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Disaster risk in Caribbean fisheries: How vulnerability is shaped and how it can be reduced in Dominica and Antigua and Barbuda

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ABSTRACT

Hurricanes and tropical storms have a substantial and sustained influence on fisheries globally. These threats present particularly significant challenges in Caribbean islands, where fisheries contribute towards economies, food security, and social and cultural identities. Yet, storm impacts on coastal communities and fisheries are a relatively neglected area of disaster risk reduction. In response, this paper reports on a novel application and adaptation of the Pressure and Release model (PAR) focused on Caribbean Island fisheries. The PAR is a well-established framework used to understand how vulnerability manifests and to identify appropriate policy and management options to reduce vulnerability and build resilience in the longer-term. This research highlights how this approach can expose underlying social, cultural, and economic factors that can either reduce or exacerbate vulnerability in the Caribbean island fisheries sector following extreme weather events using Dominica and Antigua and Barbuda as case studies. This study combines a literature review compiling data on underlying factors of vulnerability for Caribbean Island fisheries, with in-person interviews with fisheries managers from Dominica, and Antigua and Barbuda. It showcases the utility of the PAR in fisheries-focused recovery, and provides empirical evidence that fisheries play an important role in supporting immediate and medium-term coping and recovery after an extreme storm event. This approach has broader relevance for climate change adaptation as it highlights strategies for building resilience for fisheries-dependent societies.

1. Introduction

Fisheries are a vital component of livelihoods, economies and food security for coastal communities globally [1,2]. This is particularly evident in small island developing states (SIDS), where people are not only highly dependent on the sea for their livelihoods, but also vulnerable to meteorological hazards, notably storm impacts [3,4]. Growing evidence of an increase in both the strength and intensity of hurricanes due to climate change [5,6] presents a worrying challenge for fisheries because storm impacts on fisheries can have both immediate and long-term consequences on marine ecosystems and their associated social and economic systems [7,8]. Understanding the vulnerability of the fisheries sector to changing storminess, including factors that may not be immediately visible, is essential to better anticipate how climate-driven changes in meteorological hazards (primarily alternations to storms) could impact fisheries and food security in the future.

Storm impacts on the fisheries sector and fishing communities are a neglected area of disaster risk reduction (DRR), although the importance of the fishing sector is recognised for the important role it plays during and after a disaster [e.g., 9, 10], and tropical countries in the Caribbean are one of the regions at most risk from storm impacts on marine fisheries [11]. While the impacts of natural hazards on coastal regions and populations have been relatively well-studied, particularly in relation to climate change, impacts on the fisheries sector and fishing communities have been less well documented [7]. Hurricanes and other natural hazards have been referred to as 'natural disasters'. However, critical changes in the way disasters are understood have led to the well-accepted argument in the disaster literature that they are *social*

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phenomena rather than natural [e.g., 12, 13], i.e., that exposure, sensitivity and adaptive capacity determine whether a risk manifests into a disaster. It is argued that underlying social, economic and cultural factors shape the extent of loss and damage from a hazard leading to the disaster, rather than the nature of the hazard event itself [13]. However, the conceptualisation of disasters as 'natural' persists in fisheries and masks the underlying social vulnerabilities that drive disasters [14], resulting in a blind spot for building resilience to future hazards [15].

In response to growing recognition that the extent of damage and impact from a hazard is linked to social vulnerability, and disasters can in fact be viewed as expressions of social vulnerability, the Pressure and Release Model (PAR) developed by Blaikie et al. [12] can be of great utility. This conceptual model is based on the premise that a disaster occurs at the intersection of a hazard and the underlying conditions that create social vulnerability [13,14]. The PAR has been used in various sectors to understand components of risk or vulnerability and to identify appropriate and effective policy or management options to increase resilience. What the PAR offers beyond more traditional vulnerability assessments is an understanding of underlying drivers that can increase or perpetuate vulnerability, even after more immediate pressures leading to vulnerability are identified and addressed. Other vulnerability assessments have utility in highlighting these urgent needs, e.g. [17], however the PAR identifies both urgent needs and deep-rooted drivers of vulnerability [12,13]. While DRR is focused on understanding and reducing vulnerability to hazards, DRR and climate change adaptation share goals of reducing vulnerability and increasing resilience. Although there is conceptual overlap in different understandings of vulnerability and resilience in the hazard/disaster and climate change adaptation fields, these terms are used broadly to refer to existing conditions that increase susceptibility to harm (vulnerability) and the ability to resist, accommodate, adapt to, and recover from hazard events [18].

This paper applies the PAR model explicitly to fisheries for the first time with a case study of the Caribbean Island nations of Dominica and Antigua and Barbuda. The Caribbean Island region regularly experiences extreme weather in the form of tropical storms and hurricanes (i.e. tropical cyclones with wind speeds of 39–73 and over 74 miles per hour, respectively [19]), and these have substantial immediate and long-term negative consequences for food security and national economies, via impacts on marine resources and livelihoods [20]. There are clear physical, geographic, and climatic factors that make the Caribbean Island region particularly exposed to hazards including hurricanes; however, social and historic factors including levels of poverty, institutional capacity and social networks are what ultimately shape the fishing sector's vulnerability to disaster. As well as using the PAR model as a diagnostic tool to understand underlying drivers and causes of disasters, this research also uses it to highlight the ways fisheries can contribute to reducing disaster risk for other livelihoods and communities to illustrate the potential benefits of bringing together disaster risk reduction and fisheries. While applied here to Dominica and Antigua and Barbuda fisheries and disaster risk from hurricanes, the PAR is easily transferable to other areas and hazards.

This paper provides a general discussion of disaster risk and vulnerability in the fisheries sector and outlines the conceptual and methodological approach of the PAR model. Subsequently, this paper demonstrates how this model can be applied to assess disaster risk and vulnerability in Dominican and Antigua and Barbudan fisheries. The final section highlights how such risks might be reduced through effective adaptation interventions and brings together policy implications for DRR and fisheries management to build resilience.

2. General approach and conceptual framework

How a disaster unfolds and to what extent different groups or sectors are impacted is not only determined by the nature of the hazard itself, but also by social vulnerability, comprised of factors that shape the social, economic and cultural context. Geography undoubtably plays a role in disaster risk. However, vulnerability and therefore disaster risk can accumulate over time and different groups of people living in approximately the same place may still experience hazard impacts very differently due to the uneven distribution of vulnerability, exposure and adaptive capacity, e.g. [14]. These vulnerabilities and risks are shaped by decisions and approaches rooted in economic and social structures (e.g., market economies, class), history, culture, and ideologies [16,21].

