Governance Planning for Sustainable Oceans in a Small Island State

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Abstract

Promoting the UN Sustainable Development Goals (SDGs) will require aligning government institutions and must contend with the often siloed nature of institutions within organizations, making the identification of cooperative institutional networks that promote SDGs a priority. We develop and apply a method which combines SDG interlinkage analysis, which helps determine priorities and prerequisites for SDG attainment, with the transition management framework, which aligns policy goals with institutional designs and programs. Using Aruba as a model case study of a small island state with a planning committee for SDG 14 and a current economic reliance on marine tourism, we show that prioritizing increased benefits to SIDS from sustainable development of marine resources includine tourism (SDG 14.7) provides the most direct co-benefits to other SDGs. When considering indirect co-benefits, reducing marine pollution (SDG 14.1) emerged as an key supporting target to achieve other important ocean targets. In order to support sustainable ocean development, we show that Aruba depends on international support through mitigating climate change (SDG 13) and developing international partnerships (SDG 17) as well as promoting sustainable economies (SDG 8), terrestrial conservation (SDG 15), building strong institutions (SDG 16) and promoting sustainable consumption and production practices (SDG 12) domestically. Using SDG interlinkages as a guide for institutional cooperation, we find that the Aruban institutions with the most potential to coordinate action for sustainable ocean development are those that coordinate economic, social, and international policy, rather than institutions specifically focused on environmental policy. Our results provide insight for sustainable development planning across small island states where ocean resources are key for development priorities.

Introduction

The UN Sustainable Development Goals (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). However, the development of planning protocols for strategically achieving the SDGs is elusive, and an emerging major research theme in sustainability science is determining appropriate governance structures to achieve such multi-attribute goals in the face of complex systems (Rotmans et al. 2016; Singh 2020). A governance system dedicated to sustainable development must be organized to act in an interconnected way, regulating the specific linkages among and within domains to promote co-benefits and mitigate trade-offs among SDGs. Here, we propose and implement a governance planning framework to strategically align policy priorities and governance actors to achieve the SDGs.

Siloed policy prescriptions that fail to adopt integrated perspectives across social-ecological systems can be ineffective or counterproductive (Singh et al. 2017), as sustainable development requires cross-scale and, importantly, for operational planning, cross-institutional cooperation (Rotmans et al. 2016; Biermann et al. 2017). As an example of failing to integrate across social-ecological dimensions, policies focused on protecting and growing natural capital can backfire if they enhance social inequalities and ultimately undermine the legitimacy of institutions to resource users (Christie 2004). The importance of social and governance considerations in effective, sustainable development projects is a particularly important issue for the ocean and coastal systems where the top-down enforcement of large ocean spaces can be capacity-limited and voluntary compliance is often essential (Gill et al. 2017). 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 capacity-enhancing subsidies are used to support fishing communities, and this contributes to long-term fisheries decline and collapse (Cisneros-Montemayor et al. 2020). Though our comprehension and ability to represent the complexity that underlies sustainability is increasing, our ability to translate this into effective policy planning and implementation remains elusive.

Our planning method builds on and integrates the transition management framework and literature on SDG interrelationships, two fields that are influential in sustainability studies but have thus far not been integrated. Here, we focus on two scales within the transition management framework, i) strategic scales – the priorities set at the level of values and visions, and ii) tactical scales – the institutions and organizations mandated to achieve the visions (Loorbach 2007; Rotmans et al. 2016). The transition management 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 identifying synergies or trade-offs among SDGs, and the context in which they may occur. (Nilsson et al. 2016; ICSU 2017; Nilsson et al. 2018; Singh et al. 2018). The transition management framework thus provides a structure to plan sustainable development governance, and SDG interlinkage analysis can "map out" the operating space that a governance system will need to function in (Singh 2020). We specifically focus on interlinkage frameworks first trialed for the ocean, that emphasize categorical differences in kinds of interlinkages, and rely on structured expert elicitation and literature review (Singh et al. 2018). We used a transdisciplinary approach combining academic methodologies and local knowledge holders from Aruban civil service and local nonprofits. The categories of the interlinkage framework differtiate where relationships among SDG targets are co-benefits or trade-offs, where a target is a pre-requisite for another or if it is optional for another, and where a relationship holds regardless of context or not.In this study, we identify the SDG targets that government agencies are responsible for and devise collaborative institutional networks to regulate and manage the critical areas that promote or hinder specific SDG Ocean targets. The resulting network represents a new governance system organized around prioritized SDGs and their interconnections.

We develop this planning method for sustainable development planning in Aruba, a Small Island Developing State (SIDS) prioritized within SDG 10 focussing on equality across countries and within SDG 14 focusing on sustainable marine development. Additionally, Aruba has established a government commission (SDG Commission of Aruba) to develop guidance towards achieving the SDGs in the country by forming partnerships across government, non-governmental organizations, and private industry. Around 99% of Aruba's total territory is ocean, which is central to Aruban culture and generates 90% of economic activity through coastal tourism (Vaslet and Renoux 2016). Unsurprisingly, the Aruba SDG commission has prioritized SDG 14: Life Below Water (the 'Oceans' Goal) as the SDG area of most importance for directing national "Blue Economy" plans, and is the SDG topic that disproportionately impacts Aruban industries and culture. Aruba's structured planning for the SDGs makes Aruba a model study country to develop processes to help structure policy and governance systems to promote sustainable development, especially for sustainable development planning in other SIDS.

Results

Prioritizing Ocean Targets

All ocean SDG targets have direct relationships across other SDGs, except for SDG 14.6: eliminating harmful and capacity enhancing fisheries subsidies. Aruba did not provide capacity enhancing fishing subsidies, so no additional consequences were expected from acting on this target. A supermajority of experts identified no trade-off relationships from achieving any SDG ocean targets. Economic benefits to SIDS (SDG 14.7) are associated with the largest number of co-benefits to other SDGs, including the largest number of prerequisite and co-benefits/optional/context-dependent relationships, even when including indirect relationships determined through IO models (Figure 1).

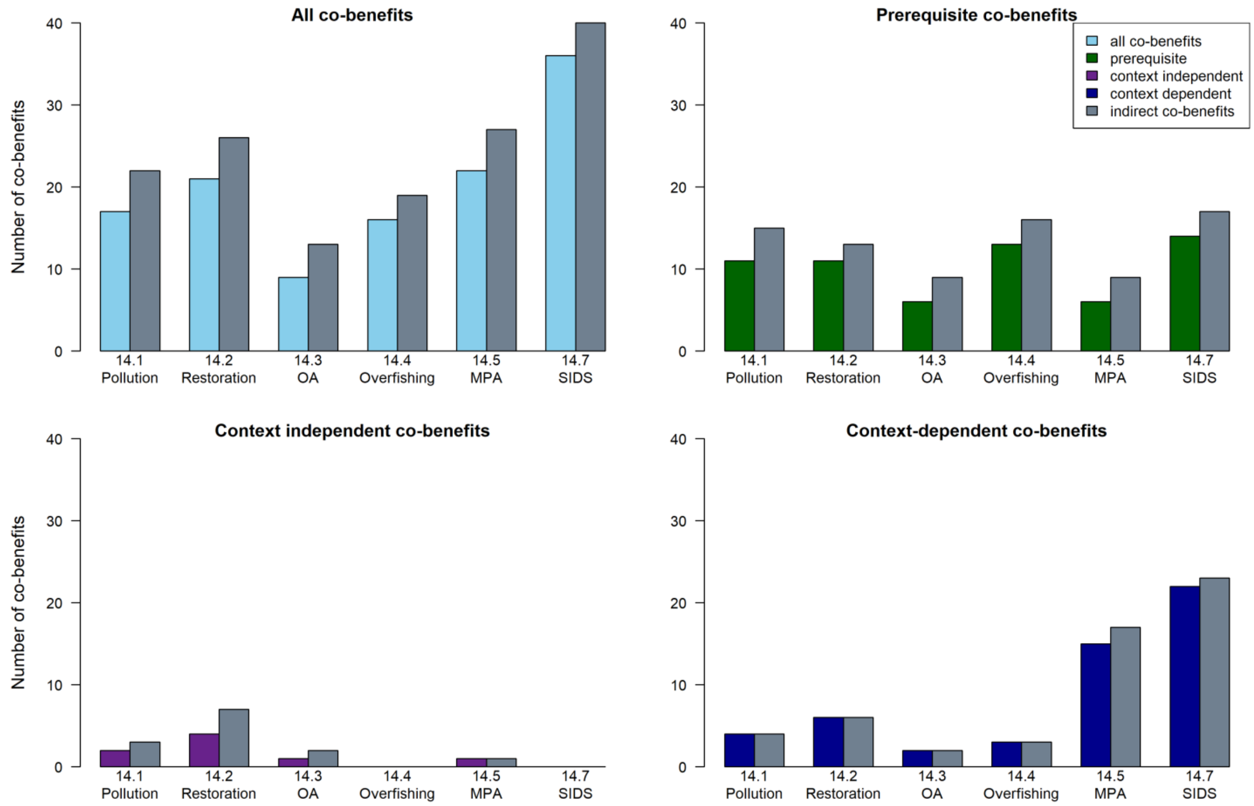

Figure 1. The number of direct co-benefits from each SDG ocean target across all SDGs, and the total (direct + indirect) co-benefits of each SDG ocean target to all SDGs. This figure does not indicate the relationship from other SDGs to SDG ocean targets.

For Aruba, increasing economic benefits to SIDS (SDG 14.7) has direct co-benefits across the largest number of other SDGs (Figure 2), followed by protecting marine areas (SDG 14.5), restoring marine ecosystems (SDG 14.2), and reducing marine pollution (SDG 14.1). This pattern also holds when considering total co-benefits including indirect relationships (Figure 1). Experts determined that all SDG 14 targets benefit from other SDG 14 targets being achieved. SDGs 1 (ending poverty), 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). Experts indicated that governance context (e.g., policy implementation) was the most prominent factor regulating whether context-dependent co-benefits were realized (Figure S1).

