# USING PARTICIPATORY MAPPING FOR COMMUNITY-BASED MARINE SPATIAL PLANNING IN ST. GEORGE'S CAYE, BELIZE



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In

Geographic Information Science

by

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CERTIFICATION OF APPROVAL

I certify that I have read *Using participatory mapping for community-based marine spatial planning in St. George's Caye, Belize* by Salma Tharwat Abdel-Raheem, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirement for the degree Master of Science in Geographic Information Science at San Francisco State University.

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USING PARTICIPATORY MAPPING FOR COMMUNITY-BASED MARINE SPATIAL PLANNING IN ST. GEORGE'S CAYE, BELIZE

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As the environmental toll of growing human populations continues to increase, coastal and island nations are hard-pressed to effectively manage their natural resources for sociopolitical, economic, and cultural benefits. Marine Spatial Planning is a holistic approach to effective natural resource management that integrates local knowledge and participation at a variety of spatial scales. Engagement through participatory mapping efforts and facilitated by geographic information systems, is an effective means to communicate local objectives and concerns. We present here a case study of participatory mapping efforts by residents of Saint George's Caye, Belize. Residents participated in guided focus group sessions on three different occasions between January and October of 2018 to map their concerns and planning objectives at two distinct spatial scales. Of the nearly 200 residents on the Caye, approximately 120 participated in the mapping sessions and provided collective feedback on 4 different threats and associated risks, 2 conservation priorities, and 4 natural resource uses. Resulting maps will be used by the local Village Council to create a comprehensive plan for the Caye for future legislative protections. This work exemplifies the need for local engagement at various spatial scales to ensure effective and holistic marine spatial planning and natural resource management.

I certify that the Abstract is a correct representation of the content of this thesis.

Chair, Thesis Committee

5/23/19
Date

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## Introduction

*Coastal marine environmental management strategies*

As human populations and their demands on the planet's natural resources increase, coastal nations are expected to increase development efforts to sustain their constituents' needs (Lewison *et al.* 2016). As such, coastal habitats will be hard hit with construction and development efforts. Some of the most damaging development activities can cause habitat loss, pollution, and lower habitat quality (Jefferson *et al.* 2009). Developing nations are experiencing, and are predicted to continue to experience, rapid economic growth that necessitate such intensive development practices (Creel 2003). Governments often struggle to balance economic improvements within an ecologically conscious mindset for their constituents, especially within the marine and coastal sectors (Verutes *et al.* 2017).

One major framework for marine and coastal ecosystem-based management is marine spatial planning (MSP) (Crowder and Norse 2008; Gilliland and Laffoley 2008; Ehler and Douvere 2009; Foley *et al.* 2010; Verutes *et al.* 2017). MSP is a coordinated framework that aims to replace the current complexity surrounding the governance of coastal and ocean waters (Foley *et al.* 2010). Specifically, MSP is a coordinated public effort to allocate the spatial and temporal distributions of ecosystem services to satisfy ecological, economic, and social objectives (Ehler and Douvere 2009).

There are three over-arching goals in an MSP project. The first is to balance human activities and oceans' abilities to provide services. Second, incorporate principles of economic, ecological, socio-cultural, and political perspectives to ensure a holistic approach to marine and coastal resource management. Lastly, implement management

that is appropriate at the scale of ecosystems but also governmental jurisdictions (Foley *et al.* 2010). An underlying requisite of MSP is the need for spatially explicit consideration of human use, compatibility, conflict, and synergy within the second goal (Gilliland and Laffoley 2008; Foley *et al.* 2010).

The strong representation of ecological principles in natural resource management is often due to the notion that the biophysical component of marine ecosystems serves as the ground-work upon which all extractive and regulatory human activities occur (Crowder and Norse 2008). Local forms of knowledge are recognized as a means by which researchers can integrate information from local peoples to supplement expert-derived knowledge (Huntington 2000; Drew 2005; Thornton and Scheer 2012). The integration of local knowledge into natural resource management generally is part of a larger shift towards the democratization of conservation science and the adoption of adaptive co-management strategies (Plummer *et al.* 2012; Salomon *et al.* 2018).

Verutes *et al.* (2017) compiled an integrated coastal management plan that encompasses several economic and political sectors and their associated stakeholder groups across the entire country of Belize. This plan was accepted in August 2016 and serves as a national guideline, yet the need for more planning and management efforts at local spatial scales remains. For example, Egan (2008) worked with local commercial fishers to create a participatory geographic information system (PGIS) of Turneffe Atoll, Belize as part of a larger biosphere implementation project. Egan was able to produce maps that compiled the information shared regarding perceived threats and their risks, species' habitats and sightings, and traditional uses and their associated areas on the Atoll. The effective use of local knowledge in conservation management can promote the

establishment of local scientific knowledge bases within communities, as well as promote effective resource management strategies upheld by local stakeholders and governments (Huntington 2000; Drew 2005; Thornton and Scheer 2012).

*Integration of local knowledge*

Local forms of knowledge are recognized as a means by which researchers can integrate information from local peoples to supplement expert-derived knowledge (Huntington 2000; Drew 2005; Thornton and Scheer 2012). The integration of local knowledge into natural resource management generally is part of a larger shift towards the democratization of conservation science and the adoption of adaptive co-management strategies (Plummer *et al.* 2012; Salomon *et al.* 2018). Local knowledge should not be thought of as a tool for research and management projects, rather as information shared by local peoples, similar to the scientific literature, from which information can be gleaned (Thornton and Scheer 2012).

For example, Golden *et al.* (2014) utilized knowledge shared by predominately older fisherwomen in Fiji to aid in setting the spatial and temporal boundaries of a proposed Marine Protected Area (MPA) along a nearby section of coral reef. Researchers combined scientific fish surveys with fished species information shared by participants to understand community use and attitudes towards managing the local coral reef resources (Golden *et al.* 2014). Ultimately, members of the community felt that a smaller MPA boundary that was flexible in its timing of opening and closing would best sustain the community while allowing the reef to replenish its resources (Golden *et al.* 2014).

Engagement and participatory efforts are often facilitated by interviews, workshops, questionnaires, and collaborative field work (Huntington 2000). Varying forms of participation are crucial to forming and sustaining regional and local investment in natural resources and their conservation (Drew 2005, Levin and Lubchenco 2008, Klain *et al.* 2014, Salomon *et al.* 2018). Because the issue of spatial scale is central to effective natural resource management, mapping and geographic information systems (GIS) are productive ways with which perceptions of scale can be collected, analyzed, and presented (Sheppard 1995).

*Participatory Geographic Information Systems (PGIS)*

GIS technologies provide powerful tools for the efficient analysis of spatial data (Thatcher *et al.* 2016). In the last 20 years GIS has been implemented to include the spatial knowledge and input of the public via participatory GIS (PGIS) (Weiner *et al.* 1995; Deshingkar and Cinderby 1998; Cinderby 1999; Arkema *et al.* 2015; Leis *et al.* 2019). Expert mapping systems provide tremendous benefits in the study of the ecology of natural ecosystems and their biophysical components, yet often fail to include information derived from local peoples (Sheppard 1995). This is particularly important in the context of development and changing land use patterns, as locals are often the most directly affected by developmental changes but left out of associated discussions (Leis *et al.* 2019). As a result, the field of participatory GIS (PGIS) was borne out of a criticism that traditional GIS was exclusionary and perpetuated a cycle of oppression and marginalization by those already in power (Cinderby 1999). PGIS aims to remedy this by opening the field to communities, particularly Indigenous or in developing countries, and

allow them to map and analyze their issues, history, and interests for their own lands and resources (Cinderby 1999).

Integrating local knowledge provides context to the scientific findings made by outside researchers and can create richer datasets upon which policy and management initiatives can be based (Drew 2005). Studies can utilize bottom-up (community to federal government) and/or top-down (federal government to community) approaches to integrate expert maps with perceptual maps of local conditions as reported by the communities being engaged (i.e. Weiner *et al.* 1995; Leis *et al.* 2019). Recently, Leis *et al.* (2019) used an exploratory mapping approach to include the perceptions of small-scale fishers operating on the Paraná coast in Brazil early in the MPA planning process. Mapping exercises were conducted in small group settings, and fishers were asked to map areas of socio-economic, cultural, and ecological concerns. Most importantly, the inclusion of small-scale fishers in the early planning process provided conservation planners with important information regarding local values and helped identify potential conflicts early in the planning process (Leis *et al.* 2019).

