TECHNICAL REVIEW REPORT

Developed under the:
Integrating digital technologies and participatory tools to support coastal community resilience in Trinidad and Tobago (Tech4CoastalResilience) project

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CANARI

Government of the Republic of Trinidad and Tobago
MINISTRY OF AGRICULTURE, LAND AND FISHERIES

TOBAGO HOUSE OF ASSEMBLY

Department of Marine Resources and Fisheries

HIT RESET CARIBBEAN

CDEMA CARIBBEAN DISASTER EMERGENCY MANAGEMENT AGENCY
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Acronyms and abbreviations

ACP	African, Caribbean and Pacific
AI	Artificial intelligence
AMEP	Assessment and Management of Environment Pollution
ATFA	All Tobago Fishing Association
CANARI	Caribbean Natural Resources Institute
CARICOM	Caribbean Community
CARiDRO	Caribbean Assessment of Regional Drought Tool
CBD	Convention on Biological Diversity
CBO	Community-based organisation
CC4FISH	Climate Change Adaptation in the Eastern Caribbean Fisheries Sector Project
CCA	Climate change adaptation
CCCCC	Caribbean Community Climate Change Centre
CCORAL	Caribbean Climate Online Risk and Adaptation Tool
CCRIF SPC	Caribbean Catastrophe Risk Insurance Facility Segregated Portfolio Company
CDB	Caribbean Development Bank
CDM	Comprehensive disaster management
CDEMA	Caribbean Disaster Emergency Management Agency
CETA	Communications, education, training and awareness
CIMH	Caribbean Institute for Meteorology and Hydrology
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CEP	Caribbean Environment Programme
CERT	Community Emergency Response Team
COMES	Council of Ministers of Environmental Sustainability
COPE	Council of Presidents for the Environment
COP21	Conference of Parties 21 to the UNFCCC
CRFM	Caribbean Regional Fisheries Mechanism
CCRIT	Caribbean Community Risk Information Tool
CSO	Civil society organisation
CSO	Central Statistical Office
CTDA	Castara Tourism Development Association
CVI	Coastal Vulnerability Index
DaLA	Damage and loss assessment
DRM	Disaster risk management
EAF	Ecosystem approach to fisheries
EMA	Environmental Management Authority
EPPD	Environmental Policy and Planning Division
ERIC	Environment Research Institute Charlotteville
ESA	Environmentally Sensitive Area
ESRI	Environmental Systems Research Institute
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FEWER	Fisheries Early Warning and Emergency Response
GDP	Gross domestic product
GIS	Geographic information system
GEF SGP	The Global Environment Facility Small Grants Programme

GOMFA	Guayaguayare, Ortoire and Mayaro Fisherfolk Association
GoRTT	Government of the Republic of Trinidad and Tobago
GPS	Global positioning system
HIT RESET Caribbean	Harnessing Innovative Technologies to Support Resilience Settlements on the Coastal Zones of the Caribbean
ICT	Information communication technology
ICZM	Integrated Coastal Zone Management
IDB	Inter-American Development Bank
IFPAMTT	Improving Forest and Protected Area Management in Trinidad and Tobago
IFRC	International Federation of Red Cross and Red Crescent Societies
IMA	Institute of Marine Affairs
IPCC	Intergovernmental Panel on Climate Change
IT	Information technology
ITCZ	Inter Tropical Convergence Zone
KAP	Knowledge, attitude and practices
LBS	Land-based sources
LiDAR	Light Detection and Ranging
MALF	Ministry of Agriculture, Land and Fisheries
M&E	Monitoring and evaluation
M2M	Matura to Matelot
MOWT	Ministry of Works and Transport
MPA	Marine protected area
NBSAP	National Biodiversity Strategy and Action Plan
NETMPA	North East Tobago Marine Protected Area
NGO	Non-governmental organisation
NIS	National Insurance System
NOAA	National Oceanic and Atmospheric Administration
OACPS	Organisation of African, Caribbean and Pacific States
ODPM	Office of Disaster Preparedness and Management
OECS	Organisation of Eastern Caribbean States
PA	Protected area
P-GIS	Participatory geographic information systems
PPAM	Participatory protected area management
PPCR	Pilot Programme for Climate Resilience
P3DM	Participatory three-dimensional modelling
RRMC	Risk Reduction Management Centre
SAMOA	Small Island Developing States Accelerated Modalities of Action
SDCR	Strengthening Disaster and Climate Resilience Program
SFDRR	Sendai Framework for Disaster Risk Reduction
SIDS	Small island developing states
SDGs	Sustainable Development Goals
SECOORA	Southeast Coastal Ocean Observing Regional Association
SES	Social and ecological systems
SME	Small and micro-enterprises
SPAW	Specially Protected Areas and Wildlife
SST	Sea surface temperature
sUSV	Small unmanned surface vehicles
SWOT	Strengths, Weaknesses, Opportunities and Threats
TATT	Telecommunications Authority of Trinidad and Tobago
Tech4CoastalResilience	Integrating digital technologies and participatory tools to support coastal community resilience in Trinidad and Tobago

TEMA	Tobago Emergency Management Agency
THA	Tobago House of Assembly
THTA	Tobago Hotel Tourism Association
T&T	Trinidad and Tobago
TNC	The Nature Conservancy
TUFA	Tobago Unified Fisherfolk Association
UAS	Unmanned aerial systems
UAV	Unmanned aerial vehicles
UN	United Nations
UNCCD	Convention to Combat Desertification and Land Degradation
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
UWI	University of the West Indies
VCA	Vulnerability and capacity assessment
VHF	Very high frequency
WECAFC	Western Central Atlantic Fishery Commission

1. Introduction

1.1 Background

Climate change poses a critical challenge to Caribbean small island developing states (SIDS) (Mycoo *et al*., 2022). In Trinidad and Tobago (T&T), coastal communities are under threat from extreme weather events, sea level rise, coastal erosion and coral bleaching with rising sea surface temperatures, which can cause immense damage to coastal and marine ecosystems, infrastructure (including ports), access roads and housing settlements, and loss of lives and livelihoods (Kumarsingh *et al.,* 2021). These impacts are compounded by ad hoc development, pollution and environmental loss and degradation.

It is critical that coastal communities understand their own vulnerabilities and can work with government agencies and the private sector to build resilience through better local planning and integrated coastal zone management. However, there are many constraints to effectively assessing vulnerabilities and building coastal communities' resilience, including: weak integration of local and scientific knowledge to understand local context and design appropriate adaptation and resilience actions; limited data and capacity to use and access new technologies which can provide an evidence base and help inform decision-making; limited funding and human resources; limited recognition and use of participatory and inclusive approaches in coastal management and resilience building; and multiple and competing priorities in terms of use of coastal areas and mandates of management agencies.

To help address these issues, the "*Integrating digital technologies and participatory tools to support coastal community resilience in Trinidad and Tobago (Tech4CoastalResilience)*" project is being implemented from 2023-2024 by the Caribbean Natural Resources Institute (CANARI) in partnership with the Fisheries Division, Ministry of Agriculture, Land and Fisheries and the Department of Marine Resources and Fisheries, Tobago House of Assembly. Its overall objective is to improve the resilience of vulnerable coastal communities to climate change impacts in T&T. Its specific objectives are:

- to empower community-based organisations (CBOs) and other community stakeholders to use participatory and digital technologies/tools to capture their local knowledge and practices and guide decision-making for coastal resilience; and
- to increase local and national government agencies' ability to use participatory and digital technologies/tools to access data and support participatory planning and execution of coastal resilience actions.

The project targets 10 vulnerable coastal communities, including fisherfolk and other coastal resource users and CBOs, for piloting and initial implementation of the drones and other digital technologies and tools. These communities include Blanchisseuse, Carli Bay, Icacos, Matelot, Mayaro and Moruga in Trinidad and Castara, Scarborough, Speyside and Roxborough in Tobago. It also seeks to support at least four key government agencies, including fisheries and coastal management authorities, to enhance their knowledge and skills to use digital technologies to capture and integrate local and scientific knowledge and apply participatory tools to engage coastal communities in planning and decision-making.

The project is supported by the "*Harnessing Innovative Technologies to Support Resilience Settlements on the Coastal Zones of the Caribbean (HIT RESET Caribbean)*" programme led by the University of the West Indies (UWI), St. Augustine, Caribbean Disaster Emergency Management Agency (CDEMA) and Anton de Kom University. HIT RESET Caribbean is funded by the ACP

Innovation Fund, Organisation of African, Caribbean and Pacific States (OACPS) Research and Innovation Programme, which is implemented by OACPS with financial contribution from the European Union (EU).

It builds on the regional "*Climate Change Adaptation in the Fisheries Sector of the Eastern Caribbean Project (CC4FISH)*" which was implemented from 2017-2021. CC4FISH used a series of participatory tools to capture local knowledge and assess local vulnerabilities and adaptation priorities in five coastal communities in Trinidad and Tobago – Blanchisseuse, Icacos, Moruga in Trinidad and Speyside and Roxborough in Tobago. Stakeholders found that tools, such as participatory geographic information systems (P-GIS), were accessible and easy to use for communities to identify their own vulnerabilities and priorities for action. Further, it allowed for the integration of local knowledge into GIS and other digital datasets to inform planning. The opportunity exists for expanding the use of participatory and digital tools to support adaptation and resilience building in coastal communities.

1.2 Purpose and scope of the Technical Review Report

This technical review report examines the application of digital and participatory technologies and tools to support inclusive and evidence-based planning and decision-making for coastal community resilience in Trinidad and Tobago. It draws on a comprehensive literature review and inputs from key government agencies and other stakeholders, and synthesises this information to inform the following outputs for the Tech4CoastalResilience project:

- Identification of at least three suitable digital technologies and two participatory tools to inform evidence-based planning and management of coastal community resilience
- Engagement of at least four coastal management agencies and ten local communities in the process and demonstration for the use of the tools and technologies selected in order to enhance knowledge and skills
- Testing of the tools and technologies in up to 10 coastal communities
- Developing a roadmap and outlining recommendations for adoption and scale-up of use of digital technologies and participatory tools to support more inclusive and evidence-based decision-making for coastal community resilience

This report will also contribute more broadly to the *Comprehensive National Coastal Monitoring Programme* initiated in 2019 by the Government of the Republic of Trinidad and Tobago (GoRTT). This involves developing a central repository for coastal data to improve access to relevant information to assess overall risk and inform sustainable shoreline management, and equipping coastal managers and communities to effectively collect and disseminate coastal data.

2. Climate change and coastal impacts in Trinidad and Tobago

The coastal zone in Trinidad and Tobago is home to 70% of the country's population, 80% of the energy-based industries and produces 90% of annual fish production (GoRTT, 2020). It is highly vulnerable to the impacts of climate change and related disasters, including from sea level rise, more intense storms and storm surge, coral bleaching and ocean acidification[1] (GoRTT, 2013; Clarke *et al.,* 2019). Current climate change model projections for Trinidad and Tobago indicate:

1. Sea level rise is likely to continue to rise in the Caribbean over the century, with an increase of around 1.5-3mm per year having been observed at tidal gauging stations in T&T and around the Caribbean region. However, model projections regarding sea level rise are not precise, owing to variability brought on by temporary conditions, such as storm surge, or vertical land movements which may exaggerate relative sea level rise (Clarke *et al.,* 2019).
2. Increases in average surface air and sea temperatures are very likely during this century. Over the last three decades there has been an upward trend in temperatures in T&T, with annual air temperatures having warmed over the period 1981-2010 by 0.8°C and 0.5°C relative to 1961-1990 and 1971-1990 for Trinidad and for Tobago respectively (Clarke *et al.,* 2019; Kumarsingh *et al.,* 2021). Warmer sea surface temperatures (SST) are also likely, which will increase the possibility of more frequent and intense coral bleaching events and more intense storms and hurricanes.
3. Rainfall variability is likely to exhibit drier dry seasons, and more intense, short-duration rainfall patterns observed during the wet season. Annual observed precipitation trends in Trinidad and Tobago do not indicate significant change. Projections span both overall increases and decreases but tend towards decreases in most models. Despite this, a preliminary vulnerability assessment conducted by the Office of Disaster Preparedness and Management (ODPM) in Trinidad and Tobago highlighted flooding to be the most frequent hazard affecting Trinidad and Tobago within recent years. The highest values of one-day rainfall recordings have increased over the last two decades, occurring within the dry season; and the highest number of extremely wet days have been recorded for the last five decades during the most recent decadal period 2001-2010 suggesting a possible trend in recent increase in intense, short-duration rainfall (Clarke *et al.,* 2019; Kumarsingh *et al.,* 2021).
4. The islands lie on the southern margins of the Atlantic Hurricane belt and normally escape the path of cyclones and hurricanes. Tobago being slightly more northerly than Trinidad has over the course of time been affected by more storms[2] (Jeppesen *et al.,* 2015; Clarke *et al.,* 2019).
5. Projected increases in ocean acidification, as the oceans continue to absorb atmospheric carbon dioxide, reducing pH, carbonate ion concentration and the availability of biologically important calcium carbonate minerals (Clarke *et al.,* 2019). This will likely affect plankton, algae, shellfish, coral reefs and related biodiversity (Monnereau and Oxenford, 2017).

The biophysical and socio-economic impacts of climate change on the coastal and marine resources place a strain on the fisheries sector and other important productive sectors, including oil and gas and tourism, that contribute significantly to the economy, local employment and livelihoods and the gross domestic product (GDP) of the nation (Clarke *et al.,* 2019). In a recent national vulnerability assessment report, fisheries are specifically noted as being at risk and vulnerable to climate change

[1] Ocean acidification: Increased carbon dioxide in the atmosphere dissolves in the ocean resulting in a lower seawater pH which can be detrimental to the fishery.

[2] During the period 1851-2010, the historical records register 11 tropical storms and hurricanes in Trinidad, compared to Tobago's 20 (Jeppesen *et al.*, 2015).

via numerous pathways where causal variables of impact include sea level rise, altered rainfall patterns, changes in wind velocity, wave action, ocean currents and chemical and physical oceanographic parameters such as pH and SST (Clarke *et al.,* 2019). Fisheries infrastructure, such as fish landing sites and facilities, were identified as being at high risk from sea level rise, storm surge and associated flooding and damages. The loss of natural resources, such as coral reefs, wetlands and associated coastal ecosystems, and the likely detrimental effects of ocean acidification on shrimp, oysters and coral reefs would have a significant effect on the fisheries sector and coastal fishing communities. The likely impacts of climate change on water resources could also have serious consequences for aquaculture development.

Figure 1: Sargassum clogging the coastline in Speyside, Tobago (CANARI, 2020)

Sargassum seaweed influxes, which are linked to higher nutrient levels due to increased erosion from rainfall extremes and changing ocean current circulation patterns, also affect the livelihoods of fishers and incurs expenditure for clean-up costs (Oxenford *et al*., 2019; UNDP, 2019). Sargassum influxes are also noted as a factor in decreasing number of seagrass colonies in Trinidad and Tobago (Clarke *et al.,* 2019). There are implications for both the fisheries and tourism sectors and the general population in coastal communities, including possible health risks associated with the decomposition of sargassum in large quantities which releases hydrogen sulphide gas and may cause effects such as nausea, irritation of the eyes, headaches and respiratory issues (Doyle and Franks, 2015).

These climate change impacts are compounded by existing pressures on the coastal zone. These pressures include: pollution such as oil spills, grey water and dumping of solid waste; unsustainable fishing practices; changes in land use; and health risks such as the COVID-19 pandemic[3]. These will prove challenging in establishing efforts towards prevention of fishery collapse, alleviating poverty and enhancing food security and socio-economic wellbeing (Clarke *et al.,* 2019).

2.1 Scoping profiles for target communities

This section provides brief descriptions of the target coastal communities for the Tech4CoastalResilience project, including Blanchisseuse, Carli Bay, Icacos, Matelot, Mayaro and Moruga in Trinidad and Castara, Roxborough, Scarborough and Speyside in Tobago. It also highlights key needs, opportunities and challenges in addressing climate change in these communities.

[3] The COVID-19 pandemic or coronavirus pandemic is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and was declared a pandemic by the World Health Organization (WHO) in March 2020.

Blanchisseuse, Trinidad

Geography

Blanchisseuse is a coastal village along the northern coast of Trinidad (FAO, 2017). It is located on the northern slopes of the Northern Range, with a variety of coastal and land-based resources including rivers and surrounding forests which support the community. It is the last accessible village along the North Coast Road. Blanchisseuse Bay, which opens unto the Caribbean Sea, is approximately 1.4km long and is bounded on both the eastern and western ends by prominent, steep cliffed headlands of low-grade metamorphic rocks (IMA, 2016). At the eastern end of the Bay is the Marianne River.

Socio-economic activities

- The two main livelihood activities are tourism and agriculture, including farming and fishing, which are supported by the varied coastal and land-based resources of the area.
- Blanchisseuse is a popular long stay holiday spot, with many large vacation homes and a few hotels along portions of the village's coast (FAO, 2017).
- There are small and micro enterprises (SMEs) which provide services to guest houses and hotels through catering and tourism activities.
- There are approximately 116 fishers operating from 58 fishing vessels (Fisheries Division/MALF, 2022). The main fishing methods include banking line, seine, trolling and a-la-vive artisanal methods, and common species landed include kingfish, carite, cavalli and ancho (FAO, 2017).
- In 2020-2021, the COVID-19 pandemic resulted in country-wide restrictions being implemented. This negatively impacted many sectors including tourism and fisheries (ECLAC, n.d.)

Demographic information

Based on the 2011 population census, Blanchisseuse is home to 1,375 residents. 722 are male and 653 are female (CSO, 2011). Of these residents, 138 are elderly (65 years and older), 391 are minors (15 years and younger) and 846 from the working population (CSO, 2011).

Key stakeholders

Civil society and other non-state actors

- Blanchisseuse Community Council
- Blanchisseuse Environment Community Organisation
- Blanchisseuse Fisherfolk and Marine Association
- Trinidad and Tobago United Fisherfolk
- Fisherfolk
- Farmers
- Network of Rural Women Producers Trinidad and Tobago
- Women's Group
- Guesthouse and hotel owners
- Recreational beach users
- Food vendors

Government

- Coastal Protection Unit, Ministry of Works and Transport
- Fisheries Division / Ministry of Agriculture, Lands and Fisheries
- Office of Disaster Preparedness and Management (ODPM), Ministry of National Security
- Ministry of Planning and Development, including
    - Environmental Policy and Planning Division (EPPD)
    - Institute of Marine Affairs (IMA)

- Local Area and Regional Planning and Development Unit, Ministry of Rural Development and Local Government
- Ministry of Sport and Community Development
- Tunapuna-Piarco Regional Corporation

Past assessments

- Vulnerability and capacity assessment (VCA) was carried out by CANARI and other partners in 2020 in Blanchisseuse under the CC4FISH project to improve the understanding of climate change impacts and vulnerabilities for effective adaptation in the fisheries sector using P-GIS and other VCA tools (Granderson *et al., in press*).
- Previous survey study done in 2015 focused on vulnerabilities of the fisherfolk in Blanchisseuse (FAO, 2017). The study highlighted key hazards due to turbulent waters that affect fisherfolk's ability to fish and earn an income and cause costly damage to fishing equipment.
- Participatory video: Fishers in Blanchiseusse developed in 2011, with CANARI's support, addressing the challenges of the Blanchisseuse fishing industry.
  See https://www.youtube.com/watch?v=8SFnazhiu9Y

Key hazards and vulnerabilities

- Rough seas, storm surge, sea level rise all contribute to coastal erosion along the entire coastline which affects infrastructure (guesthouses/resorts, cemetery and fisheries infrastructure).
- Coastal erosion has also resulted in a loss of natural vegetation (coconut trees) along the coastline and affects the main access road, the North Coast Road, resulting in restricted access in and out of the community.
- Heavy rainfall events leading to inland flooding of the community, road slippage, landslides and felled trees which blocks access to roads and tourism/recreational trails and beaches. Riverine flooding also restricts access to schools.
- Trees felled by heavy rainfall events and landslides often disrupts the electricity supply to the community and blocks access to roads and tourism/recreational trails.
- Removal of trees for small-scale agriculture has affected water flow in rivers, access to water supplies by residents, use of the river for recreation and habitat degradation within the area.
- The impacts of the COVID-19 pandemic on household and individual income also remain a concern where business closures and restrictions on mobility affected fishing and tourism activities, which are slowly recovering. Post-pandemic income levels have not returned to prior levels and there remain limited opportunities for economic development.

Carli Bay, Trinidad

Geography

Carli Bay is located along the central west coast of Trinidad. Its coastal environment has been classified as sheltered tidal flats with high habitat productivity due to the presence of seagrasses, mudflats and mangrove habitats (Nansingh and Jurawan, 1999; ICZM, 2020a). Historically, the Carli Bay mangrove system has been impacted by development activity, such as the creation and diversion of inland waterways and land reclamation. In 2007, it was estimated that there were 298.1ha of estuarine/fringing mangroves in the Couva/Carli Bay area, mainly comprising of red mangroves at the seaward border and black mangroves landward (with some instance of white mangroves) (Juman and Ramsewak, 2013; Juman and Hassanali, 2013). There are extensive mudflats alongside the mangrove forests which are exposed during low tide and have been colonised by red mangrove seedlings (Juman and Hassanali, 2013). Thus, mangroves have been shifting seawards despite the landward margin of

mangroves being encroached upon by built development. Hydrological alteration due to pollution was also recorded (Juman and Ramsewak, 2013).

Socio-economic activities

- There are a mix of livelihood activities including fishing, farming, industrial jobs at the Point Lisas industrial estate, and public sector/government jobs (CANARI, 2019).
- There are 41 fishing vessels and an estimated 82 fishers operating at Carli Bay (Fisheries Division/MALF, 2022), with daily catch records estimating 260 metric tonnes (mt) of fish landed valued at TT$1.45 million (Kishore *et al.*, 2002; Petro-Canada Trinidad and Tobago Limited, 2007). Most fishers are male and work full-time, with a smaller percentage of fishers having part-time farming or truck driving jobs (Kishore, 2021).
- A number of vessels also operate in the area but land instead at Chaguaramas.
- Fisherfolk in the area are represented by the Carli Bay Fishing Association and have access to a fishing facility and a small fishing port (Ministry of Rural Development and Local Government, 2016; CANARI, 2019; Bahaw, 2021)
- The dominant fisheries is the artisanal gillnet fishery but other fishing methods are utilised such as line fishing and Italian Seine. The main target species is the yellow mouth croaker (*Micropogonias furneri)* (Kishore *et al.,* 2003). Other species caught include carite, kingfish, salmon, crocro, redfish and cavali (Petro-Canada Trinidad and Tobago Limited, 2007).
- The mangrove forests also support livelihoods for persons engaged in hunting and crab catching (Juman and Hassanali, 2013).
- In 2020-2021 the COVID-19 pandemic resulted in country-wide restrictions being implemented. This negatively impacted many sectors including tourism and fisheries[4].

Demographic information

Estimated population in the Carli Bay community district was 3,262 persons based on census data from 2000 (Petro-Canada Trinidad and Tobago Limited, 2007).

Key stakeholders

Civil Society

- Orange Valley and Waterloo Village Councils
- Carli Bay Villagers Group
- Carli Bay Fishing Association
- Trinidad and Tobago United Fisherfolk
- Network of Rural Women Producers Trinidad and Tobago
- Fisherfolk
- Farmers
- Recreational beach users
- Religious groups and visitors to Temple by the Sea

Government

- Coastal Protection Unit, Ministry of Works and Transport
- Fisheries Division, Ministry of Agriculture, Lands and Fisheries
- ODPM, Ministry of National Security
- Ministry of Planning and Development, including
    - EPPD
    - IMA

[4] https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

- Local Area and Regional Planning and Development Unit, Ministry of Rural Development and Local Government
- Ministry of Sport and Community Development
- Couva/Tabaquite/Talparo Regional Corporation
- PowerGen Point Lisas

Private sector/large businesses

- Point Lisas Industrial Estate and various contractors
- Methanol III
- Massy Gas Products
- Nutrien
- Proman

Past assessments

- P-GIS, an impact and capacity matrix and survey exercises were carried out in Carli Bay with fisheries authorities, key government agencies and CSOs as part of a demonstration/training in 2019 on vulnerability and capacity assessment under the CC4FISH project (CANARI, 2019).
- National Disaster Preparedness Baseline Assessment (2019-2020) through the Pacific Disaster Center included a risk and vulnerability assessment along with national recommendations and a five-year plan to support national risk reduction efforts. Based on the assessment's risk index, the Couva/Tabaquite/Talparo municipality in which Carli Bay is located was categorised as having a medium risk to coastal flooding, medium vulnerability to hazards and medium resilience to disaster impacts. The municipality was also listed as very high on both the tropical cyclone wind and flood risk index (Pacific Disaster Centre, 2020; GORTT, 2022).
- Preliminary vulnerability assessment was conducted for each municipality in 2011 and in 2014 (ODPM, 2014; 2022). The 2014 assessment identified priority hazards in different municipalities, and indicated that there are community based early warning systems and community members with disaster risk management training in the Couva/Tabaquite/Talparo municipality (of which Carli Bay is a part of) (ODPM, 2014).

