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A Case Study of Community-Engaged Design: Creating Parametric Insurance to Meet the Safety Needs of Fisherfolk in the Caribbean

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Abstract: The creation of the Caribbean Ocean and Aquaculture Sustainability faciliTy (COAST) is used as a case study of community-engaged design addressing safety needs. COAST is a parametric insurance product, sold to national governments, which was designed to meet the food and nutrition security of small- and medium-scale fisherfolk. The design of COAST is an example of convergence research, where the discipline of engineering was integrated with another discipline to solve pressing societal needs of Caribbean fisherfolk. This case study demonstrates that community-engaged design helps to (1) identify and include historically underrepresented stakeholders, (2) emphasize the importance of professional responsibility for project implementation, and (3) achieve long-term sustainability of the design (i.e., COAST has been renewed for a third policy year, 2021/2022). **DOI: 10.1061/(ASCE)EE.1943-7870.0001971.**

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Introduction

One of the most widely cited definitions of sustainable development, "meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs," depends on the meaning of the word "needs" (World Commission on Environment and Development 1987). Often, needs are defined using the hierarchical structure proposed by Abraham Maslow, which includes a list of physiological needs at the base of the pyramid, then extends upward through safety needs, love and belonging, esteem, and culminates in the pinnacle of the pyramid occupied by self-actualization (Maslow 1943). Although Maslow's approach has been regularly criticized (i.e., Wahba and Bridwell 1976), the hierarchy remains a useful framework that is widely used in such diverse areas as public transport (Allen et al. 2019) and measures protecting public health during the COVID-19 pandemic (Ryan et al. 2020).

Achieving sustainable development by meeting the needs of individuals, communities, and nations around the world has been described as the grandest challenge of all for environmental engineering (Mihelcic et al. 2017). The environmental engineering literature is filled with examples of efforts to meet physiological needs in developing communities through the provision of clean drinking water, sanitation, and hygiene (i.e., Oerther et al. 2019; Bartram and Setty 2021), improved indoor air quality (Roden et al. 2009; Khandelwal et al. 2017), and in other ways.

Although meeting physiological needs is important for sustainable development, it is also important that engineers consider additional needs as targets for design efforts. The hierarchy proposed by Maslow suggests that safety needs (also known as "security" needs) become the primary motivator after physiological needs are met (Maslow 1943). Safety needs include such diverse topics as personal security, health and well-being, and financial security (Zheng et al. 2016). Safety needs also include the reliability of meeting physiological needs. For example, while clean drinking water is a physiological need, the reliable access to clean drinking water during a disaster could be considered a safety need.

In a similar fashion to clean drinking water, access to food is considered a physiological need, but food security is more than just access to food. For example, the definition of food (and nutrition) security adopted by the United Nations (UN) Food and Agriculture Organization (FAO) states that, "... food [and nutrition] security exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO et al. 2020). This definition of a safety need is highly dependent upon the individual, community, and national needs of diverse stakeholders to understand the range of preferences for nutritious food. For engineers to successfully meet the complex components of the need for food and nutrition security, engagement with stakeholders is necessary.

In general, engagement with diverse stakeholders helps to ensure that the problem being solved is fully understood and that the solution being implemented is appropriate and has a high likelihood of long-term success. For example, healthcare professionals have developed an extensive framework for engaging with communities (National Institutes of Health 2011), which includes such techniques as community-directed interventions (i.e., Odhiambo et al. 2016) as well as community-based participatory research (i.e., Israel et al. 1998).

The creation of the Caribbean Ocean and Aquaculture Sustainability faciliTy (COAST) followed the three primary steps often used in community engagement: (1) identifying stakeholders as well as the problem; (2) planning, including roles, responsibilities, resources, and timeline; and (3) executing the solution

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(Hacker 2013). As a case study of community-engaged design, this paper reports on lessons learned during the creation of COAST. Sold to national governments, COAST is a parametric insurance product designed to meet the security needs of small- and medium-scale fisherfolk. Because the creation of COAST required convergence of the disciplines of engineering and others (Oerther 2019), four techniques are described in this paper: (1) public diplomacy; (2) official development assistance (ODA); (3) bilateral diplomacy; and (4) multilateral diplomacy. The objective of this case study is to convince environmental engineers to adopt community-engaged design to meet diverse needs of individuals, communities, and nations.

Techniques

Community Engagement

A three-stage approach was used for community engagement (Hacker 2013). In the first stage (i.e., identifying), the community was defined, all stakeholders were engaged, and historical and current conditions were assessed contributing to the emergence of a shared problem statement (World Bank 2020). In the second stage (i.e., planning), all stakeholders agreed on roles and responsibilities, including theoretical frameworks and empirical approaches. In the third stage (i.e., executing), cycles of action, impact analysis, and dissemination were undertaken until successful execution solved the problem for the long term (i.e., COAST was renewed for a third policy year in 2021/2022).

