Integration of Telecommunications in Caribbean Fisheries Management: A Resilience Imperative

Integración de las Telecomunicaciones en la Gestión Pesquera lel Caribe: Un Imperativo le la Resiliencia

Intégration Des Télécommunications dans la Gestion Pesante des Caraïbes: Un Impératif de la Resilience

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ABSTRACT

Small-scale fishers are among the most vulnerable to weather- and climate-related risks. Their vulnerability is magnified as fishing activity is typically conducted outside of the range of terrestrial communications service, and conventional satellite services are generally unaffordable for these fishers. Forecasts of increased intensity of storms in the Caribbean region further increase the risks to small-scale fishers' lives and further challenge their livelihoods. As telecommunications is essential for all stages of the disaster risk management cycle (mitigation, preparation, response and recovery), it is an integral component of resilience-centric fisheries management. This paper outlines a suite of artefacts and activities recommended as the core telecommunications aspects of fisheries management planning in the Eastern Caribbean. The recommendations are structured around assessment, planning and capacity building with particular emphasis on marine band VHF radio as the communications mode of choice for seafarers. The paper draws on the case of St. Kitts and Nevis to report on prototype assessment and planning instruments and related activities; as well as early insights into a novel model of ICT capacity building for fishers.

KEYWORDS: Telecommunications, fisheries management, resilience, VHF radio

INTRODUCTION

Systemic disaster risk management (DRM) has received a great deal of attention for fisheries policy, legislation and management for over a decade. Forecasts of increased intensity of storms in the Caribbean motivate a particular emphasis on climate-related risks. In this region, the Protocol on Climate Change Adaptation and Disaster Risk Management in Fisheries and Aquaculture under the Caribbean Community (CARICOM)'s Common Fisheries Policy (CRFM 2018a) captures the commitment of the Ministerial Council of the Caribbean Regional Fisheries Mechanism (CRFM) to work within the enabling frameworks established by the Caribbean Community Common Fisheries Policy (CARICOM 2014), the CARICOM Regional Comprehensive Disaster Management Strategy and Results Framework 2014 - 2024 (CDEMA 2014), the Regional Framework for Achieving Development Resilience to climate Change 2009 - 2015 (CCCCC 2009), and CARICOM's implementation plan, Delivering Transformational Change 2011 - 2021 (CARICOM 2012).

The integration of DRM into fisheries legislation is an expectation of the Model Disaster Preparedness and Risk Management Plan for the Fisheries and Aquaculture Sector of CRFM Member States (CRFM 2018b) which seeks, inter alia, to strengthen institutions, mechanisms and capacities to build resilience to hazards, and systematically incorporate risk reduction into national emergency preparedness, response and recovery. The Model Plan sets out sector-specific DRM policies and a framework of guiding principles with the nominal specifications of scope, response and recovery actions as well as the roles of responsible DRM parties.

Recognizing that small-scale fishers are among the most vulnerable to weather- and climate-related risks, the Regional Strategy and Action Plan for Climate Change Adaptation and Disaster Risk Management in Fisheries and Acquaculture in the CARICOM Region (CRFM 2013) recognizes the need to increase fishers' capacity for safety at sea and early warning systems. It also identifies the need for a strategy and curriculum for building a culture of safety in the Caribbean. At the global level, the Hyogo Framework for Action 2005 - 2015 (UN 2005) priorities include the use of knowledge, innovation and education to build a culture of safety and resilience at all levels. A number of other UN artefacts make prescriptions and recommendations regarding policy, regulatory and procedural strategies to increase the safety of fishers in particular. Among these is the so-called SSF Guidelines, the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (FAO 2015), which poses safety as an integral part of fisheries management.

Communications features strongly in all stages of the disaster risk management cycle: mitigation, preparedness, preparation and recovery. Its inclusion in DRM policies, legislation and management is essential, particularly for increased safety of small-scale fishers. Yet communications is taxed to the extreme for small-scale fishers who operate in the marine environment often outside of the range of cellular service, have limited budgets to reach for satellite service, and are highly exposed to risks in their modest crafts which sit low on the ocean's surface.