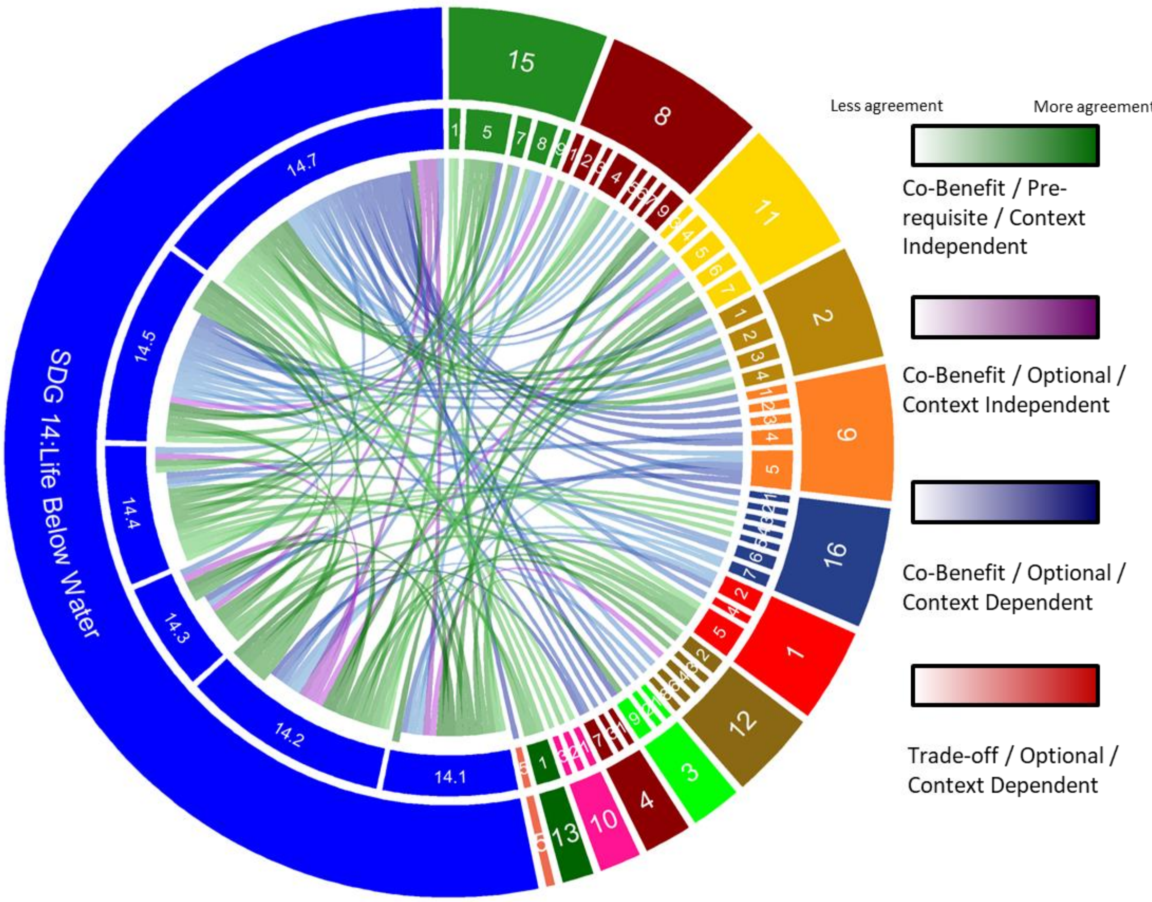

Figure 2. Characterized relationships from SDG Ocean targets to all other SDGs. The width of the nodes indicates the number of relationships originating from or receiving relationships. The origin of a relationship between SDG targets are indented, and the receiving end of the relationship extends out further. Different colors represent different kinds of relationships, and darker shades represent greater agreement among experts. SDGs are ordered by the number of relationships received by SDG Ocean targets, with the SDG with the highest number of receiving co-benefits at the top of the figure and following SDGs ordered clockwise from there. Only relationships with at least 2/3 agreement are shown.

Though increased economic benefits to SIDS (SDG 14.7) was determined to be the most important SDG Ocean target producing co-benefits to other SDGs, through IO models we determined that reducing marine pollution (SDG 14.1) contributes the most towards SDG 14.7 co-benefits among the SDG Ocean targets, considering interdependencies among SDG 14 targets (Table S1). We also found that reducing marine pollution is important in contributing to co-benefits from marine protection (SDG 14.5) and restoration (SDG 14.2) (Table S1). In particular, reducing marine pollution is the most important prerequisite for producing co-benefits through marine restoration (SDG 14.2), reduing acidification impacts (SDG 14.3), and marine protection (SDG 14.5) (Table S2). 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

While the previous analysis revealed the SDG Ocean targets that can contribute to all other SDG targets (directly and indirectly), the SDG Ocean targets also benefit from other SDG targets (Figure 3). Aruba's ability to mitigate impacts from ocean acidification (SDG 14.3) benefitted from the largest number of co-benefits (including global efforts to address climate change, SDG 13), followed by marine restoration (SDG 14.2), marine pollution (SDG 14.1), economic benefits to SIDS (SDG 14.7), and eliminating overfishing (SDG 14.4). Importantly, marine restoration (SDG 14.2), mitigating impacts from ocean acidification (SDG 14.3), and reducing marine pollution (SDG 14.1) require a large number of other SDGs to be achieved (each benefit from ten or more prerequisite co-beneficial relationships). In contrast, the remaining SDG Ocean targets require fewer other SDG targets to be achieved (each requiring five or fewer SDG targets to be achieved). Finally, 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) received tradeoff relationships.

Agreed on by a supermajority of experts, 11 of the 17 SDGs have co-beneficial relationships with the SDG ocean targets (Figure 3). Overall, SDG Ocean targets have the most co-beneficial relationships among each other. Besides SDG Ocean targets, international climate action (SDG 13) and international partnerships (SDG 17) having the most and second most co-beneficial relationships with the SDG Ocean targets. 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 7), and clean water and sanitation (SDG 6). Experts also identified the top two co-beneficial SDGs (climate action and international partnerships) as the most essential prerequisites across the SDG Ocean targets that contribute the most benefits across SDGs (14.7 – sustainable marine development, 14.1 – reducing marine pollution, 14.2 – marine restoration, and 14.5 – marine protection).

Ensuring sustainable consumption and production practices (SDG 12) and achieving decent jobs and economic growth (SDG 8) have the largest number of prerequisite co-beneficial relationships with all SDG Ocean targets. 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/prerequisite/context-independent relationships with SDG Oceans 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 prerequisite for SDG Ocean targets by a supermajority of experts, there was strong agreement among a supermajority (agreement score 0.71) that achieving policy coherence (SDG 17.14) was a prerequisite condition for reducing marine pollution and restoring marine habitats, and high agreement (agreement score between 0.5 and 0.66) that it is a prerequisite condition for all other SDG Ocean 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 greatest 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 S2).

Agreed on by a supermajority of experts, only two SDGs produced tradeoff/optional/context-dependent relationships with SDG Oceans targets: jobs and economy (SDG 8) and reducing inequalities (SDG 10). Sustaining per capita 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 tradeoffs 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). As with co-benefits, experts indicated that the governance context was the most prominent factor regulating whether tradeoffs could be avoided (Figure S2).

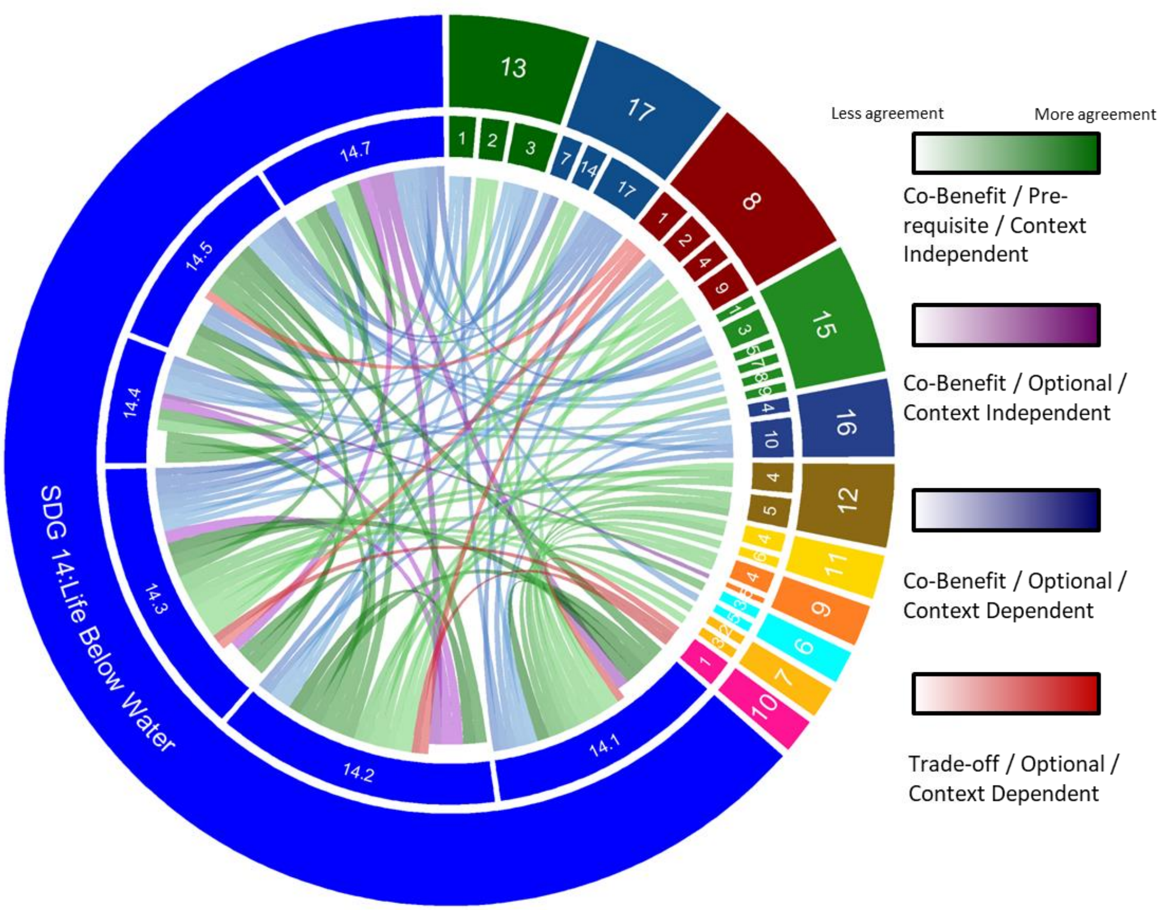

Figure 3: Characterized relationships between all SDGs and SDG Ocean targets. The width of the nodes indicates the number of relationships originating from or receiving connections. Different colors

represent different kinds of relationships, and darker shades constitute greater agreement among experts. SDGs are ordered by the number of co-benefits generated from each SDG to SDG Ocean targets, starting from the top of the figure and moving clockwise. Only relationships with at least 2/3 agreement are shown.

