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Governance Planning for Sustainable Oceans in a Small Island State

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Abstract

Achieving the Sustainable Development Goals (SDGs) will require coordinated policymaking for achievement. Aruba is a Small Island State (SIDS) with 90% of its jobs and GDP dependent on the oceans has prioritized SDG 14 – life below water, or the SDG Ocean goal – for achievement. We have developed a planning process, building off of the the literature on SDG interactions and stratetic policy planning literatures, to guide SDG policy development and implemented it in Aruba. We used a structured expert elicitation process to carry out the analysis for this process. The process involves first identifying priority areas based on determining which SDG Ocean target provides the most co-benefit across other SDGs. Next we determine the SDG areas that most contribute to key SDG Ocean targets. Using this information we determine the key policy areas important for promoting sustainable oceans. Finally, we determine the Aruban ministries and institutions responsible for the various SDG areas and based on which SDG areas are most important for SDG Ocean achievement we visualize a new institutional network to support the achievement of SDG Oceans. First, we determined that while increasing economic benfits for SIDS (SDG 14.7) was the most important SDG Ocean target when considering direct impacts, reducing marine pollution (SDG 14.1), restoring marine habitats (SDG 14.2), and marine protection (SDG 14.5) were the most important SDG Ocean targets when considering indirect impacts. SDG areas with the most beneficial consequences for the SDG Ocean targets were mitigating climate impacts (SDG 13), international partnerships (SDG 17), jobs and economy (SDG 8), conserving terrestrial area (SDG 15), strengthening institutions (SDG 16), and promoting sustainable consumption and production practices (SDG 12). When links between SDGs are not considered, the institutional network supporting sustainable oceans is relatively simple, with the Department of Nature and the Environment most central: it coordinates across the largest number of relevant institutions supporting the SDG Oceans goal. However, when SDG relationships are considered, the institutional network is relatively complex, and the Social and Economic Council is determined to be the most central and important in coordinating activities across the largest number of Aruban instutions that support the SDG Ocean goal. Transitioning to a sustainable future requires policymaking that works across social-ecological dimensions, and need to design coherent and integrative institutional structures with which to do this.

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Introduction

The achievement of sustainable development will require cross-scale and cross-institutional cooperation and planning across social-ecological systems (Rotmans et al. 2016; Biermann et al. 2017). Siloed policy prescriptions that fail to adopt integrated perspectives across social-ecological systems can be ineffective or counterproductive (Singh et al. 2017). For example, policies focused on ecological protection with the intent of replenishing primary resources can backfire if they enhance social inequalities and ultimately undermine the legitimacy of institutions to local people (Christie 2004). In a marine protected area (MPA) in the Philippines, established without consideration of local access to fish stocks or other economic prospects, the goal of increasing fish biomass ultimately failed as poaching increased following distrust of the MPA governance (Christie 2004). Similarly, initiatives to enhance the ecological resilience of agricultural ecosystems by promoting the benefits from natural pollination fell flat when farms sowed crops that do not require animal pollinators, showcasing a lack of proper attention to agricultural economics (McCauley 2006). Conversely, policies to decrease social inequity in resource-dependent communities can fail if policies do not adequately account for resource supply and dynamics, such as when fisheries in Chile crashed and led to higher unemployment and poverty rates (Defeo and Castilla 2005). Though our sophistication of the complexity that underlies sustainability is increasing, our ability to translate this into effective policy planning at national levels remains elusive.

The Sustainable Development Goals (SDGs) are the current best example of recognizing the necessity of integrative policy to achieve sustainable development. The SDGs are a set of 17 social, economic, ecological, and governance goals (and 169 specific targets) to be achieved between 2020 and 2030 have been adopted by every United Nations member state as a standard set of aspirations towards sustainable development (UN 2015). However, planning for the SDGs is a topic of continued debate, and the development of planning protocols for strategically achieving the SDGs is elusive. In general, an emerging major research theme in sustainability science is determining appropriate governance system structures in the face of complex systems and multi-attribute goals (Rotmans et al. 2016; Singh in review).

The SDGS were envisioned as interrelated, recognizing the deeply connected world we live in and that a transition to a sustainable society requires complementary dynamics across natural, social, economic, and governance domains (UN 2015). It follows then that a governance system dedicated to sustainable development would be organized to act in an interconnected way, regulating the specific linkages among and within domains to promote co-benefits and mitigate tradeoffs among SDGs. Here, we propose and implement a governance planning framework to strategically align policy priorities and governance actors to achieve the SDGs.

Our planning method builds on and integrates two fields that are influential in sustainability studies but have thus far not been integrated: the transition management framework and the literature on SDG interrelationships. The transition management framework builds on an established literature on societal change, and is primarily focused on developing coherent governance infrastructure, from i) the priorities set at the level of values and visions, to ii) the institutions and organizations mandated to achieve the visions, down to iii) the specific programs and activities taken (Loorbach 2007; Rotmans et al. 2016). The framework focuses on coordinating these multiple levels to increase the probability of achieving desired outcomes and reduce the likelihood of misaligned and counterproductive results. The SDG interrelationships research has been conducted across multiple countries and SDG areas, mainly focusing on determining which SDGs, in which contexts, can be synergistically achieved and which SDGs pose possibilities for tradeoffs (Nilsson et al. 2016; ICSU 2017; Nilsson et al. 2018; Singh et al. 2018). The transition management framework benefits from research to identify the actors and limits of a governance issue, and SDG interlinkage research can outline this operating space (Singh in review) by “mapping out” SDG co-benefit and tradeoff relationships that represent the policy arena that institutions can effectively govern. The second major component of the framework is understanding what existing governance institutions exist to regulate and manage the critical SDG areas that promote or hinder specific SDGs (identified in the first step), and their relationship to each other. The resulting governance network organized around the interconnections of the SDGs represents a new governance system organized around prioritized SDGs.

We develop this planning method for sustainable development planning in Aruba, a Small Island State prioritized within the SDGs’ aim for equality across countries. Additionally, the Aruban government has established a commission to develop guidance towards achieving the SDGs in the country. Around 99% of Aruba’s total territory is ocean, which is central to Aruban culture and generates approximately 90% of economic activity through coastal tourism. Unsurprisingly, the Aruba SDG commission has prioritized SDG 14: Life Below Water (the goal focused on the oceans) as the SDG area of most importance, and this focus on a single SDG topic that disproportionately impacts Aruban industries, makes Aruba a model study country to develop processes to help structure policy and governance systems to promote sustainable development.