Over two decades of scholarship have been dedicated to understanding how disasters are shaped by social vulnerabilities [13,22], highlighting the need to understand causal drivers of risk with the increase in global disruption and impacts from climate change [23]. Links between fisheries management, disaster preparedness and recovery in SIDS have been previously demonstrated. For example, in Vanuatu following a major tropical cyclone and subsequent drought and earthquake events which negatively impacted terrestrial food systems, coastal community reliance on marine resources increased; fishing was a vital coping strategy during and immediately after these hazard events [10]. While fisheries can provide an important service in the aftermath of some hazards, hazards can also cause significant damage to the fisheries sector [6,8,9]. Few studies have to date focused on the causal factors of disaster risk in fisheries (see e.g., [24]), and none have specially applied the PAR. While some studies have used the PAR to examine disaster risk and vulnerability in general in the Caribbean (e.g., [12,25]), none have applied this thinking directly to fisheries in Dominica and Antigua and Barbuda.

2.1. Pressure and Release (PAR) model

The PAR model of disaster risk presents a useful tool to explore the linkages between disaster impacts, responses and recovery (Fig. 1). The model is based on the premise that while natural hazards are events that occur with varying intensities, severity and duration (e.g. storms, earthquakes), a disaster is largely a human construct resulting from high exposure, limited adaptive capacity and hence elevated socio-economic vulnerability [12]. Disasters occur when vulnerable people experience the hazard and subsequent damage or disruption to the extent that it significantly disrupts their lives and livelihoods, such that recovery is not possible without external assistance [13]. Disaster risk is understood to be the consequence of the interaction between the hazard (e.g. hurricanes) and the characteristics that make people vulnerable and exposed.

The risk of a hazard event becoming a disaster is influenced by the nature of the hazard itself and by the conditions that lead to vulnerability, which can be different for different groups in the same location [13,16]. This conceptualisation of risk is often expressed as: *Risk = Hazard x Exposure x Vulnerability*. Therefore, disaster risk is the social production of vulnerability, and disasters themselves are the result of interactions between the social production of vulnerability and the hazard event. Accordingly, disasters are not politically neutral [26] as the underlying vulnerability of groups or individuals is ultimately shaped by access to resources in its broadest sense (e.g. from financial wealth and livelihoods, social networks and protection, to political power). In turn, this is influenced by historical, cultural, economic, institutional, political, and social structures and factors [16], [27]. In the PAR model, the various underlying factors that shape vulnerability are captured in two main stages: termed the 'pressure stage' if unfavourable conditions result in increased vulnerability; and 'release stage' if improved conditions lead to decreased vulnerability.

2.1.1. The Pressure Stage

The **Pressure stage** of the PAR describes the progression of vulnerability which ultimately results in 'unsafe conditions.' It is created by 'root causes' and 'dynamic pressures', that may not be immediately observable or explicitly linked (Fig. 1). **Root causes** are spatially or temporally distant, e.g. historical patterns of governance, social exclusion or economic systems and structures. **Dynamic pressures** are

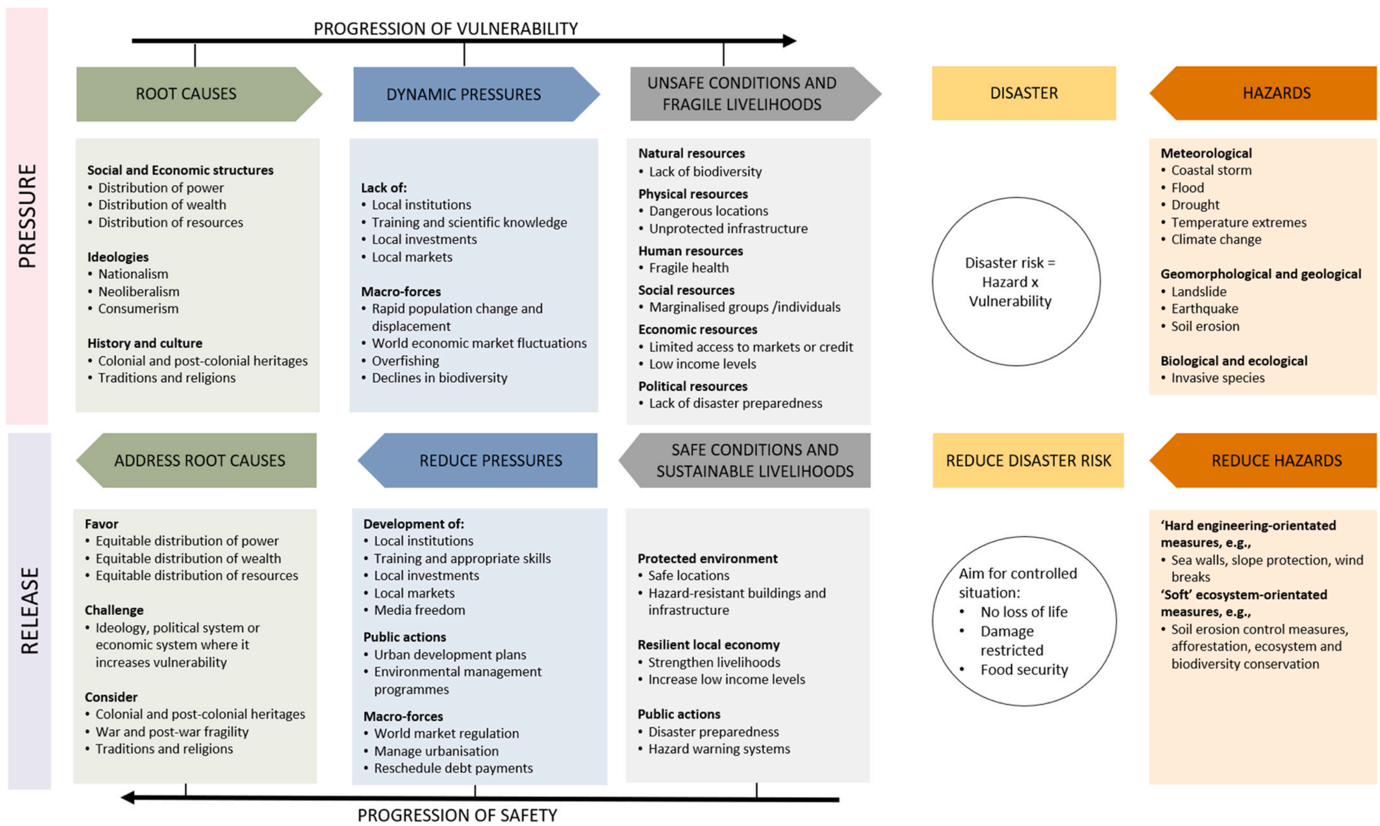

Fig. 1. The Pressure and Release (PAR) model for understanding the progression of vulnerability (Pressure stage: top row) and for identifying means to counter this leading to progression of safety (Release stage: bottom row), so reducing disaster risk and supporting safe conditions.
Adapted from [16].