This paper outlines a basic suite of assessment, planning and capacity building artefacts and activities as the starting point for integrating telecommunications matters into fisheries management. Some examples are presented for the case of a sample island in the Eastern Caribbean.

METHODS

Assessment

At GCFI 2017, the authors described the development of a MATLAB-based marine communications range analyzer and data observatory for small-scale fisheries. The communications range analyser enables exploration of the maximum range at sea achievable for standard communication technologies, and the degrees of freedom available to manipulate the achievable range. It enables comparison of technology-specific ranges against various marine boundaries, geofences and the practical limits imposed by the earth's curvature. The tool also demonstrates basic acquisition and display capabilities for available open data of potential interest to small-scale sea-farers in the Caribbean.

The range limit imposed by earth's curvature expresses the maximum achievable distance for direct radio paths, and is established at the horizon where the earth's curvature obscures the "line of sight, LOS" between two communicating devices. The devices may be a pair of wireless handsets as in the case of radios communicating directly with each other; or a handset and some form of infrastructure as in the case of a cellular network or radio repeater deployed specifically to extend the range of achievable communications.

As the predominant propagation mode for all electronic communications used by small-scale fishers is line of sight, fishers are generally unable to communicate at distances beyond the geometric limit imposed by earth's curvature. In practice the radio horizon depends on atmospheric conditions and is typically 15% greater than the geometrical line of sight. In any event, the geometrical line of sight, and consequently the radio line of sight, depends critically on the heights of both transmitter and receiver, and on the obstructions in between: the higher the transmitting and receiving antennas, the longer the range; the more obstructions, the shorter the range. LOS range limits are different for each country in accordance with the terrain and location of communications infrastructure.

Range may also be limited by the transmitted power and the receiver's capability to accurately detect the received signal. The power limit is the maximum distance between two communicating devices at which there is sufficient power at the receiver for it to discern the transmitted signal. The received power is always less than the transmitted power on account of various loss mechanisms in passage.

For this work, the marine communications range analyser is used to estimate ranges for services accessible to small-scale fishers in the English speaking Caribbean: GSM-based cellular, LTE and VHF radio. For representative purposes, GSM is considered in both the 850 MHz and the 1900 MHz bands; LTE is considered in the 700 MHz band and VHF is considered in the marine band. The received power and thus power-limited ranges are purely representative as they depend on very many technology-specific system parameters such as transmit power, antenna gain, receiver sensitivity, frequency of operation and so on. They also depend on the selection of path loss model. Practical values are used in all cases and the Two Ray Ground Reflection path loss model is used to estimate the mean distance-dependent loss over the sea paths. Large-scale and small-scale scattering effects are ignored but in practice describe the statistical variation of instantaneous path loss (and consequently achievable power limited range) about the mean. The LOS range is independent of technology, frequency of operation and other technical parameters.

The most severe limitation on range for reliable communication establishes the effective limit while the least severe establishes the best case. Where the most limiting case is LOS, no amount of power increase will extend the range. In the case of power-limiting range, an increase in transmission power will extend the range until the LOS range limit is reached. In practice, the maximum allowable transmission power may be limited by regulatory constraints as each jurisdiction's telecommunications authority specifies the limits on wireless transmission power for different frequency bands.

Communications range at sea is a fundamental basis for assessing potential channels for ICT-enabled early warning and emergency response solutions for seafaring fisherfolk. Assessment entails dimensioning the communications requirements and circumscribing the communications constraints for the small-scale fishers for each country taking account of topography, existing infrastructure, ICT adoption profiles of fishers and available means for gap filling.