Methods

Aruba and the SDGs

Tourism is the main economic driver in Aruba and the number of rooms for tourists has tripled from 1986 to 2011 the. In 2018, total economic impacts (direct, indirect, induced) from tourism were responsible for 98.3% of Aruba’s GDP and 99.1% of total employment (WTTC 2019). Revenue from tourism is used to pay for essential imports and has raised the standard of life on the island. Other (much smaller) industries on the island include fisheries, agriculture, an oil refinery, wind energy generation and a desalinization plant.

Tourism has radically altered Aruba’s coastline, with extensive hotel development along its west coast. A large proportion of Aruba’s island surface has been transformed for tourism infrastructure (Barendsen et al. 2008). The recent development on the island has had consequences for Aruba’s flora, with a measured gradient of vegetation health related to distance from tourist density (Oduber et al. 2015). Aruba’s development to date has led to marine pollution problems (the topic of SDG 14.1) as well as coastal habitat loss (the topic of SDG 14.2), such as through mangrove removal. Ocean acidification (the topic of SDG 14.3) affects marine life around Aruba, though there is little tourism based on charismatic marine habitats such as coral reefs. Fisheries (the topic of SDG 14.4) are a small industry in Aruba, and the government provides no fishing-enhancing subsidies to fishers (the topic of SDG 14.6). Aruba has a national park that extends from its rugged north-eastern coast to the only Ramsar site on the south-western coast . Since 2019 Aruba also has four multi-use , but its protection does not extend into the ocean (the topic of SDG 14.5). Though marine tourism has such high economic value, it is in its current form not necessarily sustainable (the topic of SDG 14.7) as the current tourism marketing focuses on warm weather and clean, sandy white beaches instead of a healthy marine ecosystem

Expert Elicitation Process

A workshop was convened to 1) prioritize SDG 14 targets based on the diversity and production of co-beneficial relationships with all other SDG targets; and 2) determine the SDG targets that promote co-beneficial relationships with ocean targets, while also identifying SDG targets that can act as trade-offs with ocean targets.

The workshop was held over 10 days, with each day having a set of dedicated sessions on the relationships from the oceans goal to another SDG goal or an SDG goal to the oceans goal. The beginning of the workshop focused on assessing the contribution of the seven SDG 14 targets across the 169 SDG targets (across all SDGs), with the second half of the workshop focused on determining the contribution of the 169 SDG targets (across all SDGs) to the seven SDG 14 targets. Each session lasted approximately one hour and utilized the rapid assessment framework as outlined in Singh et al. (2018). This framework uses a repeatable, hierarchical decision process to identify up to seven types of directional relationships among SDG targets. The seven relationships are

- co-benefit pre-requisite context independent, whereby the first SDG target is required to achieve the second target
- co-benefit optional context independent, whereby the first SDG target is not required but will always contribute towards the achievement of the second SDG target
- co-benefit options context-dependent, whereby the first SDG target may usually contribute towards the second SDG target, but this co-benefit is dependent on the specific context
- trade-off pre-requisite context independent, whereby the first SDG target is a necessary condition to detract from the second SDG target
- trade-off optional context independent, whereby the first SDG target is not needed to detract from the second SDG target, but if the first SDG target is progressed it always detracts from the second SDG target
- trade-off optional context dependent, whereby the first SDG target usually detracts from the second SDG target, but this trade-0ff is dependent on other contextual conditions
- Neutral, where no relationship is known

The framework was applied to Aruba at a national scale, meaning sub-national variation in relationships was not captured for this analysis. Temporally, we used the same time-lines as the SDGs, so if one SDG target had a completion date of 2020 and a second SDG target had a completion date of 2030, we considered the relationship from the first SDG target to the second including a 10-year lag. However, when considering the reverse scenario, we contemplated the immediate consequence of the second SDG target on the first regarding progress towards the second SDG target.

Workshopping SDG relationships for Aruba also had other considerations. For example, we considered SDG 15.2 (on conserving forests) to apply to the island's mangroves. Also, since Aruba is a small island state with little effect on global climate processes, we considered progress towards the climate SDG (SDG 13) to include what other countries are doing to combat climate change. That is, we were more interested in understanding how global climate change efforts would affect Aruba rather than simply considering the outcomes of national-level climate change reduction, adaptation, and mitigation efforts within Aruba.

In total, 20 experts took part in the workshops. All experts were chosen based on their familiarity with at least one (usually multiple) subject areas of the SDGs and how they intersect with the oceans in Aruba. Experts were mainly from the civil service of Aruba, from various ministries including economic development, parks, ministry of environment, as well as the Aruban SDG commission. Experts were chosen with diverse backgrounds to prevent a particular viewpoint from dominating expert responses (Fish et al. 2009). Experts nominated by other experts so that the final group of experts captures a large proportion of recognized expertise for the intersection of oceans and development in Aruba (Ban et al. 2015).

At the start of the workshop, a practice and training round was conducted to ensure that experts had familiarity with the method, and to allow experts a chance to ask questions and clarify points to reduce linguistic uncertainty among experts. Having a training session with rapid feedback is known to increase the reliability of expert knowledge (Martin et al. 2012). Additionally, after the workshop, when the data was compiled, summary findings were presented back to the experts with an option to clarify or challenge results (Brown 1968). No expert suggested a change to the findings or indicated findings that were contradictory to knowledge about Aruba, providing extra confidence in the results.

Our elicitation method is based on a strategy developed by Singh et al. (2017) involving groups of experts, which builds off of an expert group elicitation protocol by Burgman et al. (2011). Each round of elicitation had a group of experts discuss among each other which type of relationship exists between all main SDG targets within specific SDG goals. Allowing for open discussion among diverse experts allows for experts to productively challenge each other's views and prevents thought from a dominant background or domain of expertise remain unchallenged (Burgman et al. 2011; Martin et al. 2012; Singh et al. 2017). After a thorough round of discussion, experts provided specific answers confidentially on an answer sheet. Providing personalized answers allowed experts to indicate their response without being influenced by broader group processes (Singh et al. 2017). Experts were divided into groups of 8-12, with a facilitator in each group, and a roaming facilitator that moved across groups, ensuring that concepts brought up in single groups were shared and discussed across all groups. While splitting the experts into groups has the potential to lead to drastically separate discussions and conclusions by the experts in the different groups, managing the size of groups allowed for input from all expert members. Additionally, the roving facilitator ensured that all major topics were at least considered in each group. Finally, having experts separate in multiple groups also allows for an additional level of independence, akin to increasing the degrees of freedom in the data, as the probability of groupthink dynamics leading to homogenous responses across all experts is diminished (Burgman 2005; Singh et al. 2017). The effect of having experts in multiple groups is that high agreement across experts is more robust, as there is greater independence among the expert responses, akin to increasing the degrees of freedom in a statistical design. Once all the experts provided their individual assessments, their answers were compiled to generate maps of expert variation in responses.