processes that operate on shorter timescales, e.g. decades, and can be regional or global. They translate root causes into specific situations where vulnerability is expressed at a time and place – referred to as **unsafe conditions**. These conditions expose the limited (or lack of) access to resources that support coping, recovery and risk reduction. Unsafe conditions may result in **fragile livelihoods** – where people are potentially, disproportionally prone to be affected by the impacts from unsafe conditions.

For fisheries in SIDS, unsafe conditions could include infrastructure in areas exposed to high winds and storm surge, or already degraded biodiversity in key fisheries habitat. The dynamic pressures that relate to these conditions would then include the economic choice to develop coastlines for specific uses such as tourism, forcing fishing infrastructure to move to less sheltered locations, and clearing land upstream for agriculture resulting in increased runoff, further compromising coral reef health. These dynamic pressures can be traced back to root causes, for example in the Caribbean, this includes colonial and post-colonial patterns of land ownership or neoliberal ideologies influencing short-term profit prioritisation [21].

2.1.2. The Release Stage

The **Release stage** of the PAR can be used to identify strategies to reduce vulnerability through focusing on efforts addressing unsafe conditions or addressing macro-scale conditions that contribute toward vulnerability (Fig. 1). For example, many disaster risk management policy areas focus on physical infrastructure and neglect policies that support creation of social capital, despite evidence that social networks and social capital are vital for recovery trajectories [28], [29]. The Release stage of the PAR is useful for understanding why for some countries hazard fatalities are much lower than others. For example, in Cuba strong social protection, a civil defence system, early warning systems and a population with high educational attainment have contributed to reducing unsafe conditions and dynamic pressures, therefore reducing impacts including overall fatalities from meteorological hazards [24].

2.2. Materials and methods: applying the PAR to fisheries in Dominica and Antigua and Barbuda

The PAR approach was applied to assess vulnerability and disaster risk in Dominican and Antiguan and Barbudan fisheries, based on insights from existing research, literature review and data collected in 2018 (a period following several extreme hurricane events). The data presented here represents specific testing of the PAR in a scoping capacity using literature and primary data for the island nations of Dominica and Antigua and Barbuda. Precursing this study, work undertaken by the authors on historical trajectories of hazards in SIDS, specifically Dominica [21], which involved primary data collection (archival research; key informant interviews with government officials involved in disaster and natural resources management, and community leaders in three coastal areas; and community workshops focused on recent and historical experiences with multiple hazards, e.g. hurricanes, landslides, earthquakes). This initial work demonstrated the need for further research to focus specifically on the vulnerability of the fisheries sector to hurricanes, an important yet underrepresented area of enquiry (see [13]). To do so, a review of current literature focused on Caribbean Island fisheries with an emphasis on Dominica and Antigua and Barbuda (peer-reviewed and grey literature; [30]) was conducted to understand:

- medium and long-term impacts of hurricanes on Caribbean Island fishing economies;
- significance of hurricane-associated losses to the sector; and

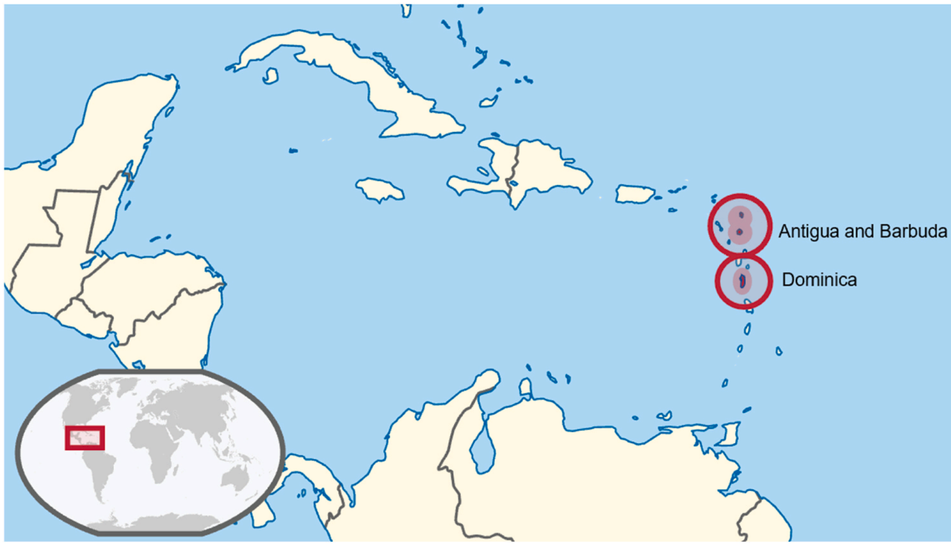

Fig. 2. Map of study area. Location of Antigua and Barbuda and Dominica in the Caribbean region. *SOURCE: TUBS, CC BY-SA 3.0* <*https://creativecommons.org/licenses/by-sa/3.0*>, via *Wikimedia Commons*.

- the role of fisheries in food security in the immediate aftermath of storm events.

While the review covered the Caribbean Island region to better situate Dominica and Antigua and Barbuda in their regional context and identify any regional patterns or themes such as shared experiences in storm frequency and severity, linked economies and distinctive colonial and post-colonial legacies, the focus was on the two countries (Fig. 2). This review built on previous considerations of the importance of understanding historical trajectories of risk [21], while focusing attention on a knowledge gap in how vulnerability to hazards accumulates over time in the fisheries sector. The authors identified the PAR as a useful tool to explore this gap in understanding disaster risk accumulation and supplemented the literature review with data from face-to-face semi--structured interviews conducted in July 2018 with government fisheries managers from Dominica, and Antigua and Barbuda, which were two of the most severely affected countries during the 2017 hurricane season. One fishery manager from Dominica and two from Antigua and Barbuda were in the United Kingdom as part of the Commonwealth Marine Economies Programme, a UK-funded programme to support the identification the potential of and developing the marine economies of 17 SIDS, including Dominica and Antigua and Barbuda.[1] The three interviewees represent national-level experts who had managerial oversight of their respective fisheries departments and were consequently best placed to contribute contextual information on how hurricanes affected the sector in these countries. Interviews took place at the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in the UK. Interviewee questions included: describing hurricane impacts on the fishing industry (e.g., on production, interruptions to operations, processing, transportation and loss of life); details of compensation to those involved in the sector; changes in hurricane impacts on fisheries over time; and response and recovery details.