Planning

Safety-conscious fisheries management should set targets for communications coverage at sea. These may coincide with any of a number of maritime boundaries such as the Exclusive Economic Zones (EEZ), Territorial Waters (TW), and Contiguous Zones (CZ). The EEZ is a sea zone, prescribed by the United Nations Convention on the Law of the Sea, over which a state has special rights regarding the exploration and use of marine resources. Territorial waters comprise the belt of coastal waters extending at most 12 nautical miles from the baseline of a coastal state. The contiguous zone is an area seaward of the territorial sea in which the coastal state may exercise legal controls.

The marine communications range analyzer is a planning tool that facilitates the visualization of communications coverage and maritime boundaries of choice on the same map. The analyser accesses EEZ, TW, and CZ boundary specifications for Caribbean countries from marineregions.org. Its mapping feature uses image data queried from the Google Static Maps Application Programming Interface (API) with additional metadata from Google Maps' Geocoding and Google Maps Elevation API, available at the urls shown in Table 1. An API access key is required to use Google Maps APIs. All Google APIs used in the analyser are linked to a single key that has a free daily quota of 2500 accesses. Additional accesses cost USD$ 0.50 per 1000. As the analyser processes a vast number of elevation points, it uses an open source elevation API, Open Elevation, which provides unlimited access to elevation data. The url for JSON-formatted data is:

https://api.open-elevation.com/api/v1/lookup

Planning for the provision of communications to support safety at sea for small-scale fishers must take account of communications technology, handset adoption and fishers' usage profiles at sea. Though VHF marine band radio is internationally recognized as the communications means of choice for small-scale fishers, adoption amongst Caribbean fishers is low. Regular usage of cellular phones on the other hand is universal amongst fishers. Specific profiles vary from country to country even within the Caribbean, with some very high rates of adoption of low-end smart phones in some countries and little in others. While some fishers carry their smart phones to sea, others leave them home and take instead feature phones to sea. As some communications range limits are imposed by the technology and handset, planning must take account of adoption and use profiles in each country.

At-sea communications planning for small-scale fishers must also take account of vessel types and profiles of use. Of highest importance are fishing distances as a reference against achievable communications range; and trip durations as a reference against battery life for fishers' communications devices. Maximum and average values, with corresponding statistical distributions, should inform the planning process. Other parameters such as average vessel speed and bow height above the waterline provide added information that improves the estimates of communications range.

Additional data that informs the planning of communications coverage at sea, is the set of separations between each local jurisdiction and its nearest neighbours. This can be determined using free applications such as Google Earth and its ruler tool. For this work, shortest routes between pairs of neighbouring Caribbean islands were selected by eye, measured using the ruler tool, marked up on Google Earth and stored for later use as a kml file.

Capacity Building

The SSF Guidelines recognize that safety at sea is a complex matter. Indeed, not only is the provision of communications service at fishing distances a highly constrained, multi-dimensional challenge but a number of other matters exacerbate the problem. Chief among these is the limited consideration for fishers' safety at sea in the planning and management operations of the parties necessary for basic provisions. While the operational aspects of safety at sea are well covered by the Coast Guard in each country, the planning and provisioning of necessary infrastructure and services lies with the telecommunications ministries and regulators as well as with the fisheries authorities.

It is the responsibility of ministries with responsibility for communications to ensure that their obligations to the International Maritime Organization (IMO) are satisfied. These obligations generally include radio communications coverage of the country's A1 sea area which roughly coincides with the LOS range of national coast stations. Coast stations service specific radio frequencies designated for distress and safety communications for the Global Maritime Distress and Safety System (GMDSS). Though vessels under 300 gross tonnage (GT) are not subject to GMDSS requirements, each A1 sea area requires a continuous VHF guard and there should be enough stations necessary to provide VHF coverage in the country's entire A1 sea area. The ministry generally delegates responsibility for coast station services to a telecommunications service provider and has the ultimate responsibility to ensure that service obligations are met.

