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Socio-economic impacts of *Sargassum* influx events on the fishery sector of Barbados

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ABSTRACT

Barbados, like other Eastern Caribbean islands, has been impacted by events of high *Sargassum* abundance, particularly in 2015. A major stakeholder group affected by these '*Sargassum* influx' events is fisherfolk. The research examined the socio-economic impacts of *Sargassum* influxes on the Barbados fishery value chain, and the corresponding coping or adaptive mechanisms developed as a result of these impacts. The ability of fish landing data to capture trends directly related to the *Sargassum* influx events between the years 2010 to 2015 was also examined.

Adaptive responses and recommendations for improved monitoring, and policy measures, for future influxes, were investigated primarily through semi-structured and informal interviews at landing sites on the east, west and south coasts of Barbados. A group interview was conducted with the Fisheries Division to discuss trends in fishery landing data and to identify a "*Sargassum* signature". Improved data management and policy measures to aid in decisions-making processes were also discussed. Key informant interviews were held with individuals from different organisations involved in the management of the *Sargassum* influx events, to discuss coping mechanisms adopted and plans for the management of future events. Focus groups were also carried out on the west, east and south coasts of Barbados. At the focus groups, *Sargassum* influx scenarios were presented to persons with different livelihoods along the value chain so that stakeholders' adaptive capacities and resilience to issues caused by an influx could be reported on in the context of plausible alternative futures.

The study found that the harvest sector was the most impacted, with differences in impacts among the different coasts and landing sites. In the post-harvest sector, vendors, scalers and boners were more socio-economically impacted, particularly those employed directly in the flyingfish fishery, than seafood processors, restaurants and the consuming public. The entire fishery sector has employed mainly coping mechanisms, dealing with issues day to day, rather than adopting long-term adaptive mechanisms. There was no comprehensive fisheries policy to deal with *Sargassum* influx events or other climate-related events, but plans for such policy were being considered. Combined, the prevalence of short-term industry coping strategies and the absence of longer-term official fisheries policy serve to maintain a higher level of vulnerability to *Sargassum* influxes than may be desirable.

Key words: Barbados, fishery, impact, *Sargassum*, socio-economic, resilience, adaptive capacity

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Contents

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1 INTRODUCTION

The colossal influxes of *Sargassum* are new phenomena occurring in Eastern Caribbean islands, and elsewhere in the Wider Caribbean, with many marine scientists, and governments being caught off guard. Although there is still much unknown about the *Sargassum* events or influxes, more research is being initiated, mostly focussed on the origin and cause of the events, aimed at prediction and tracking. Some scientists and entrepreneurs are also looking towards potential uses and benefits of the seaweed to Caribbean economies. The *Sargassum* events occurring in 2011, 2014 and continuing in 2015 have attracted a lot of attention due to their impacts off-shore and on-shore, and because of the many uncertainties. The impacts of these events are primarily ecological, economic, and social; the extents of which still need to be assessed and better understood.

In this study, the impacts of *Sargassum* on key stakeholders of coastal and marine resources in Barbados, primarily fisherfolk, were examined from a socio-economic angle. The impacts on the various aspects of the fisheries value chain, and the ability to respond to the *Sargassum* events, were investigated. The remainder of the introduction gives a brief overview of the fishery sector of Barbados, the scope of the research, the research aim and objectives, its significance, and the structure of the paper.

1.1 Overview of Barbados fishery sector

The fishery sector in Barbados plays an important economic and social role, adding to the generation of foreign revenue, and food security of the island. The industry employs approximately 6000 persons, through the fishery value chain, and contributes approximately US $14.6 million, around 0.3%, to national Gross Domestic Product (GDP) annually (Fisheries Division 2004). Additional value of ex-vessel fish, as it moves through the fishery chain, was valued at US$ 19 million (Mahon et al. 2007). The industry employs not just fishers, but persons in processing, retailing, wholesaling, exporting, and distributing of seafood. The industry also supports associated businesses such as boat repair and boat building.

Barbadian fisheries comprise flyingfish, coastal pelagics, large pelagics, shallow-shelf reef, deep slope and bank species, lobster, conch, and the now more strictly regulated sea urchin (Fisheries Division 2004). Fishing gears employed are predominantly nets, several different hook and line techniques, and traps. Diving is also practiced for reef and benthic species. Boat types include moses (3-6m), day boats (6-12m), iceboats (>12m), and longliners (>12m) (Fisheries Division 2009). These boats use 30 landing sites around Barbados. Of the 30 sites, eight are primary landing sites, meaning that they are physical fish markets. There are six secondary sites, where fishers operate out of sheds, and the rest, tertiary sites, where fishers operate from beaches without physical infrastructure (Franklin 2012).