Key hazards and vulnerabilities

- Carli Bay is vulnerable to oil spills due to the biological impact on mangroves, and was listed relatively high/above average on an oil spill environmental sensitivity index (Nansingh and Jurawan, 1999). In 2021, an oil spill from a crude oil pipeline impacted the fishing community in Carli Bay causing loss of drift nets, reduced fish sales and displacement of fisherfolk to other fishing grounds in the north coast (Bahaw, 2021).
- Carli Bay is also considered high risk for flooding and the coastline is susceptible to erosion (MOWT, 2019a; GORTT, 2021). In general, areas along the western Gulf of Paria are most likely to be impacted by coastal erosion and climate-driven sea level rise (GoRTT, 2021).
- Other key hazards identified by stakeholders, who participated in the CC4FISH VCA training and conducted surveys and field observation, include (CANARI, 2019):
    - Mosquito borne diseases
    - Pollution (garbage along beach/landing area, river pollutants, plastics, sediments, air pollution, ships dumping solid & sewage waste)
    - Loss of wetlands
    - Damage to ocean bed due to trawling
- Conflict with trawlers has been identified as an issue for fisherfolk in Carli Bay along with loss of fishing grounds due to close proximity to the Point Lisas Industrial Estate, where effluent and other waste damages coastal ecosystems and fishing grounds in the nearshore area.
- Secluded nature of landing site makes it more likely to attract criminal activity.
- Theft and larceny from neighbouring Venezuelan vessels have also been identified as another safety issue for fisherfolk operating at night (Kishore *et al.,* 2003).

Icacos, Trinidad

Geography

Icacos is located on the southwestern peninsula of Trinidad, which consists mainly of unconsolidated sediments prone to erosion and transport by ocean currents. Dynamic circulation patterns where the waters of the Columbus Channel enter the Gulf of Paria cause many areas of erosion and accretion. At Coral Point, the end of the Icacos Beach Road, the shoreline has receded about 150m in the last 100 years (Kenny, 2000). Icacos point is an area of extreme accretion where sand is deposited after being transported along the Columbus Channel and from Columbus Bay. Where longshore currents are strong, e.g. Columbus Channel, erosion and longshore movement of sand result (Kenny, 2000). Highly turbid waters are also typical of the Columbus Channel and Gulf of Paria. These factors influence the composition of fish and invertebrate communities. There are no coral reefs in the Columbus channel, influenced by the Orinoco River that empties into the Atlantic Ocean just south.

Socio-economic activities

- A small percentage of the residents of Icacos work in the surrounding coconut estates but the local economy centres primarily around fishing.
- There are approximately 198 fishers operating from 99 fishing vessels (Fisheries Division/MALF, 2022). The main fishing methods include surface handline (à la vive, monofilament and banking), and common species landed include sierra mackerel, snapper, tarpon and crocro (Fisheries Division, 2016).
- There was a dilapidated fishing facility but it has now been demolished.
- 49.7% of Icacos' population 15 years and older are engaged in work, while 1.1 % are seeking employment (CSO, 2011).
- Icacos is only 11km from Venezuela and there are reports of theft and kidnappings of fishers at sea linked to illegal activities (e.g. human and drug trafficking between Venezuela and Trinidad and Tobago).
- In 2020-2021, the COVID-19 pandemic resulted in country-wide restrictions being implemented. This negatively impacted many sectors including tourism, fisheries, agriculture[5].

Demographic information

Based on the population census 2011, Icacos is a village of 1,093 people. 586 are male and 507 are female. Of these residents, 81 are elderly (65 years and older), 239 are minors (15 years and under) and 773 from the working population (CSO, 2011).

Key stakeholders

Civil Society

- Granville Community Council
- Fullerton Community Council
- Icacos Fishing Association
- Icacos United Fishermen
- Icacos Fisherfolk Limited
- Cedros Fishing Co-op Society
- South West Fisherfolk Association
- Trinidad and Tobago United Fisherfolk

[5] https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

- Fisherfolk
- Farmers
- Network of Rural Women Producers Trinidad and Tobago
- National Trust of Trinidad and Tobago
- Recreational beach users

Government

- Coastal Protection Unit, Ministry of Works and Transport
- Fisheries Division, Ministry of Agriculture, Lands and Fisheries
- ODPM, Ministry of National Security
- Ministry of Planning and Development, including
  - EPPD
  - IMA
- Local Area and Regional Planning and Development Unit, Ministry of Rural Development and Local Government
- Public Health Unit, Ministry of Health
- Ministry of Energy and Energy Industries
- Ministry of Sport and Community Development
- Siparia Regional Corporation

Private sector/large businesses

- Constance and St. Quintan Coconut Estates
- Shell and other oil and gas operators in Colombus Channel

Past assessments

- A VCA was carried out by CANARI and other partners in Icacos in 2020 under the CC4FISH project to improve the understanding of climate change impacts and vulnerabilities for effective adaptation in the fisheries sector using P-GIS and other VCA tools (Granderson et al., *in press*).
- BioBlitz, which is an annual event led by the UWI Zoological Museum and the Trinidad and Tobago Field Naturalists' Club, was held in Icacos in 2017 to conduct a rapid biodiversity assessment of the peninsula's swamps, mud volcanoes, coconut plantations, long beaches and coastal environment. This included aquatic and oceanic surveys to assess biodiversity in the coastal environment. Oil spills in the Gulf of Paria and coastal erosion were identified as key threats to coastal biodiversity based on the rapid assessment (Rutherford, 2017).
- An assessment of coastal erosion was done in 2021 for the Third National Communication of the Republic of Trinidad and Tobago to the United Nations Framework Convention on Climate Change (UNFCCC)[6].

Key hazards and vulnerabilities

- Inland flooding due to the blockage of the river mouth during high tides and storm surge leads to infrastructural damage within the community (residential areas, religious institutions, schools, roads).
- Coastal erosion which affects beaches, mangrove ecosystems and landing sites for boats.
- Pollution from oil spills within the Columbus Channel and the improper disposal of solid waste (fishing gear, coconut trees from coconut estates, household appliances) has impacted the marine and coastal environment.

[6] https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/92154806_Trinidad%20and%20Tobago-NC3-1-THIRD_NATIONAL_COMMUNICTION_TRINIDAD_AND_TOBAGO.pdf

- The community's coastline is in very close proximity to Venezuela and there have been reports of piracy and kidnappings at sea.
- Land use change, including removal of mangroves for private development, has led to habitat destruction.
- The impacts of the COVID-19 pandemic on household and individual income due to business closures and restrictions on mobility continue to linger.

Matelot, Trinidad

Geography

The community of Matelot is located on the north east coast of Trinidad, 114.9 km from Port of Spain via Toco Main Road and Churchill Roosevelt Highway. It is the last village on the Paria Main Road (Morton-Gittens, 2011). This main road is the only land access route to the village. Matelot is therefore quite remote and access to urban centres, markets and various facilities is limited. It is one of fourteen communities that borders the Matura Forest Reserve and Coastal Zone Protected Area (PA) and utilises it heavily for livelihoods and recreation (FAO/UN, 2019). The PA encompasses 9,000 ha. Including the Matura Environmentally Sensitive Area (ESA) declared in 2004 and seasonally prohibited beaches of Rincon, Matura and Fishing Pond that are important nesting sites for endangered marine turtles including Leatherback and Hawksbill turtles (FAO/UN, 2019). The PA is also an important conservation site for the endemic and globally endangered Trinidad piping guan (*Pipile pipile*).

Socio-economic activities

- Farming and fishing are important livelihoods, and Matelot Bay is one of the main fish landing sites in Trinidad (Kairi Consultants Ltd, 2016).
- There are approximately 70 fishers operating 35 fishing vessels from Matelot Bay (Fisheries Division/MALF, 2022). The main fishing method is gillnetting (with fillet net much more dominant than monofilament) and some line methods are also used including trolling. The main species landed are croaker and weakfish (called 'salmon' locally) via gillnets, while kingfish is the main species landed via trolling (Fisheries Division/MALF, 2022).
- Tourism and recreational activities also occur at the nearby beaches and at Matelot Falls.
- There is also offshore drilling for oil and gas by BHP Biliton and other operators off the coast of Matelot.
- 53.05% of Matelot's population that is 15 years and older are engaged in work, while 8.23% are under/unemployed (CSO, 2011).
- Matelot forms part of the Matura to Matelot (M2M) Network organisation which holds an interest in sustainable fisheries governance and management in the communities within this area (FAO/UN, 2019)
- The PA includes important nesting sites for the globally threatened Leatherback Turtle (*Dermochelys coriacea*) (FAO/UN, 2019) which supports eco-tourism centred on turtle watching at the beaches during nesting season.
- In 2020-2021 the COVID-19 pandemic resulted in country-wide restrictions being implemented. This negatively impacted many sectors including tourism and fisheries, with decline in fish sales and household income[7].

[7] https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

Demographic information

Based on the 2011 population census, Matelot is a small village of approximately 553 people – 316 male and 237 female residents (CSO, 2011). Of these residents, 56 are elderly (65 years and older), 178 are minors (15 years and under) and 320 from the working population (16 to 64 years).

Key stakeholders

Civil Society

- Matelot Village Council
- Matura to Matelot (M2M) Network
- Matelot Police Youth Club
- Matelot Kingfisher's Association
- Trinidad and Tobago United Fisherfolk
- Turtle Village Trust
- Future Fishers
- Fisherfolk
- Farmers
- Network of Rural Women Producers Trinidad and Tobago
- Guesthouse owners
- Recreational beach users
- Food vendors

Government

- Coastal Protection Unit, Ministry of Works and Transport
- Fisheries Division and Forestry Division, Ministry of Agriculture, Lands and Fisheries
- ODPM, Ministry of National Security
- Ministry of Planning and Development, including
  - EPPD
  - IMA
- Local Area and Regional Planning and Development Unit, Ministry of Rural Development and Local Government
- Ministry of Sport and Community Development
- Ministry of Energy and Energy Industries
- Sangre Grande Regional Corporation

Private sector/large businesses

- BHP Biliton
- BP

Past assessments

- In a national vulnerability assessment done for T&T in 2019, Matelot was identified as an area vulnerable to sea level rise, rough seas and storm surge, with potential damage to access road, transportation links like jetties, sea defences and offshore industrial infrastructure, residential infrastructure, utilities, and plants including sewage (Clarke et al., 2019).
- A Livelihood Assessment, Socio-Economic Assessment and Knowledge, Attitudes and Practices Survey were done in 2019 under the FAO's Improving Forest and Protected Area Management in Trinidad and Tobago (IFPAMTT) project [https://protectedareastt.org.tt/index.php]. Household surveys were conducted by trained enumerators in communities that border the pilot protected area sites under the project.

Key hazards and vulnerabilities

- Adverse weather conditions (e.g. storms, storm surge, flooding) that can cause damage to infrastructure, fishing equipment, homes, etc. (GoRTT, 2017).
- Overexploitation of fish and the loss of fish stock and specific species because of seismic surveys and offshore drilling operations conducted by the energy companies for oil and gas (Kairi Consultants Ltd, 2016).
- Landslides and other issues that affect access are a key risk, as there is one main road into and out of the village. This is potentially a significant vulnerability in the context of disaster management.
- Due to its north coast location, the Matelot coastline is heavily impacted by coastal erosion due to wave action[8].
- The impacts of the COVID-19 pandemic on household and individual income remain a concern as business closures and restrictions on mobility affected fishing, tourism and offshore oil and gas activities, which are now recovering.

Moruga, Trinidad

Geography

Moruga is located along the southern coastline of Trinidad and it comprises communities including Fifth Company Village, Grand Chemin, La Lune, La Retrecht, La Rufin, L'Anse Mitan, Marac and Rock River. The main street is Grand Chemin, which ends at Columbus Beach. Historically in Trinidad and Tobago, Moruga is attributed as the location where Christopher Columbus first spotted Trinidad (Thomas, 2018).

The community is adjacent to the proposed Trinity Hills Species Management Reserve, which has a mountainous, coastal cliffside that forms the southern boundary of the proposed PA (FAO/UN, 2019). Access to the PA is mainly through Moruga via the Edward Trace Road (FAO/UN, 2019). The PA and wider area has tourism potential, with historical and culturally important sites such as the Moruga Spring Bridge and the company villages of the "Merikins" (formerly enslaved African-Americans that settled in the area).

Socio-economic activities

- In a 2018 livelihoods survey, livelihood activities in Moruga were noted as fishing, gardening, fig agriculture and hunting, with fishing being the majority response (FAO/UN, 2019).
- Moruga is one of the main fish landing sites in Trinidad.
- There are approximately 112 fishers in La Rufin operating 56 vessels and 58 fishers at Grand Chemin operating 29 vessels (Fisheries Division/MALF, 2022). The main gear type used at La Rufin is mono filament, with the most common species landed being cro cro, sierra mackerel and shark (locally called 'gummy'). At Grand Chemin, main gear type is fillet followed by á la vive, with the most common species landed being sierra mackerel, whitefish and snapper (Fisheries Division, 2016; Fisheries Division pers. comm., 2023).
- There is also offshore oil and gas operations in the vicinity of Moruga.
- The community's coastline is within very close proximity to Venezuela, and influx of migrants has led to community members in the area complaining of jobs being taken away from them by Venezuelan migrants who are willing to be paid less and work longer hours.

[8] https://www.mowt.gov.tt/Divisions/Coastal-Protection-Unit/Projects/Matelot-Shoreline-Stabilisation-Works-Phase-I

- Marijuana is planted illegally along the boundaries of the proposed PA for sale and personal use (FAO/UN, 2019).
- In 2020-2021 the COVID-19 pandemic resulted in country-wide restrictions being implemented. This negatively impacted many sectors including tourism, fisheries, agriculture[9].

Demographic information

Based on the population census 2011, Moruga is a small village of 316 people. 182 are male and 134 are female. Of these residents, 24 are elderly (65 years and older), 73 are minors (15 years and under) and 220 from the working population. 62% of Moruga's population that is 15 years and older is engaged in work, while 2.2 % are seeking employment (CSO, 2011).

Key stakeholders

Civil Society

- Basseterre Village Council
- Basseterre Women's Group
- Moruga Museum Committee
- Grand Chemin Fishing Association
- La Ruffin Fishing Association
- Trinidad and Tobago United Fisherfolk
- Council of Presidents for the Environment (COPE)
- National Trust of Trinidad and Tobago
- Fisherfolk
- Farmers
- Recreational beach users

Government

- Coastal Protection Unit, Ministry of Works and Transport
- Fisheries Division, Ministry of Agriculture, Lands and Fisheries
- ODPM, Ministry of National Security
- Ministry of Planning and Development, including
  - EPPD
  - IMA
- Local Area and Regional Planning and Development Unit, Ministry of Rural Development and Local Government
- Public Health Unit, Ministry of Health
- Ministry of Sport and Community Development
- Ministry of Energy and Energy Industries
- Princes Town Regional Corporation

Private sector/large businesses

- Shell
- Challenger Energy and other small operators

Past assessments

- VCA was carried out by CANARI and other partners in 2020 under the CC4FISH project to improve the understanding of climate change impacts and vulnerabilities for effective adaptation in the fisheries sector using P-GIS and other VCA tools.

[9] https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

- A Livelihood Assessment, Socio-Economic Assessment and Knowledge, Attitudes and Practices Survey conducted in Moruga under the FAO's IFPAMTT project in 2018. [https://protectedareastt.org.tt/index.php]

Key hazards and vulnerabilities

- Coastal erosion of Moruga's cliffs and other coastal areas due to higher tides, storm surges and swell events affects infrastructure including the Moruga Road and beach and mangrove ecosystems.
- Inland flooding along rivers impacts many communities in the wider Moruga area, including La Ruffin, Basse Terre and Saint Mary's lower areas.
- Landslides occur along coastal cliffs and steeper inland slopes leading to a loss of forested areas.
- Larceny – The community's coastline is within very close proximity to Venezuela, and reports of larceny and kidnappings at sea have occurred.
- Area is also a concern for national security and public health due to the large influx of legal and illegal migrants from Venezuela over the last 3-5 years.
- Pollution, including oil spills, as offshore drilling occurs in the waters off the south coast of Trinidad.
- The impacts of the COVID-19 pandemic on household and individual income due to business closures and restrictions on mobility continue to linger.

Mayaro, Trinidad

Geography

Mayaro is a town located on the south east coast of Trinidad. The area is bounded on the east and south by the Atlantic Ocean and the Columbus Channel. The Mayaro Bay on its east coast is defined by the headlands of Point Radix in the north and Galeota Point in the southwest, and is one of the longest stretches of beach in Trinidad at 11.5km in length (Kishore *et al.,* 2005). To the north is the Nariva Swamp, which is the largest freshwater swamp in T&T and has been designated as a Ramsar site and environmentally sensitive area (ESA), including a protected forest reserve and wildlife sanctuary.

Socio-economic activities

- Mayaro serves as a hub for the south east, including a hospital, banks, schools, market, fire station, restaurants and recreational facilities[10]. It grew from a small fishing village to a town from the 1970s to 2000s largely due to offshore oil and gas development and the influx of persons seeking employment in this sector.
- The main economic activities currently include tourism, agriculture (fishing and farming) and oil and gas sector jobs.
- There are approximately 104 fishers operating 52 vessels at Mayaro (Fisheries Division/MALF, 2022). The main fishing method used is beach seines, with gillnet landings also important (both fillet and monofilament). Whitemouth croaker, bachin and weakfish (locally called 'salmon') are the main species landed by the beach seines (Fisheries Division/MALF, 2015). Bonito and kingfish are the main species landed by fillet, while carite, mixfish and cavalli are the main species landed by the monofilament gillnets (Fisheries Division/MALF, 2015).
- There are many guesthouses, hotels and resorts, which provide jobs in catering, cleaning and landscaping for community members.

- In 2020-2021 the COVID-19 pandemic resulted in country-wide restrictions being implemented. This negatively impacted many sectors including tourism and agriculture[11].

Demographic information

- The population of Mayaro is 2,791 with 49.35% males and 53.27% females and 53.27% of the population are employed based on 2011 census (CSO, 2011).
- The area has an influx of visitors (locals and foreign) on a seasonal basis during February-April and July-August for holiday home and hotel rentals.

Key stakeholders

Civil Society

- Radix Village Council
- La Savanne Village Council
- Guayaguayare, Ortoire and Mayaro Fisherfolk Association (GOMFA)
- Mayaro Fishing Crew Association
- South East Fishing Association
- Trinidad and Tobago United Fisherfolk
- Future Fishers
- Fisherfolk
- Farmers
- Network of Rural Women Producers Trinidad and Tobago
- National Trust of Trinidad and Tobago
- Recreational beach users

Government

- Coastal Protection Unit, Ministry of Works and Transport
- Fisheries Division, Ministry of Agriculture, Lands and Fisheries
- ODPM, Ministry of National Security
- Ministry of Planning and Development, including
  - EPPD
  - IMA
- Local Area and Regional Planning and Development Unit, Ministry of Rural Development and Local Government
- Ministry of Sport and Community Development
- Ministry of Energy and Energy Industries
- Mayaro-Rio Claro Regional Corporation

Private sector

- Guesthouse and hotel owners
- Restaurants and food vendors
- BP, Shell and other oil and gas operators and contractors in Galeota Point

Past assessments

- In 2015, a Mayaro-Guayaguayare Coastal Study was carried out by the Coastal Protection Unit – Ministry of Works and Transport to appraise and design sustainable coastal protection measures to address ongoing coastal erosion and coastal flooding issues through stakeholder consultations[12].

[11] https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

[12] https://www.mowt.gov.tt/Divisions/Coastal-Protection-Unit/Projects/Mayaro-Guyaguayare

- National vulnerability assessment done for T&T where Mayaro was identified as an area with specific vulnerabilities to inland flooding, sea level rise, rough seas, storms and storm surge, leading to damage to access and major roads, transportation links such as ports and jetties, sea defences, offshore and onshore industrial infrastructure, residential infrastructure, utilities and plants including sewage (Clarke *et al.,* 2019).
- An assessment of coastal erosion was done in 2021 for the Third National Communication of the Republic of Trinidad and Tobago to the United Nations Framework Convention on Climate Change[13].

Key hazards and vulnerabilities

- Coastal erosion especially at the north end of Mayaro Bay has resulted in many structures and properties being abandoned due to ongoing shoreline retreat.
- Flooding and poor drainage
- Loss of wetlands
- Pollution from solid and sewage waste and plastics
- Oil spills, as the east coast has a very active oil and gas sector with several offshore drilling platforms. There have been several incidents of oils spills in the surrounding area.
- Tsunamis, triggered by earthquakes, are a potential risk for Mayaro and the east coast
- The impacts of the COVID-19 pandemic on household and individual income due to business closures and restrictions on mobility continue to linger and tourism recovery has been slow.

Castara, Tobago

Geography

Castara is located on the northern coast of Tobago on the leeward side of the island (Tobago Guide, 2023). Castara Bay is 308m long and is surrounded by vegetated headlands (Darsan *et al.,* 2013). The Castara River flows through the centre of the bay. The beach is wide and gently sloping and Castara's coastal profile is described as a sandy bay with slightly gravelly sand (Darsan et al., 2012; Ganase, 2020). Castara Bay experiences winds from the southeast and waves from the northwest (Darsan *et al.,* 2013). The shoreline stability for the period 2004-2008 in Castara Bay indicated that it is in a state of dynamic equilibrium (i.e. between net accretion and net erosion) (Darsan *et al.,* 2013).

Castara Reef comprises of octocoral and hard coral and has high biodiversity. Castara's coral reefs were impacted by the 2010 bleaching event (Ganase, 2020). Castara also includes one of the coral reef monitoring sites under the IMA's coral reef monitoring programme (Ganase, 2020).

Castara's coastal area is part of the proposed North East Tobago Marine Protected Area (NETMPA) (FAO/UN, 2019). There is a tree planting initiative in Roxborough, Speyside, Castara and Lambeau which aims to plant 2,500 native trees to increase coastal resilience and prevent erosion and damage to housing from rising sea levels and increasing wave action. Part of the initiative includes educating community stakeholders on climate change and coastal erosion (THA, 2019). The initiative is spearheaded by the Environment Research Institute Charlotteville (ERIC) and Environment Tobago, together with the North East Tobago Climate Change Champions Network and the Tobago House of Assembly (THA) (THA, 2019). ERIC also supported coral replanting in Castara Bay in collaboration with the Castara Tourism Development Association (CTDA) (Roach, 2023, pers. comm.).

Socio-economic activities

[13] https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/92154806_Trinidad%20and%20Tobago-NC3-1-THIRD_NATIONAL_COMMUNICTION_TRINIDAD_AND_TOBAGO.pdf

- Castara is considered one of the most popular fishing and tourism-based villages in Tobago, and fishing is the main economic activity.
- Fisherfolk engage in seine fishing due to the deep inshore waters, which is also known as 'pulling seine' and is a tradition practiced by older generations (Historical Tobago, 2014). Catch can include round-robin, balahoo, sprat, herine, sardine, flaunders, squids, bonito, jacks and needlefish (Tobago Guide, 2023). Currently there is no jetty or landing site in Castara and fisheries slipway still needs to be developed
- Fisherfolk in the area are represented by the Castara Fisherfolk Association and Castara Fisherfolk Association Reform (for the northern part of the village) and supporting facilities include the Castara Fishing Facility (THA, 2022).
- While Castara is primarily a fishing village, it is known for tourism-related activities rooted in traditional village heritage, including bonfires by the beach, waterfall hikes, fish roasts, and observing the tradition of pulling seines (Nicholas, 2022; THA, 2023). Castara hosts the annual Tobago Heritage Festival which is a cultural celebration of Tobago's African and Indigenous heritage (Tobago Guide, 2023).
- Castara is also known for its sandy beaches and the two main beaches, Big Bay and Heavenly Bay, provide calm conditions for snorkelling (Clarke *et al.,* 2019; Tobago Guide, 2023). Surrounding rainforest providing opportunities for hiking and birdwatching (Tobago Guide, 2023).
- In 2021, Castara was selected for the United Nations (UN) World Tourism Organization's Best Tourism Village upgrade programme due to the potential of Castara as a community-based tourism destination and its cultural and natural assets (Nicholas, 2022). Notably, Castara also has a growing guesthouse industry (FAO/UN, 2019). The community has adopted the model of community tourism development and aims to preserve their environment, heritage and culture through community participation and engagement of younger generations.
- The CTDA (the network of small business owners) engages and supports businesses in developing increased stewardship through recycling and a plastic bag/Styrofoam ban in the community (Mohan, 2022).