As the agency charged with the monitoring and management of the country's radio frequency spectrum, the national telecommunications regulator is responsible for listing the country's coast station/s with the International Telecommunications Union (ITU). The regulator is a key party to IMO audits that determine the extent to which sea area coverage obligations are satisfied. Collaboration between the telecommunications ministry and regulator to ensure communications coverage for distress and safety should be a part of standard operations.

Fisheries authorities are the agencies most aware of, and concerned with, the risks that small-scale fishers face each time they set out to sea. Painfully aware of fishers' communications challenges, they are the best positioned to advocate for adequate coverage at sea, at least within standard national obligations. They are also best positioned to determine the gaps between this coverage and the ranges fished; and on this basis to advocate for gap filling provisions through telecommunications service providers, research and innovation institutions, and various international agencies. Not insignificantly, fisheries authorities are the primary agencies to plan and arrange delivery of monitoring and training programmes for small-scale fishers.

The Assessment and Planning subsections in this paper represent a basic set of capacity building resources for fisheries authorities to utilize as the baseline for improving communications-centric resilience for small-scale fishers. Each resource must be localized for each country based on fishing practices, topography and existing communications infrastructure.

In addition to the development of capacity building resources for fisheries authorities to integrate into their regular management operations, corresponding resources for fishers are recommended. These are necessary to build awareness of the nature of communications range limitations at sea and to provide guidance on strategies to mitigate the risks which accompany these limitations. Indeed, the Regional Strategy and Action Plan for Climate Change Adaptation and Disaster Risk Management in Fisheries and Aquaculture in the CARICOM Region (CRFM 2013) recognizes the need to increase fishers' capacity for safety at sea and early warning systems. It also identifies the need for a strategy and curriculum for building a culture of safety in the Caribbean. The authors have developed versions of the resources described in the Assessment and Planning subsections of this paper for inclusion in fisherfolk training programmes. They have also created a 3-tiered curriculum on the mobile phone and marine band VHF radio for opportunistic delivery to small-scale fishers through an ICT Stewardship programme.

RESULTS

Figures 1 through 5 show results of sample artefacts proposed for use in basic communications assessment, planning and capacity building activities integrated into fisheries management. The island of St. Kitts, the larger of the two-island state of St. Kitts and Nevis in the Eastern Caribbean, is used for demonstrative purposes.

Figure 1 shows estimates of the inter-island separations in the vicinity of St. Kitts while Figure 2 shows the EEZ, TW and CZ boundaries for the various countries. Figure 3 plots communications ranges limited by power for twenty existing tower sites in St. Kitts for hypothetical communications transmitters: blue for GSM 1900 MHz, orange for GSM 850 MHz, gray for LTE 700 MHz and yellow for VHF radio at 174 MHz. Figure 3 shows, in red, the communications ranges limited by LOS for the twenty sites. Figure 4 plots the LOS-limited range for (a) a single site and (b) and the aggregate of 5 sites selected to provide 360° coverage, with breakdown shown in Table 2. Figure 5 shows examples of existing tower infrastructure in St. Kitts at (a) a low elevation and (b) a high elevation.

Figure 1. Sample inter-island separations in the Eastern Caribbean

Table 1. Access URLs for Google APIs Used in Range Analyzer

Google API	Data Format	Access URL
Static Maps	XML	http://maps.googleapis.com/maps/api/staticmap
Geocoding	XML	https://maps.googleapis.com/maps/api/geocode
Elevation	XML	https://maps.googleapis.com/maps/api/elevation