The fishing industry can be divided into the harvest and post-harvest sectors. Fishers and boat owners dominate the harvest sector stakeholder groups. Among the many stakeholder groups in the post-harvest sector, vendors/hawkers and boners dominate. Other groups in the sector include skinners, processors, restaurants, exporters, and regular customers (Fisheries Division 2004).

1.2 Research aim and objectives

The principal aim of the study was to analyse the adaptive capacity and resilience of the fishery sector of Barbados to socioeconomic impacts of *Sargassum*, and provide recommendations for management of the fishery sector for future events. The specific objectives of the research are:

1. To identify the socio-economic impacts of *Sargassum* on the fishing industry of Barbados, examining the entire fisheries value chain using an ecosystem-based approach, taking climate change and climate variability into account.
2. To investigate actual and potential response mechanisms of the fisheries value chain, and recommend climate-smart action for reducing the negative impacts, inclusive of potential uses and possible policy solutions.
3. To examine official fish landing statistics to determine the extent to which they capture information on *Sargassum* events that affect Barbados, and make recommendations for improving monitoring through fishery management planning.

1.3 Significance of study

Although the contribution of the fishery sector to the GDP of Barbados is relatively low, the sector provides employment for a large number of persons, and has significant social and cultural value. Investigating the socio-economic impacts of the *Sargassum* on the fishery sector was important to ascertain the extent to which the sector was affected, and its resilience to such environmental events. The information collated can then be used for more informed decision-making processes and policy responses by relevant agencies, not just in Barbados, but also in other Caribbean islands. This new research will contribute to the body of knowledge on the *Sargassum* phenomenon, and can be used as the basis for further study.

1.4 Organisation of paper

The paper hereafter summarises the information currently known about the *Sargassum* influx events, ongoing research, and outlines the analytical framework in Section 2. Section 3 details the methodology, from data collection through to data analysis. The presentation of results for each of the objectives and discussion follows in Section 4. Section 5 synthesises the findings of the study using the analytical framework, with the conclusion and recommendations in Section 6. A list of references and the appendices are also in Sections 7 and 8, respectively.

2 LITERATURE REVIEW

2.1 Basic biology, distribution and ecology of pelagic *Sargassum* seaweed

2.1.1 Basic biology

Sargassum is a genus of brown algae or Phaeophyceae, with a large number of species. *Sargassum* species are usually dark brown or golden green in colour. The seaweed is tough and fibrous in nature allowing it to withstand strong ocean currents. Most species of *Sargassum* are attached to the seafloor by a holdfast, and are particularly known for carrying berries or air

bladders, called pneumatocysts (NOAA 2014). The pneumatocysts give buoyancy to branches, allowing them to be suspended, and maximising photosynthetic processes.

There are, however, two species (the subjects of this study), *Sargassum natans* (common Gulfweed) and *S. fluitans* (broad-toothed Gulfweed), that are never attached to the seafloor. They are considered holopelagic species, that is, they thrive floating at the ocean surface for their entire life cycle. These species propagate or reproduce asexually, by fragmentation (Franks et al. 2011). This means that they can grow from broken pieces of the algae. In the open ocean, they can form large "islands" or "mats" of seaweed under calm onditions, but usually form rows of seaweed parallel to the prevailing wind direction, and are carried by sea surface currents (Franks et al. 2011).

Although both species are difficult to differentiate when they are located in large mats off-shore or piled on beaches, there are distinctive characteristics in their appearance. The *S. fluitans* has shorter stems, and broader leaves, whereas the *S. natans* is longer-stemmed, with finer leaves. The *S. natans* also has spikey, small leaves on their pods, unlike *S. fluitans* (Boyd 2013).

Figure 1. *Sargassum* collected at Consett Bay, on the east coast of Barbados in 2014. Photo taken by R. Maclean

2.1.2 Distribution

The two species of pelagic *Sargassum*, *S. natans* and *S. fluitans* are well known from the warm temperate and subtropical areas of the North Atlantic and are generally accepted as endemic to the Atlantic Ocean. However, there are reports suggesting a much wider global distribution (see Széchy et al. 2012) although these are likely misidentifications (J. Franks, pers. comm.).