Following analysis of key themes that emerged in the literature review and the primary data collected through these targeted interviews, NVivo 10 [31] was used to conduct further thematic analysis using themes within the structure of the PAR model on both the literature and the interviews. The initial inductive coding to identify factors affecting vulnerability (including proximate and distal drivers) was followed with deductive coding applying the PAR framework to the data. This combination of literature review and primary data allows this paper to unpack the myriad ways in which vulnerability accumulates and may be reduced in fisheries in Dominica and Antigua and Barbuda.

3. Results: how vulnerability develops in Dominican and Antiguan and Barbudan fisheries

3.1. Hazard: hurricanes and storms

Between 2000 and 2021 a succession of major hurricanes and tropical storm events caused over 5000 fatalities in Caribbean Islands, affected 25.7 million individuals and resulted in USD 108 billion in damage [32]. However, hurricane impacts can be highly localised within the Caribbean region. For example, Hurricane Janet in 1955 was the last hurricane to directly hit Barbados [33], whereas between 1980 and 2009 Haiti experienced 67 tropical storms, hurricanes or major flooding events [25]. These affected more than 2.5 million people and caused economic damages in excess of USD 2.5 billion over this extended period. In addition to the geographic variability of storm impacts and trajectories, storms and hurricanes directly and indirectly impact different parts of the fishing sector (Table 1), for example affecting offshore operations, resource availability or onshore infrastructure. The 2017 hurricane season had a large impact on Dominica's and Antigua and Barbuda's fisheries, with Hurricane Maria devastating Dominica [37] and impacting the island of Antigua [39]. Maria was shortly followed by Hurricane Irma which devastated Antigua and Barbuda [39]. These two storms caused USD 2.4 million in loss and damage to the fishing sector of both countries, and USD 1.2 billion in loss and damage to Dominica (226% of 2016 GDP; [37]) and USD 155 million in loss and damage to Antigua and Barbuda [39].

3.2. How does vulnerability accumulate in fisheries?

The 'Pressure Stage' of the PAR model helps to tease out how vulnerability develops in fisheries due to multiple intersecting pressures and influences. In applying the PAR to fisheries in Dominica and Antigua and Barbuda, the study first examines some of the root causes of vulnerability, any dynamic pressures, and then traces the origin of unsafe conditions and fragile livelihoods (Table 2). Tracing vulnerability using the PAR permits the examination of factors that may not be immediately obvious but are nevertheless important components of

[1] See https://www.gov.uk/guidance/commonwealth-marine-economies-programme for more information on the Programme which ran from 2016 to 2022.

vulnerability and therefore need addressing to build resilience.

3.2.1. Root causes of vulnerability

Root causes of disaster risk result from structures and systems that create and perpetuate vulnerability, but these structures and systems can be hard to identify [12,13]. Dominica and Antigua and Barbuda were colonies of the United Kingdom until 1978 and 1981, respectively. This colonial past[2] has resulted in a legacy of economic and social systems where groups and individuals have been marginalised for generations and economies are often heavily reliant on primary sectors such as agriculture and fisheries [21,63,64]. In some instances, Caribbean nations have struggled to diversify their economies away from crops such as bananas and limes, the dependency on which stems from colonial and post-colonial economic structures and markets [65,66]. Additionally, colonial land use and subsequent post-colonial shifts in land use contributed to land and soil degradation in Antigua [60] where large-scale sugar plantations were more common while the island of Barbuda did not support similar large-scale plantation systems and has less degraded soils [62,63]. Processes of land use and tenure established during the colonial era continue to shape today's exposure of people, and their adaptive capacity in the face of hazards, in both countries. Notably reflected in historical land use and tenure patterns that exacerbated hurricane impacts and where vulnerable groups live on steep hillsides prone to landslides and in flood plains; this includes poorer fishing communities often located in sites highly exposed to hurricane impacts [14,21], or where tensions over land tenure can constrain hurricane recovery efforts [60].

Another example of post-colonial influence is how neoliberal ideologies shape markets and structures, such as the conditions under which many Caribbean Island countries have borrowed money. The region is one of the most indebted in the world (see (b) on Fig. 3; [67]), and development loans provided to Caribbean Island countries by the World Bank and International Monetary Fund and their associated structural adjustments (mandating reduced government budgets) resulted in high debt levels and debt servicing that consumes large proportions of government revenues (Fig. 3; e.g., in 2021 Dominica's debt servicing accounted for 16.6% of GNI and the total value of Dominica's debt was 258% of GNI, data on debt servicing unavailable for Antigua and Barbuda; [67])]. This has, in-turn, reduced spending on public services and infrastructure [68], increased income inequality, increased focus on economic production for export rather than domestic consumption and increased environmental damage through fewer regulations [70,71]. For example, while Antigua and Barbuda is classified as high income (per capita GDP 15,781 in 2021), a heavy reliance on tourism combined with shocks from hurricanes in 2017 and 2019, as well as the COVID-19 pandemic mean that it's debt is now assessed as unsustainable by the International Monetary Fund [78]. This position has also meant that Antigua and Barbuda has been unable to raise capital to finance critical infrastructure or projects targeting existing climate vulnerabilities [78]. Due in large part to these structural adjustment programmes and debt service commitments, Caribbean countries can end up financing the cost of disasters via the diversion of already allocated (and very limited) resources to manage disaster consequences [72].