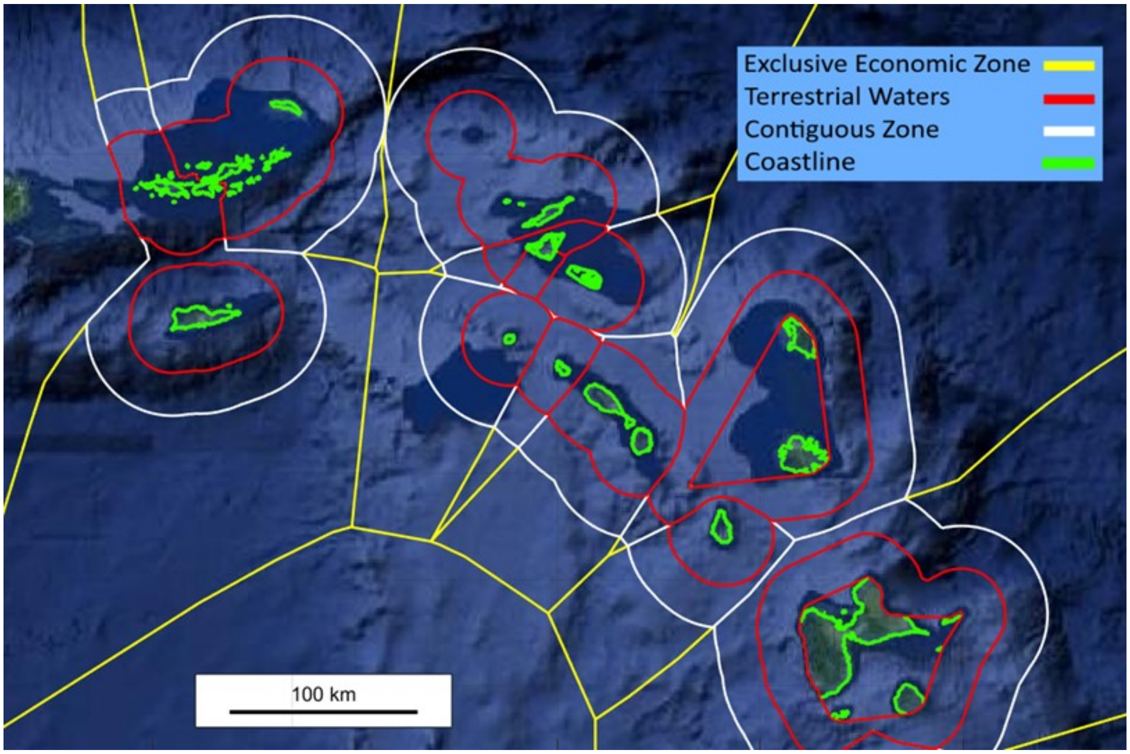


Figure 2. Maritime boundries for St. Kitts and Nevis and nearby Eastern Caribbean countries