Institutional Design

In a scenario where Aruban institution structure is guided by direct regulation of SDG ocean targets (no SDG relationships guide design), ten agencies must coordinate (Figure 4). The Directorate of Nature and Environment (DNE) is directly responsible for helping to regulate all SDG Ocean targets and is also connected to the largest number of other institutions (9) also responsible for regulating SDG ocean targets. Using a battery of network centrality measures to calculate the most important institution in this scenario (assuming agency importance to be determined by the most connected agency), we find that all the centrality measures indicate that the DNE is the most important institution to coordinate achievement of the SDG Ocean targets (see Figure S4 and Table S7).

In a scenario where Aruban institution structure is guided by considerations of prerequisite relationships where SDG Ocean targets require other SDG targets, 34 Aruban agencies must coordinate (Figure 4). While the DNE is the only Aruban agency directly responsible for all the SDG Ocean targets in this scenario, the Social and Economic Council (SEC) is directly responsible for the largest number of SDG targets that are prerequisites for the SDG Ocean targets (6 SDG targets that are prerequisites). Additionally, in this scenario, the SEC is connected to the largest number of other institutions (20) to collaboratively regulate progress on all SDG targets needed to achieve SDG Ocean targets. Assuming agency importance to be determined by the most connected agency, all the centrality measures indicate that the SEC is the most important institution to coordinate the achievement of the SDG Ocean targets (see Figure S5 and Table S8).

If the institutional structure is instead determined by considerations of all SDG relationships, including gaining from all co-beneficial relationships and avoiding the potential of tradeoffs, 66 agencies must coordinate (Figure 4). Similar to the last scenario, while the DNE is directly responsible for all SDG Ocean targets, the SEC is responsible for the largest number of SDG targets that affect SDG Ocean targets (13 SDG targets), and centrality measures again indicate the SEC as the most important institution to coordinate achievement of the SDG Ocean targets (coordinating 42 other agencies, see Figure S6 and Table S9).

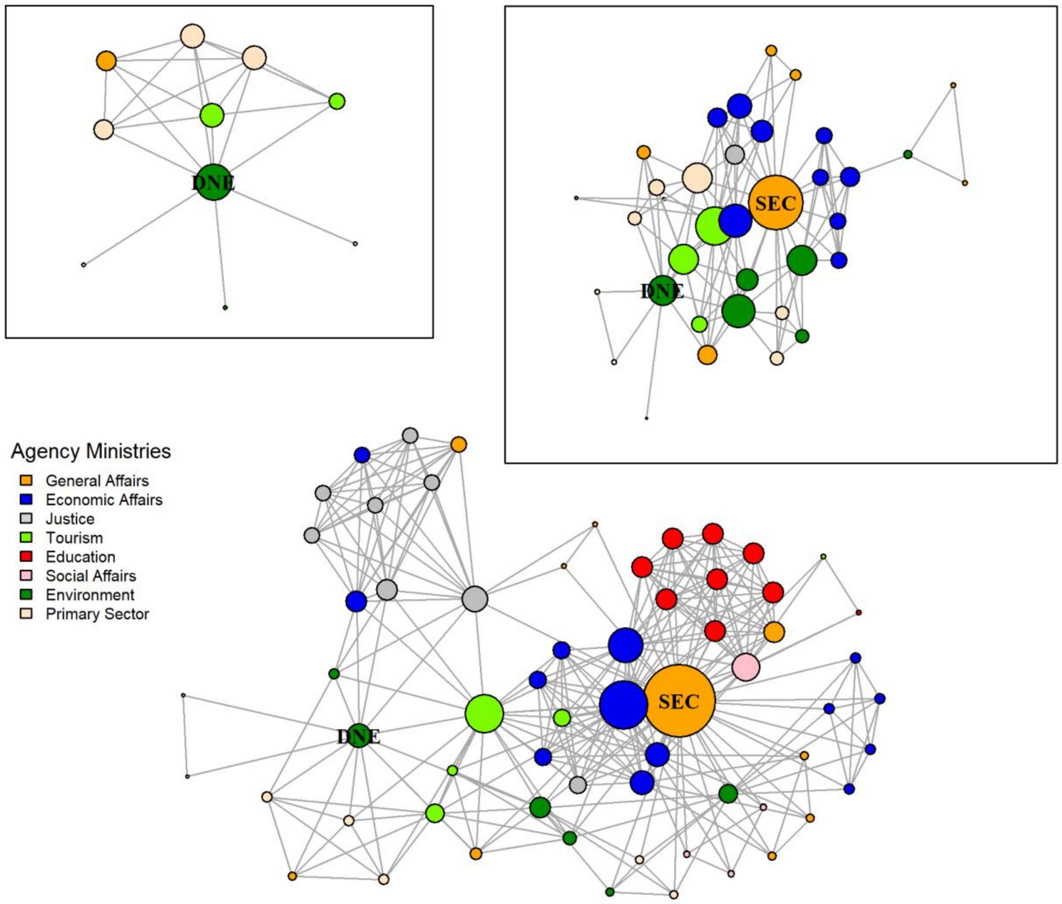

Figure 4. Network diagrams of the institutional structures needed to manage SDG Ocean targets, considering only direct management (upper left inset), considering the SDG targets with co-benefit/prerequisite/context-independent relationships with SDG Ocean targets (top right inset), and considering all SDG target relationships (main figure). The size of the institute nodes is proportional to how many nodes each institution is linked to within each scenario. The Directorate of Nature and Environment (DNE) and the Social and Economic Council (SEC) are labeled in each scenario (though SEC is not part of the direct management scenario).

Discussion

Although we find that sustainable marine use (SDG 14.7) directly contributes the most co-benefits to achieving the SDGs overall in Aruba, considering indirect and cascading contributions shows reducing pollution (SDG 14.1), restoring marine ecosystems (SDG 14.2), and marine protection (SDG 14.3) are also important in providing diverse co-benefits across the SDGs. However, we also determine that these same SDG Ocean targets receive the most co-benefits from achieving other SDGs. Importantly, these SDG Ocean targets are most dependent (as determined by assessing prerequisite relationships) on achieving other SDGs (including consumption and production systems and economic transformation, SDGs 12 and 8, respectively) being realized. In consequence, we found that the most crucial Aruban institution for coordinating regulations to achieve sustainable oceans was not an environmental agency but a socioeconomic agency (the Social and Economic Council). Therefore, while our investigation into the cascading roles of SDG Ocean targets show that environmentally focused targets underpin some of the more economic goals – and in some ways support the frameworks for "environment-based" sustainable development (Griggs et al. 2013; Reid et al. 2017) – we also found evidence against linear models of sustainable development and particularly in an operational context. That is, it may not be enough to consider the natural environment as the base of social and economic pillars of sustainable development, but to consider reflexive or circular models whereby environmental pillars are dependent on social and economic goals as well (Robinson 2004; Singh 2019).

Governance Planning in Small Island States

We found that the non-ocean SDGs with the highest number of co-benefits with SDG Ocean targets are: 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). These results showcase how important global cooperation is for Aruba to achieve ocean sustainable development, given the scale of some key drivers of ocean environmental sustainability and industries and the relative ability of small islands to mitigate their impacts. Aruban efforts to increase ocean sustainability may significantly benefit by increased engagement in international diplomacy for climate mitigation and international capacity development and technology transfer to Aruba (Keohane and Victor 2016). Global efforts to address global ocean change and promote conditions necessary for sustainable development are likely needed across multiple small island states (Bennett et al. 2019), and such states have indeed taken initiatives to plan contextually appropriate actions and establish their own needs and terms for international support (Keen et al. 2018). Proposals for a 'Blue Economy' that is focused on self-identified goals and socially equitable and sustainable ocean industries could be a path forward for national plans of small islands (who coined the term) and for global ocean development (Cisneros-Montemayor et al. 2019). However, our results imply that lack of inclusive international action may stall or even prevent sustainable ocean development in small island states (Bennett et al. 2019; Cisneros-Montemayor et al. 2019).

Only two SDGs were thought to produce tradeoffs with SDG Ocean targets (SDG 8.1 – economic growth, and SDG 10.1 – income growth for the bottom 40% of the population), and these were all tradeoff/optional/context-dependent, meaning that they can be avoided. 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 social context regulated whether these relationships would be tradeoffs 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 cleaner 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, Aruba may choose to reinvest economic opportunities in these industries. The existing infrastructure and immediate economic promises (income and employment) of these industries may provide too important for Aruba to avoid in the future. Though tradeoffs between economic growth and sustainable ocean development 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. Scientific analysis has an important role to play here in helping inform evidence-based policy decisions.

Designing Governance Institutions to Maximize the Potential of SDG Relationships

For societies emphasizing the SDGs, institutional designs that increase the probability of SDGs being achieved are relevant (Loorbach 2007; Singh 2020). 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/prerequisite relationships are considered (the connections required to achieve the priority desired SDGs), or whether all links are considered including tradeoffs and co-benefits. Designing these institutional arrangements, however, requires an understanding of which relationships exist and where, as well as the institutional flexibility to rearrange.

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/prerequisite/context-independent relationships are needed to achieve the specific SDG targets, but avoiding or mitigating tradeoffs can be critically important. We found that if SDG relationships were not considered, governance institutions commonly associated with ocean management – for Aruba, this is the Directorate of Nature and the Environment – was responsible for the most SDG ocean targets and also most connected with other governance institutions. This scenario – with ocean and environment agencies specifically regulating ocean use without clear collaboration with other economic and social agencies – is a common system of ocean governance and management around the world (Halpern et al. 2010; Singh et al. 2020). 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 – was responsible for collaboratively connecting with the largest number of other institutions in order to achieve sustainable ocean development. Given the effects that economic development has on the ocean (through pollution, coastal development, and others) and the growing recognition of the importance of the land-sea interface (Halpern et al. 2008; Cottrell et al. 2019), we believe that similar situations may exist around the world – where economic and social agencies can play central roles to ensure ocean sustainability. 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 goals. This method 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 another' (Loorbach 2010; Munck af Rosenschöld et al. 2014). Raising awareness of policy coordination among institutions has been documented to be essential, though an insufficient component of successful development policy, especially awareness-raising in institutions not traditionally considered as development agencies (CEC 2009). 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. Though our study considered the SDG targets as written, this approach can be used for different interpretations of sustainable development aspirations and policy as well. This approach, in effect, provides a high-level vantage point of the governance operating space within which other methods can add more specific actionable information. These methods can include strengths, weaknesses, opportunities, and threats (SWOT) analysis, which focuses on within-group (or institution) capacity (Freire-Gibb et al. 2014), marine spatial planning (MSP) to allocate and prioritize ocean space (Douvere 2008), and network analysis to identify key stakeholders for implementing specific management strategies (Farmery et al. 2020).