Experts were asked to provide SDG target relationships, as well as indicate – whenever they showed an optional/context-dependent relationship – the contextual element that regulated the relationship. Experts were instructed to report whether the relationship was dependent on ecological factors (defined as non-human biotic and abiotic conditions), economic factors (defined as financial, market, income, and labour conditions), social factors (defined as issues related to social norms, demographics, and non-monetary social conditions), and governance factors (defined as institutions, policy, law, and decision-making bodies).

Quantifying Expert Variation in SDG relationships

Once all expert responses were collected, they were compiled and coded through a winner-takes-all system of classification (except when "neutral" relationships were most prevalent), with the level of agreement quantified. For example, if out of 20 experts, 15 thought a relationship was co-benefit/optional/context-dependent, while 3 of the other 5 thought the relationship was co-benefit/optional/context-independent and the remaining 2 thought the relationship was co-benefit/pre-requisite/context-independent, the relationship was coded as co-benefit/optional/context-dependent with agreement level of 0.75 (15/20). Similarly, if out of 20 experts, 5 experts thought a relationship was co-benefit/optional/context-dependent, 2 thought the relationship was co-benefit/optional/context-independent, and the rest felt the relationship was neutral, the link was coded as co-benefit/optional/context-dependent with agreement level 0.25 (5/20).

To avoid the inclusion of spurious non-neutral relationships or non-neutral relationships with greater expert disagreement than agreement, we set a threshold of agreement from which to continue our analysis. We chose a supermajority of expert agreement (2/3 agreement) as a threshold to ensure that our analysis focused only on those relationships with little disagreement. Once we determined our final set of non-neutral relationships, we determined priority areas for both SDG ocean targets that are most cross-cutting for all other SDGs as well as SDGs that are most related to the SDG ocean targets.

Quantifying the SDG ocean targets in terms of their contribution across other SDGs included an additional step, because we assessed the SDG ocean targets against each other, and therefore could assess direct and secondary indirect relationships across SDGs. To calculate the total contribution of achieving the SDG ocean targets across all other SDGs, we adopt a simple model based on the Input-Output (IO) method, which is used to estimate the contribution of specific economic sectors to the economy as a whole by linking the production of each sector (or in this case, SDG target) to the consumption of others (Leontief 1951). In this way, for example, the ripple effects of some industries can be particularly important for an economy when their production is an essential input for other industries that may themselves be important for still other industries. (For example, steel production used as input into ship construction that is required for the shipping and trade industries.) To calculate the relative co-beneficial productive importance of each SDG ocean target, accounting for all ripple effects stemming from interconnections among SDGs, we calculate the Leontief inverse, summed across all SDG ocean targets, using the formula

$$x = \sum (I - A)^{-1} \cdot d$$

Where *x* is the relative co-beneficial productive importance of each SDG ocean target, accounting for the sum of ripple effects from all other SDG ocean targets, *I* is the identity matrix, *A* is the matrix of intermediate outputs (i.e., the proportion of SDG Ocean co-benefits from achieving a given SDG Ocean target that leads to further co-benefits across the SDGs), and *d* is the total output (i.e., overall SDG target benefits). Calculating the importance of interlinked SDG ocean targets was done for all co-beneficial relationships, for only co-benefit/pre-requisite relationships, and for only co-benefit/optional/context-dependent relationships. Co-benefit/pre-requisite relationships are arguably the most important, as other SDG targets cannot be achieved without the achievement of the specified SDG ocean target. Co-benefit/optional/context-dependent relationships are potential co-benefits that are realized if other conditions are met.

Quantifying the relationships of other SDGs to the SDG ocean targets were more straightforward, as we did not consider their interaction/indirect contributions to the ocean targets. We, therefore, summed the number of the different kinds of co-beneficial and trade-off relationships with the SDG ocean targets.

Once all SDG relationships were quantified, data summaries were prepared and sent out to the original experts for vetting. This stage of elicitation was carried out over email. Experts were sent files with graphics summarizing relationships and captions describing trends. Experts were asked to provide feedback (particularly if they did not agree with some findings) or suggestions for describing prominent results. After vetting, we compiled our final dataset of SDG relationships. SDG relationships were graphically represented in circus plots (using the R package circlize, Gu 2014), a multivariate network graphing technique used often in genomics research to organize nodes in nested structures (in our case nesting SDG targets within SDGs) and represent all links between nodes.

All optional/context-dependent relationships as determined by individual experts, were categorized as dependent on environmental, social, economic, or governance dimensions. We tallied up all instances of these considerations and determined what factor regulates context-dependent relationships. We plotted the results using Sankey diagrams, using the R package SanKey (Csárdi and Weiner 2017).

Institutional Identification and Network Building

To determine the structure of government institutions informed by SDG interconnections to promote sustainable oceans, we first categorized the Aruban government agencies based on the SDG area(s) they are responsible for. To do this, first, we reviewed the websites for each government agency (grouped under 5 distinct government ministries) and classified them as contributing to individual SDG targets across all SDG goals. We organized the institutions based on the description of responsibilities as stated on the website for each institution. This classification was done by one person on the author team. Next, we took our list of classified government institutions and sent it around to the experts from the earlier workshop (all who work in, or have considerable experience with, the Aruban government and collectively work in all major Aruban government ministries), in order to vet the classification for accuracy. Vetting was done over email, specifically asking experts if our classification system captured the role of Aruban institutions in practice (Singh et al. 2018). Over two iterations, our database of Aruban institutions was refined and finalized.