3.2.2. Dynamic pressures shaping vulnerability

Dynamic pressures translate root causes into unsafe conditions and can be seen in macro-level structures and networks. For fisheries, these may include a lack of investment in safe and secure infrastructure, such as storage and landings facilities (Table 2). Immediately following Hurricane Maria (2017) in Dominica, catastrophic damage to cold storage, power generation and fuel facilities meant that fishers were forced to stay close to shore and only catch what could be sold or consumed in one day [37]; these limitations persisted for months until effective infrastructure could be restored [30]. While direct damage to infrastructure clearly impacts the ability of fishers and processors to meet market demand, so can reallocation of fisheries infrastructure. After Hurricanes Irma and Maria in 2017, Barbuda's fisheries complex was one of the few buildings with minimal damage, so was used to support residents. However, neighbouring French islands (and members of the European Union) are the primary market for Barbuda's export-driven lobster fishery; with no safe facility to process lobster according to European Union food safety regulations, fishers were unable to process and sell their catch.

While damage to dock or harbour-side infrastructure is a common impact from storms and hurricanes, one of the more substantial implications for many Caribbean fishers is the loss and damage to fish traps and nets (commonly used for reef fish and lobsters) [37]. Antiguan and Barbudan fisheries managers described how new technology using GPS rather than buoys to mark the positions of fish traps was gaining prominence prior to Hurricane Irma as these were preferred by fishers to reduce theft; however, GPS-marked traps proved more difficult to relocate after a storm. Following Hurricane Irma, 44% of fish traps in Antigua and Barbuda were lost. While this added cost can be disastrous for individual fishers, it also increases the incidence of ghost fishing [38]. Ghost fishing is one of most pervasive stressors to the marine environment that, combined with overfishing, has pushed many Caribbean coral reef communities close to a critical threshold and affected their capacity to recover from hurricane damage [73,74]. By contrast, in Dominica the most important fisheries are for large offshore pelagic species such as dolphinfish and tuna around fish aggregating devices (FADs). Although many FADs were dislodged or re-located during Hurricane Maria, the pelagic fishery was able to recover relatively quickly and contribute to immediate food security pressures [12].

3.2.3. Disaster risk: unsafe conditions and fragile livelihoods

Unsafe conditions for lives and livelihoods are where accumulated vulnerability is expressed and observed. For fisheries this includes the high impact of hurricanes on fishing effort and capacity as a result of damages or losses of vessels and gear, and subsequent high costs for repair or replacement. In Dominica and Antigua and Barbuda, storm surges and high winds at sea and on the coast have regularly caused fishing vessels and gear to be lost or damaged [37,38]. However, high rainfall causing river flooding can also lead to loss of gear and vessels if these are situated near to river catchments, as well as excessive debris being washed out of rivers and so causing navigation hazards or damage to reef structures; this happened in Dominica in 2015 during Tropical Storm Erika, which was associated with extremely high rainfall rather than coastal inundation and storm surge [39,75].

Hurricane impacts highlight the vulnerability and fragility of fishing livelihoods to disruption, and damage can impact fishing livelihoods in the short and long-term. In Dominica documented fisheries landings fell from over 150 tonnes in 1980 (after two successive hurricanes in 1979 and one in 1980) to around 50 tonnes in 1989 [51] due to degraded coastal habitats and loss of fishing gear, which partly accelerated the transition towards offshore pelagic fishing (perceived as being more resilient). Interviewees suggested that following Hurricane Maria in Dominica, fishers had temporarily left the sector because they could earn greater revenues by engaging in re-construction work (more than 90% of buildings were damaged by the hurricane) than they could by continuing in the fisheries sector. Additionally, the fragility of other sectors can impact fishery livelihoods and resources. Following Hurricane Luis (1995) in Antigua and Barbuda damage to tourist infrastructure resulted in increased pressure on fish stocks as workers from the

[2] Dominica and Antigua and Barbuda were initially settled by people from South America [21,60]. Dominica was first a French and then British colony, with an economy dependent on coffee, bananas and later limes [21]. Antigua and Barbuda was a British colony, dominated by sugar and tobacco plantations, primarily focused on Antigua [60]. The plantation economies of both countries were made possible by importing and using slave labour, largely from West Africa [21,60].

Table 1

Selected severe hurricane and tropical storm impacts on Caribbean fisheries. Reported direct impacts on Caribbean Island fisheries from named storms (hurricanes and tropical storms) from 1955 to 2019. This list is not exhaustive, however encompasses the types of impacts and range of loss and damage caused by storm impacts on the fishing sector.

Hurricane or Tropical Storm	Storm category	Country	Damage to gear and vessels	Damage to fisheries infrastructure	Decline in landings *(time frame post-storm unavailable)*	Damage to habitat (e.g. recruitment, breeding areas)	Fatalities and missing persons	Cost specific to fisheries *(USD; where available)*	Source
Dorian (2019)	5	The Bahamas	X	X			> 200	11,000,000	[33, 34]
Maria (2017)	5	Puerto Rico	X	X			2,975	70,000-90,000	[35]
		Dominica	X	X			65	2,084,017	[36]
Irma (2017)	5	**Antigua and Barbuda**	X	X			3	316,126	[37]
Erika[†] (2015)	TS	Dominica	X			X	30	2,043,954	[38]
Earl (2010)	4	**Antigua and Barbuda**	X	X			1	67,641	[39, 41]
Gustav (2008)	4	Jamaica	X				15	14,000,000 *(of which 9,450,000 damage to single fishing beach)*	[42]
Dean (2007)	5	Jamaica	X				3	4,000,000	[43]
		Saint Lucia	X						[44]
Ivan (2004)	5	Jamaica		X	X		17	1,995,400	[45]
		Grenada	X	X			39	2,100,000	[46]
Lenny (1999)	4	Grenada	X		X		0	149,000	[47, 48]
		Anguilla			X		0		[49]
		Antigua and Barbuda			X		1		[50]
		Dominica				X	0	814,815	[51]
Luis (1995)	4	**Antigua and Barbuda**			X		3		[50]
		Anguilla			X		0		[48]
Hugo (1989)	5	**Antigua and Barbuda**			X		2		[50]
Gilbert (1988)	5	**Antigua and Barbuda**			X		0		[50]
		Cuba				X	0		[52]
		Jamaica	X				45		[53]
Allen (1980)	5	Saint Vincent and the Grenadines	X		X		0	26,000	[54]
		Saint Lucia	X				6		[55]
David (1979)	5	**Dominica**	X				56		[56, 57]
		Dominican Republic	X				2000		[56, 57]
		Puerto Rico	X				7		[56, 57]
Carmen (1974)	4	Jamaica				X			[58]
Camille (1969)	5	Turks and Caicos			X		0		[59]

[†] Erika was a Tropical Storm and never developed into a hurricane but had excessive rainfall.

tourism sector took up short-term employment in fisheries [79].