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 prerequisite, co-beneficial links required cooperation across thirty-four institutions in six ministries. By contrast, 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), however without bridging these boundaries society’s ability to achieve the SDGs may be limited or even impossible (as defined by prerequisite relationships). Our scenario approach links all governance institutions with the responsibility to a given SDG target (whether an SDG Ocean target or a target with a relationship to SDG Ocean targets), knowing that having a full complement of links is unlikely. However, 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 alternative approach would be to map the existing formal and informal connections between governance institutions and plan networks of governance institutions to take advantage of existing relationships. However, this would be a different aim from ours. Our study demonstrates a framework that delivers on the promise of SDG interlinkages helping governments and agencies plan to address SDGs (Stafford-Smith et al. 2017; Singh 2020).

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. We argue that research needs to move beyond merely identifying linkages (Singh 2020), towards aiding governance planning frameworks such as the transition management framework to inform how governance institutions are related to each other and can 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 (Singh et al. 2018), the SDG Ocean targets are dependent on a diverse set of SDGs.

Contrary to some arguments in the sustainable development literature, we find little 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 (Folke et al. 2016; Reid et al. 2017). Instead, we find evidence that while environmental targets influence social and economic dimensions, they are themselves influenced by social and economic aspects—and policy goals—in a reflexive causal structure (Robinson 2004; Singh 2019). 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 conditions (Broman and Robèrt 2017), are helpful but themselves not enough for effective planning. The SDGs can be an aspirational as well as an operational set of guidelines, but the latter will require specific and evidence-based connections between sustainability principles and governance planning to create governance systems to achieve these goals.

Methods

Overview

This study follows three steps along the planning structure of the transition management framework. First, we undertook an expert elicitation process to prioritize SDG Ocean targets based on each target's contribution to other SDG targets, including direct, indirect, and cascading effects. Second, we determine interrelationships between all other SDGs and SDG Ocean targets, paying particular attention to SDG targets deemed necessary to achieve SDG 14 targets. This information effectively outlines the strategic policy arena according to the transition management framework (Singh 2020) and indicates the scope of social-ecological relationships that a governance system must be built around. Finally, we identify the SDG areas that different Aruban government agencies are responsible for regulating action towards and identify scenarios of institutional networks that are informed by SDG relationships. These scenarios connect the strategic and tactical scales within the transition management framework (Singh 2020).

Aruba and the SDGs

Marine tourism is the main economic driver in Aruba. 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—including food and fuel—and has raised the quality of life on the island, as measured by the Human Development Index (Ridderstaat et al. 2016). Other (much smaller) industries on the island include other sectors of the ocean economy, such as fisheries, wind energy, and desalinization plant, in addition to agriculture and an oil refinery.

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 a need to address problems with marine pollution (SDG 14.1) and coastal habitat loss (SDG 14.2), such as through mangrove removal. Ocean acidification (SDG 14.3) affects marine life around Aruba, though there is little tourism based on charismatic marine habitats such as coral reefs. Fisheries are a small industry in Aruba, and their management (SDG 14.4) is not seen as a key challenge, and no capacity-enhancing subsidies are provided to fishers (in compliance with SDG

14.6). Aruba has a terrestrial 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 protected areas, but these protected areas do not extend into the ocean (SDG 14.5). Though marine tourism has such high economic value, it currently is not necessarily sustainable (part of the focus of SDG 14.7) as tourism in Aruba 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 maximizing the production of co-beneficial relationships across 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 tradeoffs with ocean targets. While the first objective was set to determine ocean priorities, the second was to understand the SDG support structure needed to ensure that ocean priorities can be met. Determining the structure of Aruban institutions required to support ocean SDG priorities relies on this latter objective being completed.

The workshop was held over ten days, with dedicated sessions on the relationships and effects of progress on the SDG Ocean's targets to other SDG targets and vice versa. The beginning of the workshop focused on assessing the contribution of the seven SDG 14 targets across the 169 SDG targets (across all SDGs), and the second half of the workshop focused on determining the contribution of each of the 169 SDG targets to the seven SDG 14 targets. Each session lasted approximately one hour and utilized the rapid assessment framework 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 prerequisite 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 a specific context;
- tradeoff prerequisite context-independent, whereby the first SDG target is a necessary condition to detract from the second SDG target;
- tradeoff 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;
- tradeoff 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.

While the framework we use considers the SDG targets as written in the SDGs, 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 merely considering the outcomes of national-level climate change reduction, adaptation, and mitigation efforts within Aruba. Finally, SDG 14.7 is about increasing economic benefits to SIDS and least developed countries from the sustainable use of marine resources (including tourism) on a global scale. Since Aruba is a SIDS nation, this target was considered at a national scale for promoting sustainable marine development in fisheries, aquaculture, and (importantly) tourism. In fact, many participants mainly considered growth in sustainable tourism with regard to this target.

A total of 20 experts took part in the workshops, 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 nonprofits and the civil service in various ministries of Aruba, including economic development, parks, ministry of environment, as well as the Aruban SDG commission – a special government commission set up explicitly to promote the SDGs within the country. Experts were chosen with diverse backgrounds to prevent a particular viewpoint from dominating expert responses (Fish et al. 2009) and to capture expertise across the SDG focus areas systematically. Beyond this systematic approach, experts also 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). Experts indicated agreement with the findings, 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 (Burgman et al. 2011; 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 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 the financial, market, income, and labor 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 five thought the relationship was co-benefit/optional/context-independent. The remaining two thought the relationship was co-benefit/prerequisite/context-independent. The relationship was coded as co-benefit/optional/context-dependent, with an agreed level of 0.75 (15/20). Similarly, if out of 20 experts, five experts thought a relationship was co-benefit/optional/context-dependent, two thought the relationship was co-benefit/optional/context-independent. 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 adopted Input-Output (IO) models. This method is ordinarily 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). We adapt this method 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 using the formula

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

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/prerequisite relationships, and only co-benefit/optional/context-dependent relationships. Co-benefit/prerequisite 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 could not consider their interaction/indirect contributions to the ocean targets, because we did not look at how all other SDGs interacted with each other. We, therefore, summed the number of the different kinds of co-beneficial and tradeoff 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. During the vetting period, no experts identified disagreement with the findings, and some provided extra context to describe findings. After vetting, we compiled our final dataset of SDG relationships. SDG relationships were graphically represented in circos 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 five 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. We did not include the SDG Commission of Aruba in this analysis because they have no regulatory authority over the SDG areas but instead are responsible for connecting with business and non-governmental organizations to promote the SDGs. This list was sent to the experts from the earlier workshop (who collectively work in, or have considerable experience or familiarity with, all the Aruban ministries), 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 that 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/prerequisite relationships were considered (as they are needed to achieve the ocean SDG targets), and a case where all SDG relationships were considered. The case where only direct institutional regulation was considered most strongly resembles the current situation. The prerequisite situation models an institutional structure minimally needed to ensure the achievement of the SDG ocean targets. Finally, 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 tradeoffs.

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 assumption may not be realistic, but we are interested in how SDG interlinkages change institutional design rather than assessing 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 in R 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).

References

Ashtinani, M. (2019). CINNA: Deciphering central infomative nodes in network analysis, R package version 1.1.53.

Ban, S. S., R. L. Pressey and N. A. Graham (2015). "Assessing the effectiveness of local management of coral reefs using expert opinion and spatial Bayesian modeling." PloS one **10**(8): e0135465.

Bennett, N. J., A. M. Cisneros-Montemayor, J. Blythe, J. J. Silver, G. Singh, N. Andrews, A. Calò, P. Christie, A. Di Franco and E. M. Finkbeiner (2019). "Towards a sustainable and equitable blue economy." Nature Sustainability: 1-3.

Biermann, F., N. Kanie and R. E. Kim (2017). "Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals." Current Opinion in Environmental Sustainability **26**: 26-31.

Broman, G. I. and K.-H. Robèrt (2017). "A framework for strategic sustainable development." Journal of Cleaner Production **140**: 17-31.
Brown, B. B. (1968). Delphi process: A methodology used for the elicitation of opinions of experts, RAND Corp Santa Monica CA.
Burgman, M. (2005). Risks and decisions for conservation and environmental management, Cambridge University Press.
Burgman, M. A., M. McBride, R. Ashton, A. Speirs-Bridge, L. Flander, B. Wintle, F. Fidler, L. Rumpff and C. Twardy (2011). "Expert status and performance." PloS one **6**(7): e22998.
CEC (2009). EU 2009 report on policy coherence for development. Commission staff working document accompanying the report of the Commission to the Council, European Union**:** 211 pp.
Christie, P. (2004). Marine protected areas as biological successes and social failures in Southeast Asia. American fisheries society symposium, Citeseer.
Cisneros-Montemayor, A. M., M. Moreno-Báez, M. Voyer, E. H. Allison, W. W. L. Cheung, M. Hessing-Lewis, M. A. Oyinlola, G. G. Singh, W. Swartz and Y. Ota (2019). "Social equity and benefits as the nexus of a transformative Blue Economy: A sectoral review of implications." Marine Policy **109**: 103702.
Cisneros-Montemayor, A. M., Y. Ota, M. Bailey, C. C. Hicks, A. S. Khan, A. Rogers, U. R. Sumaila, J. Virdin and K. K. He (2020). "Changing the narrative on fisheries subsidies reform: Enabling transitions to achieve SDG 14.6 and beyond Andrés M. Cisneros-Montemayor." Marine Policy: 103970.
Cottrell, R. S., K. L. Nash, B. S. Halpern, T. A. Remenyi, S. P. Corney, A. Fleming, E. A. Fulton, S. Hornborg, A. Johne and R. A. Watson (2019). "Food production shocks across land and sea." Nature Sustainability **2**(2): 130-137.
Csardi, G. and T. Nepusz (2006). "The igraph software package for complex network research." Interjournal, Complex Systems: 1695.
Csárdi, G. and J. Weiner (2017). Sankey: Illustrate the flow of information or material, R package version 1.0.2.
Douvere, F. (2008). "The importance of marine spatial planning in advancing ecosystem-based sea use management." Marine Policy **32**(5): 762-771.
Farmery, A. K., L. Kajlich, M. Voyer, J. R. Bogard and A. Duarte (2020). "Integrating fisheries, food and nutrition–Insights from people and policies in Timor-Leste." Food Policy: 101826.
Fish, R., M. Winter, D. M. Oliver, D. Chadwick, T. Selfa, A. L. Heathwaite and C. Hodgson (2009). "Unruly pathogens: eliciting values for environmental risk in the context of heterogeneous expert knowledge." Environmental Science & Policy **12**(3): 281-296.
Folke, C., R. Biggs, A. V. Norström, B. Reyers and J. Rockström (2016). "Social-ecological resilience and biosphere-based sustainability science." Ecology and Society **21**(3).
Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. S. Holling and B. Walker (2002). "Resilience and sustainable development: building adaptive capacity in a world of transformations." AMBIO: A journal of the human environment **31**(5): 437-441.
Freire-Gibb, L. C., R. Koss, P. Margonski and N. Papadopoulou (2014). "Governance strengths and weaknesses to implement the marine strategy framework directive in European waters." Marine Policy **44**: 172-178.
Fulton, E. A., A. D. Smith, D. C. Smith and P. Johnson (2014). "An integrated approach is needed for ecosystem based fisheries management: insights from ecosystem-level management strategy evaluation." PloS one **9**(1): e84242.
Gill, D. A., M. B. Mascia, G. N. Ahmadia, L. Glew, S. E. Lester, M. Barnes, I. Craigie, E. S. Darling, C. M. Free and J. Geldmann (2017). "Capacity shortfalls hinder the performance of marine protected areas globally." Nature **543**(7647): 665-669.