The target community for COAST was initially selected by the United States Department of State (US DOS) as part of public diplomacy to address issues raised by some leaders from the Caribbean basin. Global multilateral stakeholders (i.e., World Bank) were consulted by the US DOS on the basis of expertise and past experience. Regional multilateral stakeholders [i.e., Caribbean Regional Fisheries Mechanism (CRFM)] were invited to share leadership for the project through diplomatic engagement and on the recommendations of trusted global multilateral stakeholders. Individual, local fisherfolk and members of the postcatch processing industry were invited to collaborate through personal relationships as part of diplomatic engagement. Through questionnaires, internet surveys, interviews, focus-group discussions, briefings, and diplomatic engagement, stakeholders contributed to coidentifying the problem, coplanning the solution, and coexecuting success.

The creation of COAST was funded by a transfer of funds from the US DOS to a multidonor trust fund operated by the World Bank. The US DOS has not adopted the Federal Policy for the Protection of Human Subjects, also known as the "Common Rule," originally published in 1991 and most recently updated in 2017 (Federal Policy for the Protection of Human Subjects 2017). Therefore, COAST was not subject to Institutional Review Board approval. Rather, the principles of the World Bank Environmental and Social Framework were followed during planning and execution of COAST (World Bank 2017c). In addition, broader ethical considerations summarized in the literature guided the efforts to engage with communities (i.e., Mikesell et al. 2013).

Public Diplomacy

As defined in the preface to a special issue on the subject of public diplomacy appearing in the *Annals of the American Academy of Political and Social Science*, "public diplomacy [means] an international actor's attempt to advance the ends of policy by engaging with foreign publics" (Cowan and Cull 2008). Public diplomacy rose in prominence as a tool of US foreign policy in the wake of September 11, 2001, as an instrument of the "war on terror." In 2019, a special issue on the current status and future prospects of public diplomacy appeared in *The Hague Journal of Diplomacy* (Melissen and Wang 2019). In the preface, public diplomacy was defined as a nation's "efforts to create and maintain relationships with publics in other societies to advance policies and actions" (Melissen and Wang 2019), and the organizers of this special thematic issue noted that public diplomacy is "becoming a more rather than a less relevant component of diplomacy" (Melissen and Wang 2019).

Cull divided the practice of public diplomacy into five elements: (1) listening; (2) advocacy; (3) cultural diplomacy; (4) exchange diplomacy; and (5) international broadcasting (Cull 2008). Examples of public diplomacy include exchange programs, such as the Fulbright Program, as well as state-sponsored dissemination of influential content, such as the "Voice of America." Recently, "city diplomacy" has been identified as an emerging element of public diplomacy with the C40 Cities Climate Leadership Group as an early example (C40 Cities Climate Leadership 2021).

Official Development Assistance

Foreign assistance refers to financial, material, or in-kind aid provided by a donor nation to a recipient, which is typically a low- or middle-income nation (as defined by the World Bank). Historically the chief financial flow is known as ODA, which includes grants, where no repayment is required, or concessional loans, where interest rates are lower than prevailing market rates. ODA does not include foreign direct investment (FDI) (i.e., a company based in one nation with controlling ownership of a company in another nation), remittances (i.e., funds immigrant workers send to families in their nation of origin), or military assistance. Material flows include emergency relief such as food or medical supplies, while in-kind aid includes the sharing of expertise.

A recent special issue appearing in the journal *Development Policy Review* summarized a number of key messages: (1) while ODA has been important historically, current global ODA (FY17, $190 billion) is significantly less important as compared to FDI (FY17, $537 billion) and remittances (FY17, $429 billion); and (2) while the UN Sustainable Development Goals (SDGs) emphasize the importance of "country ownership," the nature of the SDGs—broad and inclusive—undermine a developing country's ability to exercise effective ownership because "virtually everything is a priority" (Keijzer and Black 2020). While the absolute value of ODA may no longer represent the chief financial flow in foreign assistance, it nonetheless remains an important diplomatic tool in finance for development (UN 2015).

Bilateral Diplomacy

In the simplest form, bilateralism is a diplomatic relationship between two individuals. As the individuals are replaced by more complex entities (i.e., families, churches, corporations, governments, etc.), the bilateral relationship remains between two individuals who represent each entity (i.e., the head of state from a host nation and the visiting ambassador personally representing the head of state from another nation). Following this model of the formal interaction of sovereign states through representation, the modern system of diplomacy emerged from the Treaty of Westphalia in 1648.

Today, the Vienna Convention on Diplomatic Relationship, first signed in 1961, provides a framework for diplomacy between sovereign states (UN 2005). Article 3 of the Vienna Convention

provides an explicit role for "science diplomacy": "(e) promoting friendly relationship between the sending State and the receiving State, and developing their economic, cultural, and *scientific* [emphasis added] relations." While modern diplomats continue to exercise the professional skills of negotiation, discretion, and statecraft, there has been an expansion in the scope of interventions. For instance, historically, the primary domain of the diplomat was politics, but today, the domains of diplomatic engagement have expanded to include areas such as climate, culture, digital diplomacy, economy, energy, environment, and nuclear nonproliferation and disarmament (Ruffini 2015).