3.3. *How can we reduce vulnerability and build resilience in fisheries?*

As shown above, the PAR can provide useful insights into how vulnerability progresses and accumulates to create unsafe conditions and fragile livelihoods. However, it is also useful for identifying points for action and intervention to increase resilience to hazards. The focus of the following section is on how unsafe conditions in Dominican and Antiguan and Barbudan fisheries can be avoided or mitigated, by identifying actions and efforts to support resilience in the face of future hazards (Table 3).

3.3.1. *Building resilience by addressing root causes and reducing pressures*

Changing or reversing the mechanisms that translate root causes into unsafe conditions can help build resilience to hazards [12]. Modifying power structures – including access to knowledge and cultural resources for vulnerable groups – is one way to change those mechanisms [11,12] as can addressing social inequalities or providing alternative livelihoods. Some actions tackling these mechanisms may not be directly related to the fisheries sector, but to broader efforts to address issues that create vulnerability. For example, reclaiming indigenous knowledge and confronting colonial legacies have resulted in buildings that can be more resilient to extreme weather (e.g. using traditional construction techniques that include using dowels rather than nails, and identifying suitable timber in forests; [8]). While not directly related to the fisheries sector, many indigenous groups are also traditionally fishers and their knowledge of marine and coastal environments can be valuable for mitigating impacts from storms [80,81]. Individuals or communities can drive development of climate-smart fisheries themselves, by learning best practice approaches from other individuals and communities who have already made that change. Fishing cooperatives can have a big part

Table 2

Progression of vulnerability in Dominican and Antiguan and Barbudan Island fisheries. The Pressure Stage in the PAR model applied here to demonstrate historic and current factors that create vulnerability in Dominican and Antiguan and Barbudan Island fisheries. Evidence used is drawn from both the collected primary data and the review of literature.

		Antigua and Barbuda	Dominica	Sources
Root Causes	Colonial and post-colonial heritages	Land and soil degradation; patterns of land tenure	Land use patterns exacerbate hurricane impacts and lead to vulnerable groups more exposed to hazard impacts	[21,59–61]
	Neoliberalism	High national debt, high levels of debt arrears, high debt servicing costs	High national debt, high debt servicing costs	[68–72]
Dynamic Pressures	Lack of investment in safe and secure infrastructure (e.g. cold storage facilities)		Lack of investment in secure cold storage, power generation and fuel facilities meant months before effective cold storage widely available following Hurricane Maria	Interviews,[30,37]
	Technological advances (and associated unintended consequences, e.g., traps marked with GPS)	GPS fishing gear markers (e.g. on traps) hard to find after hurricane, increase ghost fishing		Interviews, [38]
	Disrupted market networks	Fishery complex used as housing reducing ability of fishers to process and export catch	Local markets unavailable and/or inaccessible in aftermath of storm	Interviews, [30]
	National economies reliant on the primary sector (or single sector)	Heavy reliance on tourism, with fishing making up important food and income 'safety net'	Heavy reliance on primary sector (especially bananas), with growing importance of tourism	[21,37,38]
Unsafe conditions and fragile livelihoods	Physical resources affected by: • Unprotected infrastructure • Damaged/destroyed gear • Damage/debris restricts access to landing sites and coastal areas	Boats, gear and landing sites damaged by storm events	Boats, gear and landing sites damaged by storm events	[38,39,51,82]
	Human resources affected by trauma and/or mental health issues		Increased fear of storms and uncertainty over livelihood future for individual fishers	[77]
	Social resources affected by marginalized indigenous groups and/or disrupted social networks	Widespread impact due to fishing occupying 'fall back' economic opportunity (e.g., 25% of Barbuda population affected by Hurricane Irma's impact on fishers)	Individuals prioritise immediate family needs in aftermath of disaster reduces community cohesion	[38,77]
	Economic resources affected by: • Livelihoods easily disrupted (e.g. tourism shifting to fishing, increasing fishing pressure) • Lost revenue and high costs (e.g. lost fishing days; repair/replacement costs for gear and boats) • Lack of secure area to store boats and gear for both catch and processing	Lost revenue due to lost fishing days as well as gear, boats and infrastructure lost and/or damaged; costs of repair or replacement; individuals leaving fishing for jobs in other sectors	Lost revenue due to lost fishing days as well as gear, boats and infrastructure lost and/or damaged; costs of repair or replacement; individuals leaving fishing for jobs in other sectors	Interviews,[37,38,51,73,76,77]

to play in coordinating, supporting, and providing training, as well as offering rudimentary banking facilities. Consequently, fisheries co-operatives can be used to develop support schemes, to spread risks and provide a financial 'safety net' [4]. While these have proved helpful in Dominica, the capacity of cooperatives has declined with associated reduced potential in collective action [8], although community cohesion and support is still an important component of recovery after hurricanes [75].

Recognition that Caribbean Island countries are vulnerable to climate change, and that their limited ability to respond is partly due to high debts limiting public spending on DRR and climate change adaptation, is an important step in addressing the structures that have led to increased regional vulnerability. Proposals such as 'Debt for Climate Adaptation Swaps' [82,83] attempt to not only assist the region with preparing for climate change (including hazards such as hurricanes), they also act as recognition that the high national debts of many Caribbean nations as well as their climate change vulnerability are rooted in external factors such as the conditions under which debts were acquired [82,83]. Antigua and Barbuda has published an implementation road map for how Debt for Climate Adaptation Swaps can benefit the country, especially as it is unable to qualify for many other debt-relief initiatives due to its relatively high GDP [78,83].