Griggs, D., M. Stafford-Smith, O. Gaffney, J. Rockström, M. C. Öhman, P. Shyamsundar, W. Steffen, G. Glaser, N. Kanie and I. Noble (2013). "Policy: Sustainable development goals for people and planet." Nature **495**(7441): 305.
Gu, Z. (2014). "Circlize implements and enhances circular visualization in R." Bioinformatics **30**(19): 2811-2812.
Halpern, B. S., S. E. Lester and K. L. McLeod (2010). "Placing marine protected areas onto the ecosystem-based management seascape." Proceedings of the National Academy of Sciences **107**(43): 18312-18317.
Halpern, B. S., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert and H. E. Fox (2008). "A global map of human impact on marine ecosystems." Science **319**(5865): 948-952.
Husson, F., S. Lê and J. Pagès (2017). Exploratory multivariate analysis by example using R, Chapman and Hall/CRC.
ICSU (2017). A guide to SDG interactions: from science to implementation, International Council for Science, Paris.
Keen, M. R., A.-M. Schwarz and L. Wini-Simeon (2018). "Towards defining the Blue Economy: Practical lessons from pacific ocean governance." Marine Policy **88**: 333-341.
Kemp, R., S. Parto and R. B. Gibson (2005). "Governance for sustainable development: moving from theory to practice." International journal of sustainable development **8**(1-2): 12-30.
Keohane, R. O. and D. G. Victor (2016). "Cooperation and discord in global climate policy." Nature Climate Change **6**(6): 570.
Leontief, W. W. (1951). "Input-Output Economics." Scientific American **185**(4): 15-21.
Loorbach, D. (2007). "Transition management." New mode of governance for sustainable development. Utrecht: International Books.
Loorbach, D. (2010). "Transition management for sustainable development: a prescriptive, complexity-based governance framework." Governance **23**(1): 161-183.
Martin, T. G., M. A. Burgman, F. Fidler, P. M. Kuhnert, S. Low-Choy, M. McBride and K. Mengersen (2012). "Eliciting expert knowledge in conservation science." Conservation Biology **26**(1): 29-38.
Munck af Rosenschöld, J., J. G. Rozema and L. A. Frye-Levine (2014). "Institutional inertia and climate change: a review of the new institutionalist literature." Wiley Interdisciplinary Reviews: Climate Change **5**(5): 639-648.
Nilsson, M., E. Chisholm, D. Griggs, P. Howden-Chapman, D. McCollum, P. Messerli, B. Neumann, A.-S. Stevance, M. Visbeck and M. Stafford-Smith (2018). "Mapping interactions between the sustainable development goals: lessons learned and ways forward." Sustainability science **13**(6): 1489-1503.
Nilsson, M., D. Griggs and M. Visbeck (2016). "Policy: map the interactions between Sustainable Development Goals." Nature News **534**(7607): 320.
Reid, A. J., J. L. Brooks, L. Dolgova, B. Laurich, B. G. Sullivan, P. Szekeres, S. L. Wood, J. R. Bennett and S. J. Cooke (2017). "Post-2015 Sustainable Development Goals still neglecting their environmental roots in the Anthropocene." Environmental Science & Policy **77**: 179-184.
Ridderstaat, J., R. Croes and P. Nijkamp (2016). "The Tourism Development–Quality of Life Nexus in a Small Island Destination." Journal of Travel Research **55**(1): 79-94.
Robinson, J. (2004). "Squaring the circle? Some thoughts on the idea of sustainable development." Ecological economics **48**(4): 369-384.
Roe, E. (2012). Taking complexity seriously: policy analysis, triangulation and sustainable development, Springer Science & Business Media.
Rotmans, J., D. Loorbach and R. Kemp (2016). Complexity and Transition Management. Complexity and Planning, Routledge: 195-216.

Singh, G. G. (2019). Can aspirations lead us to the oceans we want? Predicting Future Oceans, Elsevier**:** 405-416.
Singh, G. G. (2020). "Determining a path to a destination: pairing strategic frameworks with the Sustainable Development Goals to promote research and policy." Evolutionary and Institutional Economics Review.
Singh, G. G., A. M. Cisneros-Montemayor, W. Swartz, W. Cheung, J. A. Guy, T.-A. Kenny, C. J. McOwen, R. Asch, J. L. Geffert and C. C. Wabnitz (2018). "A rapid assessment of co-benefits and trade-offs among Sustainable Development Goals." Marine Policy **93**: 223-231.
Singh, G. G., I. M. S. Eddy, B. S. Halpern, R. Neslo, T. Satterfield and K. M. A. Chan (2020). "Mapping cumulative impacts to coastal ecosystem services in British Columbia." PloS one **15**(5): e0220092.
Singh, G. G., J. Sinner, J. Ellis, M. Kandlikar, B. S. Halpern, T. Satterfield and K. Chan (2017). "Group elicitations yield more consistent, yet more uncertain experts in understanding risks to ecosystem services in New Zealand bays." PloS one **12**(8): e0182233.
Singh, G. G., J. Sinner, J. Ellis, M. Kandlikar, B. S. Halpern, T. Satterfield and K. M. Chan (2017). "Mechanisms and risk of cumulative impacts to coastal ecosystem services: An expert elicitation approach." Journal of environmental management **199**: 229-241.
Stafford-Smith, M., D. Griggs, O. Gaffney, F. Ullah, B. Reyers, N. Kanie, B. Stigson, P. Shrivastava, M. Leach and D. O'Connell (2017). "Integration: the key to implementing the Sustainable Development Goals." Sustainability science **12**(6): 911-919.
UN (2015). "Transforming our world: The 2030 agenda for sustainable development." Resolution adopted by the General Assembly.
Van Der Maaten, L. (2014). "Accelerating t-SNE using tree-based algorithms." The Journal of Machine Learning Research **15**(1): 3221-3245.
Vaslet, A. and R. Renoux (2016). EU Outermost Regions and Overseas Countries and Terrirories, Regional ecosystem profile - Caribbean Region., BEST**:** 261 pp+265 Appendices.
WTTC (2019). Aruba 2019 Annual Research: Key Highlights.

Supplementary Materials

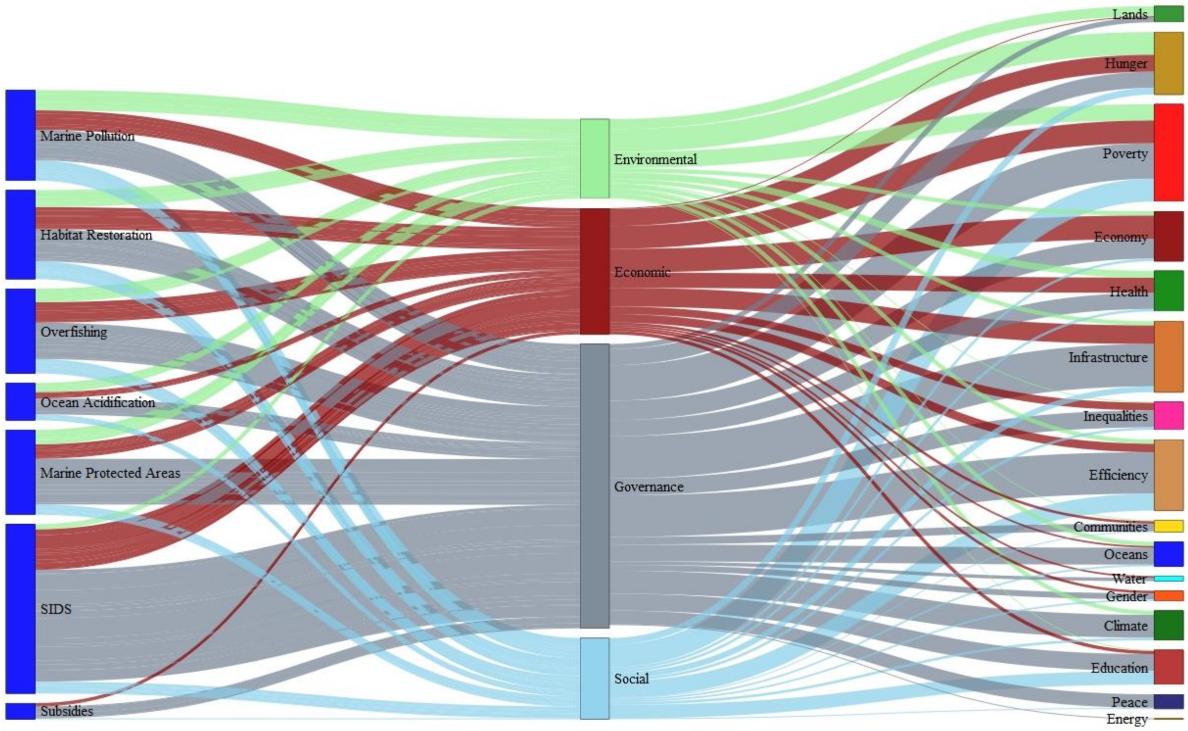

Figure S1. The four dimensions (economic, governance, environmental, and social) that regulate whether context-dependent relationships are realized from SDG Ocean targets to other SDGs

