on the oceans. We chose economic dependence in this instance because it will have a direct impact on a country's capacity to fund and implement policies focused on ending poverty.
- (2) The intersection between progress toward SDG 2 (Zero Hunger), SDG 14, and an estimate of food-security dependence on fisheries for each country. We chose food-security dependence in this instance because it will have a direct impact on a country's capacity to achieve zero hunger.

The assessments of progress toward SDGs 1, 2, and 14 were sourced from Sachs et al.¹³ (Table S1). The estimate of economic dependency on the oceans was the sum of the percentage of GDP provided by fisheries and tourism (Table S2). Other marine industries contribute to GDP, and as such our estimates are likely to be a conservative representation of economic dependence on healthy marine environments, but fisheries and tourism are the most reliant on healthy ecosystems and therefore are most relevant in this context. The analysis focused on several small island nations, primarily in the Pacific, where tourism is predominantly focused on access to marine ecosystems. It should be noted that the tourism GDP percentages for Tuvalu, Palau, Micronesia, and the Marshall Islands were based on direct tourism contributions; the remaining countries were based on total (direct and indirect) tourism contribution to GDP. The fishery GDP percentages were based on direct contributions to GDP, and as such our analysis presents a conservative estimate of the positive impacts of the oceans on GDP. The metric of food-security dependence on the oceans was based on data sourced from Blanchard et al.,⁴⁴ who estimated the percentage of animal protein provided by fish protein. It should be noted that the contribution of fish to food-security component includes freshwater fish.

DATA AND CODE AVAILABILITY

All data used in the analysis are provided in the [Supplemental Information](#) and the reference list.

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at <https://doi.org/10.1016/j.oneear.2020.01.008>.

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AUTHOR CONTRIBUTIONS

K.L.N. and E.J.M.-G. conceived the idea. All authors were involved in designing the study and editing the text. K.L.N. did the data analysis and wrote most of the text.

DECLARATION OF INTERESTS

The authors have no competing interests or other interests that might be perceived to influence the interpretation of the article.