*Present study*

Nations in the Greater Caribbean Region (GCR) provide a unique opportunity to study the effects of intensive economic and population growth upon fairly pristine ecosystems (Verutes *et al.* 2017). The GCR is home to the Meso-American Barrier Reef System (MABRS), the second largest barrier reef system in the world, and a UNESCO World Heritage Site (UNESCO 2009). Belize, bordered by Mexico to the north and Guatemala to the south and west, is home to the largest continuous stretch of MABRS in the Caribbean Sea (UNESCO 2009; Fig. 1). The MABRS provides adjacent nations with

ecosystem services that range from storm surge protection during hurricane season to billions of dollars in tourism every year (Guannel *et al.* 2016; Verutes *et al.* 2017; Wyatt *et al.* 2017). Furthermore, the MABRS hosts much of the GCR's biodiversity and marine life (Verutes *et al.* 2017). In addition to the MABRS, the shallow coastal waters of the GCR are characterized by their abundant seagrass beds and mangrove forests, which host a great number of species (Self-Sullivan and Mignucci-Giannoni 2012; Arkema *et al.* 2014,2015; Verutes *et al.* 2017 ).

For this research we have created a PGIS for Saint George's Caye (SGC), Belize. SGC is a small island located 13 km east of Belize City that is approximately one kilometer long and home to roughly 200 total people, including 75 full or part-time residents (Searle pers. comm; Fig. 1). The SGC Village Council is a locally elected governing body that represents SGC and its interests within the greater Belizean government. It is composed of a president and sitting members that organize meetings and events on SGC. Currently, SGC has no form of electrical infrastructure, and the Village Council is in the discussion process of introducing a network of solar grids (Searle pers. comm). Residents of SGC are concerned that without a plan for sustainable development, an introduction of reliable energy will open the door to developers looking to build on the small island (Searle pers. comm). Residents' fears are further fueled by large-scale commercial developments occurring on nearby San Pedro Caye, where residents recently protested 48 over-the-water bungalows built by a foreign developer (Menzies 2018).

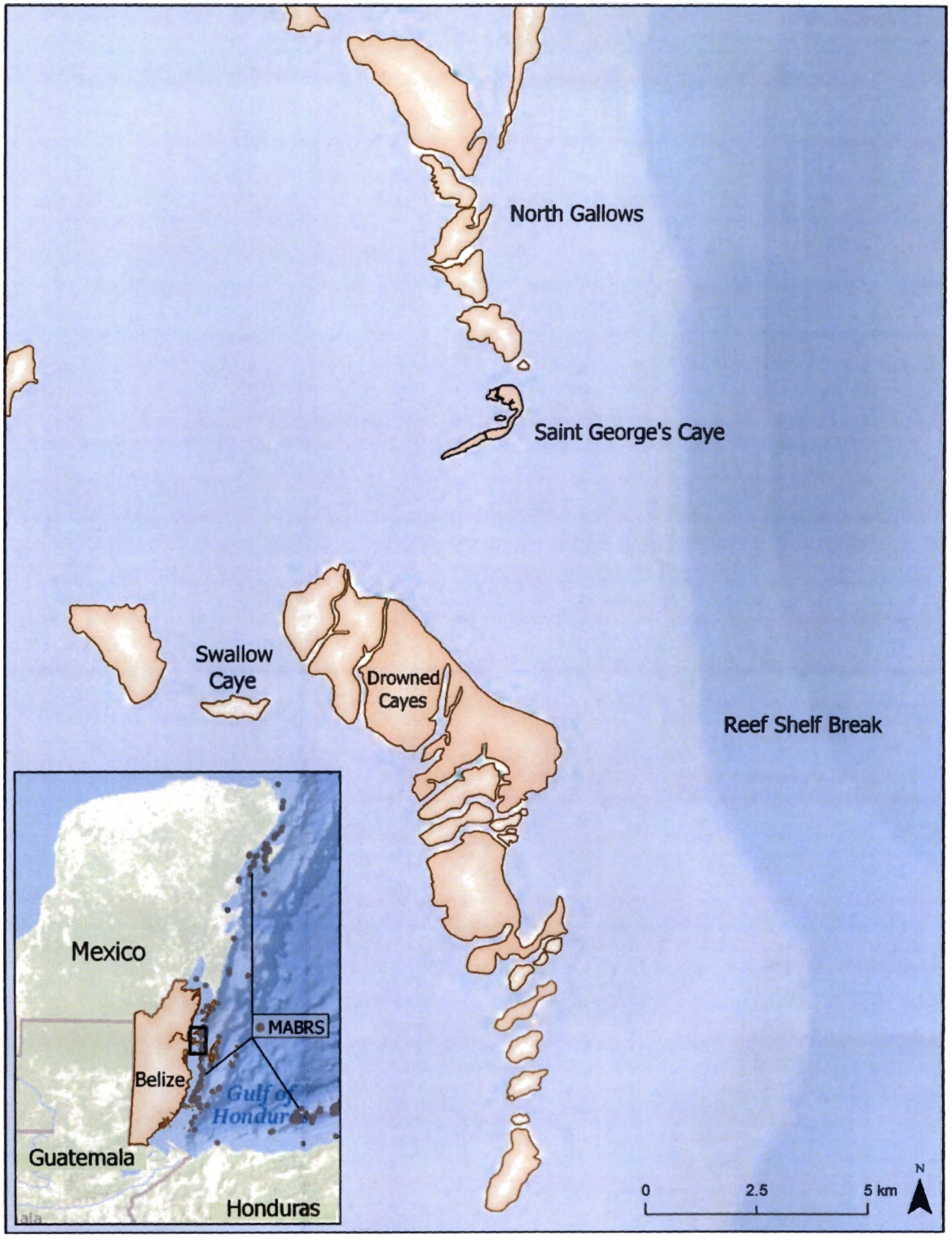


**Figure 1: Map of Belize and bordering nations. The Meso-American Barrier Reef System (MABRS) is depicted by gray dots that are known coral reef survey sites provided by UNEP-WCMC (Reefbase).**

The fundamental goals of this research were to use PGIS methods in focus groups with local people to develop a marine spatial plan for SGC. Residents believed that with a consensus-based plan of the perceived threats and priorities for SGC, they would then be able to navigate political infrastructure to attain protections for areas they collectively agreed warranted legislative protections. This was to prevent similar exploitative activities from taking place on SGC without the consent of local peoples, as have occurred on nearby islands.

The central research question focused on what kinds of spatial knowledge and concerns did peoples with direct interests (i.e. residents, workers, business owners) in SGC have of their physical, natural, and human-made features? Specifically, participants were asked to delineate areas of perceived threats, priorities, and use at three different spatial scales: the immediate terrestrial area of SGC, the immediate surrounding waters of SGC, and the greater waters around SGC. Members of the SGC community collaborated closely with one another in groups to produce hand-drawn maps that delineated areas perceived to be threatened and areas of conservation concern and priority. Ultimately, these maps reflected local opinions on the sustainable management of SGC and can be used to further local efforts to protect important geographical features.

## Methods

*Participatory mapping focus groups*

A focus group is a demographically diverse group of people who have willingly volunteered to participate in sharing their knowledge on a focused topic of interest in an interactive discussion-based setting (Lewison *et al.* 2016; Leis *et al.* 2019). For the purposes of this study, the topic of focus was to collect and compile the perceived village boundaries and the threats, concerns, and priorities for the natural resource management of SGC. People of all racial, gender, age, and socioeconomic backgrounds with direct connections to SGC were encouraged to attend and participate in the focused discussions. A direct connection was defined as anyone who was a resident, family of residents, employees/caretakers, or fished in the SGC area. The SGC Village Council publicized the participatory mapping working sessions and the Council President donated space on his private property on SGC to hold the community gatherings.

Prior to travel to SGC, base maps were created using orthorectified, stitched composite drone images. A property parcel map of SGC, provided by the SGC Village Council, was digitized and overlaid atop the composite drone image, using ArcGIS Pro (Fig. 2; ESRI 2018) to create a base map for the first exercise of the focus group session. For the second mapping exercise a satellite base map (ESRI *et al.* 2017) that extended approximately 10 km north and west, 16 km south, and 13 km east of SGC was used. The extent of this base map was set by the SGC Village Council to gain insight into the uses of the greater SGC area and to facilitate in setting their village boundaries. The base maps were printed on 60" x 48" poster paper and laminated for participants' use.