Because we were interested in building institutional structures organized by SDG relationships, we created interaction matrices of institutions regulating SDG targets which have connections with the SDG ocean targets (in that direction). We considered three scenarios of institutional arrangement: a situation where only direct institutional regulation was considered (so no SDG relationships were taken into account), a condition where co-benefit/pre-requisite relationships were found (as they are needed to achieve the ocean SDG targets), and a case where all SDG relationships were discussed. The case where only direct institutional regulation was considered most strongly resembles the current situation, the pre-requisite situation models an institutional structure minimally needed to ensure the achievement of the SDG ocean targets, and the situation with all SDG relationships models an institutional arrangement that will provide the highest potential to achieve the SDG ocean targets by capitalizing on co-benefits (both through promoting context-independent co-benefits and implementing policy to realize the potential of context-dependent co-benefits) and mitigating trade-offs.

In every situation, we modeled an ideal situation where all institutions that help regulate a specific SDG target are in communication with each other. This may not be a realistic assumption, but we are interested in how SDG interlinkages change institutional design rather than existing institutional collaboration. From the results, we determine the institutions most connected with SDG targets and most-connected with other institutions. The first indicates a measure of how important the institution is as a regulator for ocean sustainability across targets, and the second suggests a measure of how important that institution is as a collaborating entity, ensuring consistent policy planning across institutions. On top of these metrics, we use a battery of measures of network centrality to determine the most crucial institution based on network structure. To select the centrality measures, we first use principal components analysis (Husson et al. 2017) and t-Distributed Stochastic Neighbor Embedding analysis (Van Der Maaten 2014) to determine the centrality measures that are most informative given the institutional network structure (see Figure S4). We use the CINNA package to identify the proper centrality measures (Ashtinani 2019). We use the resulting four centrality measures to establish the most important institutions, and compare these results with our simple counts presented above. Institutional networks were developed in the R package igraph (Csardi and Nepusz 2006).

Results

Prioritizing Ocean Targets

All ocean SDG targets have relationships across other SDGs, except for SDG 14.6: eliminating harmful and capacity enhancing fisheries subsidies. Aruba does not provide capacity enhancing fishing subsidies so no additional consequences can be felt from acting on this target. No trade-off relationships from achieving any SDG ocean targets were identified by a supermajority of experts. Economic benefits to Small Island Developing States (SIDS) is associated with the most significant number of co-benefits to other SDGs, including the largest number of pre-requisite and co-benefits/optional/context-dependent relationships (Table 1).

Increasing economic benefits to SIDS (SDG 14.7) has direct co-benefits across the largest number of other SDGs (Figure 1), followed by restoring marine ecosystems (SDG 14.2), reducing marine pollution (SDG 14.1), and protecting marine areas (SDG 14.5). SDGs 1 (ending poverty) and 15 (life on land), and 14 (life below water) are the only SDGs that benefit from co-beneficial relationships from all SDG Ocean targets (besides SDG 14.6).

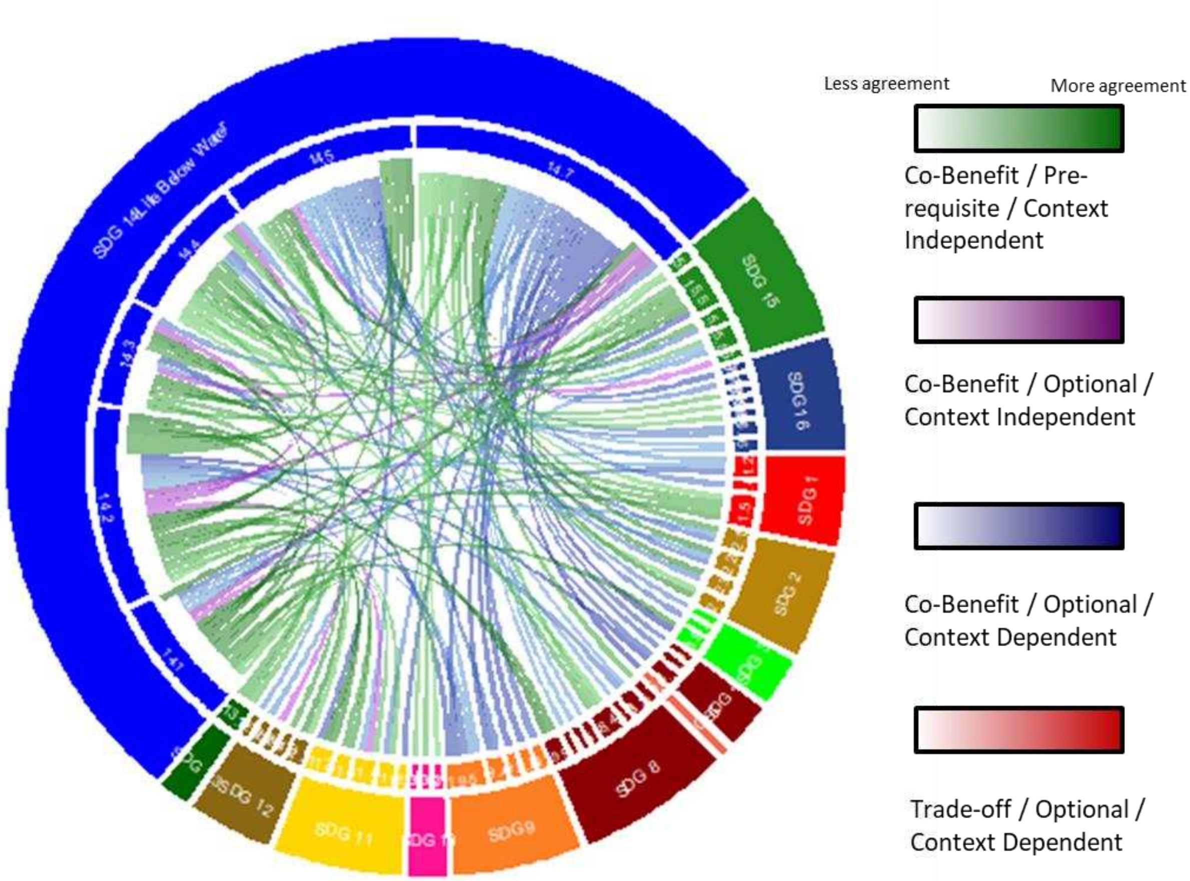

Figure 1. Characterized relationships from SDG Ocean targets to all other SDGs. The width of the nodes indicates the number of connections originating from or receiving links. The origin of a relationship between SDG targets are indented, and the receiving end of the relationship extends out further. Different colors represent different kinds of relationships, and darker shades constitute greater agreement among experts. Only connections with at least 2/3 agreement are shown.