Multilateral Diplomacy

Multilateral (i.e., "multinational") diplomacy is characterized by international relationships among multiple states such as the creation of the UN after World War II for the purposes of (1) maintaining international peace and security; (2) developing friendly relations; (3) achieving international cooperation; and (4) harmonizing the actions of states to achieve these ends (UN 1945). Some multilateral relationships are formed for mutual defense, such as the North Atlantic Treaty Organization [i.e., NATO and Article 5 of the Washington Treaty—"an armed attack against one or more of them (Parties to the Washington Treaty) in Europe or North America shall be considered an attack against them all" (NATO 1949)], and other multilateral relationships are formed for economic benefits, such as the Caribbean Community [i.e., CARICOM and Article 4 of the Treaty of Chaguaramas—"the economic integration of the Member States by the establishment of a common market regime" (CARICOM 1973)].

Compared to bilateral relationships, where the strengths and weaknesses of each state are compared and contrasted directly, in multilateral relationships, significant differences among states (i.e., differences in population, per capita economic activity, or military capabilities) may be partially or totally mitigated by the democratic process of, "one state, one vote." And while consensus building among multilateral relationships may require a significant investment of diplomatic engagement, an advantage of multilateral consensus is a weight of political will (i.e., multilateral economic sanctions or multilateral military intervention may be viewed as "more justifiable" as compared to unilateral acts). An additional advantage of multilateral relationships includes the ability to avoid entanglement in complex bilateral relationships, which were partially responsible for the "domino effect" that contributed to the outbreak of World War I (Ruffini 2015).

Results

Previous publications described COAST as a platform for promoting the adoption of technology (Oerther 2016) and as an example of "science-in-diplomacy" (Oerther 2020). The objective of this case study of COAST is to demonstrate how engineers should adopt community engagement to achieve success in design across Maslow's hierarchy of needs, including physiological needs, safety needs, love and belonging, esteem, and self-actualization (Maslow 1943).

Stage One: Identifying

The creation of COAST was initiated, at least in part, by a perceived necessity for public diplomacy to advance US national security [ICA 2015-04 (ICA 2015); Kerry 2015a]. Historically, the US approach to the Caribbean basin "has been motivated not so much to control the [Caribbean] region but to keep things from veering out of control where they could be exploited by others viewed as hostile" (Pastor 1996). The US strategy in the Caribbean over the last decade highlights strengthening resilience to emergencies and disasters as important to US national security and economic interests (US DOS 2019). COAST is a prominent example of public diplomacy in action, and through public diplomacy, the essential first step of community-engaged design, including stakeholder identification and recruitment as well as the creation of a problem statement, was accomplished.

The initial concept of COAST—a regional parametric insurance product to promote climate-smart food security and fisheries ecosystem management—was offered by the Secretary's Office of Global Food Security in response to a request by Secretary Kerry for new initiatives to be announced during the Caribbean Energy Security Summit in January 2015 (Oerther 2020). COAST was used as an instrument of public diplomacy at least four times during 2015 (Table 1). Between the initial announcement of the concept of COAST (Kerry 2015a, b) and the pledge by President Obama to support climate-related insurance during the 21st session of the Conference of Parties of the UN Framework Convention on Climate Change (COP21 UNFCC) in Paris (Obama 2015), stakeholder engagement was performed as part of six formal briefings (see Table 1). In addition, stakeholder engagement was performed through the preparation and distribution of a paper-based questionnaire and an internet survey (details included in Tietze and van Anrooy (2018) as well as one-on-one interviews and focus-group discussions (personal communication) throughout the Caribbean basin.

During "Stage One: Identifying," historical and current conditions were assessed, and two important results emerged. First, improving access to insurance was noted as a part of the Caribbean Community Common Fisheries Policy (CCCFP) [i.e., Article 10 Fisheries Sector Development, "... adopt measures to enhance the development of the fisheries and aquaculture sectors and to improve the welfare and socio-economic conditions of fishers and fishing communities, including, *inter alia*, by: (a) improving the business, financial, and *insurance* [emphasis added] environments..." (CARICOM 2014)]. Second, most fishers in the Caribbean lack insurance for their vessels, their health, and their lives [i.e., existing insurance policies covered only 3% of vessels while only 17% of fishers owned a health insurance policy and only 20% of fishers owned a life insurance policy (Tietze and van Anrooy 2018)].

The community-engaged design of COAST improved the identification and inclusion of historically underrepresented stakeholders, specifically women engaged in the fisheries sector, including: (1) as fishers; (2) as owners of vessels; and (3) as operators/owners of postcatch processing (i.e., landing sites and associated infrastructure, markets for local sales, and corporations for export sales). Furthermore, through extensive stakeholder dialogue, a shared problem statement emerged: "How can climate-smart food security and fisheries ecosystem management enhance community resilience?"