From hereon we refer to these two species simply as '*Sargassum*'. *Sargassum* has always been present along the shorelines of Caribbean countries, in negligible amounts and washes ashore seasonally in small to large amounts along the Gulf Coast and SE Coast of the USA including the Florida Keys (Abbott and Dawson 1978, Webster and Linton 2013). The seaweed is commonly known as "Gulfweed", named after the Gulf of Mexico (GOM) where it is commonly found (Kaak 2015). However, it is most well known from an area located within the North Atlantic Subtropical Gyre system named after the presense of the weed as the Sargasso Sea. The Sargasso Sea contains a consolidation of floating material comprising *Sargassum*, garbage and other flotsam held in place by the clockwise movement of key ocean currents (Figure 2). This can result in dense accumulations of the floating *Sargassum* seaweed in the form of mats, windrows or scattered plants. The Canary Current runs to the east of the Sargasso Sea, the Gulf Stream on the west, the North Atlantic Drift to the north, and the North Equatorial Current and the Antilles Current bound the south (Laffoley et al. 2011).

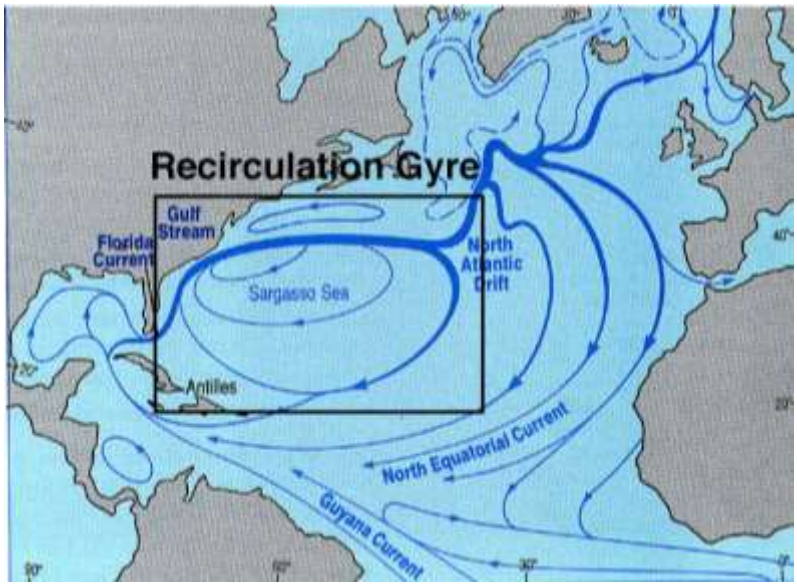

Figure 2. Map showing the Sargasso Sea at the centre of the North Atlantic Ocean gyre. Source: http://listofmaps.com/gulf-of-mexico-gulf-stream-map/

Gower and King (2011) were able to demonstrate a seasonal movement of pelagic *Sargassum* from the GOM to the Sargasso Sea using satellite imagery (Figure 3). It appears that the normal seasonal pattern of movement is for *Sargassum* to grow and expand in the GOM loop current in late spring / early summer after which it is released into the Gulf Stream and travels into the North Altantic during the summer months, ultimately becoming entrained in the Atlantic gyre (Sargasso Sea) through the fall and winter months (Figure 3). More recent studies by Frazier (2014) and Hill et al. (2016) have further elaborated on the return of at least some *Sargassum* southwards via several major passages in the Greater Antilles where it becomes entrained by the westward flowing Caribbean Current and taken back into the GOM through the Yucatan Straits. They coined the term '*Sargassum* Loop' to describe this complete cycle.