Table 1: The number of direct relationships from each SDG ocean target across all SDGs, and the relative importance scores of each SDG ocean target to interconnected (direct and indirect) co-benefits to all SDGs. This table does not indicate the relationship from other SDGs to SDG ocean targets.

	Direct					Indirect		
	Co-Benefit			Trade-Off	Total			
SDG Ocean Target	Pre-Requisite/ Context-Independent	Optional/ Context-Independent	Optional/ Context-dependent			Pre-Requisite/ Context-Independent	Optional/ Context-Dependent	All Co-Benefits
14.1 Reduce Marine Pollution	11	2	4	0	17	0.439	0	0.232
14.2 Habitat Restoration	11	4	6	0	21	0.157	0	0.233
14.3 Reduce Ocean Acidification	6	1	2	0	9	0.265	0	0.128
14.4 End Overfishing	13	0	3	0	16	0.270	0	0.097

14.5 Marine Protected Areas	6	1	15	0	22	0.253	0.399	0.236
14.6 End Harmful Fishing Subsidies	0	0	0	0	0	0	0	0
14.7 Economic Benefits to SIDS	14	0	22	0	36	0.191	0.500	0.206

However, when considering the direct and indirect co-benefits of achieving SDG ocean targets, reducing marine pollution (SDG 14.1), restoring marine habitats (SDG14.2), and protecting marine areas (SDG 14.5) are most important, reflecting that these targets all produce co-benefits towards the most number of the other SDG ocean targets (4 of the other 6 SDG ocean targets). Considering only the pre-requisite co-beneficial relationships, reducing marine pollution is the most critical SDG ocean target to implement as it is a pre-requisite for the most other SDG ocean targets. Increasing economic activity for SIDS through sustainable marine use is the most important for promoting context-dependent co-beneficial relationships across SDGs. Proper governance context (e.g., the implementation of policy) was considered as the most prominent factor in regulating whether a co-benefit/optional/context-dependent relationship was realized (Figure S1).

Prioritizing SDGs for the Oceans

Agreed on by a supermajority of experts, 11 of the 17 SDGs have co-beneficial relationships with the SDG ocean targets (Figure 2). Overall, SDG Ocean targets have the most co-beneficial relationships among each other, followed by international climate action (SDG 13) and international partnerships (SDG 17). Jobs and economy (SDG 8), conserving life on land (SDG 15), peace, justice, and strong institutions (SDG 16), and sustainable consumption and production practices (SDG 12) also provide many co-benefits for achieving ocean targets. Less prominent (in terms of the number of co-benefits) were sustainable cities and communities (SDG 11), resilient infrastructure (SDG 9), clean energy systems (SDG 6), and clean water and sanitation (SDG 6).

SDG ocean targets provide the most co-benefits with other ocean targets, followed by international climate action (SDG 12), and jobs and economy (SDG 8),when considering only co-benefit/pre-requisite/context-independent relationships. Sustainable cities and communities (SDG 11), conserving life on land (SDG 15), international partnerships (SDG 17), sustainable infrastructure (SDG 9), clean energy (SDG 7), and clean water and sanitation (SDG 6) also provided some co-benefit/pre-requisite/context-independent relationships with SDG oceans targets.

Considering only co-benefit/optional/context-dependent relationships, international climate action (SDG 13), international partnerships (SDG 17), peace, justice, and strong institutions (SDG 16), and conserving life on land (SDG 15) provided the highest number of relationships with SDG ocean targets. Other SDG Ocean targets, jobs, and economy (SDG 8), and clean water and sanitation (SDG 6) also provided context-dependent co-benefits with SDG Ocean targets. Experts indicated that governance context (e.g., policy implementation) was the most prominent factor regulating whether context-dependent co-benefits were realized (Figure S1).

Agreed on by a supermajority of experts, two SDGs produce trade-off/optional/context-dependent relationships with SDG Oceans targets: jobs and economy (SDG 8) and reducing inequalities (SDG 10). No other kinds of trade-off relationships were agreed on. As above, experts indicated that the governance context was the most prominent factor regulating whether trade-offs could be avoided.

Among the SDG Oceans targets, Aruba's ability to mitigate impacts from ocean acidification (SDG 14.3) benefitted from the most significant number of co-benefits, followed by marine restoration (SDG 14.2), marine pollution (SDG 14.1), economic benefits to SIDS (SDG 14.7), and finally eliminating overfishing (SDG 14.4). Of these, marine restoration (SDG 14.2), reducing marine pollution (SDG 14.1) and mitigating impacts from ocean acidification (SDG 14.3) required the largest number of other SDG targets to be achieved (received pre-requisite co-beneficial relationships). There was a nearly even spread of SDG ocean targets that received co-benefit/optional/context-dependent relationships, however. Considering trade-off relationships, restoring marine habitats (SDG 14.2), reducing impacts from ocean acidification (SDG 14.3), reducing marine pollution (SDG 14.1), and eliminating overfishing (SDG 14.4) were received trade-off relationships.