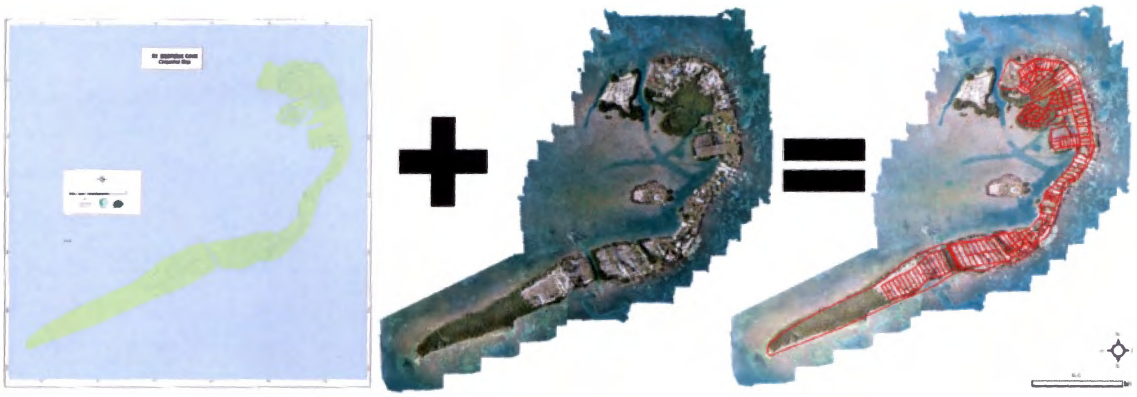

**Figure 2: Parcel map of SGC as provided by President of the SGC Village Council, John Searle, Jr., overlaid with an orthorectified stitched composite drone image.**

*Initial mapping focus group*

The first participatory mapping session was held across two days to accommodate as many interested participants as possible: the first on 13 January 2018 and the second on 20 January 2018. Mapping activities were identical across the two days, but participants were only permitted to participate in one of the two days of the session. Participants were asked the first question from Table 1 and collectively responded. Participants could vote as many times as they liked, and the top six perceived threats were chosen for the first mapping exercise. After the top six threats were voted on, participants were distributed slips of paper numbered one through five, in which each number corresponded to a unique group. Participants were then asked to move to the table that corresponded with their random number assignments and remain there for the duration of the exercises.

**Table 1: Questions participants were asked (in order) during the initial participatory mapping focus group session held on 13 and 20 January 2018.**

| ***Questions Asked to Participants during the January 2018 Participatory Mapping Focus Group Session*** |
|---|
| 1. What do you consider are the worst threats to the human and natural environment in SGC, now and in the future? |
| 2. What do you feel is the traditional SGC area (land and sea)? |
| 3. Where are your traditional recreational areas (snorkeling, sailing, scuba diving, boating, swimming, kayaking, barbeques, get-togethers, etc.)? |
| 4. Where are your traditional fishing areas? What species do you fish for? What gear do you use? When do you fish? |
| a. Recreational (any kinds that you do NOT earn money from) fishing? |
| b. Commercial (any kind that you earn money from) fishing? |
| c. Sport (catch and release) fishing? |
| 5. What are the assets or the things that make SGC special for you? |
| 6. What are some of the services, activities, and developments that you would like to see on the Caye, as the community develops forward? |
| 7. What are some services, activities, and developments that you would NOT like to see on the Caye, as the community develops forward? |

After participants were settled into their groups, they were asked to map the top six threats on the provided composite drone image-parcel base map using different colored permanent markers. Participants were also asked to designate each area's perceived risk using a colored sticky note: pink represented high risk, orange represented medium risk, and green represented low risk. Participants were encouraged to include as much detail as possible to ensure that their perceived threats and risk assessments were communicated as clearly as possible. Furthermore, participants were instructed to work under majority rule, for which most of the members of a group had to agree upon a feature and its risk designation for it to be drawn on the provided map.

After the first mapping exercise was completed, participants remained in their random group assignments for the second mapping exercise. For this exercise, participants used the satellite image base map to provide information on natural resource

use and perceived boundaries for the larger area around the Caye. Participants were asked questions 2 through 4c (Table 1), and to provide details on the type of use for each given area on a blue sticky note. Like the first mapping exercise, participants voted on three perceived threats to the greater SGC area and assigned a risk level using the same methodology as described above.

To conclude the first participatory mapping focus group session, participants were asked to call out answers to questions 5-7 (Table 1), which were recorded on the whiteboard for the group to see and later transcribed. At the end of the day, each participant was asked to anonymously provide their overall vision for SGC and feedback on the participatory mapping focus group session. Contributions were collected and later typed. At the end of the session, participants were informed of how their contributions will be compiled and analyzed, and that a follow-up session would be arranged with draft maps for their review, edits, and comments.

*Follow-up participatory mapping focus group sessions*

Researchers returned to SGC on 19 and 20 May 2018, and 28 October 2018 with digitized maps of each group's contributions from the January mapping focus group session. As in the January session, participants were randomly assigned to working groups. However, for the follow-up focus group sessions, each group was also assigned a unique marker and were asked to rotate among the different maps. Each group had between 10 and 25 minutes to review and edit each map before being asked to move onto the next. In the beginning of the mapping exercise, participants needed more time to fully understand the task, and after a few rotations, felt comfortable in their process and were able to rotate between maps more quickly. Participants also operated under majority rule,

and were asked to only add, take away, modify a feature, or re-assign an area's associated risk level if most of the participants in the group agreed.

During the May 2018 focus group session, participants were given a chart to define their perceptions of risk for each given threat. This was done to better contextualize the final maps produced and to better communicate the intentions of the finals maps to non-residents and non-participants. Participants were first asked if they attended the January participatory mapping focus group, and if so were given a specially marked chart. Charts were identical for both new and returning participants.

*GIS Analysis*

After each participatory mapping focus group session, hand-drawn maps were photographed to digitally translate participants' contributions as accurately as possible. Images were imported into ArcMap 10.4.1 (ESRI 2016) georeferenced, overlaid atop the base map, and used as a reference for digitally tracing participants' hand-drawn features. Once a feature was digitized, accompanying information, such as date, group number, threat type, risk level, and notes, were manually entered into the attribute table of the digitized feature. After each group's hand-drawn map was completely digitized and attribute tables fully populated, shapefiles that were specific to each threat, risk level, and group (i.e. group1_development_highrisk) were exported. Once a shapefile was created for each threat-risk level combination for each group, shapefiles that shared the same threat at the same risk designation were merged.

Merged threat-risk shapefiles were used in the Count Overlapping Polygons tool (GIS Stack Exchange 2014) to conduct a spaghetti and meatball overlay analysis. This tool creates digital spaghetti, which are polygons that are created based on the

overlapping areas of input polygons (Honeycutt 2012). Centroids, or meatballs, for each spaghetti polygon are then created. The newly created meatball centroids are spatially joined with the merged threat-risk shapefile, and each polygon is assigned a join count that represents how many overlaps it has with a centroid meatball (Honeycutt 2012). The join count is a measure of consensus for the threat maps, in which the higher the join count value, the greater the consensus. Join count values were not shared with mapping participants to prevent artificially attributing numerical value assignments to areas that have high or low join count values. Instead, each map was symbolized using a single-color gradient, in which high join count values were darker and low join count values were lighter. The legend on each map only informed participants that darker colors corresponded to higher levels of agreement.

To create final maps, features that were represented in both high risk and medium-low risk maps were conservatively retained in the high-risk designation unless participants indicated otherwise. Redundancies in feature risk designations were pointed out to participants in the May and October 2018 follow-up focus groups, and participants were asked to make a final determination on risk designations if possible. Participants voted on the final appearance of the maps and presented any last modifications during the October 2018 mapping focus group session.

## Results

### *Participant demographics*

Demographic data was provided anonymously by the SGC Village Council and compiled into Table 2. Overall, about 120 participants attended at least one participatory mapping focus group session in 2018 (Table 2). Of the 120 participants, approximately 24 (20%) and 35 (29%) were new and returning participants, respectively (Table 2). The January focus group sessions had the greatest participant turnout (n=61) relative to the sessions held in May and October 2018. Participation was slightly skewed by sex, as males made up the majority of participants (59%; Table 2). Most participants were middle-aged (ages 40-64; 48%), followed by retirees and the elderly (65+; 30%), and few participants were young (ages 18-39; 23%; Table 2). Across race, people of Caucasian background were the most represented group (46%), followed by Creole (28%); Mestizo/Hispanic (28%), and other (11%) (Table 2).

**Table 2: Demographic data for participants that attended any of the participatory mapping focus group sessions in 2018. Because data were anonymously provided, repeating participants across different meetings, could not be accounted for in the summed totals and percentages. * total and percentage do not account for the initial focus group session held in January 2018 in which all participants were new, and none were returning.**

| Date | Number of Participants | Sex | | Age Group | | | Race | | | | # of Returning Participants | # of New Participants |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Female | Male | 18-39 | 40-64 | 65+ | Mestizo/Hispanic | Creole | Caucasian | Other | | |
| 13-Jan-18 | 25 | 9 | 16 | 4 | 13 | 8 | 6 | 6 | 13 | 0 | N/A | 61 |
| 20-Jan-18 | 36 | 15 | 21 | 7 | 15 | 14 | 3 | 12 | 16 | 5 | | |
| 19-May-18 | 17 | 7 | 10 | 5 | 7 | 5 | 4 | 4 | 8 | 1 | 14 | 18 |
| 20-May-18 | 15 | 8 | 7 | 4 | 8 | 3 | 2 | 1 | 10 | 2 | | |
| 26-Oct-18 | 27 | 10 | 17 | 7 | 14 | 6 | 4 | 10 | 8 | 5 | 21 | 6 |
| Total | 120 | 49 | 71 | 27 | 57 | 36 | 19 | 33 | 55 | 13 | 35 | 24* |
| Percent | | 41% | 59% | 23% | 48% | 30% | 16% | 28% | 46% | 11% | 29% | 20%* |

*Chosen threats and priorities*

Participants provided several threats and conservation priorities across the initial two days of the first participatory mapping sessions on 13 and 20 January 2018. Responses were similar across the two days, and participants voted on their top six perceived threats and conservation priorities. Participants chose development, dredging & filling, overfishing, pollution, mangrove protection & conservation, and marine wildlife conservation as the respective threats and conservation priorities for the immediate SGC area (Fig. 3A). For the greater SGC area mapping exercise, participants chose development & dredging, high density (cruise ship) tourism, habitat & mangrove conservation, and marine wildlife conservation as the respective threats and conservation priorities for that spatial extent (Fig. 3B). In addition, participants mapped their perceived SGC boundary areas, as well as information regarding the recreational and fishing uses (recreational, commercial, and sport fishing) throughout the greater SGC area (Fig. 3B).