Demographic information

Total population in Castara was recorded as 580 persons in the 2011 census with 52% males and 48% females (CSO, 2011).

Key stakeholders

Civil Society

- Castara Tourism Development Association (CTDA)
- Castara Fisherfolk Association
- Castara Fisherfolk Association Reformed
- All Tobago Fishing Association (ATFA)
- Tobago Unified Fisherfolk Association (TUFA)
- Environmental Research Institute Charlotteville (ERIC)
- Environment Tobago
- Fisherfolk
- Farmers / Farmers Associations
- Village Council
- Recreational beach users
- Tourists (long and short stay)

Government

- Department of Marine Resources and Fisheries, THA
- Coastal Zone Management Unit, Division of Infrastructure, Quarries and Urban Development, THA

- Tobago Emergency Management Agency (TEMA), THA
- Division of Community Development, Enterprise Development and Labour, THA
- Division of Tourism, Culture, Antiquities and Transportation, THA
- Tobago Tourism Agency Ltd
- Environmental Management Authority (EMA), Tobago
- IMA, Ministry of Planning and Development

Private sector

- Guesthouse and hotel owners, including Castara Retreat, Castara Inn etc.
- Restaurants and food vendors
- Fish/marine supply businesses e.g. Northside Marine

Past assessments

- In national vulnerability assessment for T&T, Castara identified as an area with specific vulnerabilities from storm surge and rough seas, which can cause damage to access roads, transportation links such as sea defences, residential infrastructure, and sewage plants (Clarke *et al.,* 2019).
- Coastal erosion assessment conducted by the Caribbean Development Bank for Tobago; assessment provided estimates for a coastal protection and restoration programme of TT$1.2 billion (THA, 2023a)
- Design and Feasibility Study for a Risk-Resilient ICZM Programme in 2016 conducted by Inter-American Development Bank (IDB), which focused on increasing the level of Trinidad and Tobago's resilience to coastal management issues (GoRTT, 2021)
- Beharry-Borg and Scarpa (2010) conducted an economic valuation of coastal water quality in Tobago targeting residents and tourists visiting a wide cross-section of beaches in Tobago.

Key hazards and vulnerabilities

- Castara is susceptible to landslides (THA, 2023)
- Castara is also vulnerable to storms, storm surge and rough seas (Clarke *et al.,* 2019). Coastal development, including residences, guesthouses, restaurants and other tourism and fishing facilities, in close proximity to Castara Bay is a further risk factor (Darsan *et al*., 2003).
- Coral bleaching with rising sea surface temperatures is also a risk for Castara's reefs (Ganase, 2020)
- In Castara and wider Tobago, the tourism sector was also greatly impacted by the COVID-19 pandemic but seems to be recovering despite low economic growth and inflation challenges (GoRTT, 2022; The Commonwealth, 2023). Post-pandemic, there has been a return of tourists to the village.

Roxborough, Tobago

Geography

Roxborough is the largest town along the windward coast of Tobago and second largest town on the island. The Roxborough watershed is estimated at 20km^2 and the dominant coastal vegetation is freshwater marsh (Ministry of Planning and Development, Central Statistical Office, 2007)[14]. Additionally, coral reefs located in Roxborough Bay offer shoreline protection (Burke *et al.*, 2008). The Argyle River drains the land surrounding Roxborough and the community is located in close proximity to the Argyle Falls which is a main tourism attraction in Tobago supporting domestic, stay-over and

[14] The coastal area is part of the North-East Tobago marine area (one of the six pilot protected areas under *the Improving Forest and Protected Area Management in Trinidad and Tobago* project (FAO/UN, 2019). Proposed North-East Tobago Marine PA covers an estimated 59,280 ha, extending on Tobago along the entire coastal strip from Roxborough on the north-east coast, north to Parlatuvier on the north-west coast and extending seawards for 6 nautical miles.

cruise tourism. The community is also along the access route to tourism attractions such as Little Tobago – an offshore island off Speyside. One of Tobago's most scenic routes is a new road built from Roxborough over the Main Ridge to the north coast. The Roxborough Estate Visitor Services Cooperative manages tourism in the area (comprising of 16 members, half of whom are female).

Roxborough falls within the proposed NETMPA which protects the ecologically important coral reefs of Tobago. This area has also recently been designated under United Nations Educational, Scientific and Cultural Organization's (UNESCO) Man and the Biosphere (THA, 2023a). Public sector investments that impact on Roxborough's geography have included reconstruction of sea walls and desilting of rivers to prevent coastal and inland flooding. Also, there are ongoing coastal rehabilitation and protection works to address coastal erosion (GoRTT, 2019; THA, 2021; George, 2023). This includes a tree planting initiative in Roxborough, Speyside, Castara and Lambeau to plant 2,500 native trees to increase coastal resilience and prevent erosion and damage to housing from rising sea levels and increasing wave action. Part of the initiative includes educating community stakeholders on climate change and coastal erosion (THA, 2019). The initiative was spearheaded by the Environment Research Institute Charlotteville (ERIC) and Environment Tobago, together with the North East Tobago Climate Change Champions Network and the Tobago House of Assembly (THA) (THA, 2019).

Socio-economic activities

- Key socio-economic activities include tourism and recreation, including diving, and small-scale and commercial fishing (FAO, 2014).
- Based on a survey conducted for the VCA in Roxborough under the CC4FISH project, 35% of community respondents indicated their primary source of income was through the public sector, 13% indicated fisheries and 45% stated 'other' (self-employment, pension or the private sector) (Granderson *et al., in press*).
- Tourism includes a Roxborough Sea Sports and Seafood Festival (THA, 2017), Argyle Waterfall hikes and tours, and diving. A decompression chamber can also be found in Roxborough.
- The former sugar estate located in Roxborough has been nominated as a national heritage site (GoRTT, 2019).
- There are approximately 40 fishing vessels, with 70 fishers (registered and non-registered), and one main fish landing site (Ottley, 2019). Generally, fishing is a secondary source of income and fisherfolk are engaged in other occupations including farming, construction, tourism or are hired in the public sector (Kishore, 2021). Types of fishing include palange, fishpot, a la vive, banking, trolling, seine (Ottley, 2019).
- The Roxborough Fisherfolk Association have been identified as key stakeholders for the proposed NETMPA as they have traditional use and access rights to the coastal and marine resources, and they possess an interest in food security, income generation and a sustainable source of fish (FAO, 2014).
- Lack of jobs, poor access to services/infrastructure, youth delinquency/crime, and natural disasters were some of the key issues impacting livelihoods of community members, including fisherfolk (Granderson *et al., in press*).

Demographic information

Based on the 2011 census, Roxborough has 2,089 residents – 1,085 male and 1,004 female (CSO, 2011). Of these residents, 7.3% are elderly (65 years and older) 26.3% are minors (15 years and under) and 66.4% comprise the working population (16-64 years). 65.6 percent of Roxborough's population 15 years and older are engaged in work, while 5.1 percent are unemployed (CSO, 2011).

Key stakeholders

Civil Society

- Roxborough Fisherfolk Association
- ATFA

- TUFA
- Roxborough Estate Visitor Services Cooperative
- Roxborough Police Youth Club
- Roxborough Village Council
- Roxborough Sports Club
- Fisherfolk
- Farmers including cocoa farmers promoting tourism activities
- Recreational beach users
- Tourists (long and short stay)

Government

- Department of Marine Resources and Fisheries, Division of Food Security, Natural Resources, The Environment And Sustainable Development, THA
- Coastal Zone Management Unit, Division of Infrastructure, Quarries and Urban Development, THA
- TEMA
- Division of Community Development, Enterprise Development and Labour, THA
- Division of Tourism, Culture, Antiquities and Transportation, THA
- Tobago Tourism Agency Ltd
- EMA, Tobago
- Coast Guard/Fire Services

Private sector

- Guesthouse and hotel owners
- Restaurants and food vendors
- Other small businesses along coast lines
- Argyle Waterfall Association
- Seafields Solutions Limited

Past assessments

- VCA conducted in Roxborough under the CC4FISH project, highlighting climate change impacts, key hazards and vulnerabilities. Coping/adaptation mechanisms for the coastal and marine zone were also identified for the key hazards identified by the community. These included reinforcement of coastal protection infrastructure, safety at sea measures, utilisation of FADs, community sargassum action plan, and alternative livelihoods (Granderson *et al.*, *in press*).
- In a national vulnerability assessment for T&T, Roxborough was identified as an area with specific vulnerabilities to sea level rise and storm surges. This can damage access roads, major roads, transportation links such as marinas, ports, jetties, sea defences and offshore industrial infrastructure, residential infrastructure, utilities and industrial plants including for sewage (Clarke *et al.*, 2019).
- Flood Mitigation Feasibility Study for Roxborough (THA, 2021).
- Coastal erosion assessment conducted by the Caribbean Development Bank for Tobago; assessment provided estimates for a coastal protection and restoration programme at TT$1.2 billion (THA, 2023a)
- Knowledge, Attitude and Practices Survey[15] on coastal communities of T&T on tsunamis (Kanhai *et al.*, 2016). This supported the **"**Dark Wave**"** tsunami drill conducted by Tobago Emergency Management Authority (TEMA).

[15] Knowledge, attitude and practices of coastal communities in T&T about tsunamis. Nat Hazards. 81:1349-1372 DOI 10.1007/s11069-015-2138-3

- Participatory Three-Dimensional Modelling (P3DM) conducted in Tobago in 2012 to enhance the understanding of participants about climate change and its impacts on natural resources and natural resource-based livelihoods (CANARI, 2014).
- P3DM developed specifically for Roxborough to develop sea level rise projection models and to determine potential physical and socioeconomic impacts (Sutherland *et al.,* 2014).

Key hazards and vulnerabilities

- High wind/rain and hurricanes: climate change impact of increased intensity and frequency of extreme weather systems (e.g. tropical storms, hurricanes) which can result in damage to and loss of equipment for fisherfolk and flooding that affects infrastructure.
- For example, Tropical Storm Karen caused TT$1 million in damage in 2019 to fishing vessels in Roxborough which led to decline in fish sales; impacts from COVID-19 pandemic further added to the loss and damage by Roxborough fisherfolk post-Tropical Storm Karen (Connelly, 2019, 2020).
- Sargassum influxes impacting fisheries operations, beaches and wider Roxborough community (Granderson *et al.*, *in press*).
- Coastal erosion, storm surges and flooding due to the sea level rise and rough seas leading to property damage, economic loss, and loss of livelihoods due to impact on beaches, infrastructure (sea wall, road), road access, as well as fisheries (damage/loss to boat and fishing gear) and the hotel/restaurant tourism sector. Key stakeholders impacted were identified as fisherfolk, and business owners and property owners in low lying areas (Granderson *et al.*, *in press*).
- Inland flooding impacts nearby housing development (built on area that was previously wetland and agricultural lands) (Granderson *et al.*, *in press*).
- Additionally, Roxborough is susceptible to landslides (THA, 2023b).
- In Roxborough and wider Tobago, the tourism sector was also greatly impacted by the pandemic but seems to be recovering despite low economic growth and inflation challenges (GoRTT, 2022; The Commonwealth, 2023).

Scarborough, Tobago

Geography

Scarborough is the major town of Tobago, located in southwest Tobago on Rockly Bay and overlooking the Scarborough Harbour. The terrain slopes down from the Main Ridge in the north to the Atlantic Ocean in the south, with the town itself located on lower slopes approximately 13 km from Tobago's southwestern tip. In terms of land use, Scarborough comprises mostly commercial development, with industrial, tourist-related, and residential development, administrative buildings for the Tobago House of Assembly and its departments, and a small historical zone at the core (UN-Habitat 2012).

Socio-economic activities

- Scarborough is the administrative capital, as well as economic and cultural centre, of Tobago. It serves as the main seat of the Tobago House of Assembly, which is responsible for local governance in Tobago.
- The main economic activities are related to government business/services and tourism. Scarborough has numerous historical and cultural sites, including the botanic gardens, forts, museums and beaches, and it houses a deep-water harbour and cruise ship complex which supports the economically important tourism sector. It also accommodates most of the island's commercial offices and government agencies.
- Fishing occurs near the Scarborough Port compound and behind the Scarborough Secondary School, near Milford Road on the western part of Rockly Bay, but is not as prominent as in other more rural communities. In addition, neighbouring the Scarborough area are several communities with active fishing groups including Lambeau.

- Fisherfolk in Scarborough have access to the Scarborough Fishing Depot located at the Tobago Port compound. Notably this was built from containers as a temporary structure back in 2015. Fish is sold at the Scarborough market. Other facilities include the Lambeau Fishing Facility on Milford Road, which includes a fish market.
- Several fisherfolk associations represent fisherfolk from the Scarborough area, including the TUFA and ATFA; an umbrella organisation for all fisherfolk organisations, as well as the Scarborough Fisherfolk Association and the Lambeau Fisherfolk Association.
- Fishing activities have been affected over the last few years due to poor fisheries facilities, increased fuel prices, and sargassum influxes (including in the Rockly Bay and Lambeau area), which have caused damage to boats and contributed to losses by fishermen[16]. In addition, stay-at-home restrictions in 2020-2021 during the COVID-19 pandemic crippled markets and affected the income of fisherfolk.
- Attempts to diversify the economy included the establishment of Tobago's first ever eco-business and industrial park developed in Cove in 2009.
- Most recently an inaugural Scarborough Fisherman's Fest was held by AFTA and the business community in 2023, intended to generate economic activity in Scarborough given businesses are still struggling post the COVID-19 pandemic. Employment tends not to be stable, which results in a high incidence of second jobs (UN-Habitat 2012).

Demographic information

According to the 2011 census, the community of Scarborough has 424 households and a population of 1167 persons, including 558 males and 609 females (CSO 2011). The parish of St. Andrew in which Scarborough is located is one of Trinidad and Tobago's most densely populated areas, with an estimated population of about 17,000 persons (Tobago Hotel and Tourism Association, year?). Most of the population are of African descent, with others being of East Indian or European descent.

Key stakeholders

Civil Society

- Scarborough Fisherfolk Association
- Scarborough Multi-Purpose Fishermen Association
- Lambeau Fisherfolk Association
- ATFA
- TUFA
- Environment Tobago
- Fisherfolk
- Farmers
- Tobago Youth Council
- Police youth clubs/ schools
- Recreational beach users
- Tourists (long and short stay)

Government

- Department of Marine Resources and Fisheries, THA
- Coastal Zone Management Unit, Division of Infrastructure, Quarries and Urban Development, THA
- TEMA
- Division of Community Development, Enterprise Development and Labour, THA
- Division of Tourism, Culture, Antiquities and Transportation, THA
- Division of Health, Wellness and Social Protection
- Division of Settlements, Public Utilities and Rural Development

[16] https://newsday.co.tt/2020/05/05/sos-to-tha/

- Land Management Department, Office of the Chief Secretary
- Tobago Tourism Agency Ltd
- EMA, Tobago
- Port Authority of Trinidad and Tobago
- IMA

Private sector

- Guesthouse and hotel owners
- Restaurants and food vendors
- Craft and souvenir vendors

Past assessments

While assessments have been conducted for Tobago in general, no vulnerability assessments were found focused specifically on Scarborough. Assessments which included consideration of Scarborough are as follows:

- In 2021, USAID worked on development of a resilience profile for T&T, which identified priority risks as floods, landslides, coastal erosion, dry spells and droughts. Coastal erosion was highlighted as a priority risk for many beaches in Tobago, including Rockly Bay, with impacts on tourism and transport infrastructure.
- In December 2012, the Government of Trinidad and Tobago signed a technical cooperation agreement with IDB to undertake a pilot study on integrating climate change adaptation into coastal zone management in South West Tobago. This included climate-related hazard vulnerability and risk assessments of the coastal zone area of South West Tobago based on climate variability (existing climatic events) and climate change scenarios. The assessment was used to formulate a Coastal Vulnerability Index (CVI) to identify areas that could experience sea level rise and were significantly at risk to erosion and/or coastal flooding.

Key hazards and vulnerabilities

- High wind/rain and hurricanes: climate change impact of increased intensity and frequency of extreme weather systems (e.g. tropical storms, hurricanes) which can result in damage to and loss of equipment for fisherfolk and flooding that affects infrastructure (Pacific Disaster Center, 2020).
- Areas in and around Scarborough are prone to flash flooding, typically related to tropical storm activity or heavy or prolonged rainfall associated with the Intertropical Convergence Zone (ITCZ) or incoming tropical waves. Areas affected include along Carrington Street, in front of the Boardwalk, the Trinidad and Tobago Electricity Commission's compound in Scarborough and the Tobago Port. Flooding is thought to be exacerbated by poor drainage, unregulated and uncontrolled development and settlement in high-risk areas.
- Landslides are noted in various assessment reports as a major hazard affecting Tobago, including the Scarborough area. Some areas impacted in recent incidents (2019 to date) include Idlewild and Plymouth Road close to Scarborough. Landslides have caused closures and damage to roads, residential buildings and other infrastructure such as power lines and retaining walls.
- Sea level rise and coastal erosion have been noted as potential threats for South West Tobago, including Scarborough, based on a 2015 vulnerability and risk assessment study prepared by Halcrow for the IDB[17].
- Rough seas have been reported to hamper port operations and cause damage to fisheries facilities, including the jetty at the fishing depot in Scarborough[18]

[17] https://www.caribbeanclimate.bz/blog/2015/05/11/piloting-the-integration-of-climate-change-adaptation-and-coastal-zone-management-in-southwest-tobago/

[18] https://newsday.co.tt/2022/09/27/no-access-to-boats-say-scarborough-fishermen/

- Sargassum seasonally affects the Scarborough area, including the Rockly Bay area as well as the Scarborough waterfront area near the Esplanade, with implications for both tourism and fishing.
- Other risk factors include high population density, concentrated economic activities and unplanned settlements. According to a 2012 UN-Habitat urban profiling study, pockets of slum-like sub-standard housing are scattered throughout the Scarborough area e.g. in Bagatelle, Darryl Spring, and Sangsters Hill. These typically feature poorly constructed buildings, have little or no access to basic amenities (e.g. pipe-borne water), improper sewage facilities and very limited mechanisms for risk transfer (ODPM, 2014).

Speyside, Tobago

Geography

The community of Speyside is located on the north eastern part of Tobago, along the Atlantic Ocean coastline, exposed to the southern margins of the Atlantic Hurricane belt. The dominant relief feature of the area is the Main Ridge highland area which slopes off steeply to the north east. Vegetation includes lower montane rainforest, lowland rainforest, littoral coastal woodland, wetland mash formations, deciduous seasonal forest dry and secondary forest. There are a number of coral reef ecosystems within the coastal region of Speyside, including biologically diverse fringing reefs which support various commercial, recreational and subsistence fisheries, and tourism-related activities including reef tours, snorkelling and dive operations (Jobe, 2016).

Speyside is considered one of the best diving locations in Tobago but has experienced changes in its reefs benthic assemblages from decreasing hard coral to increasing sponge cover; this has implications for reef function and ecosystem services provided by the reef habitat. Notably, in 1998, 2005 and 2010, Speyside and other areas in Tobago experienced declines in hard coral cover due to coral bleaching caused by increased sea surface temperatures. Land-based sources of pollution have also led to decline of hard corals, and increased growth of soft corals and algae in several locations including Speyside (IMA, 2016). Reef improvement works, and work on Speyside beach facility were accounted for in 2023 budgetary allocations (Parliament Republic of Trinidad and Tobago, 2023).

There is one main road that traverses the village, the Windward Main Road, which is subject to a number of land slippages (Bachan, 2007). There is a coastal sea wall constructed along Tyrrels Bay and Speyside Bay. The wall mitigates against sea erosion and protects coastal settlements, and is a retaining wall for the Windward Main road way (Bachan, 2007).

Speyside is located within the proposed NETMPA (FAO/UN, 2019). A recent tree planting initiative in Roxborough, Speyside, Castara and Lambeau aims to plant 2,500 native trees to increase coastal resilience and prevent erosion and damage to housing from rising sea levels and increasing wave action. Part of the initiative includes educating community stakeholders on climate change and coastal erosion (THA, 2019). The initiative is spearheaded by ERIC and Environment Tobago, together with the North East Tobago Climate Change Champions Network and the THA (THA, 2019).

Socio-economic activities

- The main economic activities include tourism, fishing, farming and government programmes.
- Based on a survey conducted for the VCA under the CC4Fish project, 31% of respondents indicated the public sector as their primary income source, 17% stated fisheries, 10% for agriculture and tourism respectively, and 33% stated 'other' (self-employed, pension, National Insurance System [NIS]). Lack of jobs/employment, poor access to services and infrastructure, youth delinquency, crime and natural disasters were some of the factors impacting households and livelihoods (Granderson *et al.*, *in press*).

- The tourism industry is centred around the historical sites (e.g. Water Wheel, Bird of Paradise Inn/Mr. Lau Estate, Belmont Point Cannon) as well as the many natural attractions of Speyside (e.g. Little Tobago Island, Goat Island, coral reefs for snorkelling/diving, beaches).
- There are several popular diving areas (Japanese Gardens, Black Jack Hole, Kelleston Drain, Bookends and St. Giles) for advanced divers due to opposing currents. Other areas with gentle rifts including sloping reef areas (which includes hard corals, sponges, sea fans and sea plumes) (I, 2012). As such, there are many operating dive shops (FAO/UN, 2019).
- There are approximately 40-60 fishers and 30 vessels operating in Speyside, with a concrete jetty and a basic fish processing facility (Ottley, 2019). Types of fishing include palange, fish pot, a la vive, banking, trolling and seine (Ottley, 2019).
- Fisheries are dependent on coral reefs, which are threatened by increased sedimentation and nutrient loading (Clarke *et al.* 2019)
- The Speyside Eco-Marine Park Rangers is a group in the community which supports greater community involvement in marine management and promotes environmental awareness (The Global Environment Facility Small Grants Programme (GEF SGP, 2012)
- Also, there is a Community Emergency Response Team (CERT) Emergency Response Sub-Office located in the community (Parliament Republic of Trinidad and Tobago, 2023).

Demographic information

Speyside has a population of approximately 1,100 (Jobe, 2016). Number of males, females, elderly and youth were not readily available.

Key stakeholders

Civil Society

- Speyside Village Council
- Speyside Fisherfolk Association
- ATFA
- TUFA
- Speyside Eco-Marine Park Rangers
- Environmental Research Institute Charlotteville (ERIC)
- Fisherfolk
- Farmers
- Recreational beach users
- Tourists (long and short stay)
- SIDEYS football club

Government

- Department of Marine Resources and Fisheries, THA
- Coastal Zone Management Unit, Division of Infrastructure, Quarries and Urban Development, THA
- TEMA
- Division of Community Development, Enterprise Development and Labour, THA
- Division of Tourism, Culture, Antiquities and Transportation, THA
- Tobago Tourism Agency Ltd
- EMA, Tobago
- IMA, Ministry of Planning and Development

Private sector

- Guesthouse and hotel owners, including Blue Waters Inn
- Restaurants and food vendors
- Small businesses e.g. glass boat operators, dive associations/operators

Past assessments

- VCA conducted in Speyside under the CC4FISH project, highlighting climate change impacts, key hazards and vulnerabilities. Coping/adaptation mechanisms for the coastal and marine zone were also identified for the key hazards experienced by the community. These included development of infrastructure (e.g. slipway), safety as sea measures, ecosystem restoration, alternative livelihoods, improved communications and early warning systems, development of a community preparedness and recovery plan, and equipment and tools for sargassum clean-up, storage and use (Granderson *et al.*, 2022).
- A VCA was previously conducted in this community in 2007 (Bachan, 2007). From consultations, the community was identified as extremely vulnerable to environmental degradation, high wind, rain and hurricanes, social and health issues, unemployment, and youth issues.
- Coastal erosion assessment conducted by the Caribbean Development Bank for Tobago; assessment provided estimates for a coastal protection and restoration programme at TT$1.2 billion (THA, 2023a)
- Design and Feasibility Study for a Risk-Resilient ICZM Programme in 2016 conducted by IDB, which focused on increasing the level of Trinidad and Tobago's resilience to coastal management issues and proposed some solutions focusing on the following communities: Manzanilla, Guayaguayare, Sans Souci and Otaheite in Trinidad and Speyside in Tobago (GoRTT, 2021)
- A KAP survey was conducted in coastal communities of Trinidad and Tobago on tsunamis, including Speyside (Kanhai *et al.*, 2016).
- A strengths, weaknesses, opportunities, and threats (SWOT) analysis (Jobe, 2016) was conducted to inform the application of an ecosystem approach to fisheries (EAF) in Tobago, including Speyside.