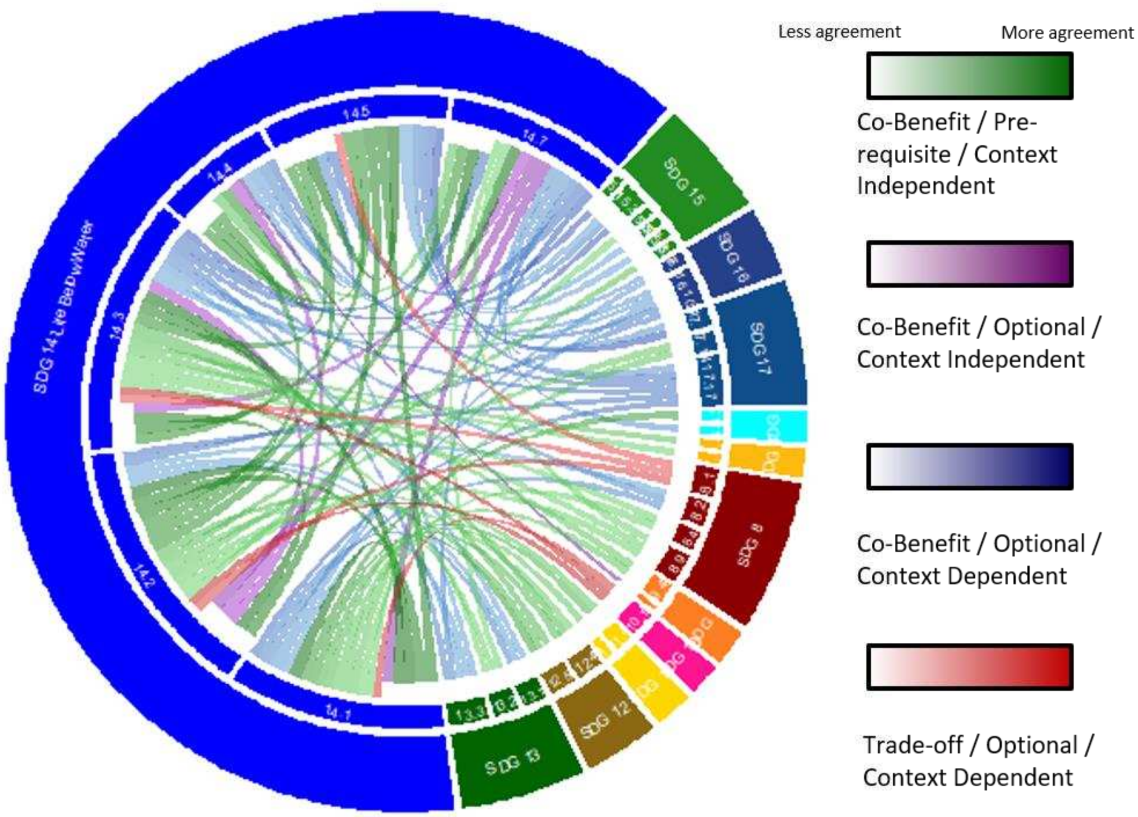

Figure 2: Characterized relationships between all SDGs and SDG Ocean targets. The width of the nodes indicates the number of relationships originating from or receiving connections. Different colors represent different kinds of relationships, and darker shades constitute greater agreement among experts. Only connections with at least 2/3 agreement are shown.

Institutional Design

Considering only direct regulation of SDG ocean targets, ten different agencies regulate the SDG Ocean targets (Figure 3). The Department of Nature and the Environment (DNE) is directly responsible for helping to regulate all SDG Ocean targets (outside of SDG 14.6) and is also connected to the most significant number of other institutions (9) to regulate progress on the SDG Ocean targets collaboratively. Only institutions that are part of the Ministry of Environment and the Ministry of Tourism are considered as management bodies responsible for SDG Oceans targets when relationships among SDGs are not considered. Ten institutions are involved in managing SDG Ocean targets in this scenario.

When considering pre-requisite relationships, the Department of Nature and Environment has responsibilities for the largest number of SDG targets (10, including SDG Oceans targets), and must collaborate with 11 other institutions. However, the Social and Economic Council has responsibility for the most significant number other SDG targets that are required for the achievement of SDG Ocean targets (6). Additionally, the Social and Economic Council is connected to the largest number of other institutions (20) to collaboratively regulate progress on all SDG targets needed to achieve SDG Ocean targets. Six government ministries are involved in managing all the SDG Ocean targets, and relevant SDG targets related to them, in this situation (Figure 3). Thirty-four institutions are engaged in managing SDG Ocean targets in this situation.

When considering all SDG relationships, including maximizing the potential of all co-beneficial relationships as well as avoiding the potential of trade-offs, the Department of Nature and Environment has responsibility for the most significant number of SDG targets (14, including SDG Ocean targets), and must collaborate with 14 other institutions. The Social and Economic Council has responsibility for the largest number of SDG targets not including Ocean SDG targets (13) and must collaborate with 42 other institutions. Eight government ministries are involved in managing all SDG Ocean targets, and relevant SDG targets related to them, in this situation (Figure 3). Sixty-six institutions are engaged in managing SDG Ocean targets in this situation. Using a battery of centrality measures to calculate the most important institution in a network of all institutions and their linkages for this exercise, we find that all centrality measures for the network indicate that the Social and Economic Council is the most important institution in connecting all others (see Table S7).