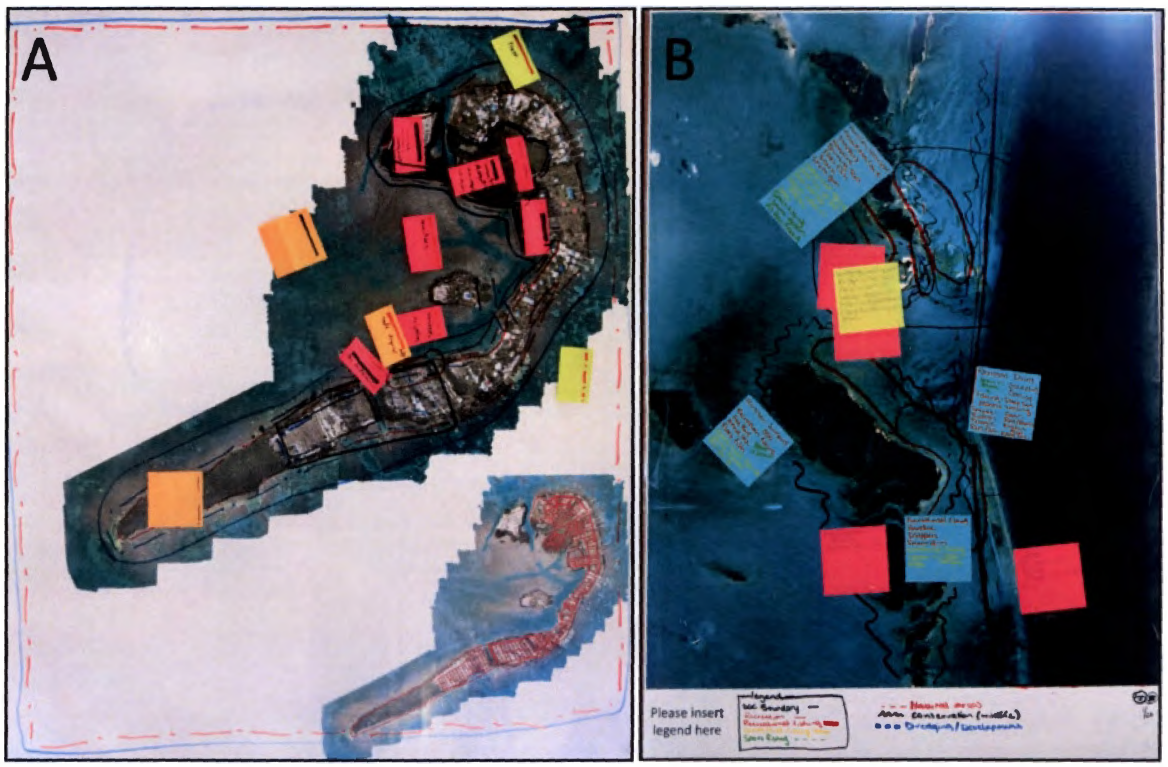


**Figure 3: Examples of hand-drawn participant contributions from the January 2018 participatory mapping focus group session. Solid and dashed, as well as different colored pen strokes denote unique threats/concerns. Different colored sticky notes correspond to an associated area's perceived risk or priority level, where high risk/priority is symbolized in bright pink, medium is symbolized in orange, and low is symbolized in bright green. Exercise 1 (A) focused on the immediate SGC area, in which the top 6 threats and concerns were mapped by each group. Exercise 2 (B) was suggested by the SGC Village council to include in mapping sessions to gain better information about participants' perceptions of a wider scale village boundary and uses, in addition to threats/concerns. Blue sticky notes were used to gather comments regarding participants' indicated use of an area.**

*Participant definitions of threat risks and priorities*

Overall, returning participants who had attended both the January and May meetings (n=14; Table 2), wrote more details regarding the different factors that constitute an area's risk for a given threat, or priority, designation than new participants (n = 18; Table 2; Tables 3A-C). Factors that contributed to an area's risk or priority designation included land ownership, purchase/development status of the land, types and

intensity of potential activities, time, potential for environmental disturbance, location, and known fishing or wildlife habitat areas (Tables 3A-C). Across all the mapped risks and priorities, similar responses were made, with participants generally more concerned if land was owned by the government, or a commercial developer than if land was owned and occupied by a residential owner. Participants also cited privately owned, but uncleared/undeveloped, land as being of medium to low concern. Participants were generally wary of high-intensity or commercial activities such as hotels, dredging, or fishing occurring near the shores of SGC, or occurring in the east-facing direction towards the reef. Participants consistently valued mangrove habitat for erosion control and the promotion of local wildlife. They also cited boating channels and areas close to shore, or development, as high priority to conserve and protect. Across all the risks and priorities, participants were highly concerned with the mangrove reserve on the southern end of the island and maintaining its protected reserve status (Tables 3A-C).

**Table 3A: Compiled participant risk definitions for development and dredging & filling threats.**

| Threat Type | | High Risk | Medium Risk | Low Risk |
|---|---|---|---|---|
| ***Development*** | **Returning participants** | – Already purchased and in speculation for development<br>– Government/commercially owned<br>– Beyond capacity of the land to sustain the type of development, unplanned<br>– Housing, hotel, etc.<br>– Historical significance<br>– Large empty parcels/properties<br>– Public marinas/gas filling stations that increase traffic on SGC | – Individually/privately owned and for sale<br>– major environmental impact | – Long time owners with history<br>– minimal environmental impact<br>– Existing or established properties including private homes or business |
| | **New participants** | – Commercial development within the next 2 years<br>– Government owned (reserve area)<br>– High story building | – Privately owned and not developed (empty lots)<br>– Rarely used or unmaintained property | – Privately owned, w/residential home |
| ***Dredging & Filling*** | **Returning participants** | – Areas close to possible development<br>– Impact on marine life (disruptive/significant)<br>– Potential for seabed/coastal erosion<br>– Significant change in water quality<br>– Areas that will be used for large-scale, commercial (resorts) developments on mangrove lots<br>– Government owned and not filled<br>– Sandy, undeveloped areas<br>– East-facing beaches – towards the reef<br>– Near animal breeding grounds<br>– Mangrove/swampy areas | – Areas already designated for dredging<br>– Insignificant impact on environmental & water quality<br>– Areas with existing lots<br>– Privately owned and not filled<br>– Close to SGC<br>– West-facing lost with waterfronts<br>– For use in building medium (1000-3000 sq. ft.) structures | – Areas already dredged/developed<br>– Areas that are not used or near development<br>– Use of the same dredge pits for refilling<br>– Privately owned and already filled<br>– Far from SGC<br>– Inland lots without waterfronts<br>– For use in building small (<1000 sq. ft) structures |
| | **New participants** | – Excessive dredging that would damage an ecosystem<br>– Without authority/approval from SGC Village Council<br>– Dredging near SGC<br>– If risk to fishing, mangroves, or causes erosion<br>– In still water, behind SGC | – Dredging that does not affect the natural ecosystem<br>– Unoccupied lots that need to fill | – No plans for dredging<br>– Dredging to maintain beachfront properties<br>– If done with proper permitting |

**Table 3B: Compiled participant risk definitions for pollution and overfishing threats.**

| Threat Type | | High Risk | Medium Risk | Low Risk |
|---|---|---|---|---|
| ***Pollution*** | **Returning participants** | – Areas close/near to village borders<br>– Already known waste disposal sites on SGC and at the sandbar<br>– High intensity (commercial/business) development with no waste management plan | – Low intensity development with waste management plan<br>– Areas with potential to become dumping sites if pre-existing sites are shut down<br>– Undeveloped residential lots | – Single family lots with waste management plan<br>– Undeveloped protected areas |
| | **New participants** | – No waste management plan that causes buildup of garbage on SGC<br>– Commercial properties<br>– Unused/overgrown properties<br>– Noise, waste-water, and garbage waste management<br>– Garbage is dumped in the ocean<br>– Garbage washes ashore | | – Disposal of waste via burning and removing non-burnables from SGC<br>– Regulated and managed waste disposal<br>– Residential/regularly used properties<br>– East-facing properties |
| ***Overfishing*** | **Returning participants** | – Already depleted or show signs of low fish stock<br>– Tourist/day cruise areas<br>– Mackerel hole<br>– Unprotected/unmanaged areas that are frequented by commercial fishermen<br>– Technology used for fishing | – Recreational fishing areas | – Unfished areas<br>– Areas too far or inaccessible to commercial fishing<br>– Subsistence fishing |
| | **New participants** | – Depleted/ing fish stocks<br>– Commercially fished areas<br>– Net fishing/drag netting close to shore<br>– Fishing undersized fish | | – Reserved/low level fishing areas |