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REFERENCES

- United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. <https://sustainabledevelopment.un.org/post2015/transformingourworld>.
- Norstrom, A.V., Dannenberg, A., McCarney, G., Milkoreit, M., Diekert, F., Engstrom, G., Fishman, R., Gars, J., Kyriakopoulou, E., Manoussi, V., et al. (2014). Three necessary conditions for establishing effective Sustainable Development Goals in the Anthropocene. *Ecol. Soc.* 19, 8.
- Nilsson, M., Griggs, D., and Visbeck, M. (2016). Policy: map the interactions between Sustainable Development Goals. *Nature* 534, 320–322.
- Organisation for Economic Co-operation and Development (2015). Policy coherence for sustainable development in the SDG framework: shaping targets and monitoring progress. <http://www.oecd.org/governance/pcsd/Note%20on%20Shaping%20Targets.pdf>.
- Gibson, R.B. (2006). Beyond the pillars: sustainability assessment as a framework for effective integration of social, economic and ecological considerations in significant decision-making. *J. Environ. Assess. Policy Manage.* 8, 259–280.
- United Nations Development Programme (2018). Sustainable Development Goals. <http://www.undp.org/content/undp/en/home/sustainable-development-goals.html>.
- International Science Council (2017). A guide to SDG interactions: from science to implementation. <https://council.science/publications/a-guide-to-sdg-interactions-from-science-to-implementation/>.
- Singh, G.G., Cisneros-Montemayor, A.M., Swartz, W., Cheung, W., Guy, J.A., Kenny, T.-A., McOwen, C.J., Asch, R., Geffert, J.L., Wabnitz, C.C.C., et al. (2017). A rapid assessment of co-benefits and trade-offs among Sustainable Development Goals. *Mar. Policy* 93, 223–231.
- Scharlemann, J.P.W., Mant, R.C., Balfour, N., Brown, C., Burgess, N.D., Guth, M., Ingram, D.J., Lane, R., Martin, J., Wicander, S., and Kapos, V. (2016). Global goals mapping: the environment-human landscape (Sussex Sustainability Research Programme, University of Sussex, and UN Environment World Conservation Monitoring Centre). <https://nerc.ukri.org/research/partnerships/international/tase/mapping/>.
- D'Odorico, P., Davis, K.F., Rosa, L., Carr, J.A., Chiarelli, D., Dell'Angelo, J., Gephart, J., MacDonald, G.K., Seekell, D.A., Suweis, S., et al. (2018). The global food-energy-water nexus. *Rev. Geophys.* 56, 456–531.
- Weitz, N., Huber-Lee, A., and Nilsson, M. (2014). Cross-sectoral integration in the Sustainable Development Goals: a nexus approach (Stockholm Environment Institute). <https://www.sei.org/publications/cross-sectoral-integration-in-the-sustainable-development-goals-a-nexus-approach/>.
- Inter-agency Expert Group on SDG Indicators (2017). IAEG-SDG Reports to the UN Statistical Commission (UN Statistics Division). <https://unstats.un.org/sdgs/iaeg-sdgs/report-iaeg-sdgs/>.
- Sachs, J.D., Schmidt-Traub, G., Kroll, C., Lafortune, G., and Fuller, G. (2018). SDG Index and Dashboards Report 2018 (Bertelsmann Stiftung and Sustainable Development Solutions Network). <https://www.sdgindex.org/reports/sdg-index-and-dashboards-2018/>.
- Nicholson, E., Collen, B., Barausse, A., Blanchard, J.L., Costelloe, B.T., Sullivan, K.M.E., Underwood, F.M., Burn, R.W., Fritz, S., Jones, J.P.G., et al. (2012). Making robust policy decisions using global biodiversity indicators. *PLoS One* 7, e41128.
- Jones, J.P.G., Collen, B., Atkinson, G., Baxter, P.W.J., Bubba, P., Illian, J.B., Katzner, T.E., Keane, A., Loh, J., McDonald-Madden, E., et al. (2011). The why, what, and how of global biodiversity indicators beyond the 2010 target. *Conserv. Biol.* 25, 450–457.
- Branch, T.A., Jensen, O.P., Ricard, D., Ye, Y., and Hilborn, R. (2011). Contrasting global trends in marine fishery status obtained from catches and from stock assessments. *Conserv. Biol.* 25, 777–786.
- Pitcher, T.J., and Cheung, W.W.L. (2013). Fisheries: hope or despair? *Mar. Pollut. Bull.* 74, 506–516.
- Singh, G.G., Hilmi, N., Bernhardt, J.R., Cisneros Montemayor, A.M., Cashion, M., Ota, Y., Acar, S., Brown, J.M., Cottrell, R., Djoundourian, S., et al. (2019). Climate impacts on the ocean are making the Sustainable Development Goals a moving target travelling away from us. *People Nat.* 1, 317–330.
- Custer, S., DiLorenzo, M., Masaki, T., Sethi, T., and Harutyunyan, A. (2018). Listening to leaders 2018: is development cooperation tuned-in or tone-deaf? (AidData at the College of William & Mary). <https://www.aiddata.org/publications/listening-to-leaders-2018>.
- Sethi, T., Custer, S., Turner, J., Sims, J., DiLorenzo, M., and Latourell, R. (2017). Realizing Agenda 2030: will donor dollars and country priorities align with global goals? (AidData at the College of William & Mary). http://docs.aiddata.org/ad4/pdfs/Realizing_Agenda_2030.pdf.
- Brackley, A., and Lee, M. (2017). Evaluating progress towards the Sustainable Development Goals (SustainAbility). <https://sustainability.com/our-work/reports/evaluating-progress-towards-sustainable-development-goals/>.
- United Nations Global Compact (2017). 2017 United Nations Global Compact progress report: business solutions to sustainable development. <https://www.unglobalcompact.org/library/5431>.
- Nash, K.L., Cvitanovic, C., Fulton, E.A., Halpern, B.S., Milner-Gulland, E.J., Watson, R.A., and Blanchard, J.L. (2017). Planetary boundaries for a blue planet. *Nat. Ecol. Evol.* 1, 1625–1634.
- Kraemer, R.A. (2017). A sustainable ocean economy, innovation and growth: a G20 initiative (Center for International Governance Innovation). https://www.cigionline.org/sites/default/files/documents/PB%20No.113WEB_0.pdf.
- Hoegh-Guldberg, O. (2015). Reviving the ocean economy: the case for action (World Wildlife Fund). <https://www.worldwildlife.org/publications/reviving-the-oceans-economy-the-case-for-action-2015>.
- Voyer, M., Quirk, G., McGillorm, A., and Azmi, K. (2018). Shades of blue: what do competing interpretations of the blue economy mean for oceans governance? *J. Environ. Policy Plan.* 20, 595–616.
- Cohen, P.J., Allison, E.H., Andrew, N.L., Cinner, J., Evans, L.S., Fabinyi, M., Garces, L.R., Hall, S.J., Hicks, C.C., Hughes, T.P., et al. (2019). Securing a just space for small-scale fisheries in the blue economy. *Front. Mar. Sci.* 6, 171.
- Convention on Biological Diversity (2018). Biodiversity at the heart of sustainable development. https://sustainabledevelopment.un.org/content/documents/18277CBD_input_to_2018_HLPF.pdf.
- Executive Committee on Economic and Social Affairs (2017). High-Level Political Forum on Sustainable Development. Thematic review of SDG 14: conserve and sustainably use the oceans, seas and marine resources for sustainable development. <https://sustainabledevelopment.un.org/content/documents/14375SDG14format-revOD.pdf>.
- World Trade Organization (2019). High-level panel highlights urgent need for WTO deal to limit harmful fisheries subsidies. https://www.wto.org/english/news_e/news19_e/fish_08oct19_e.htm.
- Global e-Sustainability Initiative (2016). #SystemTransformation: how digital solutions will drive progress towards the Sustainable Development Goals. http://systemtransformation-sdg.gesi.org/160608_GeSI_SystemTransformation.pdf.
- Newbold, T., Hudson, L.N., Arnell, A.P., Contu, S., De Palma, A., Ferrier, S., Hill, S.L.L., Hoskins, A.J., Lysenko, I., Phillips, H.R.P., et al. (2016).

- Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science* 353, 288–291.
33. Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., et al. (2010). Global biodiversity: indicators of recent declines. *Science* 328, 1164–1168.
34. Convention on Biological Diversity (2016). Biodiversity and sustainable development: technical note. Report no. UNEP/CBD/COP/13/10/Add.1 (United Nations Environment Programme). <https://www.cbd.int/kb/record/meetingDocument/110547>.
35. 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.
36. Hoegh-Guldberg, O., Northrop, E., and Lubchenco, J. (2019). The ocean is key to achieving climate and societal goals. *Science* 365, 1372–1374.
37. ATD Fourth World and Oxford University (2019). The hidden dimensions of poverty. https://www.atd-fourthworld.org/wp-content/uploads/sites/5/2019/05/Dim_Pauvr_eng_FINAL.pdf.
38. Bizikova, L. (2011). Understanding the contribution of the environment to human well-being: a review of literature (International Institute for Sustainable Development). https://www.iisd.org/pdf/2012/understanding_contribution_environment.pdf.
39. Wabnitz, C.C.C., Cisneros-Montemayor, A.M., Hanich, Q., and Ota, Y. (2018). Ecotourism, climate change and reef fish consumption in Palau: benefits, trade-offs and adaptation strategies. *Mar. Policy* 88, 323–332.
40. Sumaila, U.R., Hotte, N., Galli, A., Lam, V.W.Y., Cisneros-Montemayor, A.M., and Wackernagel, M. (2015). Eco2: a simple index of economic-ecological deficits. *Mar. Ecol. Prog. Ser.* 530, 271–279.
41. Tam, J., Chan, K.M.A., Satterfield, T., Singh, G.G., and Gelcich, S. (2018). Gone fishing? Intergenerational cultural shifts can undermine common property co-managed fisheries. *Mar. Policy* 90, 1–5.
42. Mohanty, B.P., Sankar, T.V., Ganguly, S., Mahanty, A., Anandan, R., Chakraborty, K., Paul, B.N., Sarma, D., Dayal, J.S., Mathew, S., et al. (2016). Micronutrient composition of 35 food fishes from India and their significance in human nutrition. *Biol. Trace Elem. Res.* 174, 448–458.
43. Golden, C.D., Allison, E.H., Cheung, W.W.L., Dey, M.M., Halpern, B.S., McCauley, D.J., Smith, M., Vaitla, B., Zeller, D., and Myers, S.S. (2016). Nutrition: Fall in fish catch threatens human health. *Nature* 534, 317–320.
44. Blanchard, J.L., Watson, R.A., Fulton, E.A., Cottrell, R.S., Nash, K.L., Bryndum-Buchholz, A., Büchner, M., Carozza, D.A., Cheung, W.W.L., Elliott, J., et al. (2017). Linked sustainability challenges and trade-offs among fisheries, aquaculture and agriculture. *Nat. Ecol. Evol.* 1, 1240–1249.
45. Hicks, C.C., Cohen, P.J., Graham, N.A.J., Nash, K.L., Allison, E.H., D'Lima, C., Mills, D.J., Roscher, M., Thilsted, S.H., Thorne-Lyman, A.L., and MacNeil, M.A. (2019). Harnessing global fisheries to tackle micronutrient deficiencies. *Nature* 574, 95–98.
46. Fridman, D., and Kissinger, M. (2019). A multi-scale analysis of interregional sustainability: applied to Israel's food supply. *Sci. Total Environ.* 676, 524–534.
47. Kissinger, M., Rees, W.E., and Timmer, V. (2011). Interregional sustainability: governance and policy in an ecologically interdependent world. *Environ. Sci. Policy* 14, 965–976.
48. Mascia, M.B., Claus, C.A., and Naidoo, R. (2010). Impacts of marine protected areas on fishing communities. *Conserv. Biol.* 24, 1424–1429.
49. Sowman, M., and Sunde, J. (2018). Social impacts of marine protected areas in South Africa on coastal fishing communities. *Ocean Coast. Manage.* 157, 168–179.
50. Kleiber, D., Harris, L.M., and Vincent, A.C.J. (2015). Gender and small-scale fisheries: a case for counting women and beyond. *Fish Fish.* 16, 547–562.
51. Kawarazuka, N., and Béné, C. (2010). Linking small-scale fisheries and aquaculture to household nutritional security: an overview. *Food Secur.* 2, 343–357.
52. Chapman, M.D. (1987). Women's fishing in Oceania. *Hum. Ecol.* 15, 267–288.