Stage Two: Planning

The planning for COAST was facilitated, at least in part, by the availability of ODA. Historically, the Small Island Developing States of the Caribbean have experienced frequent and costly natural disasters. These disasters include 324 separate events between 1950 and 2017 (Otker and Srinivasan 2018), as well as major events devastating nations with one-time damages in excess of annual gross domestic product. Major disaster events include Hurricane Georges in 1998 (St. Kitts and Nevis), Hurricane Ivan in 2004 (Grenada), and Hurricane Maria in 2017 (Dominica) (Otker and Srinivasan 2018). The strategy of the World Bank in the

Table 1. Public diplomacy (PD) and Stakeholder engagement (SE) to complete stage one: identifying

Purpose[a]	Date[b]	Location	Description
PD	January 26	Washington, DC	Deputy Secretary, Anthony Blinken, first announced COAST during the Caribbean Energy Security Summit (personal communication)
SE	February 11	Washington, DC	Briefing to Ambassadors from Caribbean nations to the US (personal communication)
SE	March 13	St. George's, Grenada	Briefing as part of the launch of the Blue Growth Network (World Bank 2016)
SE	March 25	Washington, DC	Briefing to Ambassadors from the United States to Caribbean nations during the Global Chiefs of Mission Conference (personal communication)
SE	May 15	St. George's, Grenada	Briefing to Ministerial meeting of the CRFM (Tietze and van Anrooy 2018)
SE	June 26	Bridgeton, Barbados	Briefing to Ministerial meeting of the CDEMA (Tietze and van Anrooy 2018)
SE	July 22	Washington, DC	Briefing to working group including World Bank, CCRIF SPC, and FAO, among others (personal communication)
PD	October 5	Valparaiso, Chile	Secretary Kerry described COAST as, "a commitment towards a clean, healthy, and productive ocean," during the Our Ocean Conference (Kerry 2015a)
PD	October 17	Milan, Italy	Secretary Kerry described COAST as, "an entirely new way to address the climate-food security nexus," during the World's Fair (Kerry 2015b)
PD	November 30	Paris	President Obama described COAST as, "a contribution to risk insurance initiatives that help vulnerable populations rebuild stronger after climate-related disasters," during the COP21 UNFCCC (Obama 2015)

[a]Public diplomacy (PD) or stakeholder engagement (SE).
[b]All dates during calendar year 2015 (CY15).

Caribbean highlights both the challenge of setbacks from natural disasters as well as the innovation of creating the world's first pooling mechanism to help nations access high-quality, affordable sovereign catastrophe risk insurance through the Caribbean Catastrophe Risk Insurance Facility [CCRIF, now known as the CCRIF Segregated Portfolio Company (CCRIF SPC)] (World Bank 2017b). COAST is a prominent example of ODA in action, and through the availability of ODA, the essential second step of community-engaged design, including agreement on stakeholder roles and responsibilities, was accomplished.

The creation of COAST—as an additional parametric insurance product for sale by CCRIF SPC—was funded by the US DOS through a donation to the Global Program on Fisheries (PROFISH), a multidonor trust fund operated by the World Bank (2019c). ODA supported six activities between 2015 and 2020 (Table 2), which were essential to the successful creation of COAST. Collectively, these activities contributed to planning, including: (1) agreement to the central importance of a high-quality model to underpin the parametric insurance policy; (2) participation in the collection of data essential to model construction; and (3) preparation of a viable business plan for the long-term commercial success of COAST as a product within a segregated cell of CCRIF SCP.

During "Stage Two: Planning," all stakeholders agreed to a solution, namely, "a mathematical model should be constructed to adequately predict, both: (1) the total annual loss of income due to business interruption from 'bad weather'; and (2) the capital

Table 2. Use of ODA to complete stage two: planning

Timeframe[a]	Cost[b]	Stakeholder(s)[c]	Description
2015	$50	FAO, CNFO, CRFM	Caribbean basin–wide environmental scan on the current status and future potential of fisheries insurance (Tietze and van Anrooy 2018)
2016–2018	$100	CCRIF SPC	Agreement on business plan, creation of segregated business cell dedicated to COAST, and inclusion in corporate strategic plan all approved by the Board of Directors (CCRIF SPC 2018)
2017–2019	$150	CCRIF SPC, World Bank	Project Implementation Coordinator (PIC) responsible for operational support, securing supplemental funding, and convening working group of stakeholders (Oerther 2020)
2017–2018	$150	CEFAS, World Bank	Developing national fisheries sector assessment, and using methodology in Grenada (World Bank 2019b) and St. Lucia (World Bank 2019c)
2018–2019	$550	CCRIF SPC, World Bank	Constructing proprietary model predicting loss of livelihoods due to business interruption and infrastructure damage (personal communication)
2019–2020	$2,400	CCRIF SPC, World Bank, Grenada, St. Lucia	Capitalizing COAST segregated business cell and subsidizing premium payments for countries to purchase COAST during the pilot phase (World Bank 2020)

[a]Approximate timeframes corresponding to calendar year (personal communication).
[b]Approximate cost in thousands of dollars (personal communication).
[c]Stakeholders include: United Nations Food and Agriculture Organization (FAO); Caribbean Network of Fisherfolks Organizations (CNFO); Caribbean Regional Fisheries Mechanism (CRFM); Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC); Centre for Environmental, Fisheries, and Aquaculture Science (CEFAS); Government of Grenada; and Government of St. Lucia.

requirements to replace or repair fishing infrastructure lost or damaged during a 'tropical cyclone.'" The importance of a robust mathematical model to underpin the parametric insurance policies sold by CCRIF SPC has been discussed in detail in prior publications, and the reader is encouraged to look to these references for further details (i.e., Grove 2012; CCRIF SPC 2016; Oerther 2016; Adam and Bevan 2020).