**Table 3C: Compiled participant priority definitions for mangrove and marine wildlife conservation.**

| Priority Type | | High Priority | Medium Priority | Low Priority |
|---|---|---|---|---|
| ***Mangrove Protection & Conservation*** | **Returning participants** | – Government or commercially owned (mangrove reserve)<br>– Areas recognized as important for erosion control<br>– Known nursery areas<br>– Lots not protected under a reserve status | – Areas bordering established mangrove protected sites<br>– Privately-owned land with mangroves<br>– Privately owned land that has not been developed | – Privately owned land that is already developed and mangroves are maintained<br>– Privately owned without mangroves |
| | **New participants** | – Excessive clearing that causes erosion<br>– Reserved areas<br>– Government owned | – Trimming for aesthetics but not complete removal<br>– Managed areas under residential control | – No mangrove clearing activity<br>– Already cleared land with a property |
| ***Marine Wildlife Conservation*** | **Returning participants** | – Areas with valued diversity close to land<br>– Already depleted of biodiversity<br>– Boat channels<br>– Unprotected areas with evidence of wildlife<br>– Open, undeveloped waterfront land | – Areas near residential development with wildlife<br>– Undeveloped housing waterfront lots | – Areas developed with consideration of conservation impacts in mind<br>– Protected/reserved areas |
| | **New participants** | – Abundance of wildlife<br>– Areas at risk of being de-reserved | – Some wildlife | – Little/no wildlife presence |

*SGC-extent threat and priority maps*

Overall, participants were in broad agreement over which areas were to be designated as high risk/priority. For development at the SGC-extent, they designated all uncleared and undeveloped lands as being at high risk (join count n = 5-7), while already developed lands were at medium-low risk (n=5; Fig. 4.1, Table 4A). For dredging and filling activities, participants indicated smaller areas on and around SGC that were of high concern (n = 1-6), but ultimately settled on a 500-meter dredging buffer, within which dredging was undesired (n=11; Fig. 4.2, Table 4A). For overfishing, participants indicated the lagoon area and several small patches within which bait fishing was known to occur and indicated high levels of risk for those locations (n=5; Fig. 4.3, Table 4A). Lastly, for the threat of pollution at the SGC-extent, participants noted areas of mangrove forests that were adjacent to occupied, or purchased plots of land, as being of the highest concern (n = 3-4). Known dumping sites were of medium concern (n=3; Fig. 4.4, Table 4B).

**Table 4A: Summary of map feature data for threats at the SGC-extent shown in Figures 4.1 - 4.4.**

| Map | Type | Level | Feature | Join Count | Area ($km^2$) | Length (km) | Description/Notes |
|---|---|---|---|---|---|---|---|
| SGC-Extent: 4.1 | Threat | High | A | 7 | 0.07 | 1.1 | Little SGC – purchased and cleared but not developed |
| *Development* | | | B | 7 | 0.07 | 1.1 | Mangrove area adjacent to Fisherman Town – parceled and purchased but not cleared |
| | | | C | 5 | 0.04 | 0.78 | |
| | | | D | 5 | 0.02 | 0.58 | |
| | | | E | 7 | 0.14 | 1.7 | Plots of land north of the mangrove reserve that have been purchased and cleared but not developed |
| | | | F | 6 | 0.14 | 1.7 | Mangrove reserve |
| | | Med-Low | G | 5 | 0.07 | 1.5 | Fisherman Town |
| | | | H | 5 | 0.08 | 1.7 | Main developed and residential area of SGC |
| SGC-Extent: 4.2 | Threat | High | A | 3 | 0.41 | 2.7 | Lagoon area |
| | | | B | 3 | 0.02 | 0.66 | Mangrove edge of Little SGC |
| *Dredging & Filling* | | | C | 3 | 0.08 | 1.3 | Mangrove area adjacent to Fisherman Town – parceled and purchased but not cleared |
| | | | D | 1 | 0.03 | 0.85 | Area north of Fisherman Town – had a strong verbal consensus in October |
| | | | E | 3 | 0.02 | 0.91 | Creek between main SGC and Mangrove Reserve |
| | | | F | 6 | 0.25 | 2.6 | Mangrove Reserve |
| | | Med | G | 11 | 3.90 | 8.6 | 500-meter buffer around the entirety of SGC |
| SGC-Extent: 4.3 | Threat | High | A | 5 | 0.50 | 4.6 | Lagoon area and south-westerly shoreline of SGC |
| *Overfishing* | | | B | 5 | 0.05 | 2.1 | Bait fishing areas – concern for over-extraction |
| SGC-Extent: 4.4 | Threat | High | A | 3 | 0.44 | 2.4 | Lagoon |
| | | | B | 4 | 0.06 | 0.91 | Little SGC – purchased and cleared but not developed |
| *Pollution* | | | C | 4 | 0.15 | 1.4 | Fisherman Town & adjacent mangrove forest area (parceled and purchased but not cleared) |
| | | | D | 4 | 0.006 | 0.77 | Boundary between Fisherman Town & adjacent mangrove forest – had a strong verbal consensus in October |
| | | | E | 4 | 0.07 | 1.8 | Inner (western) shoreline adjacent to the main developed/residential SGC area |
| | | Med-Low | F | 3 | 0.002 | 0.18 | Known waste disposal site in northern Fisherman Town |
| | | | G | 3 | 0.02 | 0.52 | Known waste disposal site near the lodge |

**Table 4B: Summary of map feature data for priorities at the SGC-extent shown in Figures 4.5 - 4.6.**

| Map | Type | Level | Feature | Join Count | Area ($km^2$) | Length (km) | Description/Notes |
|---|---|---|---|---|---|---|---|
| SGC-Extent: 4.5 | Priority | High | A | 6 | 0.07 | 1.1 | Mangrove perimeter of Little SGC |
| *Mangrove Protection & Conservation* | | | B | 5 | 0.06 | 1.4 | Mangrove area adjacent to Fisherman Town – parceled and purchased but not cleared |
| | | | C | 2 | 0.009 | 0.77 | |
| | | | D | 2 | 0.004 | 0.31 | |
| | | | E | 5 | 0.04 | 3.3 | Perimeter of lots of land north of the mangrove reserve that have been purchased and cleared but not developed |
| | | | F | 12 | 0.09 | 1.6 | Mangrove reserve |
| | | Med-Low | G | 2 | 0.06 | 1.0 | Fisherman Town – had a strong verbal consensus in October |
| | | | H | 2 | 0.002 | 0.16 | Strong verbal consensus in October |
| SGC-Extent: 4.6 | Priority | High | A | 10 | 0.04 | 0.87 | Little SGC – purchased and cleared but not developed |
| *Marine Wildlife Conservation* | | | B | 11 | 0.01 | 0.91 | |
| | | | C | 4 | 0.07 | 1.6 | Area northeast of Fisherman Town |
| | | | D | 4 | 0.07 | 1.2 | Mangrove area adjacent to Fisherman Town – parceled and purchased but not cleared |
| | | | E | 4 | 0.02 | 0.60 | |
| | | | F | 9 | 0.77 | 5.6 | Lagoon area, Mangrove Reserve, and creek between Main SGC and the Mangrove Reserve |

The areas prioritized for both mangrove protection/conservation and marine wildlife conservation were very similar (Figs 4.5-4.6; Table 4B). Participants selected all known existing mangrove areas and known areas in which mangroves were being reintroduced and planted (Fig. 4.5, Table 4B) as being of high (n = 2-12) and medium priority (n=2) to conserve respectively. For marine wildlife conservation, participants chose similar areas as being of high priority (n = 4-11) to conserve, and also included the lagoon area (n=9) to account for marine wildlife, such as manatees, that utilize those habitats (Fig. 4.6; Table 4B).