3. Policy and institutional context for coastal resilience in T&T

3.1 International and regional policies

Trinidad and Tobago is a signatory to key multi-lateral environmental agreements, the United Nations Convention on the Law of the Sea (UNCLOS) and the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement (2015), that offer guidance on climate change adaptation (CCA) and related fisheries governance issues. In addition, the Sendai Framework for Disaster Risk Reduction (2015-2030)[19] (SFDRR) and the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs)[20] offer further guidance on disaster risk management (DRM) and related development priorities which could be taken into consideration in developing and implementing VCAs for the fisheries sector (UNDESA, 2024; UNDRR, 2024). See Table 1 for further details.

There are a number of other regional policies and strategies related to climate change, disasters and building resilience. The CARICOM Liliendaal Declaration on Climate Change and Development, which sets out key climate change related interests and aims of CARICOM member states, CARICOM Regional Framework for Achieving Development Resilient to Climate Change and its Implementation Plan and the Comprehensive Disaster Management (CDM) Strategy and

[19] http://www.unisdr.org/we/coordinate/sendai-framework
[20] https://sustainabledevelopment.un.org/sdgs

Programming Framework 2014-2024[21] of CDEMA are most notable (CDEMA, 2014). The Strategy and Action Plan for disaster risk management and climate change adaptation in fisheries and aquaculture in the CARICOM region[22] builds on these and is highlighted as an overarching framework to guide new directions for the fisheries and aquaculture sector (CRFM, 2013; McConney *et al.,* 2015). See Table 2 for further details.

Table 1: Summary of major international environmental agreements and frameworks

International convention/ framework	Summary	Implications for vulnerability assessments
United Nations Convention on the Law of the Sea (UNCLOS)	UNCLOS, which was developed in 1982 and came into force in 1994, provides a framework agreement for the governance of maritime issues, including those related to the delineation of maritime boundaries. It defines the rights and responsibilities of nations in their use of the world's oceans, and establishes guidelines for businesses, the environment, and the management of marine natural resources, with the aim of lessening the risk of international conflict and enhancing stability and peace. It is a critically important framework in the Caribbean region where island states are in close proximity to each other and where many economically important marine resources, including fish species, are transboundary in nature. Under UNCLOS Article 63, countries that share fish stocks are also legally obligated to collaborate in its management. To date, most of the project countries have ratified the UNCLOS.	UNCLOS commitments will need to be factored into the framing, implementation and dissemination of findings from vulnerability assessments to support identification of adaptation measures for the fisheries sector.
United Nations Framework Convention on Climate Change (UNFCCC)	Caribbean climate challenges include sea level rise, decreasing precipitation, increased intensity of hurricanes and overall higher temperatures. Signatories to UNFCCC have committed to working towards stabilising greenhouse gas concentrations to minimise impacts to the climate system. More recently Caribbean nations have contributed significantly to drafting of the Paris Agreement at the UNFCCC Conference of Parties in 2015 (COP 21). The Paris agreement subsequently came into force in November 2016. Of critical importance to the region is the fact that the Paris agreement specifically recognises the needs of SIDS and provides support for attempts to cap global temperature increase at 1.5^{o}C. Key agreements under the UNFCCC include:	The Green Climate Fund associated with the UNFCCC is an important funding source for all Caribbean countries including the seven project countries in this initiative and the other Caribbean SIDS. This was emphasised during the recent Green Climate Fund Structured dialogue at t^{he} 4th Meeting of the Council of Ministers of Environmental Sustainability (COMES) of the OECS in Grenada from April 27 to 28, 2017.

[21] See full regional CDM Strategy 2014-2024 here: http://www.cdema.org/CDMStrategy2014-2024.pdf

[22] This Strategy and Action Plan was discussed and endorsed in 2012 in Kingston, Jamaica at technical level by representatives of climate change, DRM and fisheries agencies of 23 countries and overseas territories in the Caribbean region

	• The Kyoto Protocol which proposes binding targets for the reduction of greenhouse gas emissions • The Cancun Agreements which address the long-term challenge of climate change over time and encourages countries to take concrete action to speed up the global response. The related Cancun Adaptation Framework seeks to enhance action on adaptation and the development of national adaptation plans. Other aspects of the Cancun Agreements address mitigation, financial, technology and capacity building support. • The Paris Agreement promotes ambitious efforts to mitigate climate change and adapt to its impacts and addresses appropriate financial flows, a new technology framework and an enhanced capacity building framework to support action. The Agreement also provides for enhanced transparency of action and support through a more robust transparency framework.	
Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention)	This is the umbrella agreement protecting the Caribbean marine environment, which entered into force in 1986. At the level of the wider Caribbean, it is the only legal framework that provides for cooperative action for the protection and development of the marine environment. The Convention is supplemented by three Protocols: • the Land-Based Sources (LBS) of Pollution Protocol • the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) • the Oil Spill Protocol.	The commitments and work programmes under the Cartagena Convention will need to be factored into the framing, implementation and dissemination of findings from vulnerability assessments to support identification of adaptation measures.
Convention on Biological Diversity (CBD)	The CBD focuses on the conservation of global biodiversity including the sustainable use of its components and the equitable sharing of benefits arising from biodiversity resources. Country National Biodiversity Strategies and Action Plans (NBSAPs) under the convention address the mobilisation of financial resources, research, the regularisation and consolidation of legislation, public awareness, and use of traditional knowledge. Country reports to the Convention are framed against Aichi Targets. Of the 20 Aichi targets, the following are relevant to fisheries and the coastal and marine environment: • Target 17: Countries have developed and adopted NBSAPs • Target 5: Rate of loss of natural habitats is halved	The CBD commitments and Aichi targets will need to be factored into the framing, implementation and dissemination of findings from vulnerability assessments to support identification of adaptation measures. The attention to indigenous and local communities' needs and rights is also noteworthy and where possible and appropriate will be referenced in the production of the deliverables.

	• Target 6: Adoption of ecosystem based approaches and that all fisheries are harvested sustainably • Target 8: Pollution has been brought to levels not detrimental to ecosystem function and biodiversity • Target 9: Invasive species are managed and brought under control • Target 11: 10 per cent of coastal and marine areas are conserved through effectively and equitably managed, ecologically representative and well-connected systems of marine protected areas (MPAs) and other measures • Target 12: Extinction of endangered species prevented • Target 14: Ecosystems the provide essential services, contribute to livelihoods and well-being, are restored and safeguarded taking into account needs of women, indigenous and local communities, and the poor and vulnerable The CBD also has a 'Strategic Plan for Biodiversity 2011-2020' to guide countries', that focuses on mainstreaming biodiversity conservation into different economic sectors. Civil society rights and equity in using and sharing are addressed in the CBD's Nagoya Protocol. In a similar vein the Mo'otz Kuxtal Voluntary Guidelines are geared towards Prior Informed Consent of indigenous peoples and local communities for using their traditional knowledge.	
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	CITES attempts to control the international movement of plants and animals towards improved biodiversity protection. A key aspect is the development, enactment and enforcement of supporting legislation and regulations.	Like the CBD, CITES commitments should be factored into the framing, implementation and dissemination of findings vulnerability assessments.
Convention to Combat Desertification and Land Degradation (UNCCD)	Countries share similar issues related to land degradation including deforestation, overgrazing and soil erosion leading to high rates of surface runoff of sediment laden water. Under UNCCD, Caribbean countries have developed their National Action Plans to address these issues, reinforced by national policies and legislation (including ICZM policies).	UNCCD commitments should be factored into the framing, implementation and dissemination of findings vulnerability assessments where they relate to ICZM and fisheries and marine management.
Food and Agriculture Organisation (FAO) Code of Conduct for	The FAO Code of Conduct provides a reference framework for the development of comprehensive and integrated policies for improved fisheries management and food security. The Code sets out the principles and international standards of behaviour for	The standards and guidelines within the Code need to be factored into the framing, implementation and dissemination of findings vulnerability assessments and identification of

Responsible Fisheries	responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. The recently adopted the *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines),* which complements the Code, seeks to mainstream CCA, DRM and gender considerations to enhance the contribution of small-scale fisheries to food security and nutrition and to support the progressive realisation of the right to adequate food through empowering small-scale fishing communities to participate in decision-making, enjoy their human rights, and assume responsibilities for sustainable use of fishery resources.	adaptation measures for the fisheries sector.
FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (FAO Compliance Agreement)	Under the 1993 FAO Compliance Agreement, signatory project countries have agreed to follow specific measures for fishing on the high seas.	As for the FAO Code of Conduct, the specific measures within the Compliance agreement need to be factored into the framing, implementation and dissemination of findings vulnerability assessments and identification of adaptation measures for the fisheries sector.
International Convention on Wetlands (Ramsar)	The Ramsar Convention on Wetlands designates wetlands of international importance across the region. Under this convention countries are mandated to safeguard these ecosystems and this will be reflected in project deliverables.	Wetlands under the RAMSAR convention include coastal ecosystems such as mangroves, shallow coral reefs and coastal lagoons, which will be factored into the assessment of vulnerability of coastal and fishing communities and the fisheries sector and identification of adaptation measures.
Sustainable Development Goals (SDGs)	This is the international framework replacing the Millennium Development Goals. Established in 2015, the SDGs consist of 17 goals articulated through 169 indicators, to serve as "a plan of action for people, planet and prosperity." Specific goals address natural ecosystems and climate change and environmental management and climate change also are mainstreamed into other goals. Consideration of goals and targets relevant to each country will be reflected in project deliverables.	The implementation of the SDGs, namely Goal 13 on taking urgent climate action, can be facilitated by the vulnerability assessments increase awareness and understanding of climate change impacts and potential adaptation measures.
Small Island Developing States Accelerated Modalities of	The SAMOA pathway is the outcome and plan of action emanating from the 3rd Conference of Small Island Developing States, including Caribbean States. It builds on previous SIDS outcomes such as the Barbados Programme of Action from 1994.	The SAMOA pathway recognises the special circumstances and vulnerabilities of SIDS and emphasises actions for climate change and fisheries and marine resource management issues.

Action (SAMOA pathway)		

Table 2: Summary of major regional intergovernmental bodies and relevant agreements

Regional body	Relevant policies guidelines and frameworks	Implications for vulnerability assessments
Caribbean Community (CARICOM)	The CARICOM *Liliendaal Declaration on Climate Change and Development* sets out key climate change related interests and aims of CARICOM member states, including the seven project countries. Other relevant environmental policies and strategies developed and administered by the CARICOM Secretariat or its technical agencies include: • CARICOM Regional Framework for Achieving Development Resilient to Climate Change and its Implementation Plan (administered by the CCCCC) • Caribbean Comprehensive Disaster Management Strategy (administered with support of CDEMA) • Caribbean Community Common Fisheries Policy (administered with support of CRFM) Notably, the Caribbean Community Common Fisheries Policy seeks to: (a) govern the CARICOM fisheries through the establishment of measures for conservation, management, sustainable utilisation and development of fisheries resources and related ecosystems; (b) build capacity among fishers; (c) optimise the social and economic returns from fisheries; and (d) promote competitive trade and stable market conditions. The CARICOM Common Natural Resources Policy Framework and CARICOM Biodiversity Strategy are currently in development.	Vulnerability assessments must be developed ensuring they are aligned with provisions under the various CARICOM Frameworks.
Caribbean Regional Fisheries Mechanism (CRFM)	The CRFM was established in 2003. It is an inter-governmental organisation with its mission being to promote and facilitate the responsible utilisation of the region's fisheries and other aquatic resources for the economic and social benefits of the current and future population. CRFM has developed a number of memoranda and agreements with other relevant bodies. This includes the FAO/CRFM/ Western Central Atlantic Fishery Commission (WECAFC)/CDEMA/CCCCC *"Strategy and Action Plan for disaster risk management and climate change adaptation in fisheries and aquaculture in the CARICOM region*" which provides an	Vulnerability assessments must be developed ensuring they are aligned with the CRFM's agreements, strategies and action plans.

	overarching framework to guide new directions for the fisheries and aquaculture sector.	
United Nations Environment Programme - Caribbean Environment Programme (CEP)	The CEP Regional Coordinating Unit administers the Cartagena Convention, which is the umbrella agreement protecting the Caribbean marine environment. The Regional Coordinating Unit through SPAW also coordinates activities and develops synergies with work under international conventions like the CBD and CITES. As a consequence of the aforementioned process, the CEP currently includes the following three sub-programmes: • Assessment and Management of Environment Pollution (AMEP) • Specially Protected Areas and Wildlife (SPAW) • Communications, Education, Training and Awareness (CETA)	Vulnerability assessments should be aligned with the CEP's work and its sub-programmes.

3.2 Key national policies and plans

The Integrated Coastal Zone Management (ICZM) Policy Framework was recently adopted for Trinidad and Tobago in August 2023. The goal of the policy framework is to facilitate an integrated approach to coastal zone management aimed at maintaining, and where necessary, enhancing the functional integrity of coastal resource systems while enabling sustainable economic development through rational decision-making and planning (ICZM today, 2015). It also incorporates climate adaptation and disaster risk management considerations using an ecosystem-based approach.

An Inter-Ministerial ICZM Committee was appointed in January 2024 to coordinate and oversee implementation of the ICZM Policy Framework, with the Ministry of Planning and Development and IMA as chairs. In Trinidad, the Coastal Protection Unit, Ministry of Works and Transport (MOWT) also has a mandate to execute the Critical Coastal Protection Programme and assist in the development and implementation of government policies regarding coastal zone management and climate change shoreline adaptation. In Tobago, the Coastal Zone Management Unit, Tobago House of Assembly is responsible for conducting coastal zone risk assessments, formulating baseline studies on coastal and oceanographic processes, developing coastal infrastructure to control coastal erosion and enhancing the climate resilience of coastal infrastructure. The Fisheries Division, Ministry of Agriculture, Land and Fisheries has the mandate to manage fisheries and aquaculture in Trinidad and the Department of Marine Resources and Fisheries, Tobago House of Assembly has a similar mandate for Tobago.

In addition to the ICZM Policy Framework, there are 20 pieces of legislation and 20 other policies that relate to coastal zone management (GoRTT, 2019). These include:

- Fisheries Act, 1916, with subsequent amendments in 1966 and 1975, as the principal legislation governing domestic fishing in T&T and the Archipelagic Waters and Exclusive Economic Zone Act Ch 51:06 (Act N0 24 of 1986). The 2006 Draft Marine Fisheries Management Act when approved, will repeal relevant sections of these.

- Draft Fisheries Management Policy for T&T – This does not address the issue of climate change however. In like manner, the current Draft Trawl Management Plan does not refer to climate change.
- A policy for the development of an aquaculture industry in T&T is being prepared. This should provide an opportunity to address the challenges in relation to governance and stakeholder participation in policy formulation and implementation; fiscal and environmental incentives; investment; marketing; capacity building and the likely impacts of climate change on the sector.
- National Climate Change Policy, 2011 – This is currently up for review which presents an opportunity for integration of DRM and fisheries concerns.
- Disaster Measures Act, 1978 – This is the main disaster legislation, but is outdated and does not recognise climate change.
- Comprehensive Disaster Management Policy Framework and Hazard Mitigation Policy, although the latter is not officially recognised. These are aligned with the regional CDM Strategy 2014-2024 to which T&T also subscribes. The Office of Disaster Preparedness and Management is supporting integration of climate adaptation and DRM and has been working to facilitate 'climate smarting' work programmes of various sectors including fisheries and agriculture.

4. Building coastal community resilience in T&T

4.1 Coastal community resilience

Understanding resilience

Resilience is defined as the capacity of social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2022). Traditionally, resilience has been framed in terms of the ability to "bounce back" after climate hazards and related shocks and stresses, drawing on initial studies in the field of ecology and field of natural hazards and disaster risk reduction (Leichenko *et al.*, 2018). However, researchers have now broadened the definition to include "bouncing forward" which emphasises the capacity to anticipate and rebuild after extreme events that would allow for a reduction in vulnerability and greater preparedness for expected future shocks and stresses (Leichenko *et al.,* 2018).

While often linked to adaptation, or even seen as synonymous, resilience is generally a broader concept that takes into account a wide range of hazards, shocks and disturbances, including those that are climate related. There are a number of conceptual models and frameworks for resilience that can aid policymakers, researchers, and stakeholders in better comprehending the complex interactions and factors that influence resilience in T&T and Caribbean SIDS (Kais and Islam, 2016). These can be broadly categorised into frameworks that are systems-based versus actor-based.

Systems-based frameworks focus on exploring the interactions between society and natural environments and emphasise the need for sustainable, adaptive and integrated approaches. For example, in a coastal context, a fishery can be recognised as a social-ecological system (SES)[23]. In building its resilience, it would therefore be important to understand the exposure to climate hazards (e.g. more intense hurricanes), the ability to withstand hazards (e.g. marine ecosystem health) and any thresholds (e.g. temperature limits for survival of coral reefs and fish species) in the ecological system. Any shifts in the ecological system are in turn experienced by the socio-economic system. The level of exposure would be shaped by livelihoods (e.g. dependence on fisheries for income generation) and ability to withstand these hazards and ecological changes as well as to transform shaped by human and institutional factors (e.g. early warning systems, level of education and awareness, access to insurance and other financing).

Actor-based frameworks focus on specific actors, policies and interventions in considering resilience. This includes frameworks that seek to empower local communities and organisations to participate in decision-making, identify their local impacts and vulnerabilities, and develop strategies to adapt and build resilience tailored to their specific needs and contexts. There are also frameworks where resilience is understood through a livelihood lens and focus is on improving livelihood outcomes and shifting to more inclusive, sustainable and resilient pathways to development. More recently, an equity and justice framework has been promoted that is inclusive and allows for collaborative partnerships to ensure that the benefits of resilience strategies are fairly and equitably applied and shared, including among most vulnerable and marginalised groups.

[23] FAO. 2013. Report of the FAO/PaCFA Expert Workshop on Assessing Climate Change Vulnerability in Fisheries and Aquaculture. Rome: FAO.

Understanding coastal community resilience

Community resilience encompasses the methods by which communities face increasing threats and perceive, manage and govern their complex socio-ecological systems in such a way that it increases their inherent capacity to cope with, adapt to and shape meaningful progressive change (Asadzadeh *et al.*, 2017). Considering this, community resilience can therefore be considered the product of successful adaptation and wider development interventions that stemmed from the collective action of government, civil society organisations (CSOs), households and individuals. Community resilience is a result of strong adaptive capacity and ensures that the essential identity and structure of that community is not detrimentally altered in the aftermath of climate hazards and other disasters (Mycoo, 2018).

There has been significant attention directed towards the identification of the main characteristics of resilient communities (Leichenko *et al.,* 2018). Mycoo (2018) notes that resilient coastal communities in Caribbean SIDS demonstrate the ability to take deliberate action to reduce risk from coastal hazards. They have a united goal of continuously avoiding potential disasters and focusing on ways to accelerate recovery in the event of the occurrence of disasters while adapting to changes through experience and applying lessons learned (Mycoo, 2018). Key characteristics of resilient coastal communities include the following: 1) they can absorb or avoid the impacts of hazard events; 2) they can recover form hazard events quickly; and 3) they are flexible and can adapt quickly to changing conditions.

However, there is much less information on strategies for building community resilience (Leichenko *et al.,* 2018). Asadzadeh *et al.* (2017) and Almutairi *et al.* (2020) have attempted to identify a number of factors that can propel coastal communities from low resilience to high resilience, including:

- Governance
- Society and economy
- Coastal resource management
- Land use and structural design
- Risk knowledge
- Warning and evacuation
- Emergency response
- Disaster recovery

4.2 Coastal community resilience in T&T

Climate change poses as significant challenge for T&T, particularly our coastal communities (Mycoo, 2018; Granderson *et al.*, 2022). There are several aspects that make coastal communities and the wider coastal zone vulnerable to climatic changes and impacts, and requires a concerted effort towards building coastal community resilience (MOWT, 2019). These aspects include the following:

- housing 70% of the population of the country;
- containing 80% of energy-based industries;
- containing 50% of roads and bridges in the country;
- containing 90% of tourist facilities; and
- coastal communities are responsible for 90% of the annual fish production in Trinidad and Tobago (MOWT, 2019).

Addressing these vulnerabilities and building coastal community resilience in Trinidad and Tobago is critical due to the increasing number of threats posed by climate change and its associated impacts, such as rising sea levels, coastal erosion and more intense storms (Mycoo 2018, MOWT, 2019). The following strategies and steps (Asadzadeh *et al.*, 2017; Mycoo, 2018; Almutairi *et al.*, 2020; CANARI, 2020) have been identified to help build and enhance coastal community resilience in T&T:

1. Greater local community engagement inclusive of local governments, business owners and residents so that there can be a comprehensive understanding of each community's priorities and needs related to coastal resilience
2. Assessment of coastal communities in Trinidad and Tobago to identify the most vulnerable areas, assets and populations inclusive of current vulnerability challenges and any future climate projections, such as sea level rise projections, that may impact those specific communities
3. Establishment of monitoring systems that can efficiently track the changes in the conditions within coastal limits so that resilience strategies adopted can be specific to each community and based on information gathered in those communities
4. Greater investment in innovation and research within vulnerable communities in order to better comprehend the localised impacts which would aid in the development of innovative solutions specific to each community
5. Further development and implementation of policies, legislation and regulations that particularly support efforts towards increased coastal resilience, sustainable coastal development and protection of coastal natural resources
6. Improvement and implementation of early warning systems and emergency response plans should be considered specific to each coastal community. This would include providing timely information about meteorological hazards, evacuation routes and shelter locations which should be accessible and understandable to all residents
7. Empowerment of local communities and resource users to take action and provision of training to these local actors on practices for sustainable coastal living and resilience building. There should also be an increase in public awareness on the major importance of building coastal resilience and the role that these coastal communities can play
8. Partnerships with international technical organisations, NGOs and other relevant stakeholders that can assist coastal communities and supporting public and private sector partners to access funding and technical expertise for resilience projects, including grants and other financing that would specifically support local initiatives
9. Economic diversification in coastal communities so they are not solely dependent on vulnerable sectors, such as fishing and tourism which are already being adversely impacted by climate change

Notably, increased engagement and leadership from CSOs is needed to effectively build community resilience, recognising that government agencies and the private sector do not have adequate capacity and resources to address the impacts of climate change alone and an inclusive and 'bottom up' approach is required. Building the capacity of local community-based organisations and resource user groups within each impacted community will be an important part of promoting civil society leadership and can aid in planning and implementing resilience actions (Allam, 2019; CANARI, 2020). As part of this inclusive approach to building community resilience, there should be a major focus on the needs of the most vulnerable, including women, youth and key resource users like small-scale fisherfolk (CANARI, 2020). This also includes incorporating the principles of equity and justice to address the uneven impacts of climatic and other hazards on vulnerable and marginalised communities (Fox *et al.*, 2023).

4.3 Use of digital technologies to enhance coastal community resilience

Existing and emerging digital technologies can aid in building coastal communities' resilience to climate change and other hazards by allowing for more rapid and accurate assessment of local conditions and supporting inclusive decision-making and action (Argyroudis *et al.*, 2022). Participatory geographic information systems (P-GIS), including use of drones, have already begun to be initiated to enhance data collection and monitoring of coastal hazards and impacts, and there are emerging technologies such as digital twins, augmented and virtual reality and artificial intelligence (AI) that can also be applied.

However, there are a number of challenges that currently limit the level of usage and adoption of these technologies and the information they can generate:

1. There is a lack of consensus on which technologies to utilise.
2. There is limited capacity at national and local levels to implement these technologies and facilitate integrated and inclusive approaches with coastal communities.
3. There is limited enabling legislation and policy to support their use.
4. Digital technologies remain heavily reliant on a robust power supply, wi-fi/internet connectivity and interdependencies between the various operators.
5. Possible tensions can be experienced within human-machine interactions during decision-making processes. This might be due to the distrust that some people may have with the fact that the technologies may not have the users' best interests at heart, which often stems from the challenges in explaining and interpreting digital data into actionable and human terms. This exacerbates the challenges of increasing infrastructure digitalisation, which must comply with the equitable principles and 'leave no one behind'. Therefore, unfortunately, in some cases, the adoption of such technologies in developing economies might be slower such as in T&T (Argyroudis *et al.*, 2022). It is therefore important that these challenges are noted and incorporated in the development phase of projects to mitigate any unwanted future challenges that may arise.