53. Di Ciommo, R.C. (2007). Gender, tourism, and participatory appraisals at the corumbau marine extractive reserve, Brazil. *Hum. Ecol. Rev.* 14, 56–67.
54. Di Ciommo, R.C., and Schiavetti, A. (2012). Women participation in the management of a Marine Protected Area in Brazil. *Ocean Coast. Manage.* 62, 15–23.
55. Republic of Palau (2019). Progressing with our past toward a resilient, sustainable, and equitable future (United Nations). <https://sustainabledevelopment.un.org/memberstates/palau>.
56. Pakoa, K., Lasi, F., Tardy, E., and Friedmann, K. (2009). The status of sea cucumbers exploited by Palau's subsistence fishery (Secretariat of the Pacific Community). https://palau-data.sprep.org/system/files/Pakoa_09_Subistence_Sea_Cucumber_Fishery_Palau.pdf.
57. Hanich, Q., Wabnitz, C.C.C., Ota, Y., Amos, M., Donato-Hunt, C., and Hunt, A. (2018). Small-scale fisheries under climate change in the Pacific Islands region. *Mar. Policy* 88, 279–284.
58. Carlisle, K.M., and Gruby, R.L. (2019). Customary marine tenure in Palau: social function and implications for fishery policy. *Hum. Ecol.* 47, 527–539.
59. Devillers, R., Pressey, R.L., Grech, A., Kittinger, J.N., Edgar, G.J., Ward, T., and Watson, R. (2015). Reinventing residual reserves in the sea: are we favouring ease of establishment over need for protection? *Aquat. Conserv.* 25, 480–504.
60. Morrison, T.H., Hughes, T.P., Adger, W.N., Brown, K., Barnett, J., and Lemos, M.C. (2019). Save reefs to rescue all ecosystems. *Nature* 573, 333–336.
61. Fulton, E.A., Smith, A.D.M., and Punt, A.E. (2005). Which ecological indicators can robustly detect effects of fishing? *ICES J. Mar. Sci.* 62, 540–551.
62. Shin, Y.-J., Houle, J.E., Akoglu, E., Blanchard, J.L., Bundy, A., Coll, M., Demarcq, H., Fu, C., Fulton, E.A., Heymans, J.J., et al. (2018). The specificity of marine ecological indicators to fishing in the face of environmental change: a multi-model evaluation. *Ecol. Indic.* 89, 317–326.
63. Larrosa, C., Carrasco, L.R., and Milner-Gulland, E.J. (2016). Unintended feedbacks: challenges and opportunities for improving conservation effectiveness. *Conserv. Lett.* 9, 316–326.
64. Shepherd, E., Milner-Gulland, E.J., Knight Andrew, T., Ling Matthew, A., Darrah, S., Soesbergen, A., and Burgess, N.D. (2016). Status and trends in global ecosystem services and natural capital: assessing progress toward Aichi Biodiversity Target 14. *Conserv. Lett.* 9, 429–437.
65. Suich, H., Howe, C., and Mace, G. (2015). Ecosystem services and poverty alleviation: a review of the empirical links. *Ecosyst. Serv.* 12, 137–147.
66. Hák, T., Janoušková, S., and Moldan, B. (2016). Sustainable Development Goals: a need for relevant indicators. *Ecol. Indic.* 60, 565–573.
67. Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., et al. (2013). Social-ecological systems as complex adaptive systems: modeling and policy implications. *Environ. Dev. Econ.* 18, 111–132.
68. Homer-Dixon, T., Walker, B., Biggs, R., Crepin, A.S., Folke, C., Lambin, E.F., Peterson, G.D., Rockstrom, J., Scheffer, M., Steffen, W., et al. (2015). Synchronous failure: the emerging causal architecture of global crisis. *Ecol. Soc.* 20, 6.
69. Fischer, J., Gardner, T.A., Bennett, E.M., Balvanera, P., Biggs, R., Carpenter, S., Daw, T., Folke, C., Hill, R., Hughes, T.P., et al. (2015). Advancing sustainability through mainstreaming a social-ecological systems perspective. *Curr. Opin. Environ. Sustain.* 14, 144–149.
70. Sugihara, G., May, R., Ye, H., Hsieh, C.H., Deyle, E., Fogarty, M., and Munch, S. (2012). Detecting causality in complex ecosystems. *Science* 338, 496–500.
71. Daw, T.M., Hicks, C.C., Brown, K., Chaigneau, T., Januchowski-Hartley, F.A., Cheung, W.W.L., Rosendo, S., Crona, B., Coulthard, S., Sandbrook, C., et al. (2016). Elasticity in ecosystem services: exploring the variable relationship between ecosystems and human well-being. *Ecol. Soc.* 21, 11.