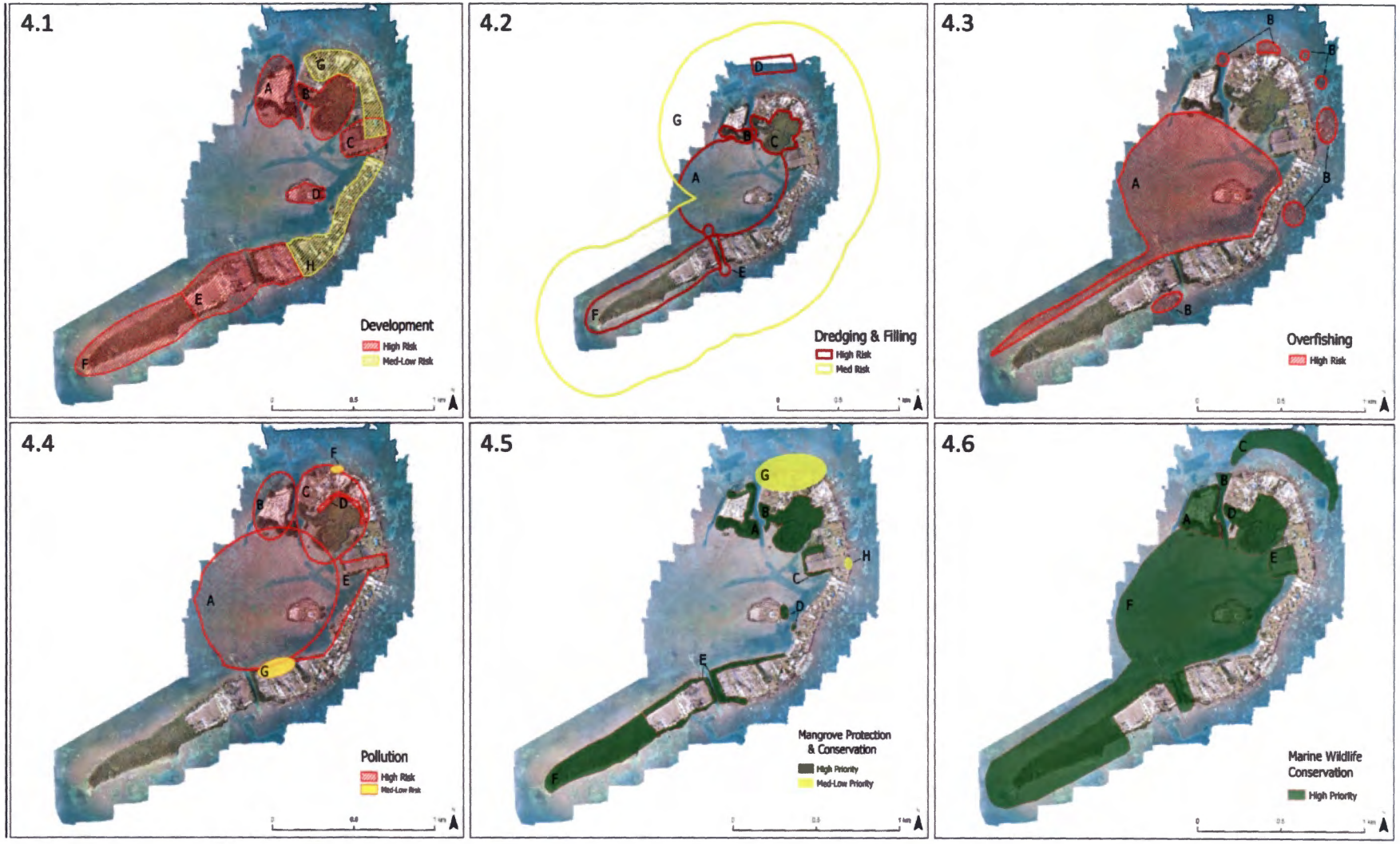


**Figure 4: Threat (4.1-4.4) and priority (4.5-4.6) maps for the SGC-extent. Letters denote different features as mapped by participants and detailed in Table 5A and 5B, respectively.**

*Greater SGC area extent: boundary, threat, priority, and use maps*

Participants were unanimously in agreement over the proposed SGC boundary area (Fig. 5). This feature had one of the highest join counts (n=15) of all mapped features across the various participatory mapping sessions. The proposed boundary area was approximately 84 $km^2$ and extended to adjacent use areas such as North Gallows, the Drowned Cayes, and the reef shelf break (Fig. 5).

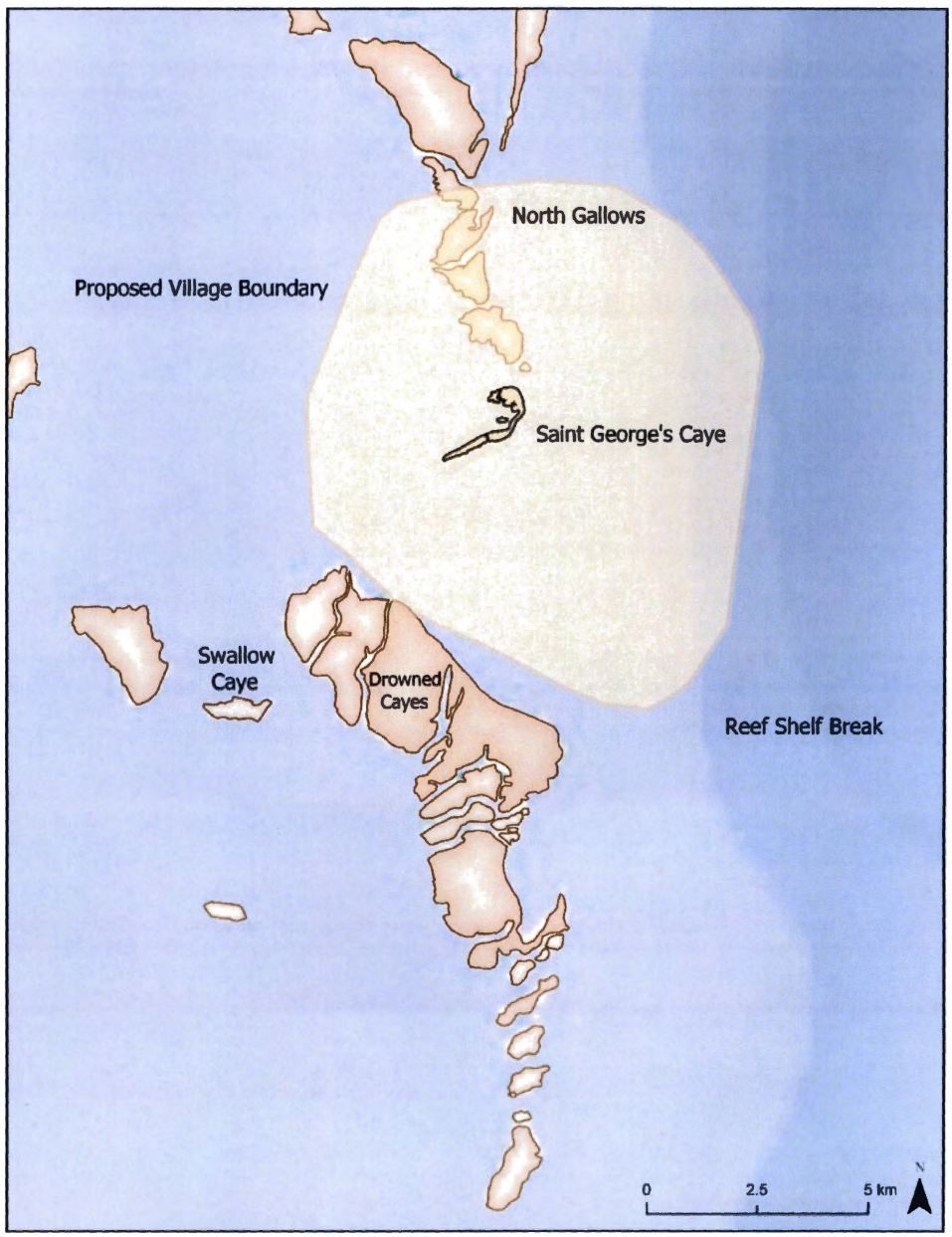


**Figure 5: Proposed Saint George's Caye Village boundary.**

For the greater SGC area extent maps, participants indicated that the Drowned Cayes to the south (n=11), the immediate SGC area (n=10), and North Gallows (n=7) were areas of highest risk for the threat of development and dredging, (Fig. 6.1; Table 5). Mapped boundaries for high density tourism (cruise ship) showed two features that extended from North Gallows to the southern Drowned Cayes (n=5) and Swallow Caye (n=2) as being at high risk for this threat (Fig. 6.2, Table 5). For habitat and mangrove conservation, participants indicated that the Drowned Cayes to the south (n=7), the immediate SGC area to North Gallows (n=6), and the eastern reef area (n=6) were the highest priority areas for conservation (Fig. 6.3, Table 5). Participants had the greatest insight regarding areas for marine wildlife conservation, of which seven final features were mapped (Fig. 6.4; Table 5). They also included the Drowned Cayes (n=4) as high priority for wildlife conservation, as well as the lagoon area near SGC (n=6; Fig. 6.4; Table 5). In addition, participants, particularly fishermen, indicated several fishing areas as being of high priority for conservation (n = 3-6; Fig. 6.4; Table 5).