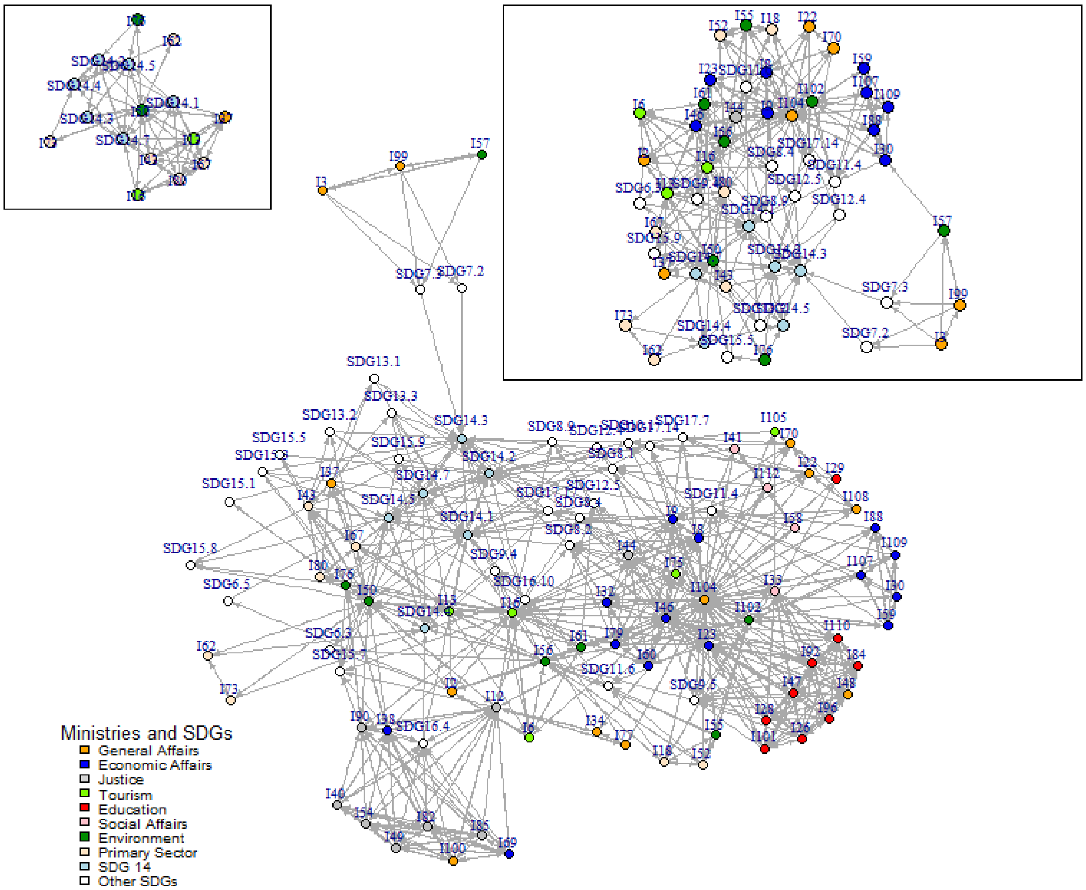

Figure 3. Network diagrams of the institutional structures needed to manage SDG Ocean targets, considering only direct management (upper left inset), considering the SDG targets with co-benefit/pre-requisite/context-independent relationships with SDG Ocean targets (top right inset), and considering all SDG target relationships (main figure). Codes for the different nodes can be found in the Supplementary Materials.

Discussion

Governance structures in support of the SDGs are highly dependent on the relationships of the SDGs to each other, and which kinds of relationships are considered. For societies placing emphasis on achieving the SDGs, institutional designs that increase the probability of SDGs being achieved is relevant (Loorbach 2007; Singh in review). We find that there are very different potential institutional networks to support SDG Ocean targets in Aruba depending on whether SDG relationships are considered or not, whether only co-benefit/pre-requisite relationships are considered (the connections required to achieve the priority desired SDGs), or whether all links are considered including trade-offs and unnecessary but

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helpful co-benefits. Designing these institutional arrangements, however, requires an understanding of which relationships exist and where, as well as the institutional flexibility to rearrange.

Considering Indirect Relationships

Considering the important supporting roles that SDG targets have among each other can shift manager's conclusions about priority management areas. While we found that achieving SDG 14.7 (increasing economic benefits to SIDS) was directly related to the more significant number of all SDGs, this target itself was dependent on several other SDGs, including other SDG Ocean targets. Within SDG Ocean targets the importance of reducing marine pollution (SDG 14.1) became more critical when interactions among SDG Ocean targets were considered. While reducing marine pollution was not directly related to as many other SDGs and SDG targets as increasing economic benefits to SIDs, establishing marine protected areas, and restoring marine ecosystems, and had similar indirect importance scores as these targets for all co-benefits, it was considered a pre-requisite or co-benefit/optional/context-independent condition for many of the other SDG Ocean targets that are themselves pre-requisite requirements for many other SDGs. Most notably, it was the most essential SDG Ocean target for considering direct and indirect context-independent co-benefits for increasing economic benefits to SIDs, which was the most crucial direct contributor of all co-benefits, and co-benefit/pre-requisite relationships with all other SDGs. Considering the importance of both direct and indirect contributions of SDG Ocean targets across all SDGs, the Aruban government may want to prioritize SDG 14.7: increasing economic benefits to SIDS, as well as reducing marine pollution. The final decision will depend on the specific decision context (e.g., if context-independent relationships are considered more critical than context-dependent relationships) and specific SDGs that the Aruban government prioritizes, but we show how assessing SDG relationships may help aid decisions.

Considering Relationships in Two Directions

While the SDG Ocean targets are thought to be important for a variety of other SDGs, the SDG Ocean targets themselves benefit from progress made on other SDGs. In fact, we found that relationships with the highest agreement across experts (at least 2/3 agreement) were co-benefit/pre-requisite/context-independent for other SDGs to SDG Ocean targets, indicating that achieving SDG Ocean targets are dependent on achieving other SDG targets. The other SDGs with the highest number of co-benefits with SDG Ocean targets are making progress on climate action (13), international cooperation (11), peace, justice, and strong institutions (10), land conservation (8), decent work and economic growth (8), and sustainable consumption and consumption (6). Given that in the context of the Aruban workshop "climate action" was assumed to be a global effort to reduce climate change and help mitigate climate impacts, so combined with the importance of international cooperation (SDG 17), global cooperation (SDGs 13 and 17) for Aruban sustainability is very beneficial. These two SDGs also contribute the highest number of co-benefits to SDG 14.1 (reduce marine pollution) and SDG 14.7 (increase economic benefits to SIDS). Aruban efforts to increase ocean sustainability may benefit significantly by the Aruban government engaging in international diplomacy for climate mitigation and international capacity development and technology transfer to Aruba. This recommendation, of course, is dependent on the efficacy of diplomatic means to avoid and mitigate climate impacts and increase international capacity building and technology transfer to Aruba (Keohane and Victor 2016).

Ensuring sustainable consumption and production practices (SDG 12) and achieving decent jobs and economic growth (SDG 8) have the most significant number of pre-requisite co-beneficial relationships with SDG Ocean targets. In particular, SDG Oceans targets are dependent on Aruban economies developing resource efficiencies (SDG 8.4), promoting sustainable tourism (SDG 8.9), reducing waste generation through reduction, recycling, waste prevention and reuse (SDG 12.5). While no targets among SDG 16 (peace, justice, and strong institutions) were considered to be pre-requisite for SDG Ocean targets by a supermajority of experts, there was strong agreement among a supermajority (agreement score 0.71) that achieving policy coherence was a pre-requisite condition for reducing marine pollution and restoring marine habitats, and high agreement (agreement score between 0.5 and 0.66) that it's a pre-requisite condition for all other SDG Ocean targets.