Digital technologies can potentially increase vulnerability to cyber-attacks that in some cases may even escalate to cyberwarfare. These can eventually lead to risks involving security and citizens' privacy as well as misinformation

5. Applying digital and participatory technologies and tools to build coastal community resilience

5.1 Digital technologies

Digital technology is an umbrella term that refers to a variety of technologies (electronic devices, systems, or resources that generate/store/process data and information) which are included under the subsets of information technology (IT) and information communication technology (ICT) (see Figure 2). Technology is defined here as the "application of scientific knowledge of practical purposes" (Fontes de Meira and Bello, 2020). Whilst there is some overlap, IT includes computing technologies (e.g., hardware, software, internet) whilst ICT refers to technologies that provide access to information through telecommunications (e.g., internet, mobile phones, wireless networks) (ADB, 2021).

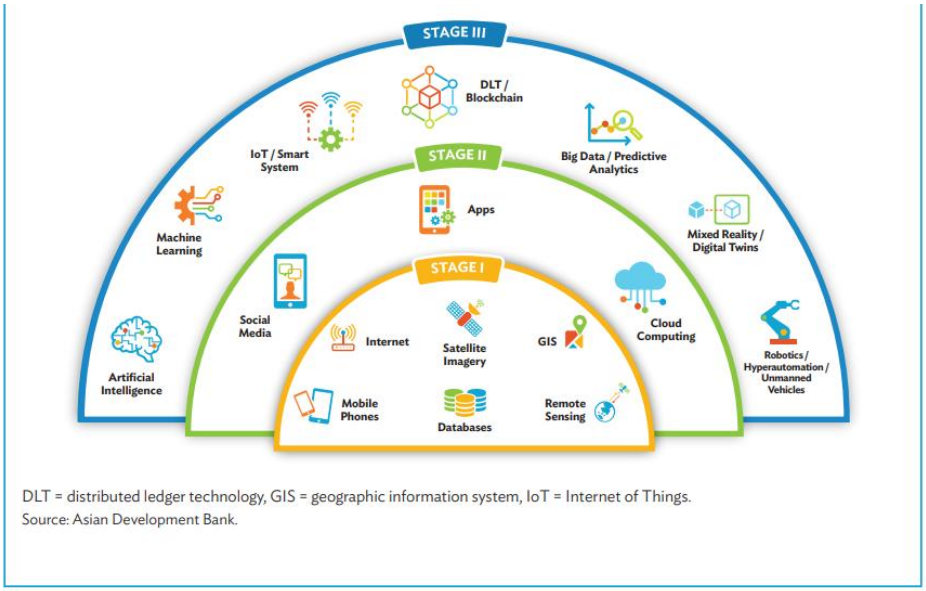


Figure 2: Classification of digital technology (ADB, 2021)

Digital technologies can be used to support innovative approaches to manging climate and disaster risks and support decision-making processes in the coastal zone through supporting data connections, analysing data, enabling communications, monitoring and tracking ecosystem changes etc. In Figure 2, Stage I technologies have been well established and adopted into the mainstream (particularly in low income communities in developing countries) and are currently used to support climate change mitigation and adaptation, and disaster risk management particularly through capturing information, storing online repositories (information systems) and enabling communications (ADB, 2021). Stage II technologies are built upon Stage I technologies and recently entered into mainstream commercial application and mostly work to enable information exchange and interaction and collaboration through social media and apps; it was recognised that in general Stage II technologies are not being utilised to their full potential in addressing climate change adaptation/mitigation and disaster risk management (ADB, 2021). Stage III technologies have potential to be further mainstreamed in the future but may be slow to uptake due to lack of

technical knowledge/skills required for the use of these technologies as well as the high up-front costs (ADB, 2021).

Fontes de Meira and Bello (2020) have analysed the roles of technology and innovation within the region according to the five pillars of climate and disaster risk management: vulnerability and risk identification, risk reduction, preparedness, financial protection and resilient recovery. They noted low levels of application of innovation and technologies, including ICTs, for climate and disaster risk management within the Caribbean region based on the availability of studies/information (Fontes de Meira and Bello, 2020). This can be attributed to low research and development, limited private sector involvement, under-equipped agencies, a shortage of human resources, and limited funding and investment. Fontes de Meira and Bello (2020) further indicated the need to facilitate data sharing, collaboration and sharing of best practices, tools, knowledge and expertise to ensure greater action amongst stakeholders.

Below are outlined key digital technologies that have been applied in the Caribbean context, including in T&T.

Geospatial analysis and technologies

Geospatial technologies can be used to set a baseline pre-event for a specific geographic area or location and can inform subsequent assessments of vulnerability, post-disaster impacts and M&E, and so used in risk identification, reduction and response (Fontes de Meira and Bello, 2020). The complexity of geospatial tools is generally high in terms of data analysis, but low in terms of obtaining imagery if available from a third party/partner organisations. The challenges utilising this tool would be the availability of personnel, equipment and tools for data analysis.

<u>Drones</u>

Unmanned aerial vehicles (UAVs), or drones, are radio-controlled, unmanned aircraft, which can be a very valuable tool for geospatial analysis where they have a global positioning system (GPS)-guided flight plan and data is integrated into a geographic information system (GIS). They have been used in T&T and the wider region to map and monitor coral reefs, mangroves and watersheds as well as key hazards, such as coastal erosion and mass sargassum influxes.

Through the Mapping of Ocean Wealth project, training has been conducted on using UAVs for both aerial and land-based surveys, including for small unmanned surface vehicles (sUSV) which can be used by marine managers to monitor and map shallow marine areas (TNC, 2023a). This process is able to collect information to generate high resolution underwater orthophoto mosaics and digital survey models (TNC, 2023a).

Training was also conducted in the application of drone technology to support environmental monitoring and management in 2018 as part of a regional capacity building initiative under The Caribbean Aqua-Terrestrial Solutions Programme Phase II (Building Climate Resilience from the Ridge to the Reef). This focused on Saint Lucia with the hope that the technology will facilitate effective management of the Soufriere watershed, Pitons Management Area World Heritage Site and the Soufriere Marine Protected Area (Caribbean Aqua-Terrestrial Solutions, 2019).

Through the UWI-CERMES' SargAdapt project and CANARI's "Sustainable sargassum management in Anguilla, British Virgin Islands and Montserrat" project, relevant management agencies and coastal

community stakeholders from participating Eastern Caribbean countries have been trained in utilising drone technology to assess and monitor sargassum influxes and impacts along vulnerable coastlines. Through the SargAdapt project, a Sargassum Monitoring Protocol was developed and training delivered to participating countries on execution of baseline flight surveys, sargassum drone surveys and ground measurements, data handling, processing and management, and analysis and reporting of findings (UWI-CERMES, 2022). Through the SargAdapt project, UWI-CERMES also developed a rapid Sargassum Drone Monitoring Protocol to support rapid field surveys utilising simple drones and cloud-based drone software (not requiring prior GIS experience) to provide non-technical accurate estimates of sargassum influxes (Baldwin *et al.,* 2022*)*.

The Caribbean Institute of Meteorology and Hydrology (CIMH) also aims to strengthen regional capacity to respond to natural disasters and climate variability through the use of drones to assist in gathering climate data and imagery in countries such as Antigua and Barbuda, Barbados, Dominica, Grenada, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines and T&T. Drones were provided to the CIMH through the United States Agency for International Development (USAID) under their initiative "Strengthening Disaster and Climate Resilience Program" (SDCR) (US Embassy in Barbados, the Eastern Caribbean and the Organisation of Eastern Caribbean States [OECS], 2021). Additionally, a *Drones in the Coastal Zone* virtual workshop series was hosted in 2020 by the Southeast Coastal Ocean Observing Regional Association (SECOORA) and targeted participants from the Caribbean. The workshop covered information gaps in coastal management that can be supported by drone technology, assessed expertise in the Caribbean and other regions, demonstrated emerging technologies, shared best practices for drone missions planning/operations and data management, and established a community of practitioners/stakeholders (SECOORA, n.d).

Drones have also been used for post-disaster assessments, including to collect information for Damage and Loss Assessment (DaLA) post-Hurricane Irma in Sint Maarten in 2017 and post-Hurricane Maria in Dominica in 2017, particularly for the housing sector and number of houses impacted (Fontes de Meira and Bello, 2020). Also, as part of Dominica's 'Build Back Better' strategy results from drone field surveys have informed guidelines for reducing vulnerability and exposure to hurricane related floods (Fontes de Meira and Bello, 2020).

In Trinidad and Tobago, the Ministry of Agriculture, Land and Fisheries (MALF) aims to utilise drones to support its national aerial surveys and mapping exercises including coastal monitoring surveys (Ministry of Agriculture, Land and Fisheries, 2023). Further examples of local use of drones are include: (i) The Trinidad and Tobago Meteorological Service utilising drones for flood surveillance (Trinidad and Tobago Meteor; (ii) The Institute of Marine Affairs and Coastal Protection Unit use of drones in monitoring coastal areas (ACS, 2023; Ministry of Work and Transport, 2020); and (iii) The ODPM UAV Volunteer Programme (2020) which is intended to leverage network of certified pilots to support disaster management including situational awareness, expediting damage assessments, identification of critical areas to target response action (ODPM, 2020). See Table 3 for a summary of use of drone technology in the region.

Table 3: Summary of use of drone technology within the region

Initiative	Application
Mapping of Ocean Wealth project (TNC-led)	Use of Unmanned Aerial Systems (UAS) since 2014 specifically for mapping and monitoring coral reefs and mangroves Location: Region wide – Dominican Republic, Grenada, Jamaica, St. Vincent and the Grenadines), Cuba, Bahamas
The Caribbean Aqua-Terrestrial Solutions Programme Phase II (Building Climate Resilience from the Ridge to the Reef)	Application of drone technology to support environmental monitoring and management in 2018 as part of a regional capacity building initiative. Expected to support effective management of the Soufriere watershed, Pitons Management Area World Heritage Site and the Soufriere Marine Protected Area Location: Saint Lucia
UWI-CERMES' SargAdapt project CANARI's "Sustainable sargassum management in Anguilla, British Virgin Islands and Montserrat" project	Relevant management agencies and coastal community stakeholders from participating countries trained in utilising drone technology to assess and monitor sargassum influxes and impacts along vulnerable coastlines. Rapid Sargassum Drone Monitoring Protocol developed Location: Eastern Caribbean, Overseas territories – Anguilla, British Virgin Islands, Montserrat
Caribbean Institute of Meteorology and Hydrology (CIMH) "Strengthening Disaster and Climate Resilience Program" (SDCR)	Strengthening regional capacity to respond to natural disasters and climate variability through the use of drones to assist in gathering climate data and imagery Location: Antigua and Barbuda, Barbados, Dominica, Grenada, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines and T&T.
Post-disaster assessments (Dominica)	Damage and Loss Assessment (DaLA) post-Hurricane Irma in Sint Maarten and post-Hurricane Maria in Dominica in 2017.
'Drones in the Coastal Zone' virtual workshop series, 2020 (NOAA/Southeast Coastal Ocean Observing Regional Association (SECOORA) collab.	Covered information gaps in coastal management that can be supported by drone technology, assessed expertise in the Caribbean, demonstrated emerging technologies, shared best practices for drone mission planning/operations and data management, established a community of practitioners/stakeholders

<u>Geographic information systems (GIS)</u>

GIS refers to a system where geographic or locational information is stored in layers and integrated with geographic software so that spatial information can be created, stored, manipulated, analysed and visualised/mapped. GIS tools can support in identifying problems, monitoring change, managing/responding to events, forecasting, prioritising action, understanding trends (ESRI, n.d.). GIS can be applied to participatory processes in coastal and marine spatial planning to support decision making (e.g. using participatory GIS [P-GIS], participatory three-dimensional modelling [P3DM]) and communication products. P-GIS combines GIS technology with community mapping to capture local knowledge in digital maps to enhance spatial planning and are used to support VCAs in coastal and fishing communities e.g. P-GIS helps to map out vulnerable areas and groups, and coastal and marine ecosystems. P3DM (also a VCA tool) combines elevation data and local spatial knowledge to develop a scaled, geo-referenced three-dimensional model of the area which can be digitised to GIS. Maps developed can be used in communication products aimed at a wide variety of stakeholders to support decision making and spatial planning (FAO and CANARI, 2022).

In Trinidad and Tobago, GIS tools have been utilised by various government ministries and agencies to support disaster management and coastal and marine management. The IMA's online platform, the *Marine Data Hub* was developed through web-based GIS technologies to support collecting, analysing, and sharing of geospatial data related to the marine and coastal environment. The platform allows users to explore data on biodiversity, build digital maps, analyse datasets using spatial tools as well as map and monitor coastal ecosystems. The development of the platform was funded by the European Union and the Global Biodiversity Information Facility through the Biodiversity Information for Development Programme (IMA, 2023). The Ministry of Agriculture, Land and Fisheries, GIS Unit focuses on geospatial analysis, GPS field investigation, producing, analysing and distributing datasets, maps and interactive mapping applications. Some projects/programmes under the Ministry include the: (i) Spatial Information Management System (supports efficient use of resources through geospatial visualisation, analysis and modelling), (ii) Mobile Data Collection of Asset Management (GPS equipment used to capture data on agriculture, fisheries and forestry), and (iii) Marine Geodatabase (focuses on Gulf of Paria ecosystem and bottom trawl fisheries and aims to develop datasets from various agencies and local knowledge of fisherfolks in order to support Fisheries Division) (GoRTT, 2019). The Office of Disaster Preparedness and Management (ODPM) also utilises GIS for hazard mapping and analysis to support disaster risk reduction, and have also developed GIS toolkits and conducted GIS training workshop to improve local capacity at community-based Risk Reduction Management Centres (e.g. in Mayaro/Rio Claro) (ODPM, 2014).

In Cuba, the Risk Reduction Management Centre (RRMC) model integrates disaster management with development planning and utilises GIS as a tool to visualise data to support decision making for land use planning and risk and disaster impact assessments. The RRMC model was also piloted in Jamaica, Dominican Republic, and T&T. The T&T pilot project occurred in 2013 in the Mayaro Rio Claro Regional Corporation and offered GIS training to local stakeholder groups (UNDP, 2014).

One scientific study by Lam *et al.* (2015) utilised GIS analysis to vulnerability and resilience assessment (Resilience Inference Measurements model) to determine the resilience of 25 Caribbean countries to hurricanes based on exposure, damage, recovery and social-environmental capacity. Sutherland and Seeram (2011) also utilised GIS as part of their study to model sea level rise in Grande Riviere in Trinidad to inform socio-economic impact analysis (using sea level rise models created based on IPCC projections). The methodology included primary spatial data collection (topographic and hydrographic surveying techniques), secondary spatial data collection and GIS processing of all collected data through Triangulated Irregular Network creation, dataset overlays and simulations of static sea level rise flooding. The models developed suggested that a 0.4m in sea level rise could impact turtle nesting sites and in turn negatively the socioeconomic well-being of the community.

The Caribbean Disaster Emergency Management Agency (CDEMA) developed the Caribbean Community Risk Information Tool (CCRIT) as a hazard and vulnerability data collection tool with Barbados GIS to support risk management. The tool is intended to select communities to apply risk reduction actions (improving coordination amongst various agencies/stakeholders) through collecting hazard and vulnerability data, creating hazard database, conducting geospatial data analysis, ranking vulnerable communities and using community-based data to establish priorities in managing hazards and vulnerabilities (UWI, 2017; STEPS, 2022).

The Mexican National Institute of Statistics and Geography has also supported the development of the Caribbean Territorial Information Platform for Disaster Prevention which is an online GIS multi-risk analysis tool for sharing risk information in the region.

Remote sensing

Satellite remote sensing has been utilised in T&T to: 1) monitor and map the distribution of turbidity and chlorophyll-a along the Gulf of Paria coastline; 2) improve the detection of floating Sargassum between Trinidad and Tobago; and 3) create a marine vegetation species distribution map of the Caroni Swamp in Trinidad through spectral reflectance of the three mangrove species. This technology aims to support monitoring of critical ecosystems and utilised the earth observation data from Landsat-8-Operational Land Imager (launched in February 2013) and Sentinel-2A-Multispectral imager (operational since June 2015) to support these monitoring systems (Ramsewak *et al.,* 2017).

Mohammed *et al.,* (2015) utilised satellite remote sensing through the new the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Watch Decision Support System to obtain satellite information on sea surface temperatures (SST) to monitor coral bleaching on near reef scales (5km resolution) in Buccoo Reef, Culloden and Speyside. Results of the near reef scale to the broad scale (50km) indicated better predictability in the near reef scale model to accurately and consistently match to in situ bleaching observations. Further to this, NOAA additionally incorporated a Light Stress Damage product to its Coral Reef Watch programme that combines SST with estimates of photosynthetically available radiation from satellite sensing. NOAA also supports measurement of ocean acidification in the region using satellite data and a data assimilative hybrid model to measure the carbonate system of surface water (Hedley *et al.,* 2016). Ocean acidification is a result of atmospheric carbon dioxide dissolving in the ocean's surface layer resulting in carbonic acid which can impact various species and ecosystems including shallow tropical coral reefs which are made primarily of calcium carbonate (Hedley *et al.,* 2016).

A Light Detection and Ranging (LiDAR) programme (*Support for Conducting Air-Borne Light Detection and Ranging Surveys and Training Project*) is currently being executed by the Caribbean Community Climate Change Centre (CCCCC) to collect LiDAR data for an estimated 10,000km^2 of vulnerable Caribbean coastal areas through flight mapping services. LiDAR is a remote sensing technology which can be used to gather high resolution topographic coastal and bathymetric data (CDB, 2018). The LiDAR programme aims to build greater climate resilience through increased use of technology to acquire quality spatial datasets. These datasets will inform new climate resilient investments, retrofitting of infrastructure, identification of natural hazards, and support coastal zone management and disaster risk management. The programme is funded through the Caribbean Development Bank (CDB) and aims to conduct limited LiDAR surveys in CDB Borrowing Member Countries with ten countries indicating interest including Antigua and Barbuda, Barbados, Belize, Guyana, Suriname, Saint Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Trinidad and Tobago and Turks and Caicos (CCCCC, 2021). For example, in Antigua and Barbuda, the aerial LiDAR surveys will be done on the entire land area of Antigua as well as on marine sections of the northeast area, Willough Bay and the Nelson's Dockyard National Park to provide high resolution geospatial data to support land use planning, sustainable development, building climate resilience and improving disaster risk management (The Observer, 2023). The programmes also support training in the use of LiDAR technology (CCCCC, 2021). In 2022, the Ministry of Agriculture, Land and Fisheries began process of initiating aerial and LiDAR survey of Tobago (Ministry of Finance, 2022).

Other Geospatial Tools

The Caribbean GeoPortal Programme supported by the Environmental Systems Research Institute (ESRI) is a cloud-based platform which provides free data/tool to support community mapping and geospatial analysis to assist with islands resilience building and responses to disasters. The platform provides analytical tools and web services and open data hosting for governments.

The Blue Carbon Explorer app (Google Earth Engine app) developed by The Nature Conservancy (TNC) to utilise data from drone and satellite imagery to identify areas for restoration and protection and supports visualising of degraded or healthy ecosystems (TNC, 2023b). The app is currently being used by project partners in Bahamas to restore mangroves destroyed by Hurricane Dorian in 2019 (Caribbean Science Atlas, TNC, n.d.).

ICTs

As noted earlier, ICTs refers to technologies that provide access to information through telecommunications (e.g., internet, mobile phones, wireless networks, radio) (ADB, 2021). This information can be related to forecasts or early warning to allow the target users to prepare and plan in advance of a climate hazard, or related to how to manage and take actions to adapt and build resilience or monitoring and evaluation (M&E). Below are some of the key ICTs that are currently in use in T&T and the wider Caribbean.

Online Apps

The Fisheries Early Warning and Emergency Response (FEWER) is an application which aims to reduce fisherfolk's vulnerability to climate change impacts through ICT early warning systems. The app supports small-scale fishers through the entire disaster response cycle providing information on weather checks, alerts, hazard warning, post disaster damages, and the ability to file reports on missing persons. One of the eight modules of the application also provides knowledge on local ecological information. The app has been developed in collaboration with the ICT4Fisheries consortium with technical support from the Caribbean Regional Fisheries Mechanism (CRFM) and funding from the Caribbean Regional Pilot Programme for Climate Resilience (PPCR) (Caribbean Regional PPCR, 2017). Updates to the app have aimed to connect small-scale fishers to disaster risk management agencies (Ministry of Agriculture Fisheries, Food Security and Rural Development, 2021). In St. Vincent and the Grenadines, 30 male and female fishers were trained in the FEWER app in 2018; this workshop also sought feedback from users. As part of integrating the technology into overall national emergency response and disaster risk management frameworks, the workshop was also conducted with relevant national agencies/administrators that can support with mainstreaming and administering the app in-country, including fisheries departments, national emergency management organisations and the coast guard (Nurse, 2018). The project has been piloted in Dominica, Grenada, Haiti, Jamaica, Saint Lucia, and St. Vincent and the Grenadines (Nurse, 2018).

The Barbados Environment Conservative Trust is also aiming to support sustainable management of fisheries through the DigiFish initiative which aims to build capacity of fisherfolk in digital technologies and analytical data methods. The initiative is a collaboration between Government of Barbados and private sector and civil society to capture and digitise fishing data to improve data collection in the fisheries sector (IFC, n.d).

Regionally, the BlueDigital initiative aims to apply digital tools to improve segments of the blue economy, including ecosystems and value chains for fisherfolk, government, tourism industry partners and the general public as consumers (UNDP Barbados and the Eastern Caribbean, 2023b).

Digital solutions/services will be provided through four portals on the BlueDIGITAL mobile app targeted at four key stakeholders:

- BlueFish: to support sales of fisherfolk through supporting measuring catch data including species/size through image recognition technology, and also aims to support transition to digital business management)
- BlueData: to support government in data collection for sustainable fisheries management through collection of fish catch data (size, species, quantity, sustainability factors)
- BlueTrace: to support the public to trace seafood products including creation of a traceability system for fisherfolk and seafood products through virtual offerings
- BlueSeal: to support the private tourism sector to develop a sustainable verified seal and support nature and conservation-based tourism activities

VHF Radio

In Trinidad and Tobago, the Smart Seas Toolkit for Disaster Resilience (Smart Seas) project aims to increase resilience of small-scale fishers through ICTs by addressing issues with maritime communications through various innovations including increasing capacity for marine very high frequency (VHF) radio operation. The project will also utilise VHF radio and other ICTs to close data gaps and improve disaster risk resilience including through an online toolkit aimed to support compliance, efficiency and VHF radio capacity. The project is a joint initiative through the International Telecommunication Union, Caribbean Telecommunications Union and the Telecommunications Authority of Trinidad and Tobago (TATT), supported by the Government of the Republic of Trinidad and Tobago (TATT, n.d.)

Blockchain

Through the support of the UNDP, the Government of Grenada is utilising technology, human capital and innovation to develop into a Smart Small State with a vision for digital transformation of the entire society focusing on digital upskilling, experimentation and innovation (UNDP Barbados and the Eastern Caribbean, 2021). One of the areas being focused on is the blue economy and tracking of fish sales on the blockchain. Under the area of climate resilient infrastructure, the aim is also to have real time access to emerging climate risks through mobile alerts.

A blockchain is a database technology which acts as a distributed decentralised digital ledger that stores data of any kind. The digital ledger is referred to as a 'chain' comprised of individual 'blocks' of data and support efficient financial and asset transfers, provides extra security and reduces need for intermediaries . Blockchain technology is used in cryptocurrency, asset transfers and supply chain monitoring. In supply chain monitoring, blockchain makes it easier to monitor information along the supply chain to track food from harvest to consumption and to trace any sources of issues e.g. sources of vendor poor-quality goods (Rodeck and Adams, 2023).

Artificial Intelligence

As part of the UNESCO's Caribbean Artificial Intelligence (AI) Policy Roadmap, one of the six principles included in the roadmap is the "resiliency to enable environmental management and fight climate change" and includes policy considerations for use of AI in disaster mitigation and the "climate change fight: through actions such as early warning systems for rising seas and hurricanes" (UNESCO, 2021).