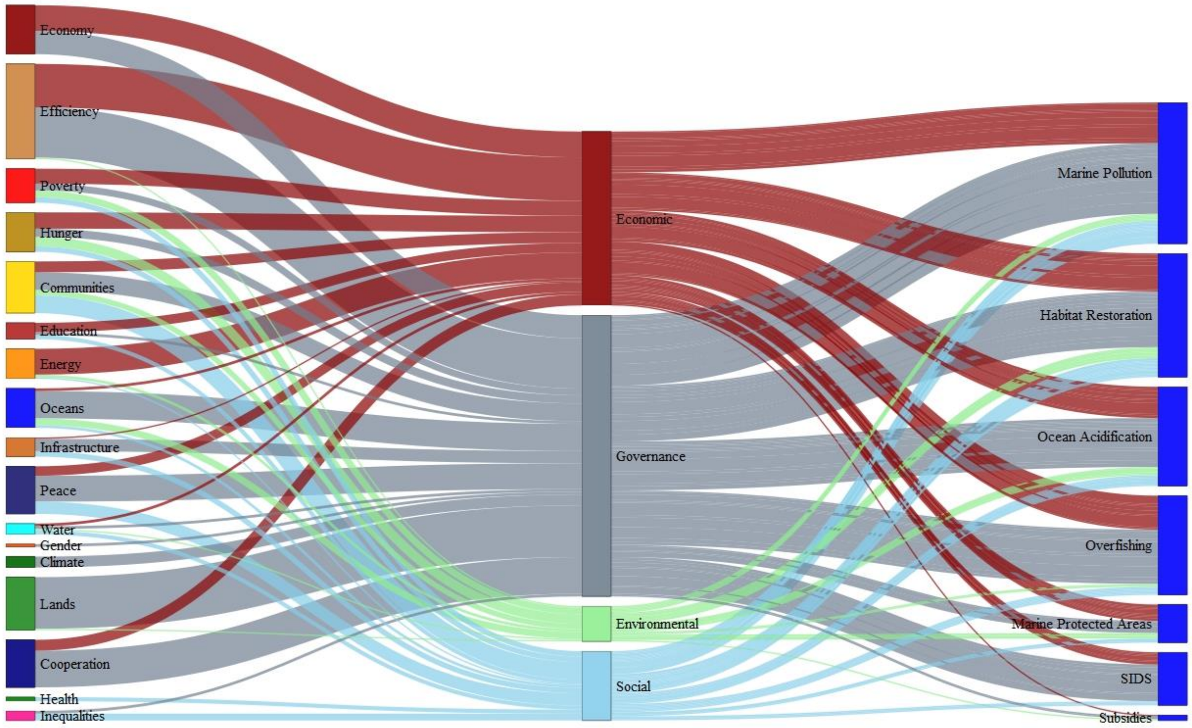

Figure S2. The four dimensions (economic, governance, environmental, and social) that regulate whether context-dependent relationships are realized from other SDGs to SDG Ocean targets

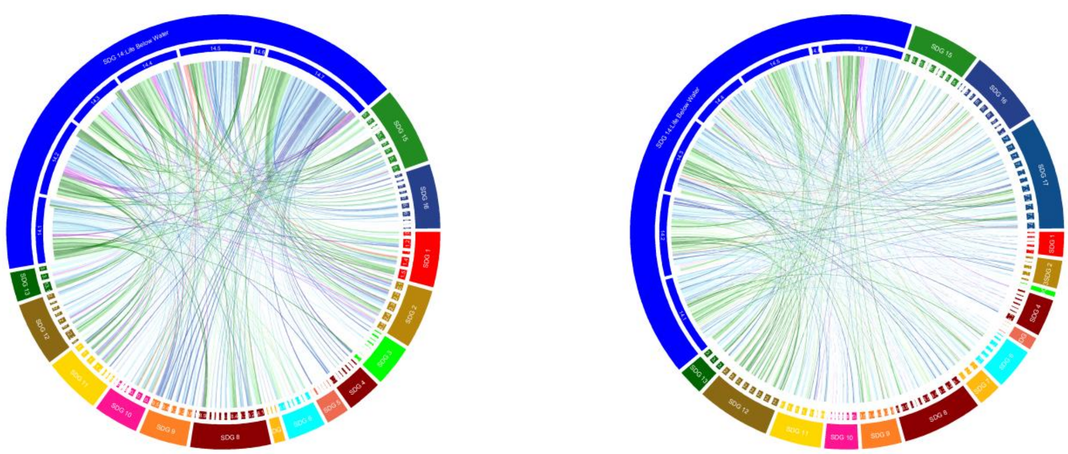

Figure S3. All relationships accounted for all expert input, including relationships with less than 2/3 support. The left figure is from SDG Ocean targets to other SDGs, and the right is from other SDGs to SDG Ocean targets.

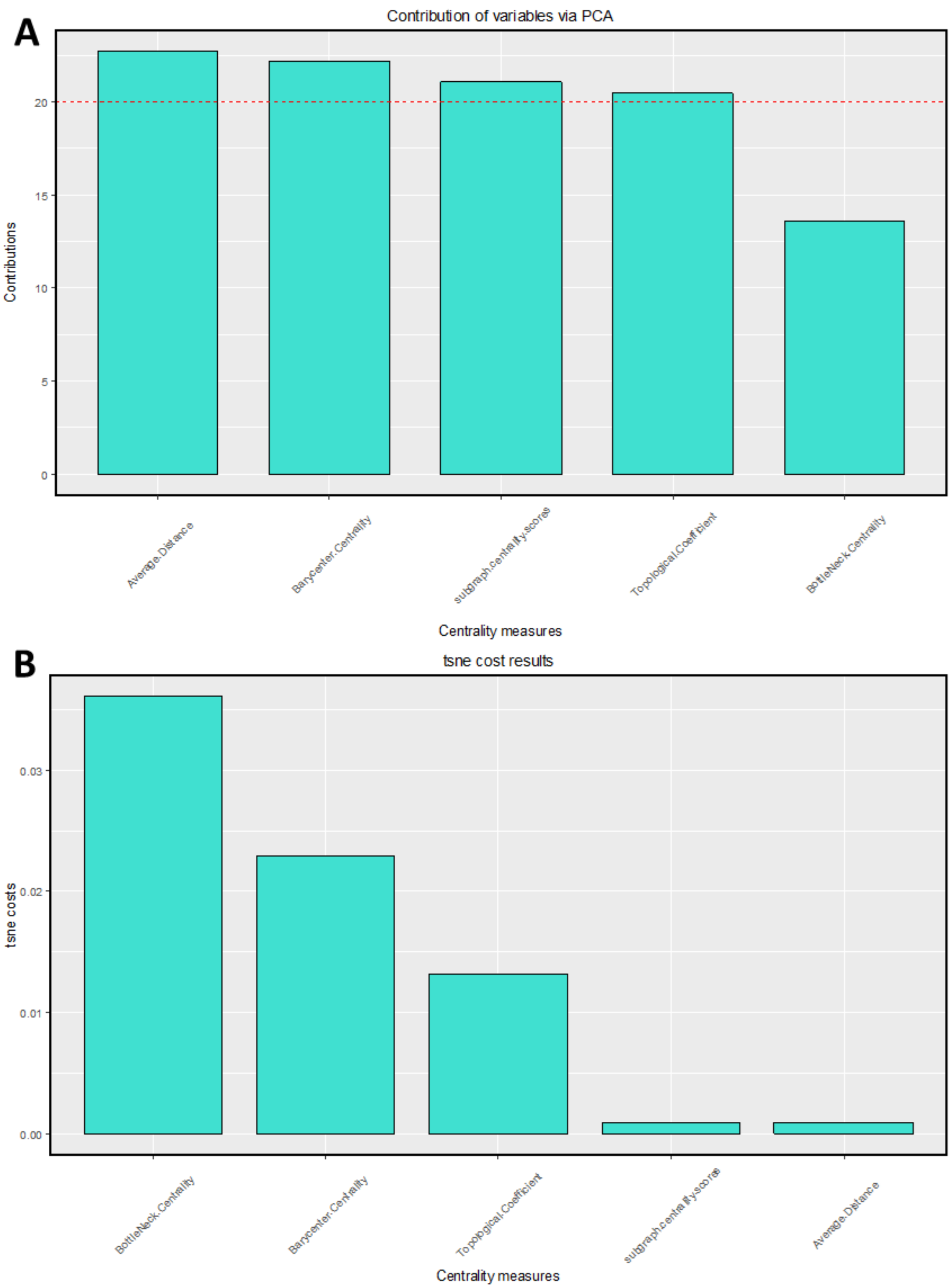

Figure S4. The centrality measures that were most informative for analyzing institutional metrics, according to A) PCA and B) t-Distributed Stochastic Neighbor Embedding analysis, in a scenario where no relationships between SDG targets and SDG Ocean targets are considered.