**Table 5: Summary of map feature data for threats (red) and priorities (green) at the greater Saint George' s Caye-area extent shown in Figures 6.1 - 6.4.**

| Map | Type | Level | Feature | Join Count | Area ($km^2$) | Length (km) | Description/Notes |
|---|---|---|---|---|---|---|---|
| SGC-Extent: 4.5 | Priority | High | A | 6 | 0.07 | 1.1 | Mangrove perimeter of Little SGC |
| *Mangrove Protection & Conservation* | | | B | 5 | 0.06 | 1.4 | Mangrove area adjacent to Fisherman Town – parceled and purchased but not cleared |
| | | | C | 2 | 0.009 | 0.77 | |
| | | | D | 2 | 0.004 | 0.31 | |
| | | | E | 5 | 0.04 | 3.3 | Perimeter of lots of land north of the mangrove reserve that have been purchased and cleared but not developed |
| | | | F | 12 | 0.09 | 1.6 | Mangrove reserve |
| | | Med-Low | G | 2 | 0.06 | 1.0 | Fisherman Town – had a strong verbal consensus in October |
| | | | H | 2 | 0.002 | 0.16 | Strong verbal consensus in October |
| SGC-Extent: 4.6 | Priority | High | A | 10 | 0.04 | 0.87 | Little SGC – purchased and cleared but not developed |
| *Marine Wildlife Conservation* | | | B | 11 | 0.01 | 0.91 | |
| | | | C | 4 | 0.07 | 1.6 | Area northeast of Fisherman Town |
| | | | D | 4 | 0.07 | 1.2 | Mangrove area adjacent to Fisherman Town – parceled and purchased but not cleared |
| | | | E | 4 | 0.02 | 0.60 | |
| | | | F | 9 | 0.77 | 5.6 | Lagoon area, Mangrove Reserve, and creek between Main SGC and the Mangrove Reserve |

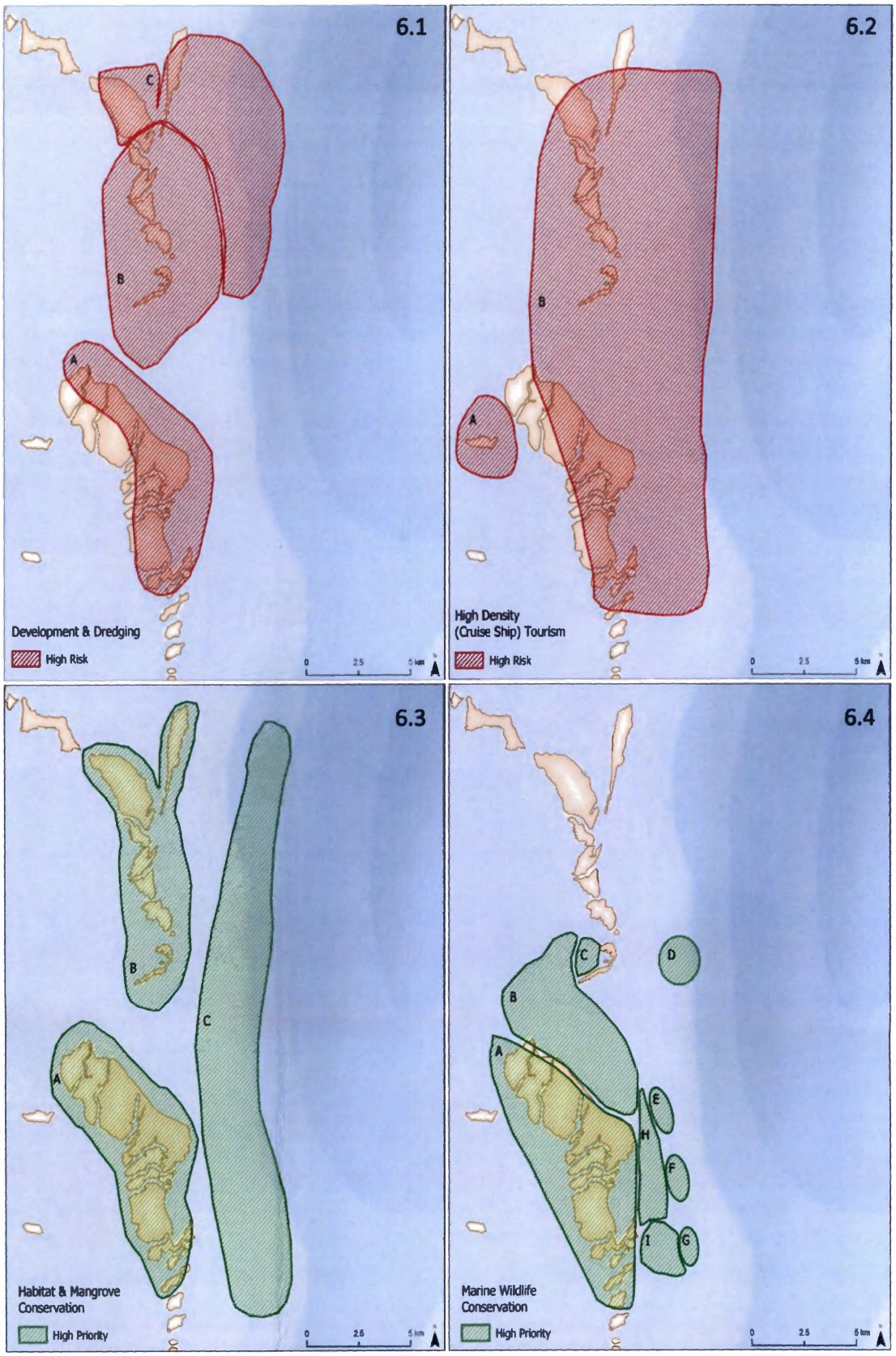


**Figure 6: Threat (6.1-6.2) and priority (6.3-6.4) maps for the greater SGC-area extent. Letters denote different features as mapped by participants and detailed in Table 5.**

For recreational use, participants selected the immediate SGC area (n = 10), North Gallows (n=14), slightly east of SGC (n=13), and the southern reef area as traditional recreational areas (n=13; Fig. 7.1; Table 6). Recreational activities included swimming, kayaking, wildlife viewing, snorkeling/diving, and barbequing (Table 6). Recreational fishing areas were in similar areas to recreational use areas and had high levels of agreement (n = 11 and 15; Fig. 7.2; Table 6). For commercial and sport fishing, levels of agreement were generally lower, as it was agreed that fishermen could most accurately speak about these areas (n = 4-5; Table 6). For commercial fishing, participants indicated areas generally south of SGC and near the Drowned Cayes as being used for lobster (n=5), mackerel (n=5), reef (n=4), and conch (n=5) fishing respectively (Fig. 7.3; Table 6). For sport fishing, participants indicated large areas that constituted almost the entirety of the provided map extent (Fig. 7.4). They indicated that areas used to catch big game fish such as billfish, mahi, wahoo, and tuna (n=6; Table 6) were located along the reef break east of SGC where the water becomes much deeper (Fig. 7.4, Feature C).

**Table 6: Summary of map feature data for recreation and recreational fishing (yellow) and commercial and sport fishing (indigo) uses at the greater SGC-area extent shown in Figures 7.1 - 7.4.**

| Map | Type | Level | Feature | Join Count | Area ($km^2$) | Length (km) | Description/Notes |
|---|---|---|---|---|---|---|---|
| Greater SGC-Area: 6.1 | Threat | High | A | 11 | 30.0 | 26.3 | Drowned Cayes – South of SGC |
| *Development & Dredging* | | | B | 10 | 38.7 | 23.8 | SGC area |
| | | | C | 7 | 39.2 | 35.1 | North Gallows |
| Greater SGC-Area: 6.2 | Threat | High | A | 2 | 6.9 | 9.6 | Swallow Caye – had strong verbal consensus in October |
| *High Density (Cruise Ship) Tourism* | | | B | 5 | 148.4 | 53.2 | |
| Greater SGC-Area: 6.3 | Priority | High | A | 7 | 37.0 | 27.5 | Drowned Cayes – South of SGC |
| *Habitat & Mangrove Conservation* | | | B | 6 | 33.7 | 33.1 | SGC area & North Gallows |
| | | | C | 6 | 60.6 | 50.1 | Reef area |
| Greater SGC-Area: 6.4 | Priority | High | A | 4 | 37.4 | 27.8 | Drowned Cayes – South of SGC; concern for manatees and crocodiles |
| *Marine Wildlife Conservation* | | | B | 4 | 21.2 | 20.8 | Concern for (lobster) overfishing |
| | | | C | 6 | 1.2 | 4.2 | SGC lagoon area |
| | | | D | 3 | 2.7 | 5.8 | Concern for (mackerel) overfishing |
| | | | E | 3 | 1.3 | 4.5 | Wildlife conservation concern |
| | | | F | 3 | 1.5 | 4.6 | Concern for (conch) overfishing |
| | | | G | 3 | 1.0 | 3.8 | Wildlife conservation concern |
| | | | H | 3 | 4.7 | 11.9 | Concern for (lobster) overfishing |
| | | | I | 3 | 3.2 | 6.8 | Concern for (lobster) overfishing |