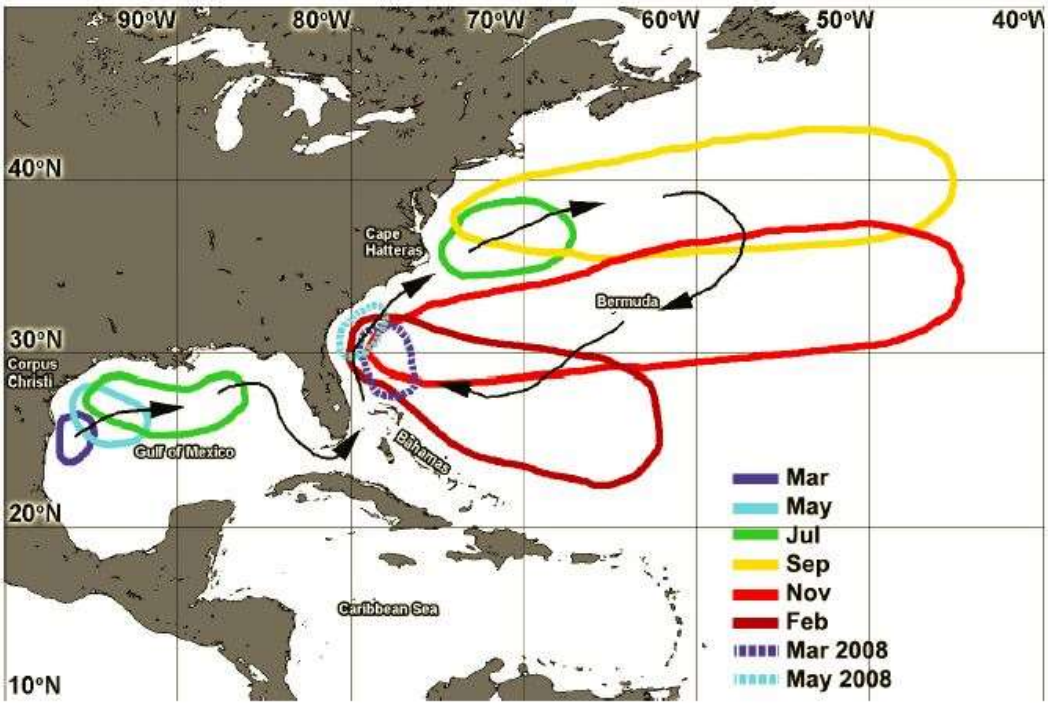

Figure 3. Map showing monthly extent of *Sargassum* for the years 2002 to 2008 as detected by satellite imagery from the European Space Agency (ESA) Medium Resolution Imaging Spectrometer (MERIS) optical sensor. Source: Gower and King (2011).

2.1.3 Ecological role

Pelagic *Sargassum* plays an important ecological role in the open ocean, providing foraging areas for seabirds (Trott et al. 2011), some even being identified as "*Sargassum* specialists" (Moser and Lee 2012), and supporting a multitude of species including crabs, shrimps and other invertebrates (Rooker, Turner and Holt 2006). It is also a critical habitat for many fish and marine turtles at different developmental stages, and supports a number of endemic species that are found only in floating *Sargassum*, including the emblematic *Sargassum* angler fish (*Histrio histrio*) and *Sargassum* crab (*Planes minutes*).

Studies have indicated that there are at least 100 fish species, four species of marine turtles (Coston-Clements et al. 1991), and 145 marine invertebrates (Trott et al. 2011), that associate with *Sargassum.* Studies also suggest that commercially important species such as dolphinfish, tunas, wahoo and billfishes use *Sargassum* in juvenile stages (Comyns et al. 2002).

2.2 Impacts of Sargassum influx events in Barbados and the Caribbean

The 2014 *Sargassum* influx event has continued into 2015, with large blankets of the seaweed covering the east and southeast coasts of Barbados. Fishers have been reporting a decrease in catch which they associate with the *Sargassum,* and the tourism industry is also feeling the effects of inaccessible bathing beaches and unpleasant odours (CAST 2015, Nation News 2015). *Sargassum* invasions first occurred in 2011, but the quantity of seaweed has increased drastically

in the last two events, 2014 (NCC 2014) and continuing in 2015. This also occurred on other Caribbean islands such as Trinidad and Tobago, Antigua and Barbuda, Grenada and St Lucia (Alemu I 2014).

Although it has not been determined if the stranded *Sargassum* has any major health impacts, the production of foul smelling hydrogen sulphide gas by rotting *Sargassum* along the shorelines is of some concern and has been reported to cause disturbed sleep, nausea, eye irritations, headaches, and may adversely affect persons with asthma (Doyle and Franks 2015). The large quantities of *Sargassum* have caused a number of problems in both the fishery and tourism sectors of Barbados (Nation News 2015). For fisheries, it has been reported to tangle in fishing nets, leading to gear damage, and a disruption of day-to-day activities of fishers due to limited access to boats. The large quantities of *Sargassum* are also believed to smother coral reefs and mangroves. Recreational beach users are often encumbered by the seaweed suspended in the nearshore, and the smell of the rotting seaweed along the beach (Franks et al. 2011).