Briefly, unlike the more common indemnity insurance, where actual ex post (i.e., based on actual results rather than forecasts) observed damage is used to calculate a policy payout, in the case of parametric insurance a modeled ex ante (i.e., based on forecasts rather than actual results) prediction of assumed damage is used to calculate a policy payout. This means that detailed inspections of the assets being protected are not needed before an insurance policy may be written. While the possibility exists that the ex ante modeled losses and the ex post observed losses will be different for any event, a major advantage of parametric insurance is that ex post observations are unnecessary, which allows payouts to be made quickly while avoiding the costly process of claims adjustment. This means that detailed inspections of the assets being protected are not needed after a disaster occurs.

Community-engaged design of COAST emphasized stakeholders sharing responsibility for problem coidentification, solution coplanning, and coexecution of success. During "Stage Two: Planning," stakeholders agreed on roles and responsibilities, including how and when to collect data supporting the creation and testing of a mathematical model. For instance, the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) prepared an assessment of Grenada's fisheries (World Bank 2019a) and an assessment of St. Lucia's fisheries (World Bank 2019b).

Shared responsibility for community-engaged design did not automatically translate into equal professional responsibility for every stakeholder at each stage in the process. For instance, expertise in collecting data (i.e., CEFAS) or constructing mathematical models (i.e., CCRIF SPC), was different from expertise in overall project management, including operational support, securing supplemental funding, and diplomatic engagement among sovereign states and multilateral institutions (i.e., see Supplemental Materials, Terms of reference (TOR) for "COAST Project Implementation Coordinator"). Community-engaged design of COAST recognized the importance of personal professional responsibility for project implementation.

Stage Three: Executing

The creation of COAST was executed, at least in part, through bilateral and multilateral diplomacy to achieve enduring success. In 2004, after the devastation of Hurricane Ivan, the Government of Japan provided grants (valued at $1.8 million) to the World Bank to fund the planning process to create the CCRIF (World Bank 2012). The corporate structure of CCRIF follows a mutual company, which is a private corporation owned by its policy holders (i.e., in the case of CCRIF, the nations who purchase insurance policies). When CCRIF was launched in 2007, the corporation offered for sale parametric insurance covering damages from tropical cyclones and earthquakes to nations throughout the Caribbean basin. COAST, as a new product offered by CCRIF SPC, is a prominent example of bilateral and multilateral diplomacy in action, and through diplomatic engagement, the essential third step, including sustainable cycles of action, analysis, and dissemination, was accomplished.

The creation of COAST utilized bilateral diplomacy between representatives of the US DOS and representatives of the governments of various nations throughout the Caribbean basin. For instance, after Deputy Secretary Anthony Blinken first announced COAST at breakfast on the morning of January 26, 2015, at the Caribbean Energy Security Summit, a bilateral response was offered by the Prime Minister of Grenada, Doctor the Right Honorable Keith Mitchell, which included a formal intervention to welcome the announcement of COAST and to encourage other Heads of State also to welcome the announcement (personal communication). Similarly, after Secretary Kerry reprised COAST during plenary remarks on the morning of October 5, 2015, during the Our Ocean Conference (Kerry 2015b), a bilateral response was offered by the Foreign Minister of Jamaica, Mr. Arnold Joseph Nicholson, which included a public commitment of the intent to purchase a COAST insurance policy, when it became available for Jamaica (personal communication). The creation of COAST utilized multilateral diplomacy including: (1) the World Bank as the trustee of the PROFISH multidonor trust fund (World Bank 2019c); (2) the FAO who assisted in the performance of the initial environmental scan on fisheries insurance in the Caribbean (Tietze and van Anrooy 2018); and (3) various Caribbean regional multilateral stakeholders including the CRFM, the Caribbean Network of Fisherfolk Organizations (CNFO), the Caribbean Disaster Management Agency (CDEMA), and CCRIF SPC, among others.

During "Stage Three: Executing," a positive feedback loop with action, analysis, and dissemination was created through political, commercial, and operational alignment among the leaders of the governments of Caribbean nations, the Board of Directors of CCRIF SPC, and leaders of regional multilateral stakeholders. For instance:

1. A sustainable political environment for COAST was created in December 2017, when Caribbean leaders of CARICOM announced the formation of the world's first "climate-smart zone" after the devastation of Hurricane's Irma and Maria (World Bank 2015, 2017a).
2. A sustainable commercial environment for COAST was created in September 2018 when the Board of Directors of CCRIF SPC adopted the 2018–2021 Strategic Plan including, "Strategic Objective 1: Innovative and Responsive Parametric Products: ... CCRIF will focus on bringing to market two new products based on models that have already been developed: drought and fisheries (through the COAST initiative)" (CCRIF SPC 2018).
3. A sustainable operational environment for COAST was created in March 2019 when CRFM and CCRIF SPC entered into a Memorandum of Understanding for the purpose of, "establishment of climate-resilient fisheries and aquaculture industries in the Caribbean Region," including, "[collaboration] on the COAST initiative ... to reduce the risk that climate change poses to food security and nutrition in the fisheries and aquaculture sectors, and to mitigate climate change impacts on sustainable food production" (CRFM 2019).