Timely compensation and risk pooling (e.g., via insurance) can mitigate the economic impacts caused by hurricanes on livelihoods and communities. Insufficient compensation can be devastating to both fishers and those whose livelihoods are linked with fishing as compensation and recovery assistance enables fishers and the sector in general to quickly recover fishing livelihoods. However, if there is no accurate and up-to-date database on fishers it can be challenging to support claims [7]. Following Hurricane Maria (2017), Dominica fishery managers described how a lack of an accurate database (especially of fishers who were not part of an organised cooperative) was a challenge to manage compensation claims. Many fishers had lost their boats and gear in addition to their homes and vehicles and yet received compensation worth only half the cost of a boat replacement, and so chose not to return to fishing and rather to invest the money received in rebuilding their dwellings. Insurance for high intensity rainfall events or hurricanes is becoming widespread in the region for the agricultural sector, and two countries are participating in a pilot programme trailing similar insurance products for the fisheries sector. The Caribbean Oceans and Aquaculture SusTainability Facility (COAST) scheme is operating in St Lucia and Grenada [84]. In addition to being one of the first parametric insurance available to the fishing sector, the scheme is available to all those registered as working in the fishing sector, so includes not only fishers, but also vendors and processers (often women). Pay-outs are made for losses due to bad weather (e.g. high waves or rainfall) as well

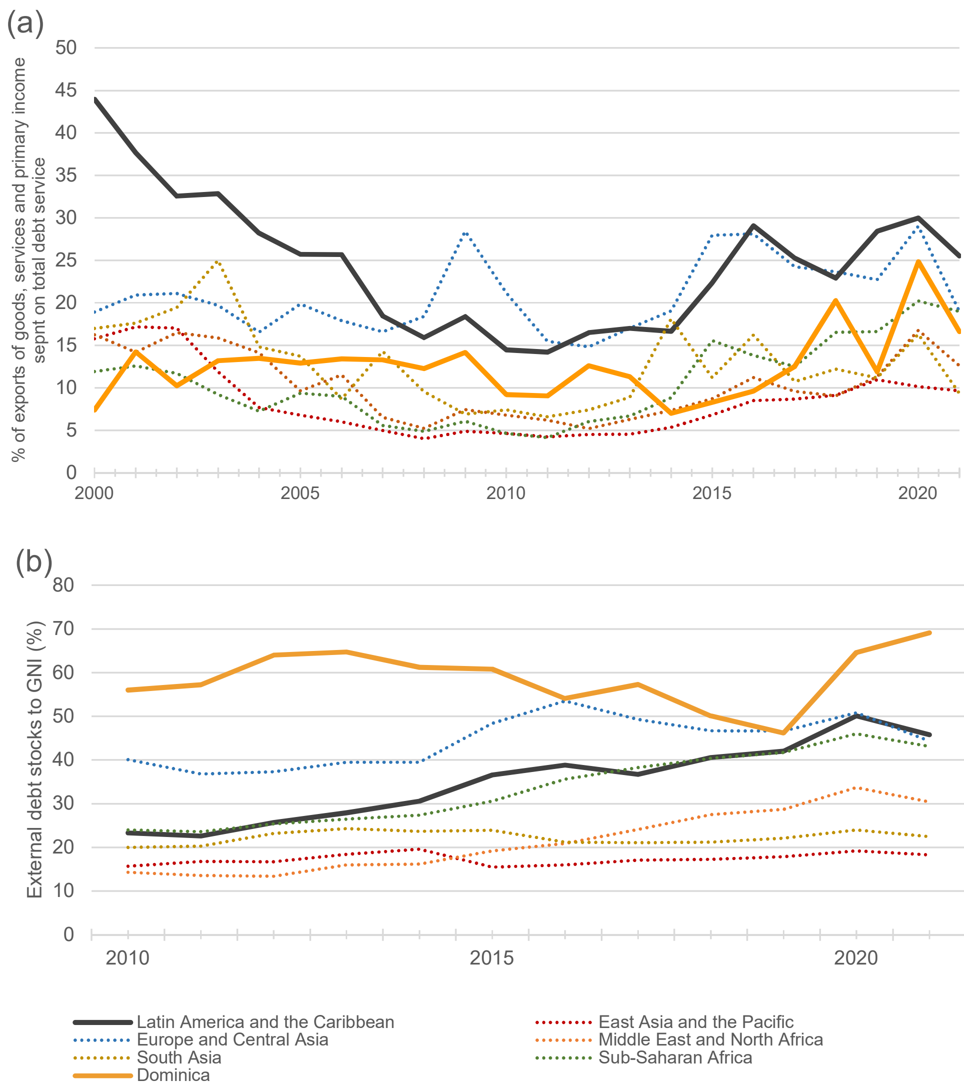

Fig. 3. Debt and debt servicing for Dominica and six world regions, excluding high income countries (no data available for Antigua and Barbuda). (a) *Total Debt Service*. Total debt service to exports of goods, services, and primary income, where total debt service is the sum of principal repayments and interest actually paid in currency, goods, or services on long-term debt, interest paid on short-term debt, and repayments (repurchases and charges) to the IMF. (b) *Total external debt stocks to gross national income*. Total external debt is the sum of public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt. Short-term debt includes all debt having an original maturity of one year or less and interest in arrears on long-term debt. GNI (formerly GNP) is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. *Data from World Bank International Debt Statistics.*

as for direct damage caused by tropical storms [84].

National policy focused on reducing vulnerability and building resilience demonstrates national-level commitment to addressing many of the issues highlighted in this paper. Dominica has declared its intention to be the world's first climate resilient country and established the Climate Resilience Execution Agency (CREAD) in 2018 [85]. Under CREAD's leadership, the National Resilience Development Strategy 2030 and the Climate Resilience and recovery Plan provides guidance for recovery from disasters as well as focusing on climate resilience systems, disaster risk management systems and effective disaster response and recovery [86,87]. Additionally, the Caribbean Regional Fisheries Mechanism and the Caribbean Disaster Emergency Management Agency signed a Memorandum of Understanding in 2019 to advance disaster management and climate resilience in the fisheries and aquaculture sector in the region and have developed a strategy to integrate disaster risk management, climate change adaptation and the fisheries sector [89].

3.3.2. *Moving toward safe conditions and sustainable livelihoods*

As demonstrated above, addressing processes that ultimately lead to vulnerability can increase resilience, however creating safe conditions and supporting sustainable livelihoods also mitigates immediate and sector-specific disaster risk. Some Dominican fishers began to trade with neighbouring islands when local markets were disrupted following Maria, and those trade links continue at least two years post-Maria [8]. Adaptive practices that outlive their initial storm response demonstrate an ability to take advantage of opportunities, important for sustainable and resilient livelihoods [89].

Knowing when storms are coming is key to disaster preparedness. In the Eastern Caribbean an app-based early warning system is now available under the Pilot Programme for Climate Resilience [90]. The app sends alerts of bad weather conditions or sea state to fishers, giving them early warning of any potentially dangerous conditions. Users can share information on local conditions and about missing persons. Having information direct to mobile phones is valuable, as fishers may not check weather conditions each day before they go to sea. The app is

Table 3

Progression of safety in Caribbean Island fisheries. The Release Stage in the PAR model applied here to demonstrate historic and current factors that create vulnerability in Antiguan and Barbudan, and Dominican fisheries. These work to reduce disaster risk by creating safer conditions and sustainable livelihoods, reducing pressures and addressing root causes. Many of these efforts overlap with climate change adaptation as they share the same goal of building resilience to climate-related events. Information drawn from literature review and primary data from Dominica, and Antigua and Barbuda.