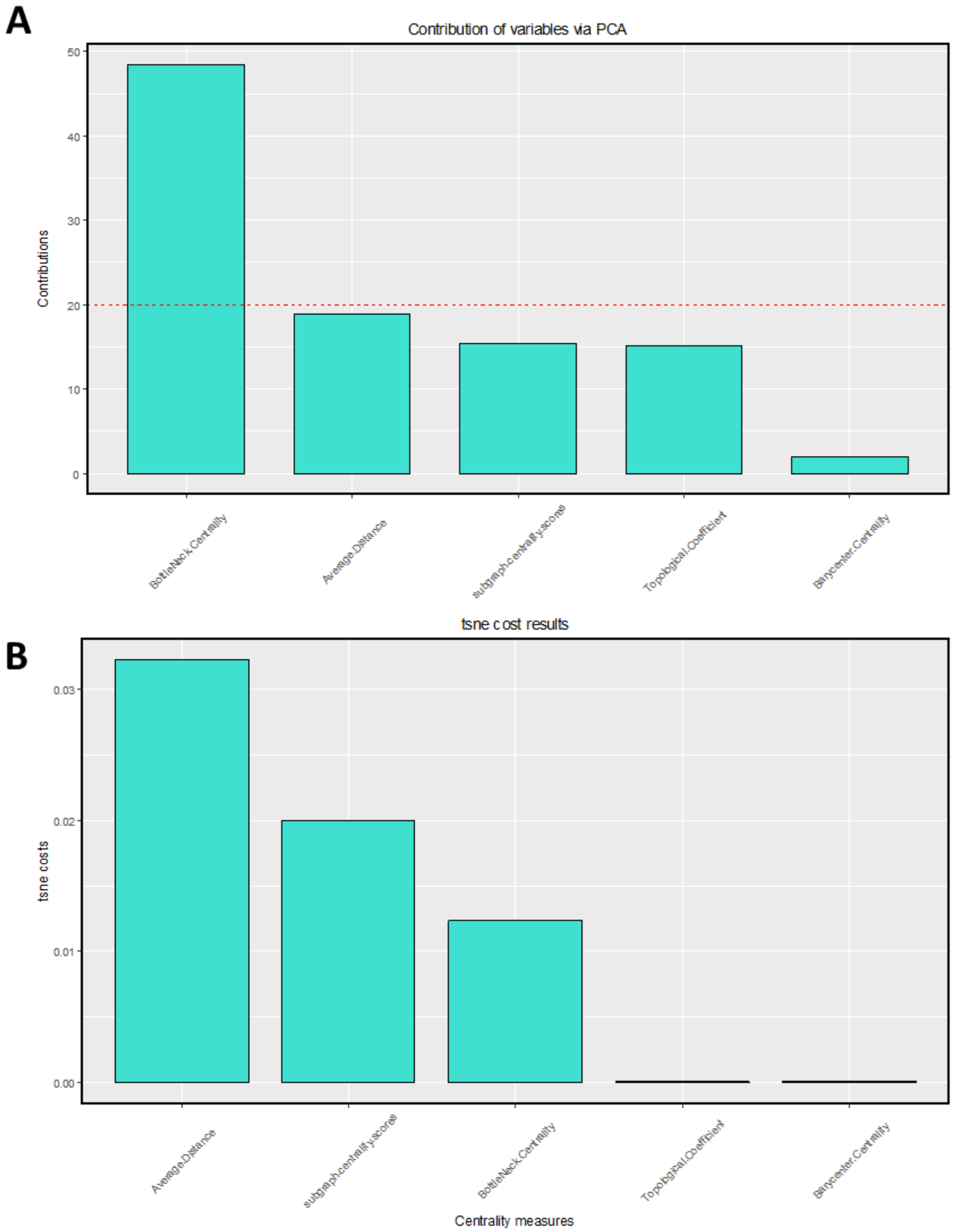

Figure S5. The centrality measures that were most informative for analyzing institutional metrics, according to A) PCA and B) t-Distributed Stochastic Neighbor Embedding analysis, in a scenario where prerequisite relationships between SDG targets and SDG Ocean targets are considered.

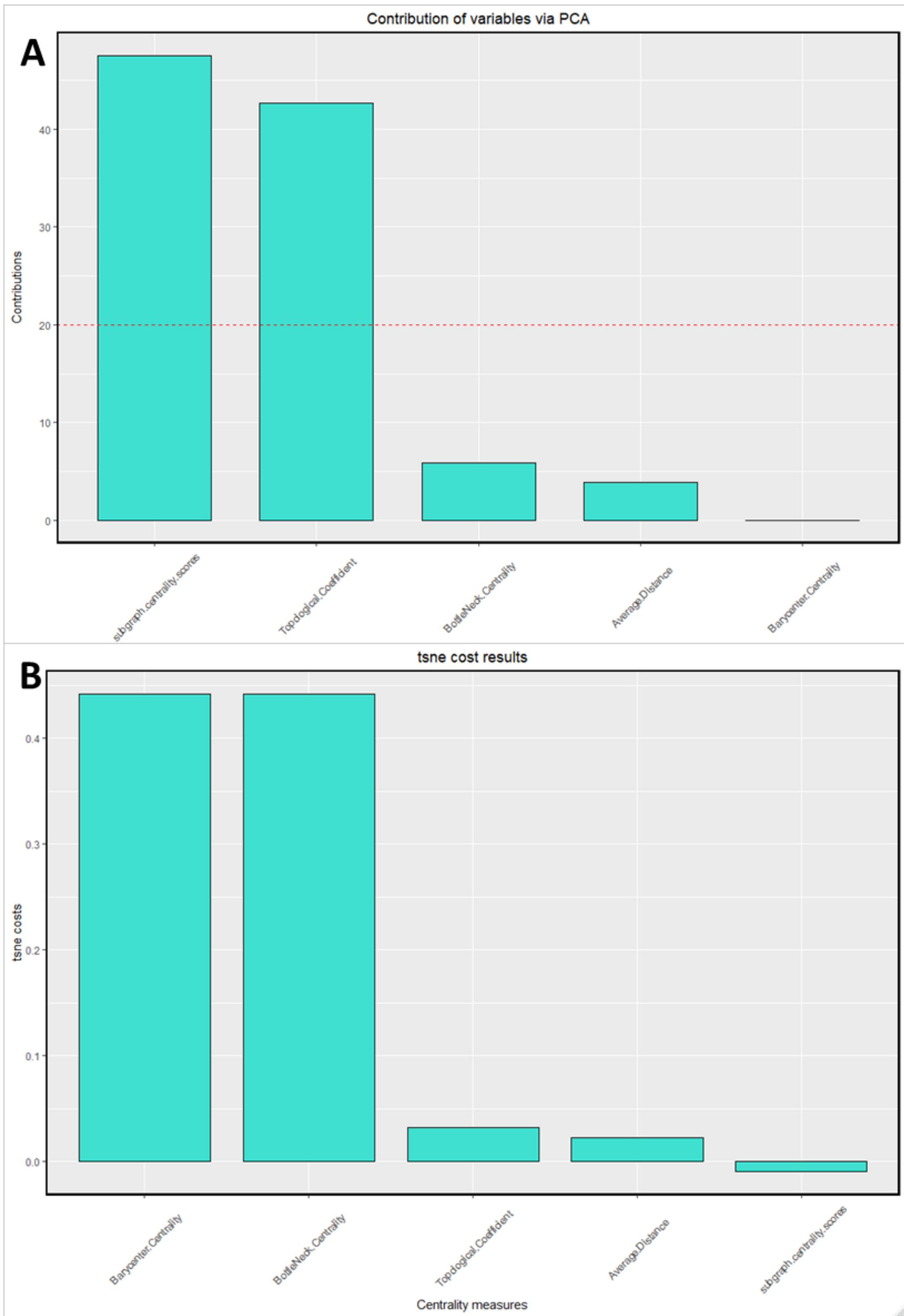

Figure S6. The centrality measures that were most informative for analyzing institutional metrics, according to A) PCA and B) t-Distributed Stochastic Neighbor Embedding analysis, in a scenario where all co-benefits and tradeoffs between SDG targets are considered.

Table S1. Leontief inverse matrix of indirect co-benefit production for all co-benefits for SDG Ocean targets

	SDG1	SDG2	SDG3	SDG4	SDG5	SDG7
SDG1	1.047619	0.049226	0.097907	0.007071	0.046224	0.03182
SDG2	0	1.049332	0.093851	0.062567	0.046375	0.030501
SDG3	0	0.046988	1.093457	0.006749	0.044123	0.030374
SDG4	0	0.04453	0.007479	1.060542	0.04279	0.002431
SDG5	0	0.049332	0.093851	0.062567	1.046375	0.030501
SDG7	0	0.047505	0.090375	0.06025	0.00762	1.029372

Table S2. Leontief inverse matrix of indirect co-benefit production for prerequisite co-benefits for SDG Ocean targets

	SDG1	SDG2	SDG3	SDG4	SDG5	SDG7
SDG1	1.071429	0.116179	0.154905	0	0.167814	0
SDG2	0	1.096386	0.017403	0	0.139224	0
SDG3	0	0.108434	1.144578	0	0.156627	0
SDG4	0	0.102811	0.018563	1.066667	0.148505	0
SDG5	0	0.108434	0.144578	0	1.156627	0
SDG7	0	0.096436	0.002655	0.070833	0.021241	1.0625

Table S3. Leontief inverse matrix of indirect co-benefit production for all context-independent co-benefits for SDG Ocean targets

	SDG1	SDG2	SDG3	SDG4	SDG5	SDG7
SDG1	1	0	0	0	0	0
SDG2	0	1	0.5	0	0	0
SDG3	0	0	1	0	0	0
SDG4	0	0	0	0	0	0
SDG5	0	0	0	0	0	0
SDG7	0	0	0	0	0	0

Table S4. Leontief inverse matrix of indirect co-benefit production for all context-dependent co-benefits for SDG Ocean targets

	SDG1	SDG2	SDG3	SDG4	SDG5	SDG7
SDG1	1	0	0	0	0	0
SDG2	0	1	0	0	0	0
SDG3	0	0	1	0	0	0
SDG4	0	0	0	1	0	0
SDG5	0	0	0.021739	0.333333	1	0.043478
SDG7	0	0	0.5	0	0	1

Table S5. The number of direct relationships from each SDG to the SDG Ocean targets

	14.1				14.2				14.3				14.4				14.5				14.7			
SDG	benefit/Pre-requisite/context-depend	benefit/optional/context-independent	benefit/optional/context-dependent	Trade-off/optional/context-dependent	benefit/Pre-requisite/context-depend	benefit/optional/context-independent	benefit/optional/context-dependent	Trade-off/optional/context-dependent	benefit/Pre-requisite/context-depend	benefit/optional/context-independent	benefit/optional/context-dependent	Trade-off/optional/context-dependent	benefit/Pre-requisite/context-depend	benefit/optional/context-independent	benefit/optional/context-dependent	Trade-off/optional/context-dependent	benefit/Pre-requisite/context-depend	benefit/optional/context-independent	benefit/optional/context-dependent	Trade-off/optional/context-dependent	benefit/Pre-requisite/context-depend	benefit/optional/context-independent	benefit/optional/context-dependent	Trade-off/optional/context-dependent
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
7	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	1	0	1	0	1	1	2	0	1	1	0	0	0	0	0	0	0	1	1	0	0	0
9	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
10	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	2	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	1	0	2	0	0	0	2	0	1	0	2	0	0	0	1	0	0	0	0	0	1	0	1	0
14	1	0	0	0	6	0	0	0	3	1	1	0	2	1	1	0	5	0	0	0	1	3	1	0
15	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0	1	0
16	0	0	2	0	0	0	1	0	0	0	1	0	0	0	2	0	0	0	1	0	0	0	0	0
17	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	2	0	0	0	2	0

Table S6. The Aruban institutions and their associated codes used in the network analysis