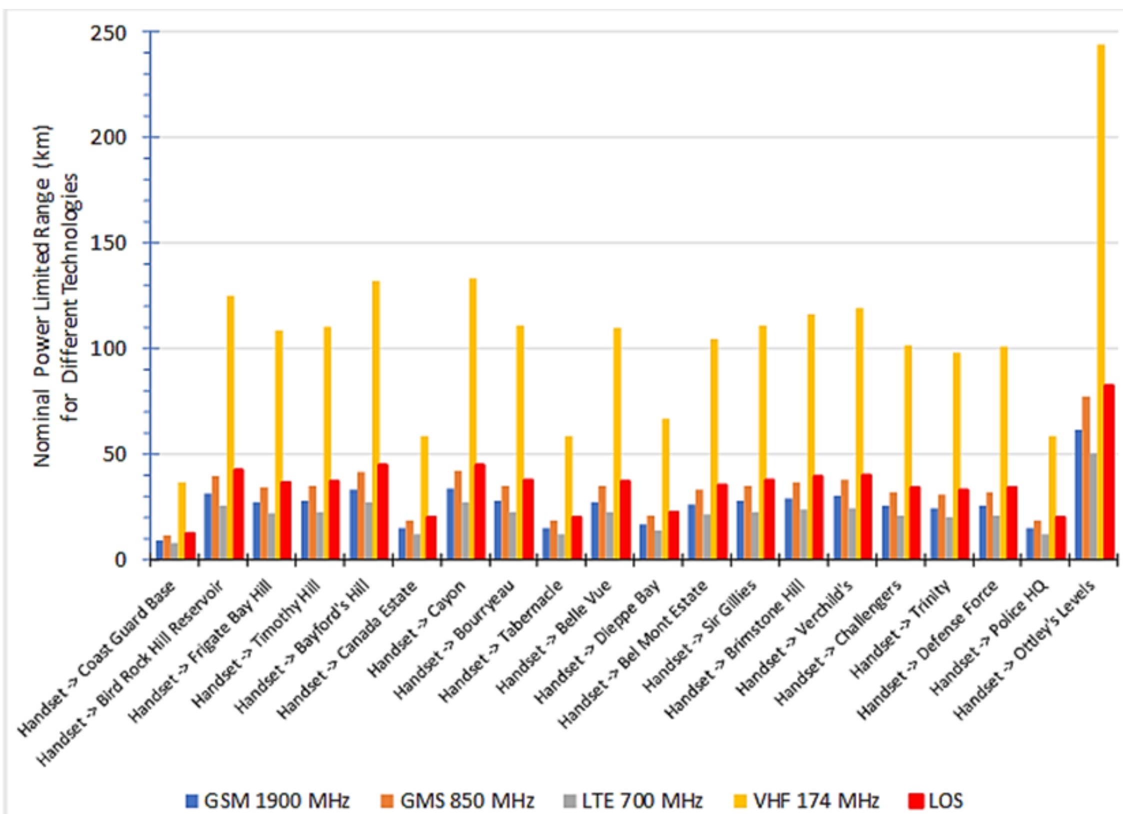
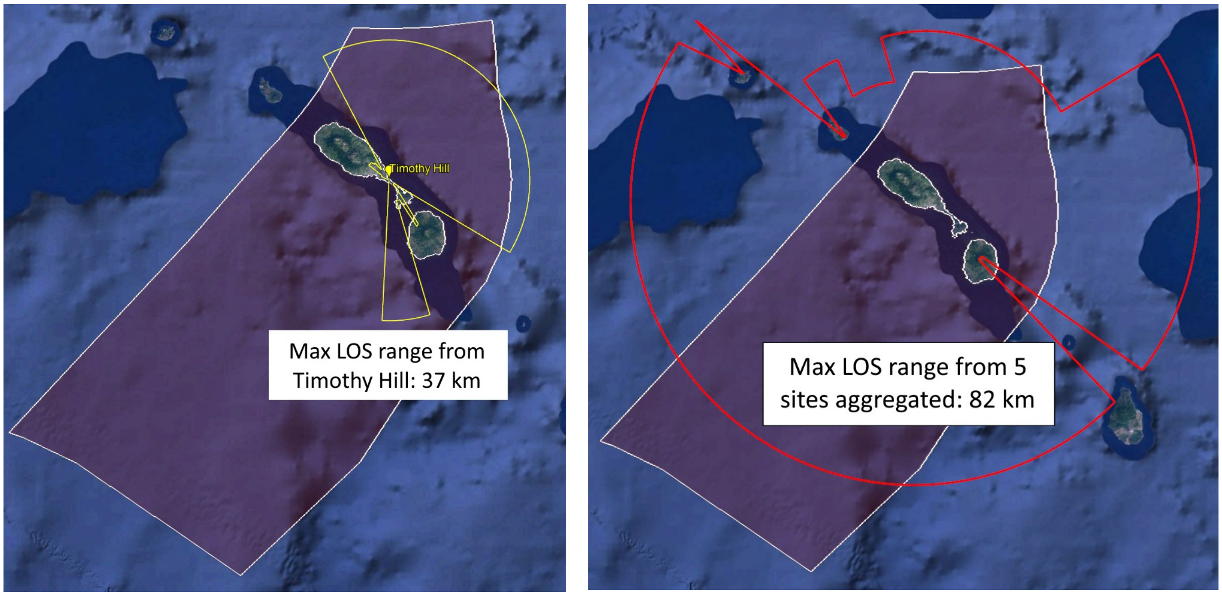