According to UNESCO's *First Draft of the Recommendation of the Ethics of Artificial Intelligence*, AI systems are defined as "technological systems which have the capacity to process information in a way that resembles intelligent behaviour and, typically includes aspects of reasoning, learning, perception, prediction, planning or control" (UNESCO, 2020). Machine learning and deep learning are both subsets of AI based on the principle that systems can make decisions with minimal human interference based on learned data and identified patterns (Figure 3); examples of machine learning include virtual personal assistants, self driving cars, produce recommendations, and social media services. Some recommendations on the use of AI from the *Caribbean AI Policy Roadmap* included uses in: disaster mitigation (early warning systems, environmental monitoring), predictive analysis (monitoring of climate/weather, pollution, coral reef temperature), smart island infrastructure (data hubs), e-tourism experiences and augmented reality experiences (UNESCO, 2021).

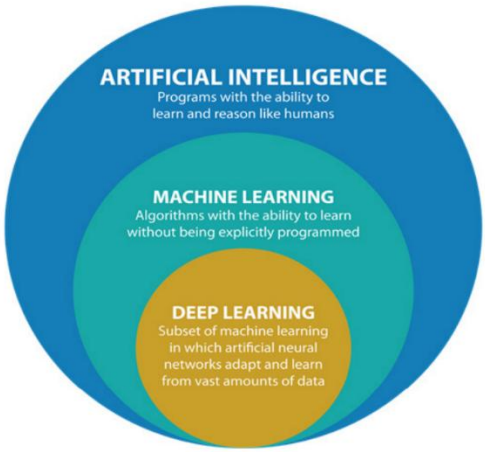


Figure 3 - Artificial Intelligence, machine learning and deep learning (UNESCO, 2021)

In terms of the use of AI to support coastal resilience, The TNC's Mapping Ocean Wealth project aims to support mapping of ocean ecosystem services, and is utilising AI to assess the economic value of tourism. This includes calculating the economic value of coral reefs by applying AI to the Recreation and Tourism web app to gather and analyse large volumes of crowd-sourced data so as to assess distribution and extent of travel to coral reef countries to estimate economic value (TNC, 2021).

Through the Grenada Smart Small State project, the use of AI by underwater reef robots has been proposed to support in monitoring of species, tides, climate change patterns to promote conservation and sustainable fisheries and enable digital transformation in the blue economy sector. The use of real time and virtual reality images of marine life will also support the tourism industry whilst preserving vulnerable reef ecosystems (UNDP Barbados and the Eastern Caribbean, 2021).

Digital Twins

Digital twins are virtual digital models to reflect intended or actual real-world physical products, systems, or processes. It is used to enhance human observation and support simulation/scenario testing and monitoring (IBM, n.d.; TWI Ltd., 2023). Digital twins have been used to support monitoring of: power generation equipment, manufacturing operations and large physical structures based on generated models. Digital twin modelling has also been used in urban planning to display 3D and 4D spatial data in real time, in the area of disaster management to support creating resilient infrastructures, disaster response plans and climate monitoring and in developing virtual models of smart cities (IBM, n.d.).

Grenada has been one of the first country to create a digital twin through the use of LiDAR and high-resolution imagery to create a 3D model. The model aims to inform sustainability development plans and has already supported the creation of a landslide susceptibility map to test how infrastructure would be affected by such disasters (Chadha, 2022). The *Bluefields Climate Smart and Resilient Settlement* project funded by HIT RESET Caribbean also seeks to design and build a digital twin of the

Bluefields fishing community in Jamaica. The digital twin will support prediction of natural hazards and climate impacts and to inform decision making for management and planning of coastal settlements (OACPS R&I, 2023).

Other technologies/applications

Potential digital technologies to support coastal community resilience are listed below (noting that these have not specified any use in coastal communities to date but may have the potential to do so):

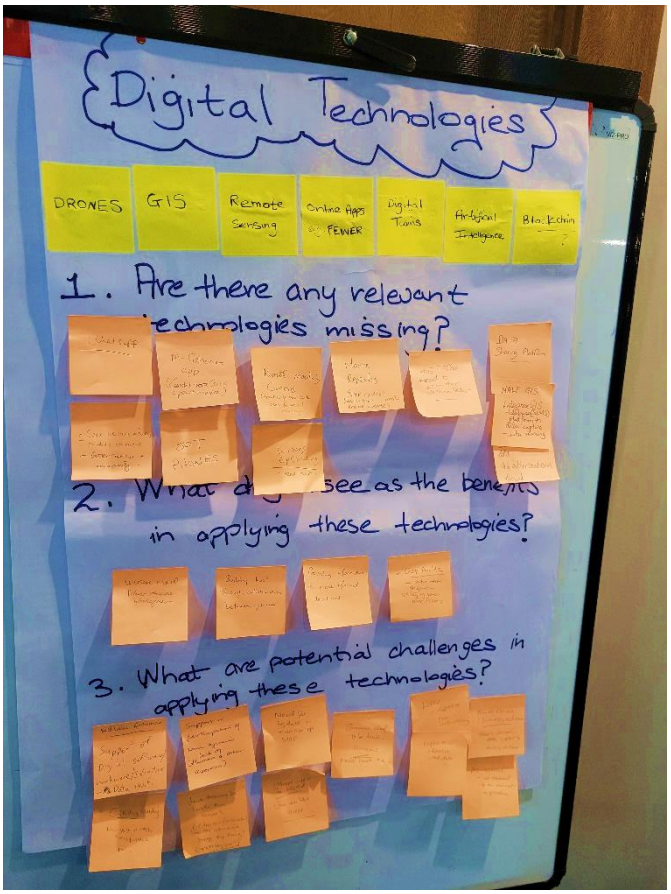
- Climate risk information platforms / support tools such as the online risk assessment tool Caribbean Climate Online Risk and Adaptation Tool (CCORAL) which is a collaboration between the Global Water Partnership – Caribbean, CCCCC, and Caribbean Assessment of Regional Drought Tool (CARiDRO) and is designed to support climate resilient decision making (CCCCC, 2023).
- The CCRIF SPC (formerly known as the Caribbean Catastrophe Risk Insurance Facility) is a regional catastrophe fund and utilises ICT and knowledge management tools to maintain its catastrophe risk models and country risk profiles and risk exposure databases (ECLAC, 2018).
- CCRIF also developed web-based platform called the Web Monitoring Application or We Map which consists of various ICT tools to monitor different hazards – earthquake, heavy rainfall, tropical cyclones, analyse intensity/impact, check whether active insurance policy may be triggered; it also supports real time forecasting system for tropical cyclones to support disaster risk management (CCRIF SPC, 2019).
- Digital transformation aims to leverage technology to alleviate societal issues and use ICTs to improve resilience to natural disasters e.g. in Jamaica, their data centres are being upgraded to a fibre optics network to ensure reliable network connectivity amongst Government agencies during natural disasters (Mejia Giraldo, 2018).

Additionally, findings from a study conducted in Jamaica on ICT and coastal resilience planning are noteworthy. The study suggested that satellite sensing and use of ICT to support data collection and sharing is feasible (Blake Gilmore, 2023). However, barriers to implementation were noted, including limited ICT technology and training, limited staff, and technology aversion. Recommendations provided to address these barriers included capacity building, data-driven policymaking, and collaboration in planning. The study further recommends development of an ICT-driven coastal resilience planning framework before implementation with coastal communities so that ICT-driven coastal resilience strategies fit the needs of community members (Blake Gilmore, 2023). Therefore, considerations for choosing the most applicable digital technology should include: ease of uptake by stakeholders, availability of trainers for technology, and also cost of accessing and utilising.

According to ADB (2021), evaluation criteria for digital technologies should include: enabling infrastructure to support and are compatible with digital technologies, cost efficiency (investment is high/low in relation to degree of climate adaptation/disaster risk management work), initial capital required to set up technology, technology maturity (whether technology is in initial/prototype stage vs. commercial use) and existence of local capacities in implementation of technologies.

Potential challenges and opportunities in applying digital technologies in T&T

Based on stakeholder review and inputs on their experience in applying digital technologies in the coastal community context, a number of specific opportunities and challenges were identified for T&T (Figure 4).



The key opportunities and benefits in applying these technologies noted were as follows:

- Further information to make informed decisions and support improved resource management
- Ability to conduct a gap analysis and better understand needs
- Safety of small-scale fishers e.g. in using ICTs like VHF radio, mobile apps etc.
- Building trust through collaboration between agencies to collect, store and share coastal related data

The potential challenges in applying these technologies were:

- Need for better infrastructure to support use of digital software/hardware/ infrastructure, including wi-fi connectivity and data storage
- Agencies often lack human or other resources to support use of technologies
- Lack of training and other capacity constraints to apply the technologies for data collection and analysis and implement longer term actions to address identified concerns
- Siloed approach among agencies and other key stakeholders working across coastal and marine resource management, climate change and disaster risk management
- Lack of systems to determine where will technologies and data generated be hosted and who will have access
- Some of the technologies can be costly and time consuming to access and utilise

See Table 4 for summary of digital technologies for coastal communities in T&T.

Table 4: Digital technologies for coastal communities in T&T

Tool	Description	Application of Tool				Advantages & Challenges	Resources/ skills needed
		VCA	Planning	Management	M&E		
Geospatial analysis and technologies							
Drones or Unmanned Aerial Vehicles (UAVs)	Radio-controlled, unmanned aircraft, which can be a very valuable tool for geospatial analysis where they have a GPS-guided flight plan and data is integrated into a GIS		**x**	**x**	**x**	**Advantage:** • Can be applied to larger, inaccessible areas ensuring quick access to sites • Wide range of applications • Quick collection of data **Challenges:** • Purchase of equipment/drones and software costly • Limited data collection in areas of dense vegetation • Authorisation required for restricted areas • Limited by weather conditions	• Specialised training in use of drones required • GIS knowledge required for data analysis
Geographic information systems (GIS)	System where geographic or locational information is stored in layers and integrated with geographic software so that spatial information can be created, stored, manipulated, analysed and visualised/mapped	**x**	**x**	**x**	**x**	**Advantages:** • Access to wide range of data from various sources (satellite imagery, remote sensing, surveys, census, field data) • Can support spatial analysis and modelling of complex environment systems • Can support communication and visualisation of data • Free tools available but some software products can be costly	• Specialised knowledge/training required • Storage required for datasets

						Challenges: • Data quality and availability would vary (resolution, accuracy, reliability of data) – to be careful in understanding limitations and uncertainties of data; assumptions may be required • Requires specialised software and hardware that can be costly	
Remote sensing	Process of measuring reflected and emitted radiation at a distance to detect and monitor physical features of an area (USGS, n.d.)		**x**	**x**	**x**	**Advantages:** • Efficiency in collecting real time data from large areas and can support quick decision making and response in disaster response • Can be used to take images at different angles and wavelengths, making it useful for valuable layering of information **Challenges:** • Expensive to implement so limited accessibility for use • Requires specialised skills and knowledge • Resolution and quality limited can by technical constraints	• Specialised knowledge/training required • Specialised hardware and software needed • Storage required for datasets

						• Data collection impacted by atmospheric conditions and sun angle • Updating equipment and software can be time consuming • Interpretation of results can be subjective leading to differing results impacting reliability of usefulness in application • Large amount of data generated and challenge in storing, managing and analysing (need specialise software and hardware)	
ICTs (e.g., internet, mobile phones, wireless networks, radio)							
Online Apps	Application program that is stored on a remote server and delivered over the internet through a browser interface/ mobile devices (IGI Global, 2024)		**x**	**x**	**x**	**Advantage:** • Readily available to use / easy access via mobile devices • Cost effective **Challenges:** • Restricted functionality and limited by scope of app • Requires reliable internet connection	• Mobile Device • Reliable connectivity to wifi
VHF (Very High Frequency) Radio	Marine mobile radio service to send distress messages via two-way communicators that transfer/receive messages to and		**x**	**x**		**Advantages**: • Readily available to use / easy access • High clarity communication • Low power usage	• Training on use and equipment

	from responding station (Marine Insight, 2024).					• Easy installation **Challenges:** • Limited range (dependent on antenna, power output, obstacles, and location) • Susceptible to dead spots • Radio signals impacted by weather conditions	
Blockchain	A blockchain is a database technology which acts as a distributed decentralised digital ledger that stores data of any kind (Rodeck and Adams, 2023).	**x**	**x**	**x**	**x**	**Advantages** • Prevents data tampering i.e. erasure/replacement of recorded data • As it is decentralised, transparency of data is ensured as data can be verified • Allows for traceability of data • Free from censorship **Challenges:** • Slower than traditional databases • Does not allow for easy data modification • High implementation costs • High energy use	Specialised skills and knowledge required
Artificial Intelligence	Technological systems which have the capacity to process information in a way that resembles intelligent behaviour and, typically includes aspects of reasoning, learning, perception, prediction, planning or control" (UNESCO, 2020).		**x**	**x**	**x**	**Advantages** • Reduced human errors and unbiased analysis • Faster analysis of complex/large amount of data to support decision making processes	Specialised skills and knowledge required

						Challenges: • High implementation cost • Limited by scope of programming	
Digital Twins	Virtual digital models to reflect intended or actual real-world physical products, systems, or processes. It is used to enhance human observation and support simulation/scenario testing and monitoring (IBM, n.d.; TWI Ltd., 2023)	**x**	**x**	**x**	**x**	**Advantage** • Customisable and can create various simulations for different scenarios helping to predict/prevent potential issues **Challenges:** • Limited by input of inaccurate/incomplete data • Requires long term maintenance to reflect changes of physical systems • Requires specialised digital infrastructure and software that is costly	• Requires specialised skills and knowledge • Requires digital infrastructure

5.2 Participatory tools

Participatory tools involve a bottom-up and inclusive approach to capturing, storing, analysing and communicating data/information that seeks to engage local communities and other resource users and ensure relevance to the local context and needs. The level of participation in the application of the tools can range from information sharing and communities providing inputs via consultations to active engagement and a community-led process (see Box 1).

Participatory tools can be applied to key aspects or steps in the process of building coastal community resilience and addressing climate and disaster risks. These key aspects include: vulnerability and risk assessment, prediction and planning, management actions and M&E. The participatory nature of the process helps to empower local communities and other coastal resource users to identify their own needs, priorities and take actions to address these needs (IFRC 2014; CANARI 2020).

Vulnerability assessments

Vulnerability and capacity assessments (VCAs) have emerged as one of the more prominent and useful vulnerability assessment tools at the community level that have been applied globally and within the Caribbean region. IFRC (2014) describes the VCA as 'a process of participatory investigation designed to assess, analyse and address major risks affecting communities in a timely manner. It aims to determine the level of people's vulnerability to those risks, and their capacity to cope and recover from them.' VCAs use various participatory tools in a structured way to gauge people's vulnerability, including their level of exposure, sensitivity and capacity to adapt to slow onset changes as well as extreme weather events (FAO and CANARI, 2022).

The VCA methodology provides an entry point for planning community-based interventions on the basis of understanding people's needs and perceptions, resources that can be used to address their needs and minimise risks and of how they can be supported in strengthening resilience. In addition, VCAs support communities to link adaptation and resilience actions to local development plans and actions, and is very useful in developing baseline information that can be used for raising public awareness and for evidence-based advocacy initiatives to influence policies.

A spectrum of participatory tools can be applied to conducting rapid to in-depth assessments as follows (see also Table 5):

- **Rapid VCA tools:** These involve simple tools which can be deployed quickly and easily in short time frame for rapid assessments, which are low cost and require minimal time, resources and technical skills/effort to prepare and implement. Examples include: community mapping, seasonal calendars and transect walks.
- **Intermediate VCA tools:** These can be done fairly quickly but generally require additional time and effort to prepare and implement exercises and specialised communication and facilitation skills. Examples include: surveys, key informant interviews and participatory photo-journalling.
- **In depth VCA tools:** More complex tools that require significant time, resources and effort required in preparation and implementation including technical expertise or specialised skills required to facilitate and undertake data analysis. Examples include: livelihood analysis and value chain analysis.

VCAs can utilise digital technologies to support data capture and analysis using a participatory process, including participatory GIS. For example, under the regional CC4FISH project, CANARI implemented vulnerability and capacity assessments (VCAs) in coastal and fishing communities in Grenada, Saint Kitts and Nevis, and Trinidad and Tobago in 2019-2021. P-GIS was utilised in five

communities in Trinidad and Tobago - Blanchisseuse, Icacos, Moruga, Roxborough, and Speyside (see Box 2). Through this tool, fisherfolk and other stakeholders identified climate-related hazards for their coastal communities, and the local knowledge captured was digitised and integrated with spatial data to develop maps for the various communities (Granderson *et al.,* 2022).

Box 1: Community Mapping and Photo-Journaling

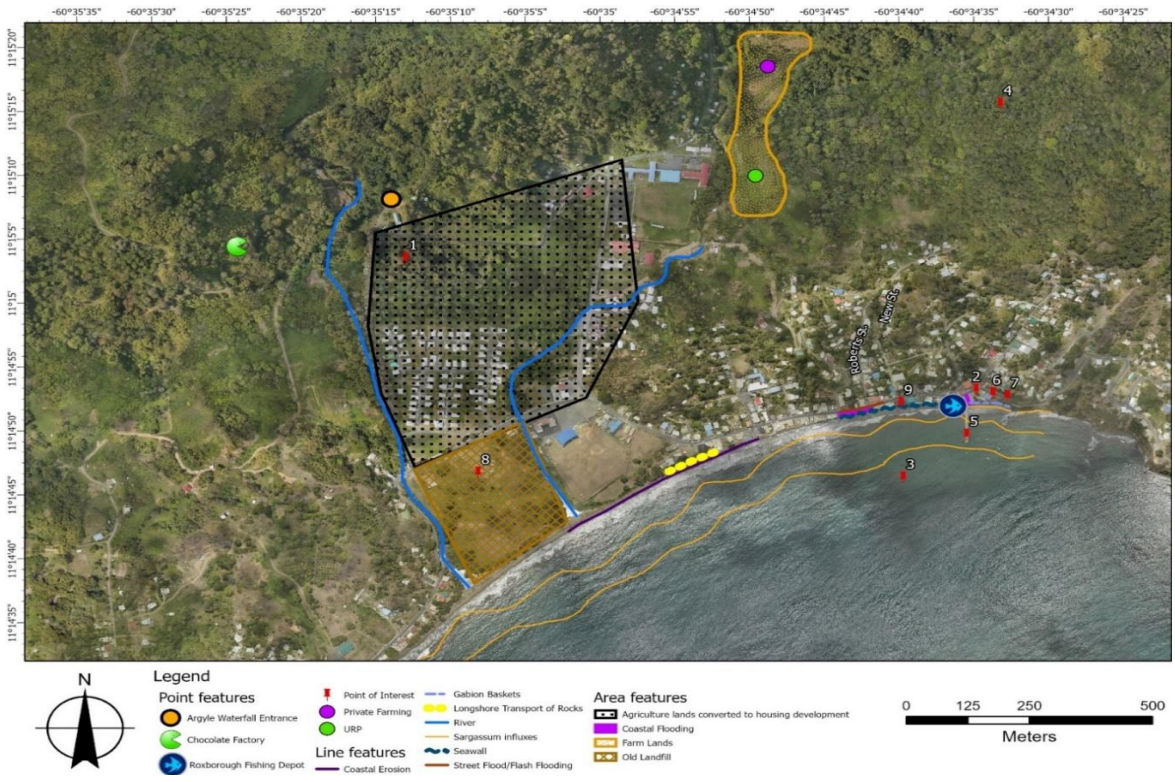
Under the CC4FISH project fisherfolk and other community stakeholders in Newcastle, St. Kitts & Nevis, engage in community mapping (Figure 5) and photo-journaling (Figure 6) at a workshop held in October 2020.

Figure 4: Community stakeholder in St. Kitts & Nevis engaged in community mapping (CANARI, 2021)

Figure 5: Community stakeholders in St. Kitts & Nevis engaged in photo-journalling (CANARI, 2021)

Box 2: Participatory-GIS

Under the CC4FISH project a P-GIS map of Roxborough developed through discussions with community stakeholders on key climate-related hazards, impacts and vulnerabilities.



Prediction and planning

The participatory development and analysis of scenarios is a valuable tool for assessing possible future impacts and vulnerabilities with a coastal community due to climate change and other threats and identifying and planning appropriate strategies to adapt and build coastal resilience for various contexts (FAO and CANARI, 2022). For example, fisherfolk and other coastal resource users can brainstorm, assess and consider different alternatives of what the future might be, taking into account a wide range of imaginable futures and integrating climate modelling information and projections at national and regional levels. Possible future conditions, including changes in temperature, rainfall, storm intensity, sea level, ocean acidity and currents, and the likelihood of their occurrence can be identified for a given time period (e.g. 10, 25 or 50 years into the future). The resulting impacts and vulnerabilities on the community can then be identified for different conditions and time periods. Based on this, appropriate actions can be identified to address these impacts to inform long-term planning, as well as the required resources and the role of different stakeholders for the actions.

Coastal and marine spatial planning is another tool that supports an ecosystem-based approach to management of marine resources that brings together different stakeholders, including government officials and resource managers, fisherfolk, divers and other resource users and coastal residents, to discuss their interests, any conflicts and forge a path forward (Mahadeo, 2022). The process enables multiple uses of a coastal and marine area to be identified, mapped and zoned and can ensure sustainability and resilient ecosystems and livelihoods. It can support the development of marine

protected areas/managed areas and policies and plans for the blue economy or ICZM, as seen in recent initiatives in the Caribbean (TNC, 2024). Its effectiveness hinges on meaningful stakeholder participation so that it is democratic, legitimate and sustainable over the long term. For example, if fisherfolk are not engaged in the design or co-management of MPAs including no-take zones or fish sanctuaries, they are unlikely to buy-in to these areas and enforcement will be difficult. A participatory process is therefore crucial for effective coastal and marine spatial planning, involving innovative and inclusive decision support tools, stakeholder consultations and community engagement.

Governance and management actions

There are a number of participatory approaches and tools that support coastal and marine governance and management, including ICZM, the ecosystem approach to fisheries (EAF) and participatory protected area management (PPAM). These three key approaches and tools are outlined further below.

ICZM

ICZM is a dynamic, participatory and multidisciplinary process for the sustainable management and use of coastal zones, taking into account the fragility of coastal ecosystems and the needs and values of coastal communities and resource users. It aims to maintain, and where necessary, enhance the functional integrity of coastal resource systems while enabling sustainable livelihoods and economic development (Kannen *et al.*, 2008; ICZM today, 2015). It takes into account the marine and terrestrial components of the target coastal area and the dynamic interactions and feedbacks. It also incorporates climate adaptation and disaster risk management considerations using an integrated, ecosystem-based approach. ICZM covers the fully cycle of data collection, planning, decision-making, implementation and monitoring and evaluation as part of a rational management process. Through informed participation and engagement of all stakeholders to assess the goals in managing a given coastal area, ICZM seeks to balance environmental, socio-economic, cultural and recreational interests over the long-term within the limits set by natural dynamics.

EAF

EAF recognises that fisheries are social-ecological systems and takes an integrated, risk-based approach to fisheries management to ensure ecological integrity, human well-being and good governance (FAO, 2013). It adopts risk management principles that recognise that complete knowledge is never available and not essential to start the process; it works to identify and assess all relevant issues and establish participatory processes to help address high priorities effectively and efficiently using a precautionary and adaptive approach. It takes into account the ecological, economic and social context, and drivers of risk and vulnerability from 'ridge to reef' within the wider oceanscape, to inform planning and actions to address hazards/stressors holistically. EAF therefore seeks to develop comprehensive fisheries management systems that enable the sustainable and equitable use of the whole system (ecological and social) to best meet coastal and fishing communities' needs and values (FAO, 2013). It also supports ecosystem-based adaptation, disaster risk reduction and resilience building.

For example, EAF can enable coastal communities to address various risks from climate change and other hazards through reducing land-based pollution and habitat degradation, protecting fish nurseries and key coastal biodiversity within mangroves and coral reefs and strengthening the resilience of coastal ecosystems and of fisherfolk and related livelihoods.

PPAM

PPAM enables the active, informed and equitable participation of all relevant stakeholders, including government, civil society and the private sector, in the process of managing a designated protected area (e.g. marine protected area, marine managed area, fisheries conservation area) (CANARI, 2011). This includes participation in the design of the protected area, defining management goals and objectives, data collection and analysis, development of a management plan, implementation and M&E. PPAM helps to establish institutional arrangements for the protected area where rights and management responsibilities are distributed effectively and equitably. A key focus is giving voice to stakeholders who are less powerful and may otherwise be marginalised from the process (CANARI, 2011). It seeks to shift from top-down models where there is full control by an agency and other stakeholders are simply informed of decisions to multi-stakeholder models where there is joint decision-making among key stakeholders and bottom-up models where responsibility is delegated to a CSO or local community.