		Antigua and Barbuda	Dominica	Sources
Address Root Causes	Increase vulnerable group access to power structures and resources		Fishing cooperatives utilise traditional knowledge and pool resources to increase access for marginalised groups	[8]
	Confront colonial heritage and what it means for vulnerability	Debt for climate swaps		[78,82,83]
Reduce Pressures	Development of: • Support and compensation for recovery • Strengthen regional and domestic policy recognition of link between disaster risk management and fisheries • Disaster risk insurance for the fishing sector	Countries participate in regional disaster scheme, regionally being rolled out for fishers Regional policy recognition of link and incorporation of fisheries with DDR	Countries participate in regional disaster scheme, regionally being rolled out for fishers Regional policy recognition of link and incorporation of fisheries with DDR Compensation identified as a gap in Dominica	Interviews, [85–88]
Safe conditions and stable livelihoods	Support for the vulnerable within communities, including immediate food provision in the aftermath of a hurricane/storm		Prioritising elders with fish in immediate aftermath of hurricane	Interviews, [39]
	Livelihood adaptation and adaptive practices	Recognition of need to modify current practices to secure boats in high winds	Trading links with neighbouring islands following local market disruption continued; FADs less impacted than nearshore traps so offshore fishing resume quickly	[40]
	Disaster preparedness		Pilot programme for climate resilience early warning system	[84]

being rolled out in Grenada, Saint Vincent and the Grenadines, Saint Lucia, and Dominica. Community-level disaster planning can play a vital role in disaster preparedness, and the Red Cross has supported the development of community disaster groups, working with fishers and fisher's organisations, e.g., in Dominica [8,29,75].

The ability to resume fishing quickly can be crucial to maintaining food security when damage to terrestrial food crops is high and there is disruption to markets or imports. Following Hurricane Maria at least 24,000 in Dominica faced severe or borderline food insecurity [37]. Highlighting the importance of fisheries during the critical post-hurricane period, a Dominican fisheries officer described how even residents who had lost all their crops or household gardens could go back to the sea to fish after Maria. Additionally, fishers were reported to supply free fish to elders in communities, providing important support for vulnerable community members. The role of fishers in meeting food needs, including for the more vulnerable, highlights the importance of cohesive and resilient social networks within communities – critical elements for adapting to, and mitigating disaster risk [28].

4. Policy implications and conclusions

This study has demonstrated how a conceptual framework based around disaster risk can be applied to a Caribbean Island fisheries context to present a different way of thinking about how vulnerability accumulates in a fisheries context and how risk can be mitigated in ways that include more holistic consideration of conditions that lead to vulnerability. This study highlights thinking prevalent in the disaster risk community but is a novel approach for those working in fisheries management. While this paper does not set out to generalise the ways in which vulnerability accumulates in Caribbean Island fisheries, it does highlight different ways vulnerability may accumulate, manifest and be reduced in different fishery contexts. This application of a framework from disaster studies to fisheries also demonstrates the potential utility in applying this understanding of vulnerability in other contexts, including other SIDS or other regions.

The application of the PAR model in this test-case of Dominica's and Antigua and Barbuda's fisheries [12,13] has highlighted the extent to which underlying socio-cultural conditions (and not only the hazard intensity itself), lead to unsafe conditions and fragile livelihoods. Conversely, resilience against hurricanes may be built through recognising and addressing root causes, reducing pressures or inequalities, thereby leading to improved safety and more secure livelihoods. This broadly agrees with lessons learned from climate change adaptation research, where adaptation measures are commonly aimed at reducing vulnerability [4,91] or enhancing adaptive capacity [92]. Recognising how 'release of pressure' (i.e. in the PAR Release stage) may reduce vulnerability and thus disaster impact, has important policy implications as it implies that fishers and their communities can be strengthened to become less vulnerable and therefore more resilient. Caribbean Islands and their fisheries are often seen as 'disaster prone', due to their location and/or physical geography, yet this narrative may dissuade certain types of investment or development [93]. Instead, by recognising that the root causes of a disaster are not purely due to natural causes, (i.e. due to an 'act of god' or 'out of our hands'), this can encourage policy action at different levels to build resilience in the sector [91]. This thinking is in line with a recent change in emphasis, away from quantifying vulnerability towards identifying risk and building resilience [94].

One of the most effective interventions to enhance resilience is to reduce or remove other pressures such as overfishing, inappropriate development and habitat degradation. Many different fishery management and land-use policies have been put in place across the Caribbean Islands region, including the establishment of Marine Spatial Plans in some jurisdictions with a stated objective to encourage actions that contribute to greater resilience to hazards and to mitigate the long-term impacts of climate change [95]. Country and region-wide policies and plans, such as National Adaptation Plans and Nationally Determined Contributions, often provide the links with policy that are used to leverage climate financing [4].

When the essential role of fisheries in wider disaster recovery is recognised [8], this can encourage further investment in reducing vulnerability of the sector and/or building resilience. Fisheries can represent a safety net during a crisis (e.g., when other food supplies disappear; [89]). Recognising the welfare function of fisheries for food security and survival (rather than just its wealth function, import/export revenue) can be highly beneficial, and that it is worth investing in and protecting fishing communities [96]. For Dominican and Antigua and Barbudan fisheries the PAR model has shed light on pressures such as underinvestment in fisheries infrastructure, limiting market access for fisheries products, or weakening social ties within fishing and coastal communities. The importance of strong social capital and networks in the immediate aftermath of a disaster as well as for positive medium and long-term recovery trajectories, is well known [28,29].

While each of these pressures may differ, and the extent and characteristics of vulnerability are by no means universal across the two countries examined here, they do represent issues present in different fishery contexts. With climate change expected to lead to increasing frequency of severe hurricanes in the Caribbean region – and potentially globally [5,6] – it is important to recognise both how vulnerability and disaster risk are shaped, and how societies can move towards safer conditions.

CRediT authorship contribution statement

Shelton: Conceptualization, Analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **White:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Forster:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Conlon:** Formal analysis, Investigation. **Engelhard:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Pinnegar:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors confirm there are no competing interests.

Data Availability

Data will be made available on request.

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