Institutions	Code
Directie Onderwijs.,	I1
WEB NV. (Utilities Aruba N.V.)	I2
ELMAR NV.	I3
Advisory Board of Aruba (Raad van Advies)	I4
Air Navigation Services Aruba N.V. (ANSA N.V.)	I5
Aruba Airport Authority N.V. (AAA)	I6
Aruba Fire Department	I7
Aruba Free Zone	I8
Aruba Investment Agency	I9
Aruba Kingdom Games Foundation (SKA)	I10
Aruba Olympic Committee (COA)	I11
Aruba Police Force	I12
Aruba Ports Authority N.V.(APA)	I13
Aruba School of Music Rufo Wever	I14
Aruba Sports Union (ASU)	I15
Aruba Tourism Authority (ATA)	I16
Aruban National Archives	I17
Arubus N.V.	I18
Aruparking	I19
Biblioteca Nacional Aruba (BNA)	I20
Bureau City Inspector (BCI)	I21
Bureau European Union and Kingdom Relations,	I22
Bureau Intellectual Property (BIE)	I23
Bureau Landsbemiddelaar (BLB)	I24
Bureau of Addiction Care and Counselling (BOV)	I25
Bureau of Compulsory Education (BLP)	I26
Bureau Sostenemi (BSO)	I27
Bureau Traimerdia (BTm)	I28
Bureau Vrouwenzaken (BVZ)	I29
Cas di Cultura/Stichting Schouwburg Aruba (CdC/SSA)	I30
Central Audit Department (CAD)	I31
Central Bank van Aruba	I32
Centro pa Desaroyo di Aruba (CEDE Aruba)	I33
Civil Registry office (Dienst Burgerlijke Stand en Bevolkingsregister DBSB)	I34
Commission of Sports Subsidy (SSC)	I35
Correctional Institute Aruba (KIA)	I36
Crisis Management Office	I37
Departamento di Aduana (Douane)	I38
Departamento di Impuesto (DI)	I39
Departamento di Integracion, Maneho y Admision di Stranhero (DIMAS)	I40

Instituto Pedagogico Arubano (IPA)	I84
Joint Court of Justice of Aruba, Curaçao, Sint Maarten and of Bonaire, Saint Eustatius and Saba	I85
Medical Institute San Nicolas (IMSAN)	I86
Medical Laboratory Services Aruba Foundation (Fundacion Servicio Laboratorio Medico) Aruba (FSLMA)	I87
Monuments Office Aruba	I88
Museo Historico Arubano/Historisch Museum Aruba (MHA/HMA)	I89
National Criminal Investigation Department (LR)	I90
National Health Insurance Aruba (AZV)	I91
Nationale 'United Nations Educational, Scientific and Cultural Organization' Commissie Aruba (UNESCO)	I92
Objection Advisory Board	I93
Office for Government Grant Coordination	I94
Office Internal Services (BID)	I95
Openbaar Onderwijs (OO)	I96
Post Aruba N.V.	I97
Public Prosecutor's Office	I98
Refineria di Aruba N.V.	I99
Royal Dutch Coast Guard	I100
Service Unit Public Schools (DPS)	I101
Servicio di Limpieza di Aruba (Serlimar)	I102
Setar N.V.	I103
Social and Economic Council (SEC)	I104
Social Security Bank of Aruba (SVB)	I105
Stichting Algemeen Pensioenfonds Aruba (APFA)	I106
Stichting Monumenten Fonds Aruba (SMFA)	I107
The Minister plenipotentiary of Aruba	I108
Union di Organisacionnan Cultural Arubano (UNOCA)	I109
University of Aruba (UVA)	I110
Veterinary Services (VET)	I111
Volkskredietbank van Aruba (VKB)	I112

Table S7. Centrality measures for the importance of Aruban institutions in regulating progress on the various SDG Ocean targets, in a scenario where relationships between SDG targets are not considered. The Social and Economic Council (SEC, institution code I104) is not included in this scenario. The topological coefficient is a relative measure for the extent to which a node shares nodes with other nodes, so low values here indicate that an institution is connected with other institutions that are not otherwise connected. We interpret that as suggesting that institutions with low topological coefficient scores are more important for coordinating activities across institutions that are otherwise not connected with the broader institutional system. The average distance is a measure of how far, on average, a node is from other nodes, so a lower number indicates a more central node.

Institution Code	Barycenter Centrality	Subgraph Centrality Scores	Topological Coefficient	Average Distance

I50	0.111111111	50.59247045	0.592592593	0.818181818
I13	0.083333333	42.42479989	0.648148148	1.090909091
I67	0.083333333	42.42479989	0.648148148	1.090909091
I80	0.083333333	42.42479989	0.648148148	1.090909091
I37	0.076923077	33.83334661	0.711111111	1.181818182
I43	0.076923077	33.83334661	0.711111111	1.181818182
I16	0.071428571	23.30942505	0.75	1.272727273
I76	0.058823529	2.883671299	1	1.545454545
I73	0.058823529	2.883671299	1	1.545454545
I62	0.058823529	2.883671299	1	1.545454545

Table S8. Centrality measures for the importance of Aruban institutions in regulating progress on the various SDG Ocean targets, in a scenario where prerequisite relationships from SDG targets to SDG Ocean targets are considered. The average distance is a measure of how far, on average, a node is from other nodes, so a lower number indicates a more central node.

Institution Code	Bottleneck Centrality	Average Distance	Subgraph Centrality Scores
I104	33	1.457142857	1525.380287
I16	24	1.628571429	1256.153312
I56	23	1.685714286	813.5010801
I80	23	1.714285714	730.9733276
I102	20	1.8	434.1955397
I50	20	2	385.4800844
I30	10	2.057142857	166.4691073
I57	9	2.857142857	6.090843572
I13	7	2	667.477462
I46	6	1.771428571	1040.936563
I61	4	1.885714286	539.6708255
I8	4	1.942857143	433.982441
I9	3	1.857142857	547.5386151
I22	1	2.285714286	105.8188317
I37	1	2.314285714	121.8309032
I43	1	2.314285714	121.8309032
I70	1	2.285714286	105.8188317
I107	0	2.142857143	161.3783791
I109	0	2.142857143	161.3783791
I18	0	2.057142857	154.6884178
I2	0	2.114285714	389.4212437
I23	0	1.914285714	458.1527561
I3	0	3.742857143	2.82858344
I44	0	1.914285714	458.1527561

I52	0	2.057142857	154.6884178
I55	0	2.057142857	154.6884178
I59	0	2.142857143	161.3783791
I6	0	2.228571429	318.4298999
I62	0	2.885714286	8.839093957
I67	0	2.257142857	205.4978634
I73	0	2.885714286	8.839093957
I76	0	2.914285714	6.447722789
I88	0	2.142857143	161.3783791
I99	0	3.742857143	2.82858344

Table S9. Centrality measures for the importance of Aruban institutions in regulating progress on the various SDG Ocean targets, in a scenario where all co-benefits and tradeoffs between SDG targets are considered. The topological coefficient is a relative measure for the extent to which a node shares nodes with other nodes, so low values here indicate that an institution is connected with other institutions that are not otherwise connected. We interpret that as suggesting that institutions with low topological coefficient scores are more important for coordinating activities across institutions that are otherwise not connected with the broader institutional system.

Institution Code	Subgraph Centrality Scores	Topological Coefficient	Barycenter Centrality	Bottleneck Centrality
I100	1402.92489	0.6888889	0.00617284	0
I101	48165.28615	0.3740741	0.00763359	0
I102	5062.57032	0.2114625	0.00775194	7
I104	160245.2346	0.1650246	0.01162791	62
I105	2506.03322	0.484127	0.00689655	0
I107	2256.04774	0.3055556	0.00704225	0
I108	4388.05916	0.3809524	0.00699301	2
I109	2256.04774	0.3055556	0.00704225	0
I110	48165.28615	0.3740741	0.00763359	0
I112	3943.49674	0.4333333	0.00719425	0
I12	6317.37529	0.1903226	0.00917431	43
I13	5856.40607	0.2536998	0.00757576	15
I16	46499.86058	0.207478	0.00980392	57
I18	2363.30758	0.326087	0.00740741	0
I2	4898.2664	0.3355482	0.00735294	3
I22	4388.05916	0.3809524	0.00699301	2
I23	99212.45073	0.2882353	0.00869565	9

I26	48165.28615	0.3740741	0.00763359	0
I28	48165.28615	0.3740741	0.00763359	0
I29	2506.03322	0.484127	0.00689655	0
I30	2256.04774	0.3055556	0.00704225	0
I32	28101.63704	0.3529412	0.008	0
I33	63571.22545	0.3222222	0.00787402	2
I34	1322.48095	0.3773585	0.00769231	0
I37	283.6938	0.5058824	0.00574713	3
I38	2892.83834	0.3142857	0.00719425	13
I40	1402.92489	0.6888889	0.00617284	0
I41	3943.49674	0.4333333	0.00719425	0
I43	373.34547	0.4705882	0.00578035	3
I44	28101.63704	0.3529412	0.008	0
I46	126099.178	0.2304582	0.00952381	35
I47	48165.28615	0.3740741	0.00763359	0
I48	48165.28615	0.3740741	0.00763359	0
I49	1402.92489	0.6888889	0.00617284	0
I50	3375.3943	0.2271062	0.0075188	37
I52	2363.30758	0.326087	0.00740741	0
I54	1402.92489	0.6888889	0.00617284	0
I55	2363.30758	0.326087	0.00740741	0
I56	12278.22642	0.2484848	0.00840336	17
I58	3943.49674	0.4333333	0.00719425	0
I59	2256.04774	0.3055556	0.00704225	0
I6	4382.49514	0.3577236	0.00719425	0
I60	28101.63704	0.3529412	0.008	0
I61	9478.83701	0.3278302	0.008	5
I62	28.27895	0.5714286	0.00518135	0
I67	942.56889	0.4102564	0.00649351	2
I69	1402.92489	0.6888889	0.00617284	0
I70	4388.05916	0.3809524	0.00699301	2
I73	28.27895	0.5714286	0.00518135	0
I75	28101.63704	0.3529412	0.008	0
I76	1247.34309	0.3857143	0.00689655	1
I77	1322.48095	0.3773585	0.00769231	0
I79	28101.63704	0.3529412	0.008	0
I8	39008.83326	0.289916	0.00826446	6
I80	942.56889	0.4102564	0.00649351	2
I82	1402.92489	0.6888889	0.00617284	0
I84	48165.28615	0.3740741	0.00763359	0
I85	1402.92489	0.6888889	0.00617284	0
I88	2256.04774	0.3055556	0.00704225	0
I9	39008.83326	0.289916	0.00826446	6

I90	2892.83834	0.3142857	0.00719425	13
I92	48165.28615	0.3740741	0.00763359	0
I96	48165.28615	0.3740741	0.00763359	0