Within this political, commercial, and operational alignment, the true success of COAST—in terms of answering the original research question, "How can climate-smart food security and fisheries ecosystem management enhance community resilience?"—was accomplished through "country ownership" via the COAST Operational Manual.

With the purchase of a COAST policy, each country specified (1) the identity of insurance beneficiaries; (2) the procedure for distributing funds from a policy payout after a trigger event; and (3) the procedure for auditing the distribution of funds and for assessing the use of funds (CCRIF SPC 2019). These details, provided by each country, became memorialized as part of the insurance policy—a legally binding contract between CCRIF SPC and each government.

Community-engaged design of COAST leveraged evidence-based policy and practice to ensure long-term success of the design.

Among the 28 articles of the CCCFP, Article 5 specifies, "The following fundamental principles shall guide the implementation of this Agreement: use of the best available *scientific* [emphasis added] information in fisheries management decision-making, taking into consideration traditional knowledge concerning the resources and their habitats as well as environmental, economic, and social factors" (CARICOM 2014). The identification of individual fishers—artisanal, small- and large-scale—is the first step in ecosystems-based fisheries management, and the incentive to purchase a COAST insurance policy provided each government with an opportunity to formalize the fishing sector, including artisanal and small-scale fishers.

Discussion

The environmental engineering community has called for greater recognition of efforts by faculty participating in community engagement (Montoya et al. 2021), and graduates of environmental engineering degree programs have shared a desire to help people and society through their jobs including the service aspects of their work (Bielefeldt and Canney 2019). In a recent special issue of *Environmental Engineering Science*, the lead-off editorial described the range of efforts underway to partner with marginalized communities globally and in the United States (Masten et al. 2021), and the coauthors concluded that "we hope this special issue will serve as a bellwether for the emerging interest within the environmental engineering and science scholarship community to play a role in the transition to environmentally sustainable, just, and peaceful world" (Masten et al. 2021).

To succeed in community-engaged design, environmental engineers benefit from convergence research where the solution of a pressing social needs is cocreated at the interface of two or more disciplines (Oerther 2019). One way to achieve convergence is through the pioneering efforts of V-shaped professionals who "strike boldly into the unknown ... to forge successful partnerships with other disciplines (Oerther and Oerther 2021). Because community engagement requires the development of personal relationships, engineers benefit from collaborating with and learning from diplomats (a person who is appointed by a national government to conduct official negotiations and maintain political, economic, and social relations with another country).

The motivation for COAST, as an instrument of public diplomacy, may be traced back to the United States–Africa Leaders Summit that was held in Washington, DC, from August 4–6, 2014, and hosted by President Barack Obama. The Summit was advertised as the "*first of its kind* [emphasis added]," with the aim of, "strengthening ties between the US and *one of the world's most dynamic and fastest growing regions* [emphasis added]" (Obama 2014). The effort of the Obama administration to engage with leaders from the African continent was viewed with skepticism by some leaders from the Caribbean basin who, in a show of dissatisfaction with US foreign policy, publicly expressed gratitude to the governments of Venezuela, China, and Taiwan for regional financial support (Charles 2015). As part of public diplomacy to address the issue of dissatisfaction on the part of some Caribbean leaders, US Vice President Joseph Biden hosted the "*first ever* [emphasis added]" Caribbean Energy Security Summit in Washington, DC, on January 26, 2015 (Biden 2015). At the request of Secretary of State John Kerry, the concept of COAST was announced during the Summit as an example of US support for climate-smart food security and fisheries ecosystem management to enhance community resilience in the Caribbean.

After the initial announcement of COAST, diplomatic engagement on behalf of the US government included an emphasis on the theme of "inclusion" as highlighted in the current US Global Food Security Strategy, specifically, "increasing access to finance, financial inclusion, and financial intermediation throughout agriculture and food systems, including to financial services and digital tools, particularly among *women, youth, and other marginalized groups* [emphasis added]" (United States Agency for International Development 2016). Diverse stakeholders (Table 3) were invited to partner by identifying, planning, and executing the details of COAST. Beyond these institutional stakeholders, paper-based questionnaires and an internet-based survey [both included as Supplemental Materials in Tietze and van Anrooy (2018)] were distributed to a sampling of representative individual fishers as well as to the leaders of national fisherfolk associations affiliated with CNFO and to the chief fishery officer of all 17 member countries of the CRFM: Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, and the Turks and Caicos Islands (Tietze and van Anrooy 2018).

To coordinate planning among diverse stakeholders (Table 3), a "COAST Project Implementation Coordinator" (PIC) was hired using funds from the ODA contribution by the USG to the World Bank. The scope of services of the PIC, memorialized in a contract between the PIC and CCRIF SPC with approval from the World Bank [see Supplemental Materials, Terms of reference (TOR) for "COAST Project Implementation Coordinator"], included coordinating: (1) diplomatic engagement of all relevant stakeholders; (2) data collection and parametric insurance design including trigger type and form of payout; (3) technical assistance supporting individual purchasing countries to develop their own COAST Operational Manual; and (4) commercial success of the segregated business cell, within CCRIF SPC, dedicated to COAST. As previously described, the role of PIC provided a "once-in-a-lifetime opportunity to learn science-in-diplomacy firsthand" (Oerther 2020).