Two of the main fishery species in Barbados, flyingfish and dolphinfish are said, by fishers, to be affected by the large quantities of *Sargassum* in the waters around Barbados. Flyingfish are known to spawn on the *Sargassum* mats (Trott et al. 2011), however, fishers have repeatedly reportedg decreased catches (Nation News 2015) and the event in 2011 saw a large reduction in fishing effort (Madden 2011). *Sargassum* is also known to host assemblages of young female dolphinfish (Perez and Roman 2005). Reports have indicated that there are smaller sized dolphinfish caught in *Sargassum* event years, than other years. In a study done by Farella et al. (2013) it was indicated that this may be true, as dolphinfish associated with *Sargassum* were smaller. However, the correlation between smaller sized fish and landings in years of *Sargassum* events, has not been properly documented.

2.3 Current research on *Sargassum* events and a "new" source

The movement of *Sargassum* into the Caribbean in 2011 (termed here the '2011 influx event') was initially examined by back-tracking from the landing sites using the Inter-American Seas Nowcast/Forecast System (IASNFS) archived surface current data derived from satellite monitoring of sea surface height (SSH). This research indicated that there was movement of seaweed from the South American coast up towards the Eastern Caribbean, pushed by the north Brazil Current, the Guiana Current and eventually the Caribbean Current and Antilles Current, and that there was no direct connection between the Sargasso Sea and this event (Franks et al. 2011).This study was expanded in the following year, using satellite tracked mixed-layer drifter data and the HYCOM current model to backtrack the movement of *Sargassum* making landfall in the Caribbean and the west coast of Africa. This provided strong evidence of a new area of consolidation and release of *Sargassum* in the North Equatorial Recirculation Region (NERR) (Johnson et al. 2013). The NERR, being an area of recirculation (via the North Equatorial Current and the North Equatorial Counter-current, see Figure 4), with high input of nutrients from major rivers including the Amazon (west side) and Congo (east side) and increasing sea surface temperatures, provides ideal conditions for the growth and consolidation of the *Sargassum*, and subsequent release and transport to the Caribbean. This finding was further supported by direct visualisation of high densities of *Sargassum* in the NERR in 2010 for the

first time, using novel processing of satellite images going back as far as 2003 (Gower, Young and King 2013).

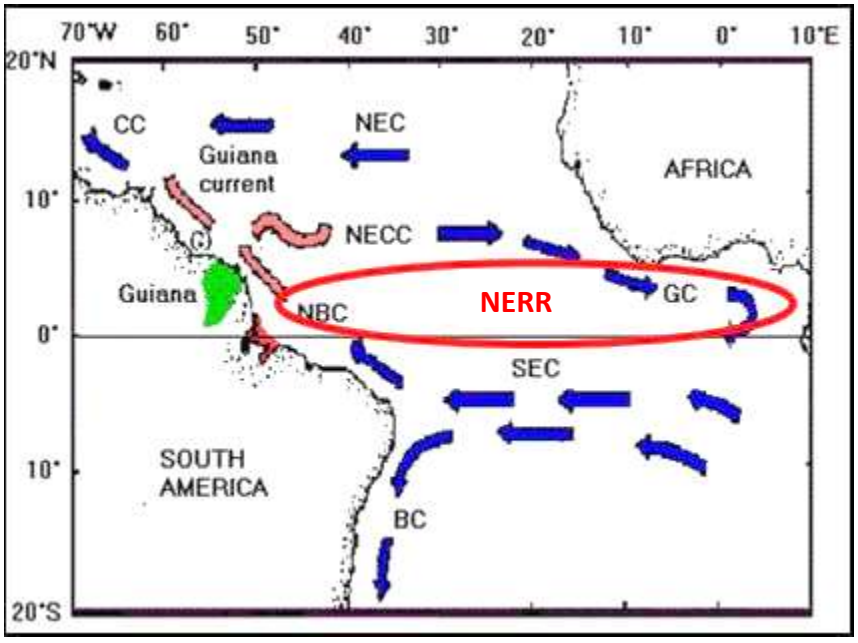

Figure 4. Diagram of the main sea surface currents contributing to the North Equatorial Recirculation Region (NERR, indicated by the red elipse). The pink arrows indicate currents that show significant seasonal and annual variation which can retain or relesae surface water from the NERR. NEC – North Equatorial Current; NECC – North Equatorial Counter Current; GC – Guinea Current; SEC – South Equatorial Current; NBC – North Brazil Current and CC – Caribbean Current. Adapted from Franks, Johnson and Ko (2015).