M&E

Citizen science and participatory approaches to M&E are also important for gathering data and information to assess progress and impact in building coastal resilience and inform future planning and decision-making. There are a number of approaches that use citizen engagement as well as online portals, apps and other tools to support M&E. These include:

- T&T Bioblitz – An annual event organised by the Field Naturalists' Club and Department of Life Sciences, UWI St. Augustine to conduct an intense biological survey to record living species in a designated area that engages interested citizens, students and practitioners. This can help set a baseline for further assessments of the area.
- Reef Check[24] - This is a well established global methodology for ecological monitoring of coral reefs and other key coastal ecosystems, which aims to be participatory and engage a wide range of stakeholders including fisherfolk, recreational divers, tour guides and operators, government agencies, and academics in the assessment. It is used in T&T and wider Caribbean.
- CoastSnap[25] – This is a global initiative to involve local communities, resource users and tourists in the research and monitoring of accretion and erosion of beaches. It uses a simple installation comprising a holder for smartphones to ensure all pictures are taken from the same angle and position, and photos are shared via email or social media noting the date and time. Photos are then collated into one large set for researchers to map changes in beaches. It has been piloted in a few Caribbean locations but is not yet widely used.
- Sargassum Watch[26] – This is a regional initiative to monitor the influxes of pelagic Sargassum seaweed on local coasts in the Caribbean and Florida, USA. It uses the app, Epicollect5, to collect observational data of both the site and Sargassum species present. This data is then uploaded to a database and available online via the Sargassum Information Hub for use in research and M&E across the region.

Overall, the critical success factors for participatory tools are:

- Ability to access relevant data, including local/traditional knowledge on climate and environmental changes, impacts, and strategies to adapt and build resilience
- Willingness or capacity of the community to participate
- Facilitators skilled in the relevant aspects of building resilience, including interpretation and analysis of the data in an accessible manner

[24] See https://www.reefcheck.org/
[25] See https://www.coastsnap.com/
[26] See https://five.epicollect.net/project/sargassum-watch

- Ongoing community access to and 'ownership' of the process
- Ability to adapt and be flexible when circumstances change (e.g. more up-to-date climate data, community affected by a disaster, etc.)

Table 5 below outlines a range of participatory tools that have/can be applied in T&T and the wider Caribbean for coastal community resilience, highlighting advantages, challenges and resources required for implementation.

Table 5: Participatory tools for coastal communities in T&T

Tool	Description	Application of Tool				Advantages & Challenges	Resources/ skills needed
		VCA	Planning	Management	M&E		
Climate hazard trend analysis / Timeline	Qualitative and quantitative tool Climate hazard trend analysis is a participatory tool that helps in capturing the impact of climatic hazards but also the changes in impact over time. It also captures the reactions to the hazards and coping/adaptation strategies for climatic hazards in the past The process starts with the earliest hazard event that can be recalled. A timeline for e.g. lasting 50 years is developed to show large climatic hazard events. Participants can stand on the line at the appropriate place and describe the event	**x**	**x**			**Advantages:** • Can be a rapid method • Can provide information for different time scales of assessment - current decision/ short-term planning/ long-term planning • Reveal information on sensitivity and adaptive capacity **Challenges:** • The availability of knowledgeable persons who can provide historical insights can be a challenge	Facilitator with good communication and analysis skills Knowledgeable community persons
Impact and Capacity Matrix	Qualitative and quantitative tool The aim of an impact and capacity matrix is to link up with the outputs of the 'Climate hazard trend analysis' (see above). It is used to differentiate vulnerability to and capacity to address climatic hazards across different sectors and social groups and to identify the most vulnerable groups within the community and the most vulnerable sectors. Hazards identified through the 'Climate hazard trend analysis' are	**x**	**x**			**Advantages:** • Can provide information for different time scales of assessment - Current decision/ short-term planning/ long-term planning • Can reveal information on current vulnerability and adaptive capacity based on coping/adaptation strategies **Challenges:** • Difficult to include the most marginalised if they are unable to attend	Facilitator with good communication and analysis skills Knowledgeable community persons

	listed along the vertical axis of a grid. Different social groups (age, gender, ethnic groups etc) or different sectors (fisheries, agriculture, water, tourism, etc.) are listed on the horizontal axis. Participants discuss the vulnerability of each sector and social group to each climatic hazard to determine if they are: not affected, moderately affected, or heavily affected. They also identify past and current coping/adaptation strategies and assess their effectiveness in addressing identified hazards.					• Depends on the participants' knowledge and understanding about climate change issues	
Rapid community mapping	Qualitative and quantitative tool (e.g. number of buildings, length of beaches, etc.) Community mapping can be used to gather and interpret spatial or geographic information about climate change vulnerability. Participants are asked to indicate the spatial location of resources, sources of livelihoods, settlements of different social groups within the community, land use, and other features. Community mapping can be a rapid exercise where, for example, participants draw a rough map on a sheet of paper or it could be a detailed exercise where carefully scaled and drawn maps are used in the exercise.	**x**	**x**		**x**	**Advantages:** • Rapid process • Can be less costly and time-consuming than other methods • Can provide information for different time scales of assessment - Current decision/ short-term planning/ long-term planning • Can reveal information on sensitivity and adaptive capacity **Challenges:** • Certain socio-economic infor-mation may not be captured (e.g. while the map may easily show the location of fishing depots or landing sites, it may not easily show the number	Cartographer/GIS expert or facilitator with good understanding of geography or spatial analysis skills

						of fishers whose boats were affected by hazards in the area without first performing a literature review or interviewing fishers	
Seasonal Calendar	Qualitative and quantitative method Participatory tool for documenting regular cyclical periods and significant events that occur during a year and influence the life of a community. Major climatic and environmental periods and hazards should be marked in the calendar. May be useful for coastal/fishing communities to document trends and patterns with respect to e.g. fishing seasons, impacts and allow for planning of appropriate adaptation actions	**x**	**x**		**x**	**Advantages:** • This exercise can provide insight into the community's perceptions of change. • Can help reveal the gender- and age-related differences in the perception of change. • Can reveal information on exposure **Challenges:** • This tool provides only general insights, which will need further validation as the tool very much depends on the experience and knowledge of the participating members.	Facilitator with good communication skills
Transect walk	Qualitative tool A transect walk is a structured walk through an area to get a qualitative map of that area. The walk includes assessing the availability and quality of resources, land use and infrastructure, including problems and risks encountered.	**x**			**x**	**Advantages:** • This method only gives a snapshot of a situation in a specific geographic location, which changes over the course of the seasons and years. • Useful for short and long-term planning • May reveal information on sensitivity and adaptive capacity **Challenges:**	Skilled facilitator with good communication skills

						• May have limited applicability to marine areas unless modified; more applicable to terrestrial coastal zone	
Participatory photo journalling	Qualitative and quantitative tool Participatory photo journaling involves stakeholders from communities, businesses and/or government agencies working together to take photographs that are then organised to tell the story of climate change vulnerabilities in a given area or sector. The stakeholders decide what they want to show and how they want to show it. The photos can be used to help stakeholders to determine exposures, sensitivities and adaptive capacities	**x**			**x**	**Advantages:** • Can be a rapid method • Involves a wide range of stakeholders • Very visual so makes vulnerabilities easier to understand and see • Good method to use for people with low literacy **Challenges:** • May not capture all aspects of vulnerability without further written or spoken explanations	Good photographer to train others
Participatory video	Qualitative tool Participatory video facilitates the community and other stakeholders in making their own video to tell the story of their vulnerability and capacity to adapt to climate change. The community and other stakeholders are fully involved in all stages of the production of the video including deciding what the issues and questions are, who should be part of the process, who needs to hear the messages and how those messages should be crafted and possible solutions.	**x**			**x**	**Advantages:** • Can help visually capture information on exposures, sensitivities and adaptive capacities • Gives the community a direct voice using a very powerful communication medium that brings their challenges and issues alive for a wider audience. • Can be useful for supporting advocacy, building consensus and exchange of ideas and experiences between groups or communities	Facilitator able to coordinate participants to come to consensus, create story board and capture footage PV trainers able to train others in effective video making and interviewing skills Video editing skills

	This includes creating a storyboard, capturing video clips of interviews with stakeholders and scene shots, and direct editing of the video clips.					• Can be used for participatory monitoring and evaluation. **Challenges:** • Can be time consuming if difficult to reach consensus on storyboard or delays in capturing needed footage or interviews • May require technical skill and additional expertise in effective interviewing and shooting and editing video • May be difficult to facilitate to ensure the perspectives and interests of all stakeholders are taken into account	
Participatory scenario analysis: 'What if?' tool	Qualitative tool The development and analysis of participatory scenarios is a powerful tool for creating and assessing possible future developments. Scenarios are possible futures. The future is unknown and so it is necessary to consider many alternatives of what the future might be, taking account of the full range of imaginable futures.	**x**	**x**			**Advantages:** • Bottom-up scenarios are more likely to capture local vulnerabilities and dynamics. **Challenges:** • This method demands sufficient diversity in the group in terms of knowledge, age, etc. • All elements may not be considered or change over time	Skilled facilitator with some background knowledge of the decision being discussed is useful
Problem Tree	Qualitative tool A problem tree helps to visualise and evaluate what are the root causes of the problems affecting a local community or specific group and the possible courses of action. It is a useful process for	**x**	**x**			**Advantages:** • Provides information for short-term planning/ long-term planning • Can reveal information on the root causes of vulnerability	Skilled facilitator with some background knowledge of the problems being discussed

	facilitating participatory problem analysis, including of climate related problems. Problem trees start by identifying the various problems affecting the community or specific group. Once the linkages between these problems are determined, a problem tree can then be created by arranging the problems to show how they are inter-linked. 'Root' problems are put at the bottom of the tree, while 'effect' problems that result from other problems are put at the top. The problems in the middle of the tree are the core ones, which should be the focus of the analysis to determine priorities and strategies for action.					and potential adaptation actions. **Challenges:** • May be difficult to facilitate to ensure the perspectives and interests of all stakeholders are taken into account • Analysis can be challenging when quite a complex web of inter-related problems is created and stakeholders may find it difficult to single out specific problems to tackle and/or identify feasible solutions.	
Semi-structured interviews and focus groups	Mainly qualitative apart from basic demographic data Focus groups provide a forum for stakeholders to discuss their opinions on certain topics and help elicit dominant perspectives from people at the local level.	**x**	**x**	**x**	**x**	**Advantages:** • Facilitates for more in-depth exploration and discussion of people's knowledge attitudes and practices • More flexible and adaptive to respondents' interests and responses **Challenges:** • Requires more skill to compile and administer effectively (e.g. ability to think and adapt on their feet without introducing personal bias or influencing answers, good recording skills).	Interviewer/focus group facilitator with relevant skills, preferably perceived to be neutral (i.e. no personal stake in the outcomes). Where possible, an assistant facilitator to organise the digital recorder, note down people's

						• Transcribing responses can be very time-consuming • There may be reluctance on the part of focus group members when dealing with sensitive topics • Selected groups may or may not be representative of the majority view.	responses and summarise them afterwards (essential for focus groups, desirable for all but short interviews to allow the interviewer to engage in uninterrupted conversation with respondents)
Surveys	Quantitative tool Yes/No or multiple-choice responses to questions about KAPs Surveys can provide insights into people's level of awareness of climate change and its impacts, the types of strategies for addressing impacts, and the various resources available in a community or sector.	**x**	**x**	**x**	**x**	**Advantages:** • Facilitates collection of the same information from every respondent • Eliminates or limits interviewer bias (depending on how administered) • Can be administered without using human resources (e.g. online, via mail or email) • Analysis is relatively simple, particularly if confined to closed-ended questions and/or online survey tools are used **Challenges:** • Low response rates to surveys administered online or via email/mail • May require a lot of interviewers if administering a large face-to-face survey • Interviewees seeking to provide the 'right' answer	Interviewers with at least basic training in interview techniques Interviewers good understanding of the purpose of the survey and of the organisation administering it.

						rather than reflecting on and providing their own opinions /perceptions • Analysis software can be costly	
Coastal and marine ecological assessments[27]	Qualitative and quantitative tool Ecological assessments are more in-depth and can form part of long-term monitoring efforts and commonly include fish, benthos and coral surveys focused on indicators of healthy habitats such as algae cover, coral cover, fish species diversity, overall fish abundance and size of commercially and ecologically important fish families. Other variables can include water quality, pH levels and mangrove and sea grass productivity.	**x**	**x**		**x**	**Advantages:** • Provides information on exposure, sensitivity and adaptive capacity • Can be integrated with other complementary VCA tools • Provides information to support long-term monitoring as well as assessing vulnerability **Challenges:** • Can be time consuming • Needs trained divers to conduct assessments and trained marine biologists to do detailed data analysis	Self-contained Underwater Breathing Apparatus (SCUBA) gear, snorkel gear, and trained divers, boat, underwater camera, data sheets and other equipment
Livelihood vulnerability analysis	Qualitative tool Livelihood vulnerability analysis is a systematic, participatory approach which aims to engage the community in identifying how climate change is affecting their livelihoods, the drivers of vulnerability and ways to build resilient and sustainable livelihoods. Analysis focuses on	**x**	**x**		**x**	**Advantages:** • Provides information on exposure, sensitivity and adaptive capacity • Takes into account cultural, economic, environmental, social and political factors in assessing vulnerability • Can be integrated with other complementary VCA tools	Facilitator for livelihood analysis with relevant skills, preferably perceived to be neutral (i.e. no personal stake in the outcomes)

[27] These build on well-known methodologies and existing tools for coastal and marine ecological monitoring including the Atlantic and Gulf Rapid Reef Assessment (AGGRA), GCRMN – Caribbean coral reef biophysical monitoring guidelines, Healthy Reefs scorecard methodology and Reef Check, which aim to be participatory and engage fisherfolk, recreational divers, tour guides and operators, government agencies and academia.

	livelihood activities and the assets they draw upon: • Exposure and sensitivity of livelihood activities and assets to climate change hazards • Current and future adaptive capacity • Priority actions to reduce livelihood vulnerability					• Provides information on ways to improve livelihoods as well as assessing their vulnerability **Challenges:** • Can be time consuming • Needs a trained facilitator to help with livelihood analysis	
Value chain analysis	Qualitative and quantitative tool Value chain analysis used to gain in-depth understanding of the entire process involved in delivering a product or service (e.g. number of persons or inputs such as funds and materials involved in activities) and assessing strategies that could be taken to reduce costs and increase the value of the product or service.	**x**	**x**	**x**		**Advantages:** • Provides information on ways to improve the enterprise while assessing its vulnerability • Provides information of all the enterprise's assets • Provides information on sensitivity, exposure and adaptive capacity of the enterprise **Challenges:** • Can be time consuming • Requires a small business development expert to help with value chain analysis • Requires background information on the enterprise and its operations	Small business development expert Climate change expert
Ecosystem Approach to Fisheries (EAF)	Qualitative and quantitative tool EAF recognises that fisheries are social-ecological systems and takes an integrated, risk-based approach to fisheries management to ensure ecological integrity, human well-being and		**x**	**x**	**x**	**Advantages:** • Provides information to effectively manage coastal zone • Holistic in approach taking into account the ecological,	Trained experts with relevant skills

	good governance. It adopts risk management principles that recognise that complete knowledge is never available and not essential to start process, and works to identify and assess all relevant issues and establish participatory processes to help address high priorities effectively and efficiently using a precautionary and adaptive approach.					economic, and socio-cultural dimensions. **Challenges:** • Can be time consuming • Requires trained experts/practical experience in fisheries and coastal management • Requires background information/data on target coastal areas and fisheries	
Integrated Coastal Zone Management (ICZM)	Qualitative and quantitative tool ICZM is a dynamic, participatory and multidisciplinary process for the sustainable management and use of coastal zones, taking into account the fragility of coastal ecosystems and the needs and values of coastal communities and resource users.		**x**	**x**	**x**	**Advantages:** • Provides information to effectively manage coastal zone • Holistic in approach taking into account the ecological, economic, and socio-cultural dimensions. **Challenges:** • Can be time consuming • Requires trained expert/practical experience in ICZM • Requires background information/data on target coastal areas	Trained experts with relevant skills

6. Recommendations for moving forward

Applying digital technologies and participatory tools has significant potential to enhance the process of coastal planning, management and M&E. It can enable broader and more efficient capture, storage and analysis of data and information and support communications. It also enables the integration of local and scientific knowledge and practices and the active engagement of coastal communities and resource users to allow for well-informed decisions tailored to local context and needs.

Taking into account the suite of technologies and tools identified and assessed in Section 5, it is worth noting that these range from purely digital technologies that often require specific technical knowledge/skills and high up-front costs for their application (e.g. blockchains, machine learning and remote sensing) to participatory and digital technologies that are more user-friendly and less costly and can engage a wide range of stakeholders (e.g. participatory video, participatory GIS and drones) and solely participatory tools that do not integrate ICTs but can engage a wide range of stakeholders (e.g. community mapping, seasonal calendar, livelihood and value chain analysis).

Given T&T's coastal context and the capacity of the project partners and other key stakeholders, including fisherfolk and CBOs, the participatory and digital technologies that combine the qualities of these two types of technologies/tools appear to be particularly well suited. Drone technology can enable government agencies in T&T with limited human and financial resources to more effectively support regular data collection and monitoring of the coastal zone to inform planning and management in collaboration with CBOs and other relevant stakeholders. Drones can support P-GIS, where there is active community engagement in mapping and monitoring changes on the ground, and integrate local and traditional knowledge to support collaborative planning and management. P-GIS also allows for assessing vulnerability to climate change and other impacts and identifying priorities for action to build resilience in coastal communities. Further, drones support effective communications via video footage of the coastal zone and changes from a unique vantage point, which can help to enhance awareness and understanding of the problem, and buy-in to take action.

To ensure these participatory and digital technologies are effectively applied to build coastal community resilience, below are outlined guiding principles and recommendations including:

- recognising the coastal zone as a complex social-ecological system and adopting a systems approach to assessment and developing the relevant actions;
- capturing both quantitative and qualitative data on various dimensions, including biophysical, cultural, institutional and socio-economic dimensions;
- selecting methods which are well matched to the local context, needs and capacities of project partners, other management agencies and key stakeholders in coastal communities, and can be readily adopted and applied to support future work;
- engaging a diverse range of stakeholders at the community level, including fisherfolk, other coastal resource users and CBOs, to contribute to a more holistic understanding of local vulnerability and appropriate resilience actions; and
- ensuring linkages with sectoral and national initiatives and policies to enable effective multi-level governance of the coastal zone.

The Tech4CoastalResilience project will therefore take the opportunity to pilot the use of drones and P-GIS, document the process and lessons, and seek to support greater uptake of participatory and digital technologies to support adaptation and resilience building in coastal communities in T&T.

References

Allam, Z. and Jones, D., 2019. Climate change and economic resilience through urban and cultural heritage: The case of emerging small island developing states economies. *Economies*, *7*(2), p.62.

Almutairi, A., Mourshed, M. and Ameen, R.F.M., 2020. Coastal community resilience frameworks for disaster risk management. *Natural Hazards*, *101*, pp.595-630.

Argyroudis, S.A., Mitoulis, S.A., Chatzi, E., Baker, J.W., Brilakis, I., Gkoumas, K., Vousdoukas, M., Hynes, W., Carluccio, S., Keou, O. and Frangopol, D.M., 2022. Digital technologies can enhance climate resilience of critical infrastructure. *Climate Risk Management*, 35, p.100387.

Asadzadeh, A., Kötter, T., Salehi, P. and Birkmann, J., 2017. Operationalizing a concept: The systematic review of composite indicator building for measuring community disaster resilience. *International journal of disaster risk reduction*, *25*, pp.147-162

Asian Development Bank (ADB), 2021. *Digital technologies for climate action, disaster resilience, and environmental sustainability.* Available at: https://www.adb.org/sites/default/files/publication/700396/digital-technologies-climate-action.pdf

Bahaw, Darren, 2021. Fishermen worry about impact of oil spill: Is the fish in the Gulf safe to eat? *Newsday*, 15 August. Available at: https://newsday.co.tt/2021/08/15/fishermen-worry-about-impact-of-oil-spill-is-the-fish-in-the-gulf-safe-to-eat/?fbclid=IwAR0lF7v387bWOz2LUTCQWSFECaol14bu9SvNAhseTfGwqiM82JZGS4082FE [Accessed 26 May 2023]

Baldwin, K., H.A. Oxenford, J. Weekes, M. Small, J. Irvine and A. Desai, 2022. *Sargassum Monitoring Protocol: monitoring sargassum abundance using drones.* SargAdapt Good Practice Guide Series: 1(2). University of the West Indies, Centre for Resource Management and Environmental Studies (UWI-CERMES), Barbados, 41 pp.

Blake Gilmore, Ren-Neasha R, 2023. *Information and Communications Technology Within Coastal Resilience Planning Frameworks: The Case of Jamaica, a Small Island Developing State*. Doctor of Philosophy (PhD), Dissertation, School of Public Service, Old Dominion University, DOI: 10.25777/8zeb-tz47

Boodan, Shashtri, 2019. Tobago fishermen robbed of boats. *Guardian*, 27th July. Available at: https://www.guardian.co.tt/news/tobago-fishermen-robbed-of-boats-6.2.895621.fa5338369e [Accessed 26 May 2023]

Caribbean Aqua-Terrestrial Solutions, 2019. *Drone Training for Environmental Management Officers through the CATS Programme*. Available at: https://cats.carpha.org/Home/ArticleID/39/Drone-Training-for-Environmental-Management-Officers-through-the-CATS-Programme

Caribbean Community Climate Change Centre, 2023. CCORAL Risk Management Tool. Available at: https://www.caribbeanclimate.bz/caribbean-climate-chage-tools/tools/

Caribbean Development Bank (CDB), 2018. *CDB announces USD1.5mn to build greater climate resilience through technology*. Available at:https://www.caribank.org/newsroom/news-and-events/cdb-announces-usd15mn-build-greater-climate-resilience-through-technology
The Caribbean Regional Track of the Pilot Programme for Climate Resilience, 2020. *FEWER: The app making fisherfolk more secure*. Available at: https://caribppcr.org.jm/fewer-the-app-making-fisherfolk-more-secure/

Brot für die Welt (Bread for the World). 2020. Participatory Assessment of Climate and Disaster Risks (PACDR)- A Tool for Integrating Climate and Disaster Risks into Community Planning and Development. Version 9. Swiss Interchurch Aid. Available at https://pacdr.net/wp-content/uploads/2020/07/PACDR_adaptation_tool_16July2020-small-pages.pdf

Caribbean Natural Resources Institute (CANARI). 2011. Facilitating participatory natural resource management: A toolkit for Caribbean managers. Available at: https://canari.org/publications/facilitating-participatory-natural-resource-management-a-toolkit-for-caribbean-managers/

CANARI. 2018. Technical Review Report on the Application of Vulnerability and Capacity Assessments (VCAs) in Coastal and Fishing Communities in the Eastern Caribbean. Food and Agriculture Organisation of the United Nations (FAO).

Caribbean Natural Resources Institute (CANARI), 2019. *Report of the Vulnerability and Capacity Assessment Training Workshop in Trinidad and Tobago under the Regional Implementation of the Vulnerability and Capacity Assessment for the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector Project (CC4FISH).* Available at: https://canari.org/wp-content/uploads/2018/02/CC4FISH-TT-VCA-Training-Workshop-Report-Jan2020.pdf [Accessed 26 May 2023]

CANARI. 2020. Rising to the climate challenge: Coastal and marine resilience in the Caribbean. Available at https://canari.org/wp-content/uploads/2020/08/CANARI-Coastal-Marine-Resilience-Issue-Paper.pdf

Central Statistical Office. 2011. UNECLAC and CSO 2011 Trinidad and Tobago Census. Available at: https://cso.gov.tt/census/2011-census-data/

Clarke, J., de Berdt Romilly, G., McCue, J., Pinder, S., Pounder, C., Campbell, D., Fields, N., Khan, K., Members of TWGs & TAC. 2019. Vulnerability and Capacity Assessment (VCA) Report, Trinidad and Tobago 2019. EUROPEAID/136530/DH/SER/TT, Particip GmbH, Merzhauser Str. 183, D-791000 Freiburg, Germany.

Doyle, E. and J. Franks. 2015. Sargassum Fact Sheet. Gulf and Caribbean Fisheries Institute.

Economic Commission for Latin America and the Caribbean (ECLAC), n.d. Assessment of the Social and Economic Impact of COVID-19 in Trinidad and Tobago. Available at:

https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

ECLAC, 2018. FOCUS: AN integrated approach to ICT. Issue 4, October-December, 2018. Available at: https://repositorio.cepal.org/server/api/core/bitstreams/41cfa3f4-32c1-45cc-9629-4d7008ab4382/content

Emanuel, E. 2022. Assessment of the Social and Economic Impact of COVID-19 in Trinidad and Tobago. [online].Available at: https://www.cepal.org/sites/default/files/events/files/presentation_1_-_assessment_of_the_social_and_economic_impact_of_covid-19_on_trinidad_tobago.pdf

Fisheries Division – Ministry of Agriculture, Land and Fisheries. 2015. Fishing landing records for Trinidad. Port of Spain, Trinidad.