While lower overhead costs and rapid payouts often are cited as major advantages of parametric insurance as compared to the more traditional indemnity insurance, an additional advantage of parametric insurance includes flexibility in the model that underpins the insurance product. Conceptualizing and constructing a mathematical model is a technique of the discipline of "engineering." In fact, "systems-based," "humanitarian focused," and "using interdisciplinary knowledge" have been identified as among the hallmarks of "engineering diplomacy" projects, (Meshkati 2012). The inviting language found in Article 5 of the CCCFP, including the admonition to use the best available scientific information in fisheries management decision-making, provided the critical link between individual fisherfolk, their national government, and bilateral and multilateral stakeholders.

Beyond the aspirations of the CCCFP, the provision of insurance to support the livelihoods of fishers begins to address the broader "safety needs" coidentified by UN International Labor Organization (ILO), including the Work in Fishing Convention (ILO 2007). For instance, to formalize the fisheries sector in the Caribbean, including artisanal and small-scale fishers, the ILO promotes, "compulsory insurance, workers' compensation, or other schemes," to protect workers in the case of work-related sickness, injury, or death (i.e., Article 38, Work in Fishing Convention 2007). The model that underpins the COAST insurance policy currently incorporates the total annual loss of income due to business interruption from "bad weather" as a trigger to provide a payout supporting the livelihoods of fisherfolk. Combined with the identities of beneficiaries included in the COAST Operational Manual, these two items

Table 3. A summary of stakeholders who participated in the creation of COAST (ordered by founding date)

Name[a]	Founding	Mission and website
US Department of State	1789	"The US Department of State leads America's foreign policy through diplomacy, advocacy, and assistance by advancing the interests of the American people, their safety and economic prosperity." https://www.state.gov
CEFAS	1902	"CEFAS priorities are directly aligned with Defra's strategic objectives and support the government's ambitions for sustainable blue growth (the sustainable growth of marine and maritime sectors) in associated marine industry sectors that contribute over £38.5 billion to the UK economy and bring broader socio-economic benefits." https://www.cefas.co.uk
World Bank Group	1944	"With 189 member countries, staff from more than 170 countries, and offices in over 130 locations, the World Bank Group is a unique global partnership: five institutions working for sustainable solutions that reduce poverty and build shared prosperity in developing countries." https://www.worldbank.org
UN FAO	1945	"Helping to build a food-secure world for present and future generations." http://www.fao.org/home/en/
CARICOM	1973	"The Community works together to deepen integration and build resilience so as to: [12 bulleted points]" https://caricom.org
CDEMA	1991	"To empower participating states, influence, collaborate and partner with other organizations, to build disaster resilience in the Caribbean." https://www.cdema.org
CRFM	2002	"To promote and facilitate the responsible utilization of the region's fisheries and other aquatic resources for the economic and social benefits of the current and future population of the region." http://www.crfm.net
CCRIF SPC	2007	"Our mission is to assist member governments and their communities in understanding and reducing the socioeconomic and environmental impacts of natural catastrophes." https://www.ccrif.org
CNFO	2009	"To improve the quality of life for fisherfolk and develop a sustainable and profitable industry through networking, representation and capacity building." https://cnfo.fish

[a]Stakeholders include: United States Department of State; Centre for Environmental, Fisheries, and Aquaculture Science (CEFAS); World Bank Group; United Nations Food and Agriculture Organization (FAO); Caribbean Community (CARICOM); Caribbean Disaster Emergency Management Agency (CDEMA); Caribbean Regional Fisheries Mechanism (CRFM); Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company (CCRIF SPC); and Caribbean Network of Fisherfolks Organizations (CNFO).

provide an initial level of social protection to all laborers in the fisheries sector, including artisanal and small-scale fishers. As the conceptual and mathematical model that underpins the COAST insurance policy is improved, and as countries update their COAST Operational Manual, the long-term success of COAST includes provision for meeting "safety needs" including secure employment.

While engineering design has been applied to create new "products"—such as the Brooklyn Bridge, iPhone, or Apollo Space Program—increasingly, community-engaged design is applied to create new "processes," such as sustainable development, social justice, and community resilience (Amadei 2014). COAST was designed to meet the very real, yet very abstract "safety needs" of (1) ensuring food and nutrition security; (2) managing disaster risks triggered by severe weather that is becoming more frequent and more severe due to climate change; and (3) formalizing an economic sector, including artisanal and small-scale fishers, to promote ecosystem-based fisheries management.

As summarized in Table 4, the problem statement that emerged in "Stage One: Identifying," was answered by engineering design. The solution created in "Stage Two: Planning," was tested by engineering design. The coexecuted success of COAST in "Stage Three: Executing," was realized by engineering design. Through the intentional transdisciplinary integration of engineering and diplomacy, community-engaged design was enhanced.