Although the periodic mass influxes of pelagic sargassum is a fairly new phenomenon to the Caribbean region and research on potential uses of these pelagic *Sargassum* species is only just beginning in this region, there have been numerous studies done in other regions and/or on other similar species of the same genus, *Sargassum* (see Appendix 1 for examples). These range from use of the seaweed in agriculture (mulch, plant tonic, fertilizer, animal feed), in consolidation of beach sand and building of sand dunes, in the production of bio-energy, to extraction of chemicals for use in the production of pharmaceuticals, nutraceuticals and personal care products.

The potential uses of the *Sargassum* as a raw material for new products has been a topic of much discussion in Barbados. In this study, the role of fisherfolk and the creation of additional income, for persons within the fishery sector, from the *Sargassum* was explored.

2.4 Analytical framework of study

The analysis of data gathered for this study was done using conceptual frameworks associated with the complexity theory and resilience thinking. The intent was to apply these concepts; socio-ecological systems, resiliency, absorptive capacity, adaptive capacity, transformative

capacity, and other associated ideas, to the experiences of the fishery value chain. The objectives of the study were to determine the socio-economic impacts of *Sargassum* on the fishing industry, just one of the major stakeholder groups affected by the *Sargassum* influxes, and its ability to cope with these impacts.

We started with the hypothesis that 'Every actor within the fishery value chain was not impacted the same, and each group differs in their capacity to cope short-term, and adapt long-term, to the changing environment brought about by the presence of the *Sargassum* influxes'. Based on this assumption the analytical framework was used to explore these distinctions, and show the relationships between the groups and the environment in which they function, as well as their relationship to each other within the context of the fishery value chain, and the *Sargassum* events.

2.4.1 Social- ecological systems

Social-ecological system (SES) describes the interdependent relationship between humans and ecosystems, that is, humans acting within or as a part of ecosystems, and the feedback generated by these interactions (Folke et al. 2010). SESs show characteristics of nonlinearity or non-uniformity; exist within thresholds, and exhibit varying degrees of integration, connectivity, and complexity (Folke et al. 2002). The fishing industry in Barbados was viewed as an SES with integration among various actors in the fishery value chain (Figure 5), operating within, and dependent on ecosystems, primarily the coastal and marine environment of Barbados.

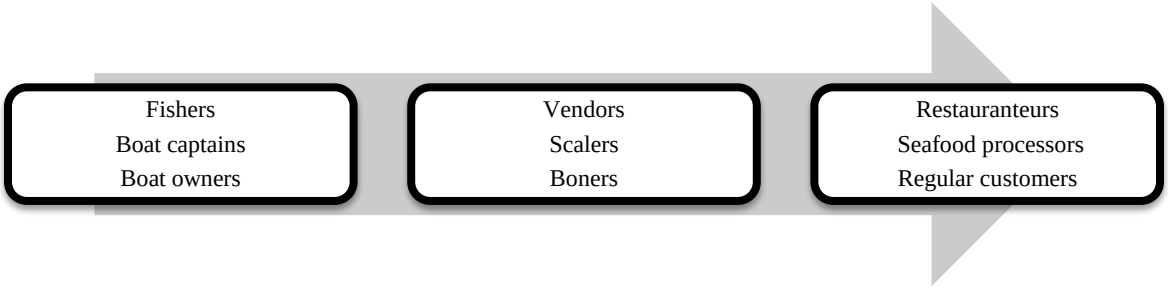

Figure 5. A simplified fishery value chain showing the main stakeholder groups involved in resource extraction and subsequent transfer of resources to other groups.

Resilience thinking, introduced by Folke et al. (2010) establishes that an SES is comprised of multiple domains. Each domain occurs in a stable state, which is regulated by controlled variables. These domains also function within thresholds. Collectively the domains make up a landscape, also existing in a state of stability (Folke et al. 2010). In this analysis, the fishery sector was comparable to the stability landscape, and the domains analogous to the space in which actors operate. The domains, and by extension the landscape, undergo gradual, continuous change over time, as the system evolves in response to environmental changes (Folke et al. 2010). Therefore, the fishery sector changed as the environment in which it functioned in, constantly, and slowly, changed.