72. Merrie, A., Keys, P., Metian, M., and Österblom, H. (2018). Radical ocean futures-scenario development using science fiction prototyping. *Futures* 95, 22–32.
73. Lotze, H.K., Tittensor, D.P., Bryndum-Buchholz, A., Eddy, T.D., Cheung, W.W.L., Galbraith, E.D., Barange, M., Barrier, N., Bianchi, D., Blanchard, J.L., et al. (2019). Global ensemble projections reveal trophic amplification of ocean biomass declines with climate change. *Proc. Natl. Acad. Sci. USA* 116, 12907–12912.
74. Salafsky, N., and Margoluis, R.A. (1998). *Measures of Success: Designing, Managing, and Monitoring Conservation and Development Projects* (Island Press).
75. Margoluis, R., Stem, C., Swaminathan, V., Brown, M., Johnson, A., Placci, G., Salafsky, N., and Tilders, I. (2013). Results chains: a tool for conservation action design, management, and evaluation. *Ecol. Soc.* 18, 22.
76. United Nations (2013). Resolution adopted by the General Assembly on 9 July 2013. Format and organizational aspects of the high-level political forum on sustainable development (A/RES/67/290). <https://sustainabledevelopment.un.org/index.php?page=view&type=111&nr=1888&menu=35>.
77. Division for Sustainable Development Goals (2019). Sustainable development knowledge platform: inputs to the high-level political forum on sustainable development (UN Department of Economic and Social Affairs). <https://sustainabledevelopment.un.org/inputs/>.
78. Persson, Å., Weitz, N., and Nilsson, M. (2016). Follow-up and review of the Sustainable Development Goals: alignment vs. internalization. *Rev. Eur. Comp. Int. Environ. Law* 25, 59–68.