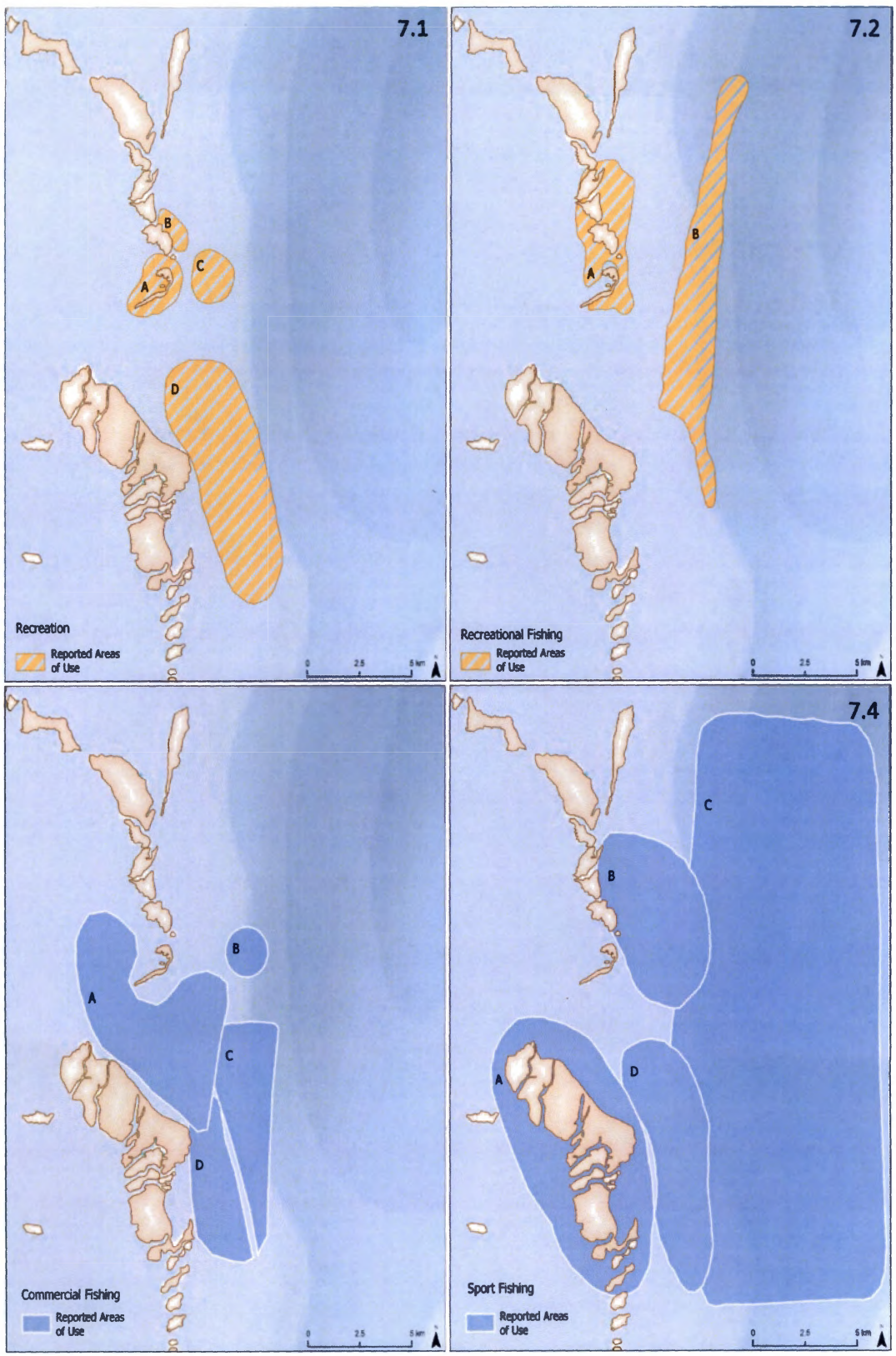


**Figure 7: Recreational (7.1), recreational fishing (7.2), commercial (7.3), and sport fishing (7.4) use maps. Letters denote different features as mapped by participants and detailed in Table 6.**

**Discussion**

This research used PGIS in focus groups to compile and report the overall perceptions of threat risks and priorities of a small island in a developing country. The overall goal of the resulting maps was to provide a foundation upon which residents in conjunction with the SGC Village Council could institute a development plan.

These maps were a direct reflection of the high level of concern and engagement among the local people of SGC. One hundred and twenty unique participants attended at least one participatory mapping focus group session between January and October 2018. Participant engagement was slightly skewed in that middle-aged Caucasian males were the dominant group in attendance (Table 2). However, women made up approximately 41% of participants, and non-Caucasian racial groups comprised nearly 55% of all participants (Table 2). Participants of Creole (African descent) were the second most represented group, followed by Mestizos (mixed Spanish and Native decent), and other (including Middle Eastern/Arab and Asian decent; Table 2). Although, non-Caucasian racial groups were in the overall majority, they should not be grouped together, due to the nuanced differences in needs and objectives held by members of the different represented racial groups. Generally, the participants in attendance reflected the diversity of opinions and voices on SGC.

Overall, participants were more concerned with development and dredging activities near and around SGC. The concerns associated with these two threats greatly influenced the remaining threats and concerns at the two mapped spatial scales. Participants regularly cited government or commercial ownership as a factor that contributed greatly to whether an area was designated as high or medium to low risk

(Table 3A-C). Participants often mentioned how government officials in the past have sold off land to private entities without the consultation or approval of the SGC Village Council. That distrust manifested prominently in the final maps, particularly for the mangrove reserve at the southern end of the island, which was classified as high risk and a priority for most of the maps at the SGC extent (Figs. 4.1-4.2 & 4.5-4.6).

Furthermore, participants also cited private ownership of undeveloped lots as medium to low risk as those lots can be sold to commercial developers for a profit (Tables 3A-C). Proximity to the SGC was another major factor that influenced the risk and priority level designations for threats such as development, dredging and filling, and pollution (Tables 3A-B). Areas closer to SGC were considered as high risk for those threats than areas further from SGC (Figs. 4.1-4.2 & 4.4). This reflected residents' strong desires to maintain the current residential way of life on SGC. Environmental concerns, such as mangrove protection, marine wildlife conservation, and overfishing, guided strongly the other threats in terms of the factors that influenced risk/priority designations and the actual areas that were mapped (Tables 3B-C; Figs. 4.3 & 4.5-4.6). This showcased residents' knowledge on how man-made activities impacted the surrounding natural components of a habitat. These concerns were further expressed in the greater SGC-extent maps in which residents selected nearby mangrove and coral reef habitats as being of high concern for conservation priority (Fig. 6.3).

Although residents articulated great concern for the natural ecosystem around them, there was great overlap between these natural habitats and residents' uses (Figs. 7.1-7.4). This was reflective of local reliance upon the surrounding natural environment for different aspects of life. It was therefore difficult to differentiate whether residents

were concerned about maintaining ecosystem integrity and local biodiversity or maintaining current use of the area.

This research provided a unique, up-close perspective on the values and involvement of residents of SGC on issues that they felt were important and warrant planning and management attention. By examining the concerns of residents in such a specific geographical location, more refined management approaches that suit the nuanced needs of an area can be created and implemented. The maps reported are a culmination of nearly 18 months of close collaboration and communication with the SGC Village Council and feedback from participants on three different occasions.

Participants chose and guided the discussion in the ways that they collectively felt were relevant. Researchers moderated to provide a general structure and framework within which participants could initiate conversations. Additionally, participants were asked for their feedback and reviewed maps on two different occasions to decide upon the final maps reported here. Therefore, these maps are the visualizations of local perceptions and attitudes in SGC as edited and revised by residents.

Although the close involvement of participants in this study was remarkable, there remains room for improvement. Future participants should be asked to provide explicit definitions and associated activities for the threats and priorities chosen. Furthermore, participants should have been instructed to provide information on how different risk and priority levels were to be assigned prior to the start of the mapping activities. This is to establish a more concrete baseline that has been collectively agreed upon and therefore better guide the mapping activities.

As the strain on natural resources increases, the need for the effective management of these resources will become imperative (McLeod *et al.* 2005). The inclusion of local peoples should be considered a baseline component of research that aims to collect information or make recommendations for the effective management of coastal environments (Thornton and Scheer 2012). Scientists should consider the intersections between local peoples and their environments to better inform management recommendations (Arkema *et al.* 2015; Verutes *et al.* 2017; Leis *et al.* 2019).

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