Figure 3. Communications Range Limited by Power for Sample Technologies (left) and LOS (right)



(a) (b)

Figure 4. EEZ and LOS limited ranges in St. Kitts from: (a) a single site and (b) aggregate of 5 sample sites

(a) (b)

Figure 5. Sample existing tower infrastructure in St. Kitts: (a) low elevation (b) high elevation

Table 2. Estimated LOS-limited communications range and maximum angular coverage for 5 selected sites

Site Name	Estimated LOS-limited Range (km)	Estimated Maximum Angular Coverage
Ottley's Levels	82	256°
Bayford's Hill	45	122°
Dieppe Bay	23	205°
Brimstone Hill	39	100°
Timothy Hill	37	210°

DISCUSSION

Figure 3 reveals that in all cases, the power-limited range for marine band VHF radio is the least severe of all limits. For the system parameters used, the results show that if the range were power limited, VHF radio could achieve distances of up to nearly 250 km for a base or relay station located at Ottley's Levels, the highest of all elevations considered. The results also show, however, that the line of sight limit is more severe than the VHF power limit. This is to say that the ranges for VHF radio communications are in fact limited by line of sight. The range to a mobile handset at a meter or so above sea level lies roughly between 10 km and 80 km, depending on the elevation of the land-based tower infrastructure. In fact, under normal environmental conditions the radio horizon is likely to be 15% higher than this: 12 km – 92 km. More unusual environmental conditions may yield even greater distances but it is best to use conservative estimates for planning and assessment.

In the case of St. Kitts, inter-island distances with nearest neighbours range from 3 km (to sister-island of Nevis) to 110 km (to Antigua and Barbuda). While 3 km range is achievable from all St. Kitts sites *without obstruction*, direct VHF communications can normally only be supported at 110 km with adequate tower heights on *both* St. Kitts and Antigua, not between any land-based infrastructure in St. Kitts and a handset in a small-scale fishing vessel. Note that when the LOS limit is exceeded, no amount of increase in transmit power or other system parameters is able to extend the communications range.

The results of Figure 3 show that VHF radio has the longest range of all the technologies under consideration for all cases, LOS displays the next highest limit and then all cellular technologies feature lower range limits, with GSM 850 MHz the next highest. This is expected as higher ranges are achievable at lower frequencies and for less complex communications technologies. The range of marine band VHF radio is similarly derived from these two advantages.

The range profile in Figure 4 (a) is non-contiguous on account of topographical obstructions observed from a single site. Though the aggregated range for five transmitting sites is constant from north west to south east, counter clockwise; there are considerable range perturbations from north west to south east, clockwise. This is due to the different coverage profiles achievable from the different towers at different elevations and obscured by different clutter. The maximum LOS range overall is 82 km which is shy of the EEZ in the south west of the island but otherwise provides fair coverage. Greater range coverage off the north and east of the island requires towers at locations with unobscured views in these directions.

Many Caribbean fishers report average fishing distances of 48 km and maximum distances of 110 km. With maximum LOS distances under normal environmental conditions of 80 km at best, off of less than three quarters of the island, collaborative arrangements between the authorities in neighbouring islands is recommended.

The artefacts described in this paper are the baseline for examining the challenge of communications at sea for small-scale fishers. They provide essential data required to manage expectations and to contemplate practical and practicable strategies to mitigate risks. The risks of exposure can only be mitigated through structured assessment, planning and capacity building. Integration of these matters into the standard operating procedures of fisheries management is essential, as is deliberate collaboration between key organizations which at a minimum include: fisheries authorities, ministries and regulators of telecommunications, service providers and the Coast Guard.

ACKNOWLEDGEMENTS

This work was conducted with the support of the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) project funded by UN FAO with Global Environment Facility/ Special Climate Change Fund as Resource Partner.

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