Fisheries Division – Ministry of Agriculture, Land and Fisheries. 2022. Fishing landing records for Trinidad. Port of Spain, Trinidad.

Fontes de Meira, L. and Bello, O., 2020 "The use of technology and innovative approaches in disaster and risk management: a characterization of Caribbean countries' experiences", Studies and Perspectives series-ECLAC Subregional Headquarters for the Caribbean, No. 93 (LC/TS.2020/106-LC/CAR/TS.2020/3), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).

Food and Agriculture Organization of the United Nations (FAO). 2019a. Management plan for Matura Forest and Coastal Zone Protected Area. Food and Agriculture Organization of the United Nations (FAO). 2017. Social protection to foster sustainable management of natural resources and reduce poverty in fisheries-dependent communities. Report of the FAO Technical Workshop 17–18 November 2015, Rome. [online]. Available at: http://www.fao.org/3/a-i6880e.pdf

Food and Agriculture Organization of the United Nations (FAO). 2019b. Management Plan for the Trinity Hills Species Management Reserve.

FAO and CANARI. 2022. Toolkit for vulnerability and capacity assessments in Caribbean coastal and fishing communities – Developed under the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector Project (CC4FISH). Rome. https://doi.org/10.4060/cb6786en

FAO and GEF. 2015. Climate change adaptation in the Eastern Caribbean fisheries sector (CC4FISH). Project Document. Bridgetown: FAO.

Fox, N., Tilt, J.H., Ruggiero, P., Stanton, K. and Bolte, J., 2023. Toward equitable coastal community resilience: Incorporating principles of equity and justice in coastal hazard adaptation. *Cambridge Prisms: Coastal Futures*, *1*, p.e36.

GoRTT – Government of the Republic of Trinidad and Tobago (2013). Second National Communication of the Republic of Trinidad and Tobago Under the United Nations Framework Convention on Climate Change. Port-of-Spain, Trinidad and Tobago. 104pp.

Government of the Republic of Trinidad and Tobago (GoRTT). 2017. Matelot and Grand Riviere farmers and fisherfolk receive relief cheques from Agriculture Ministry. [online] 18 June 2017. Available at: http://www.news.gov.tt/content/matelot-and-grand-riviere-farmers-and-fisherfolk-receive-relief-cheques-agriculture-ministry#.XaiQ0-hKjIU [Accessed 21 October 2019].

Government of the Republic of Trinidad and Tobago (GoRTT). 2019. Revised Integrated Coastal Zone Management (ICZM) Policy Framework. Integrated Coastal Zone Management Steering Committee, Ministry of Environment and Water Resources. Available at http://www.iczm.gov.tt/wp-content/uploads/2019/04/Draft-Integrated-Coastal-Zone-Management-Policy-Framework-Amended-April-2019.pdf

Government of the Republic of Trinidad and Tobago (GoRTT), 2020. Comprehensive National Coastal Monitoring Programme (CNCMP). Ministry of Works and Transport - Coastal Protection Unit. Available at https://mowt.gov.tt/MOWT/media/General/Documents/Coastal%20Protection%20Unit/CNCMP-Informational-Kit-WEB.pdf

Government of the Republic of Trinidad and Tobago, 2021. *Third National Communication of the Republic of Trinidad and Tobago to the United Nations Framework Convention on Climate Change.* Available at: https://cso.gov.tt/wp-content/uploads/2023/03/Third-National-Communication-Trinidad-and-Tobago.pdf [Accessed 26 May 2023]

Government of the Republic of Trinidad and Tobago, 2022. *Midterm Review of the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 Voluntary National Report – Trinidad and Tobago, 2022*. Available at: https://www.preventionweb.net/publication/trinidad-and-tobago-voluntary-national-report-mtr-sf [Accessed 26 May 2023]

Granderson, A. and Ramkissoon, C. 2021. Report of the Vulnerability and Capacity Assessments in Coastal and Fishing Communities in Saint Kitts and Nevis. Prepared by the Caribbean Natural Resources Institute for the Food and Agriculture Organization of the United Nations.

Granderson, A., Albert, D., Ramkissoon, C. and Jehu, A. 2022. *Report of vulnerability and capacity assessment in coastal and fishing communities in Trinidad and Tobago.* Rome, FAO. https://doi.org/10.4060/cb7530en [Accessed 22 May 2023]

Hedley, J.D. *et al,* 2016. Remote Sensing of Coral Reefs for Monitoring and Mangement: A Review. *Remote Sens.* 8(118). Available at: doi:10.3390/rs8020118

Holman, C.B., Bachoon, D.S., Otero, E. and Ramsubhag, A., 2014. Detection of Helicobacter pylori in the coastal waters of Georgia, Puerto Rico and Trinidad. *Marine Pollution Bulletin,* 79 (2014), pp 354–358. Available at: https://www.researchgate.net/profile/Ernesto-Otero-Morales/publication/259317826_Detection_of_Helicobacter_pylori_in_the_coastal_waters_of_Georgia_Puerto_Rico_and_Trinidad/links/5f6cfd14299bf1b53ef09acd/Detection-of-Helicobacter-pylori-in-the-coastal-waters-of-Georgia-Puerto-Rico-and-Trinidad.pdf [Accessed 26 May 2023]

CZM, 2020a. *ICZM News, March 2020*. Available at : http://www.iczm.gov.tt/2020/07/21/march-2020-newsletter/ [Accessed 26 May 2023]

ICZM, 2020b. *ICZM News, June 2020*. Available at: http://www.iczm.gov.tt/wp-content/uploads/2020/07/ICZM-NEWSLETTER-June-2020-FINAL.pdf [Accessed 26 May 2023]

IFC, n.d. Barbados' Blueprint for Climate Resilience. Available at: https://ifc.shorthandstories.com/barbados-blueprint-for-climate-resilience/index.html

IFRC. 2014. Integrating climate change and urban risks into the VCA: Ensure effective participatory analysis and enhanced community action. IFRC, Geneva Switzerland.

Improving Forest and Protected Area Management in Trinidad and Tobago (IFPAM TT). 2014. Project Document. FAO/Global Environment Facility. Available at: https://drive.google.com/file/d/0B0I4K5zeRGEPdzVVbjZJRUgzZE0/edit

IFRC. 2010. Regional Evaluation. Review of the implementation of the vulnerability and capacity assessment (VCA) methodology in the Caribbean region. IFRC, Geneva, Switzerland.

Institute of Marine Affairs (IMA). 2012. Coastal Conservation Project – Status of beaches and bays in Trinidad (2004-2008). Available at https://www.ima.gov.tt/wp-content/uploads/2018/04/Coastal-Con-March-2012-Status-Beaches-Bay-Trinidad-2004-08-Final-Dec2016.pdf

Jeppesen, G.; Jensen, R.; Tomicic, B.; Miralles-Wilhelm, F.; Castillo, R. (2015). Climate Change Adaptation Case Study: Sea Level Rise in Trinidad and Tobago. InterAmerican Development Bank Technical Note 182. 130pp

Juman, R. and Hassanali, K., 2013. Mangrove Conservation in Trinidad and Tobago, West Indies. In G. Gleason and T. Victor. Eds. 2013. *Mangrove Ecosystems.* Nova Scienc Publishers, Inc. Available at: https://www.ima.gov.tt/wp-content/uploads/2018/04/Mangrove-Conservation-in-TT.pdf . [Accessed 26 May 2023]

Juman, R. and Ramsewak, D., 2013. Status of Mangrove Forests in Trinidad and Tobago, West Indies. *Caribbean Journal of Science*, Vol. 47, No. 2-3, 291-304. Available at: https://www.researchgate.net/profile/Rahanna-Juman/publication/291615305_Status_of_Mangrove_Forests_in_Trinidad_and_Tobago_West_Indies/links/56cb00d108ae5488f0dad5cf/Status-of-Mangrove-Forests-in-Trinidad-and-Tobago-West-Indies.pdf

Kairi Consultants Ltd. 2016. Municipality of Sangre Grande Local Area Economic Profile (Final Report). [online]. Available at: https://rdlg.gov.tt/wp-content/uploads/MLG-Final-Sangre-Grande-LAEP-Report-20160229.pdf

Kais, S.M. and Islam, M.S. 2016. Community capitals as community resilience to climate change: Conceptual connections. *International Journal of Environmental Research and Public Health*, 13(12), p.1211.

Kannen, A., Ramanathan, A.L., Glavovic, B.C., Green, D.R., Krishnamurphy, R.R., Tinti, S., Agardy, T. & Han, Z. 2008. *Integrated Coastal Zone Management.* Future Earth Coasts.

Kenny, J. 2000. Views from the Ridge. Exploring the natural history of Trinidad and Tobago. Prospect Press. ISBN 976-95057-0-6. Available: https://books.google.tt/books?id=lYZeFBUXhWIC&printsec=frontcover#v=onepage&q&f=false

Kishore, R. 2021. Diversity: A Key to Reducing Vulnerability in the Fishing Industry. Online article contributing to Institute of Marine Affairs (IMA) series on United Nations Decade of Ocean Science and Sustainable Development 2021-2030. Available at https://www.ima.gov.tt/2021/08/27/diversity-a-key-to-reducing-vulnerability-in-the-fishing-industry/

Kishore, R., Ramsundar, H. and Clarke-Marshall, M. 2002. A report of the fishery system of the fishing communities from Ortoire to Guayaguayare, Trinidad. Document prepared for the IDRC under the Community-Based Coastal resource Management Program (Phase II). 260pp.

Kishore, R., Chin, X., and Ramsundar, H., 2003. *Potential impacts of industrial development on coastal fisheries in the Gulf of Paria, Trinidad*. IMA – 54th Gulf and Caribbean Fisheries Institute. Available at: https://aquadocs.org/bitstream/handle/1834/29481/gcfi_54-2.pdf?sequence=1 [Accessed 26 May 2023]

Kishore, Rosemarie, 2021. *Diversity: A key to reducing vulnerability in the fishing industry*. Institute of Marine Affairs. Available at: https://www.ima.gov.tt/2021/08/27/diversity-a-key-to-reducing-vulnerability-in-the-fishing-industry/ [Accessed 26 May 2023]

Kumarsingh. K., Singh, S., Roopnarine, K., Kerr, K., Lal-Roopnarine, D. 2021. First Biennial Update Report of the Republic of Trinidad and Tobago under the United Nations Framework Convention on Climate Change. Available at https://unfccc.int/sites/default/files/resource/FIRST_%20BUR_TRINIDAD_AND_TOBAGO.pdf

Kumarsingh. K., Singh, S., Roopnarine, K., Kerr, K., Roopnarine, D. 2021.Third National Communication of the Republic of Trinidad and Tobago to the United Nations Framework Convention on Climate Change. Available at https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/92154806_Trinidad%20and%20Tobago-NC3-1-THIRD_NATIONAL_COMMUNICTION_TRINIDAD_AND_TOBAGO.pdf

Lam et al. 2015. Mapping and assessing coastal resilience in the Caribbean region. Cartography and Geographic Information Science. Volume 42, Issue 4. Available at: https://www.tandfonline.com/doi/citedby/10.1080/15230406.2015.1040999?scroll=top&needAccess=true&role=tab

Leichenko, R., McDermott, M. and Bezborodko, E. 2018. Barriers, limits and limitations to resilience. In *Towards Coastal Resilience and Sustainability* (pp. 33-56). Routledge.

Mejia-Giraldo, C. 2019. Could Digital Transformation Help the Caribbean become more resilient to natural disasters. IDB. Available at: https://blogs.iadb.org/caribbean-dev-trends/en/could-digital-transformation-help-the-caribbean-become-more-resilient-to-natural-disasters/

Mahabir, D. and L. Nurse. 2007. An assessment of the vulnerability of the Cocal area, Manzanilla, Trinidad, to coastal erosion and projected sea level rise and some implications for land use. CERMES Technical Report No.4. 44 pp. Available at

https://www.cavehill.uwi.edu/cermes/docs/technical_reports/mahabir_2007_vulnerability_sea_leve_-rise_land_use.aspx

Mahadeo, S. 2022. Marine spatial planning in the Eastern Caribbean: Trends and progress. *Marine Policy* 145(7): 105277. DOI:10.1016/j.marpol.2022.105277

Morton-Gittens, D. 2011. The Golden Age and Decline of Matelot, Trinidad (1885-1945). History in Action. Vol. No. 2, ISSN:2221-7886 The University of the West Indies (St. Augustine, Trinidad and Tobago) Dept. of History

Ministry of Agriculture, Fisheries, Food Securing and Rural Development, 2021. FEWER app Download. Available at: https://moaslu.govt.lc/fewer-app-2/#:~:text=FEWER%20APP%20DOWNLOAD&text=Fisheries%20Early%20Warning%20and%20Emergency,of%20information%20and%20communications%20facilities.

Ministry of Rural Development and Local Government, 2016. *Local Area Economic Profile: Couva-Tabaquite-Talparo Municipality Final Repor*t. Available at: https://rdlg.gov.tt/wp-content/uploads/MLG-Couva-Tabaquite-Talparo-Final-LAEP.pdf [Accessed 26 May 2023]

Ministry of Works and Transport, 2019a. *Drainage Division National Desilting Programme*. Available at: https://mowt.gov.tt/MOWT/media/General/Documents/Drainage/Drainage-Desilting-Programme-2019.pdf [Accessed 26 May 2023]

Ministry of Works and Transport, 2019b. MOWT launches the comprehensive coastal monitoring programme. Available at: https://www.mowt.gov.tt/Divisions/Coastal-Protection-Unit/Latest-News-Announcements/News-Article-3 [Accessed 26 May 2023]

Ministry of Works and Transport (MOWT), Coastal Protection Unit. 2019. Comprehensive National Coastal Monitoring Programme. Accessed 2023. https://mowt.gov.tt/MOWT/media/General/Documents/Coastal%20Protection%20Unit/CNCMP-Informational-Kit-WEB.pdf

Mohammed, Shaazia S., Scott F. Heron, Rajindra Mahabir, and Ricardo M. Clarke. 2016. "Performance Evaluation of CRW Reef-Scale and Broad-Scale SST-Based Coral Monitoring Products in Fringing Reef Systems of Tobago" *Remote Sensing* 8, no. 1: 12. https://doi.org/10.3390/rs8010012

Mycoo, M. 2018. Beyond 1.5C: Vulnerabilities and adaptation strategies for Caribbean Small Island developing states. *Regional Environmental Change*, *18*(8), pp. 2341-2353.

Mycoo, M., Wairiu, M., Campbell, D., Duvat, V., Golbuu, Y., Maharaj, S., Nalau, J., Nunn, P., Pinnegar, J. and Warrick, O. 2022. Small Islands. In: Pörtner, H.-O., et al. (eds.). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the

Intergovernmental Panel on Climate Change, p. 2043 – 2121. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Chapter15.pdf

Nansingh, P. and Jurawan, S., 1999. Environmental Sensitivity of a Tropical Coastline (Trinidad, West Indies) to Oil Spills. Spill Science & Technology Bulletin, Vol. 5, No. 2, pp 161±172 . Available at: Spill Science & Technology Bulletin, Vol. 5, No. 2, pp 161±172 https://www.academia.edu/49124588/Environmental_sensitivity_of_a_tropical_coastline_Trinidad_West_Indies_to_oil_spills [Accessed 26 May 2023]

Nurse, M. 2018. *Eastern Caribbean fisherfolk, fisheries administrators introduced to new Early Warning Systems.* CARICOM. Available at: https://today.caricom.org/2018/03/17/eastern-caribbean-fisherfolk-fisheries-administrators-introduced-to-new-early-warning-system/

ODPM, 2014. Preliminary Vulnerability Assessment of Trinidad and Tobago. Available at: https://odpm.gov.tt/sites/default/files/Preliminary%20Vulnerability%20Assessment%20of%20Trinidad%20and%20Tobago%20Rmaharaj%202014_0.pdf[Accessed 26 May 2023]

ODPM, 2022. *Vulnerability and Risk Assessments*. Available at: https://odpm.gov.tt/VRAs[Accessed 26 May 2023]

Oxenford, H.A., Johnson, D., Cox, S.A. and Franks, J., 2019. Report on the Relationships Between Sargassum Events, Oceanic Variables, and Dolphinfish and Flyingfish Fisheries. *University of the West Indies*, p.32.

Pacific Disaster Centre, 2020. *Trinidad and Tobago National Disaster Preparedness Baseline Assessment.* Available at: https://www.pdc.org/wp-content/uploads/NDPBA_TTO_Final_Report.pdf[Accessed 26 May 2023]

Particip GmbH, 2019. *Vulnerability and Capacity Assessment (VCA) Report, Trinidad and Tobago: Technical assistance for the environment programme*. Prepared for the EU Delegation to Trinidad and Tobago. Available at: https://www.planning.gov.tt/sites/default/files/Final%20TAEP%20Vulnerability%20and%20Capacity%20Assessment%20Report%20Trinidad%20and%20Tobago%20Jan%202019.pdf [Accessed 26 May 2023]

Petro-Canada Trinidad and Tobago Limited, 2007. *Report on the Marine Resources & Fisheries of the Gulf of Paria for the Environmental Impacts Assessments for Exploratory Drilling Activities in Block 1a and 1b.* Available at: http://www.reefball.org/album/TrinidadandTobago/OldDisk/Appendix%20H%20-%20Reports%20of%20Fisheries%20and%20Socio-Cultural%20Asses%E2%80%A6.pdf [Accessed 26 May 2023]

Rutherford, M.G. 2017. Icacos Bioblitz 2017 Saturday 4th- Sunday 5th November. General Report. Quarterly Bulletin of the Trinidad and Tobago Field Naturalists' Club. The Field Naturalist. 4/2017. Available at http://ttfnc.org/photojournals/2017-4.pdf

Ramsewak, D. et al. 2017. Marine and Coastal Applications of Landsat-8/OLI and Sentinel2A/MSI data in Trinidad and Tobago. UTT presentation at the International Ocean Colour Science Meeting, Lisbon.

Available at: https://www.researchgate.net/profile/Priya-Pollard-2/publication/332798171_IOCS_2017_Lisbon_UTT_PP/links/5cca01594585156cd7c1a3bc/IOCS-2017-Lisbon-UTT-PP.pdf

SECOORA. 2020. US Southeast and Caribbean Regional Workshop: Drones in the Coastal Zone Workshop. Available at: https://secoora.org/drones-in-the-coastal-zone-workshop/

Sutherland, M. and Seeram, A. 2011. Sea Level Rise Modelling in Support of Socioeconomic Impact Analysis Grand Rivierier, Trinidad and Tobago. C-Change Working Paper#34 Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=5cd3e2a552439bf3eb1f297c8f637366a583800a

The Nature Conservancy (TNC). 2021. AI for conservation. Available at: https://coastalresilience.org/project/ai-conservation/

TNC. 2023. *Mapping Ocean Wealth – Caribbean*. Available at: https://oceanwealth.org/project-areas/caribbean/

TNC. 2024. *Marine Spatial Planning – Caribbean*. Available at: https://oceanwealth.org/project-areas/caribbean/

The Observer. 2023. *Antigua and Barbuda to receive support in conducting LiDAR surveys*. Available at: https://antiguaobserver.com/antigua-and-barbuda-to-receive-support-in-conducting-lidar-surveys/

Telecommunications Authority of Trinidad and Tobago (TATT). n.d. *The Smart Seas Toolkit (SST) for Disaster Resilience Project.* Available at: https://tatt.org.tt/DesktopModules/Bring2mind/DMX/API/Entries/Download?Command=Core_Download&EntryId=1667&PortalId=0&TabId=222

United States Embassy in Barbados, The Eastern Caribbean, and the OECS. 2021. Drones gifted by the united states will help the eastern caribbean predict and respond to climate variability. Available at: https://bb.usembassy.gov/drones-gifted-by-the-united-states-will-help-the-eastern-caribbean-predict-and-respond-to-climate-variability-and-natural-disasters/

UNDP. 2014. Sharing what works: South-South Cooperation for Disaster Risk Reduction in the Caribbean. Available at: https://www.undp.org/sites/g/files/zskgke326/files/migration/latinamerica/UNDP_RBLAC_SSCAndDRRCaribbean.pdf

UNDP Barbados and the Eastern Caribbean. 2021. Digital Technology for Future Smart Grenada. Available at: https://www.undp.org/barbados/news/digital-technology-future-smart-grenada

UNDP Barbados and the Eastern Caribbean. 2023. BLUEDIGITAL. Available at: https://www.undp.org/barbados/projects/bluedigital

UNESCO. 2021. *Caribbean AI Policy Roadmap*. Available at: https://ai4caribbean.com/wp-content/uploads/2021/07/Caribbean-Artificial-Intelligence-Policy-Roadmap.pdf

United Nations Office for Disaster Risk Reduction – Regional Office for the Americas and the Caribbean, 2022. *Trinidad and Tobago gears up to increase resilience to disasters*. Available at: https://mcr2030.undrr.org/news/trinidad-and-tobago-gears-increase-resilience-disasters

United States Agency for International Development, 2021. *Trinidad and Tobago Resilience Profile.* Available at: https://pdf.usaid.gov/pdf_docs/PA00XHZM.pdf
[Accessed 26 May 2023]

UWI-CERMES. 2022. *Sargassum Landing Page*. Available at: https://storymaps.arcgis.com/stories/0c5f06f84f944db381f3f0d77f0e2aa4

Appendix 1 - Stakeholder listing from Tech4CoastalResilience project launch

Name	Title	Organisation
Alicia Franklyn	Fisheries Assistant	Fisheries Division
Allison Thomas	Secretary	Tobago Unified Fisherfolk Association
Allys Forte	Fisheries Officer	Fisheries Division
Ayanna La Forest	Adaptation Planning Officer	Environmental Management Authority
Carl M.	Assistant Executive Secretary	Division of Food Security, Natural Resources, Environment and Sustainable Development, Tobago House of Assembly
Collin Asgarali	Fisheries Assistant	Fisheries Division
Dayreon Mitchel	GIS Specialist	Tobago Emergency Management Agency
Errol Roach	President	Castara Fisherfolk Association
Esther Tobias-Clarke	Research Officer	Department of Marine Resources and Fisheries, Tobago House of Assembly
Farahnaz Solomon	Senior Research Officer	Institute of Marine Affairs
Garth Ottley	Director (Ag.)	Department of Marine Resources and Fisheries, Tobago House of Assembly
Gia Gaspard Taylor	President	Network of Rural Women Producers Trinidad and Tobago
Haniff Mohammed	Fisherfolk	Orange Valley Fishing Association
Howard Robin	Climate Change Specialist	Coastal Zone Management Unit, Tobago House of Assembly
Imtiaz Khan	Fisherfolk	Orange Valley Fishing Association
Jamie St. George	GIS Officer	Ministry of Agriculture, Land and Fisheries
Jenise Kirk	Fisheries Services Officer	Department of Marine Resources and Fisheries, Tobago House of Assembly
Johnny Baptiste	President	South West Tobago Fishing Association
Logan Raymond	Intern	IAMovement
Nerissa Lucky	Director	Fisheries Division
Nigel Taitt	Assistant Secretary	Division of Food Security, Natural Resources, Environment and Sustainable Development, Tobago House of Assembly
Recardo Mieux	Fisheries Officer	Fisheries Division

Ryan Mohammed	Council Member	Council of Presidents for Environment
Ryan Seemungal	Research Assistant	Environmental Management Authority
Sasha Sahadeo	Gender Officer	Caribbean Women In Leadership
Shandra Ankiah	Fisheries Officer	Fisheries Division
Simone Titus	Chief Technical Officer	Ministry of Agriculture, Land and Fisheries
Wendy Thomas	Fisheries Extension Officer	Fisheries Division
Perry Polar	HIT RESET Caribbean Programme Manager	University of the West Indies, St. Augustine
Olivia Ramkissoon	HIT RESET Caribbean Programme Assistant	University of the West Indies, St. Augustine
Asad Mohammed	HIT RESET Caribbean Programme	University of the West Indies, St. Augustine
Ainka Granderson	Senior Technical Officer and Resilience Lead	Caribbean Natural Resources Institute (CANARI)
Candice Ramkissoon	Senior Technical Officer	CANARI
Aditi Thanoo	Technical Officer	CANARI
Kerresha Khan	Technical Officer	CANARI
Krystal Seecharan	Communications Officer	CANARI