Table 4. Major milestones for community-engaged design and lessons learned during the creation of COAST

Stage	Community-engagement milestone(s)	Design improvement
State one: identifying need(s)	Historical condition: "Insurance is part of CCCFP." Current condition: "Most fishers lack insurance for vessels, health, and lives." Problem statement: "How can climate-smart food security and fisheries ecosystem management enhance community resilience?"	The identification and inclusion of historically underrepresented stakeholders [i.e., specifically women engaged in the fisheries sector, including: (1) as fishers; (2) as owners of vessels; and (3) as operators/owners of postharvest processing].
Stage two: planning solution(s)	Proposed solution: "A mathematical model should be constructed to adequately predict, both: (1) the total annual loss of income due to business interruption from 'bad weather'; and (2) the capital requirements to replace or repair fishing infrastructure lost or damaged during a 'tropical cyclone.'"	The recognition of professional responsibility for project implementation [including: (1) diplomatic engagement; (2) data collection and parametric insurance design; (3) technical assistance; and (4) commercial success of the segregated business cell].
Stage three: executing success(es)	Country ownership: Via the COAST Operational Manual including the identification of individual fishers to support ecosystems-based fisheries management.	The use of evidence-based policy and practice to ensure long-term success of the design.

Note: CCCFP = Caribbean Community Common Fisheries Policy.

Although COAST is not a typical example of environmental engineering meeting Maslow's physiological needs (i.e., through a new drinking water filter, a new toilet, or a new cook stove), it is none the less an example of meeting a need coidentified by diverse and inclusive stakeholders. Furthermore, because of the convergent nature of the research, an "engineer" was required to take on "diplomatic engagement of all relevant stakeholders" as part of professional responsibility for project implementation; an example of the emergence of a V-shaped professional. Finally, the design of an insurance product supported the "process" of community resilience as a coexecuted success.

At times, the profession of engineering has been the subject of criticism, namely that engineering design is biased toward meeting the needs of the wealthiest clients while the needs of the "global poor" are often ignored (Polak 2009; Polak and Warwick 2013). Although a binary view of clientele—wealthy or poor—is attractive due to its simplicity, others argue that sustainable development should be viewed as a "ladder" with individuals, communities, and nations occupying a system of hierarchical "ladder rungs" (i.e., Sachs 2005, 2015). In the ladder analogy, an ongoing debate is the necessity or impediment of foreign assistance to "boost" clients to the first rung of the ladder (i.e., Easterly 2007, 2014). The term "design for development", often makes use of a binary view of clientele and often corresponds to providing a boost to the first rung of the ladder by meeting the physiological needs of communities through humanitarian engineering and technology (Oerther 2021)

The process of engineering design should view individuals, communities, and nations as ever striving to climb a "ladder" of sustainable development. As eloquently described in the first chapter of his book, *To Engineer is Human*, Henry Petroski noted,

> Engineering has as its principal object not the given world but the world that engineers themselves create. And that world does not have [constancy] . . . for human structures involve constant and rapid evolution. It is not simply that we like change for the sake of change, though some may say that is reason enough. It is that human tastes, resources, and ambitions do not stay constant. We humans like our structures to be fashionable as our art; we like extravagancy when we are well off, and we grudgingly economize when times are not so good . . . All of these extra-engineering considerations make the task of the engineer perhaps more exciting and certainly less routine (Petroski 1985).

When engineers participate in the coidentification of needs, in the coplanning of solutions, and in the coexecution of successes, the engineering design process is improved through community engagement.

This case study of COAST is one example of a larger and growing effort leveraging parametric insurance to support a wide range of safety needs. For example, Broberg recently compared three risk pooling schemes—the CCRIF SPC, the Pacific Catastrophe Risk Insurance Pilot, and the African Risk Capacity—and concluded that parametric insurance may be useful as one of a combination of multiple financing tools to promote resilience to climate change (Broberg 2020). In a similar approach, Kousky and coworkers evaluated the possibility of leveraging parametric insurance to improve financial security among low-income households in the United States (Kousky et al. 2021). The results of these early studies all point toward a similar tentative conclusion, namely that the results of the case study of COAST may be more generally applicable as engineers partner with other disciplines to address societal grand challenges through convergence research approaches including community-engaged design.

Conclusion

This case study of COAST demonstrates that community-engaged design may be used to meet the range of Maslow's hierarchy of needs in the pursuit of sustainable development. Specifically, safety needs, including food and nutrition security, climate resilience, and the long-term sustainable operation of marine capture fisheries, are demonstrated in COAST. The results of this case study highlight important aspects of community-engaged design: (1) identifying and including historically underrepresented stakeholders; (2) recognizing the importance of professional responsibility for project implementation; and (3) using evidence-based policy and practice to ensure long-term success of the design (i.e., COAST was renewed for a third policy year in 2021/2022). Engineers should directly engage with communities to design solutions that meet Maslow's hierarchy of needs.

Data Availability Statement

Some or all data, models, or code generated or used during the study are proprietary or confidential in nature and may only be provided with restrictions. This includes the COAST actuarial model, which belongs to CCRIC SPC, and the various COAST Operational Manuals, which are part of the legal contracts between sovereign nations and CCRIF SPC.

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Supplemental Materials

Terms of reference (TOR) for "COAST Project Implementation Coordinator" can be found online in the ASCE Library (www.ascelibrary.org).

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