Only two SDGs were thought to produce trade-offs with SDG Ocean targets, and these were all trade-off/optional/context-dependent, meaning that they can be avoided. Sustaining per capital economic growth (SDG 8.1) and progressively achieving income growth of the bottom 40% of the population above national averages (SDG 10.1) were the two SDG targets with potential trade-offs with minimizing ocean pollution (SDG 14.1), marine restoration (SDG 14.2), mitigating ocean acidification impacts (SDG 14.3), and effectively protecting marine areas (SDG 14.5). These relationships are important to consider for policy coherence because if they are not held in check, they could destabilize progress on SDG Ocean targets. Experts indicated governance, economic, and contextual social conditions that regulated whether these relationships would be trade-offs or not. In particular, they pointed to where investment was directed (whether primary, secondary, or tertiary economic sectors were invested in for economic and income growth), whether policies enforcing waste reduction, recycling, and cleaner production practices were followed, and whether more decent consumption practices could be encouraged and followed. Given that Aruba has seen significant economic benefits from oil and gas refining in the near past, as well as the construction of desalinization processing, it may be difficult to avoid going this route again. Though trade-offs may have the potential to be avoided does not mean they are easy to avoid, and Aruba may have to accept the compromises and make decisions on which SDG target is more important, and future decision analysis (such as cost-benefit analysis) may be required to make this decision in an informed way.

The dependency of sustainable oceans on economic and policy strategies as well as social behaviors challenges the common sustainable development model that economies are subsets of the environment and that therefore environmental goals should be prioritized over economic and social goals (Robinson 2004; Griggs et al. 2013; Reid et al. 2017; Singh et al. 2018). Additionally, experts highlighted governance, social, and economic concerns over environmental concerns as regulating whether context-dependencies would be realized (Figures S1, S2). Similar to some findings in previous research on SDG linkages, our evidence suggests that the relationship between economy, environment, and society is reflexive with all three affecting each other and no domain being *a priori* more important than the other (Singh et al. 2018; Singh in press).

Designing Governance Institutions to Maximize the Potential of SDG Relationships

The importance of individual governance institutions, and the collaborative structure between them, to achieve the SDGs can change dramatically if SDG relationships are or are not considered. Achieving specific sustainable development goals will require active collaboration on the part of governance institutions to contribute to the specific targets directly as well as promote co-beneficial SDG targets (Kemp et al. 2005; Loorbach 2010). At the very least, the co-benefit/pre-requisite/context-independent relationships are needed to achieve the specific SDG targets, but avoiding or mitigating trade-offs can be just as important. We found that if SDG relationships were not considered, governance institutions commonly associated with ocean management – for Aruba this is the Department of Nature and the Environment – were responsible for the most SDG ocean targets and also most connected with other governance institutions. However, when SDG relationships that support the SDG Ocean targets were considered, then governance institutions not commonly associated with ocean sustainability – for Aruba this is the Social and Economic Council – were responsible for the most significant number of supportive SDGs (considering cases of only pre-requisite co-beneficial relationships as well as considering all SDG interactions), as well as being the institution that was collaboratively connected to the largest number of other institutions. Designing an integrative and coherent policy for ocean sustainability will require an explicit consideration of which institutions have responsibilities across the suite of sustainable ocean targets, and which institutions are most centrally collaborative across relevant institutions to collaboratively achieve sustainability goals.

The methodology in this study directly addresses the imperative need for institutional and program integration as we increasingly recognize the need for cross-scale and multidisciplinary development goalds. This may eventually require a re-imagining of institutional purviews and relationships but, given historical institutional architectures and inertia, in practice this implies in the short-term an increased awareness of the implications of progress within one institutions' mandate on the outcomes of anothers'. The fundamental benefit of the approach in this study is thus its explicit focus on co-creating a formal and highly detailed map of diverse policy mandates, the institutions tasked with achieving them, and all of the relationships between them. This in effect provides a high-level vantage point of the governance operating space within which other approaches can add more specific actionable information. This can include strengths, weaknesses, opportunities, and threats (SWOT) analysis, which focuses on within-group (or institution) capacity, marine spatial planning (MSP) to allocate and prioritize ocean space, or network analysis to identify key stakeholders for implementing management strategies.

As reflected in our results, governing transitions to sustainable oceans will likely require cohesive planning among multiple governance institutions, which will introduce new challenges (Loorbach 2007; Rotmans et al. 2016). We found that working towards SDG Ocean targets considering all SDG relationships required collaboration across sixty-six institutions in eight ministries. Just accounting for pre-requisite, co-beneficial links required cooperation across thirty-four institutions in six ministries. Only considering SDG Ocean targets directly (most like current ocean planning) required collaboration across ten institutions in 2 ministries. Many governance institutions are siloed and are concerned with institutional boundaries and responsibilities, so creating new collaborative structures could be very difficult (Halpern et al. 2010; Fulton et al. 2014). We chose to link all governance institutions with responsibility to a given SDG target (whether an SDG Ocean target or a target with a relationship to SDG Ocean targets) knowing that this is unlikely, but our emphasis was to highlight the institutions with the greatest potential to connect with and collaborate across institutions given the goal of achieving the SDG Ocean targets. An additional approach is to map the existing formal and informal connections between governance institutions and plan networks of governance institutions to take advantage of existing relationships.

Conclusions

If transitioning to a sustainable future requires initiatives that work across social-ecological dimensions, then nations around the world need to design coherent and integrative policy and collaborative institutional structures to act across social-ecological dimensions. While research exists that propose methods to determine the linkages between SDGs, we argue that research needs to move beyond merely identifying linkages (Singh in review). We propose that SDG linkage research can aid governance planning frameworks such as the Transition Management framework to inform how governance institutions are related to each other and collaborate towards the SDGs. We show that, given the inherent bi-directional nature of SDG relationships, prioritization of SDGs needs to consider the indirect contribution of SDGs towards other SDGs. Additionally, despite research showing the contribution of the ocean towards other SDGs, the SDG Ocean targets are dependent on a diverse set of SDGs.

Contrary to some arguments in the sustainable development literature, we find no evidence that the relationship between environmental, social, and economic dimensions are linear and directional (with the environment at the base) as has been proposed elsewhere (Reid et al. 2017). Instead, we find evidence that while environmental targets influence social and economic dimensions, and we find that ecological targets are influenced by social and economic aspects in a reflexive causal structure (Robinson 2004; Singh in press). Other proposed principles of sustainable development, that highlight the existence of complex interrelationships (Roe 2012), the ability to resist shocks (Folke et al. 2002), and the need for a strategy to move from current conditions to preferred future terms (Broman and Robèrt 2017), are helpful but themselves not enough for effective planning. The prospect that simple, linear, sustainable development models based on a robust environmental condition are incorrect means that planning for sustainable development may not be adequately addressed with general rules, but instead must be based on the best available analysis in context. Future studies to connect sustainability principles to governance planning is needed around the world if we are to pursue the SDGs effectively.

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