According to Folke et al. (2010) thresholds are the limits of the controlled variables. When these variables go beyond the threshold limits, it causes the system to reorganize and redirect from its

usual path. This change in path from the slower state, at which the SES normally operates, occurs when variables are skewed spontaneously due to an external shock. Shocks or perturbations change the state of the domains and the landscape; creating a regime shift. In this scenario, the shocks or perturbations, which created change in the domain of the fishery sector are the *Sargassum* events. Changed domain variables, for instance, were the presence of thick mats of *Sargassum* off-shore, or mounds of *Sargassum* on-shore; where there was once little to no presence of the seaweed.

2.4.2 Resilience, absorptive capacity, adaptive capacity, and transformative capacity

The definition of resilience is constantly evolving as new ideas and concepts emerge. For this analysis, resilience is taken to be the ability of an SES to absorb an environmental shock or disturbance, while retaining essential characteristics; the capacity of the SES to self-organise; and the ability of the system to facilitate learning, adaptation, and capacity building (Folke et al. 2002). In the context of SES, resilience is seen as the result of learning, creativity and innovation, that is, its adaptive capacity. This influences the type of management systems in the SES, moving from one that attempts to control and retain the previous stability landscape, to one that allows the system to adapt, learn and reorganize (Folke 2006). Adaptive capacity is the ability to create resilience within an SES (Folke et al. 2010). According to Armitage (2005) there are four dimensions by which adaptive capacity can be analysed, as seen in Figure 6.

These dimensions were adapted to the SES framework, and the core concepts utilised in the analysis. The ideas of learning in the face of an ever-changing environment; using past experiences to generate innovation within the sector; using the knowledge of the various stakeholders; and recognising opportunities for growth, were applied to the relatively unpredictable *Sargassum* influx events.

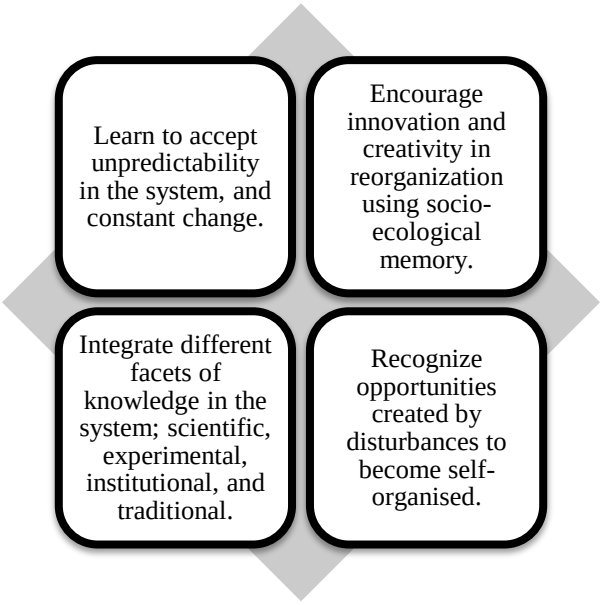

Figure 6. The four attributes for analysing the adaptability of the actors in an SES as outlined by Armitage (2005).

There are three components to resilience as it relates to capacity (OECD 2014), which were used to determine the capacity of livelihoods in the fishery sector, as a result of the events. These components are:

- *Absorptive capacity*: which refers to the capacity of a domain or landscape to organise and reduce the negative impacts of a shock or perturbation, by adopting already established response mechanisms, to retain the natural state of the domain.

- *Adaptive capacity:* which refers to the changes made in the domain or landscape to prepare and anticipate future negative impacts caused by a shock or perturbation, and to use opportunities to create positive outcomes, to ensure that there is no drastic changes in the natural state.

- *Transformative capacity*: which refers to the creation of a new domain state so that it becomes unaffected by the shock or perturbation. The creation of a new domain may entail changing biological, physical, economic, social or political characteristics of the system (OECD 2014).

Figure 7 suggests that all three types of capacity can occur simultaneously, and that resilience can develop on account of all three. Each of these types of capacities then leads to diverse effects. Absorptive capacity leads to persistence; adaptive capacity leads to incremental adjustment, and transformative capacity leads to transformational responses (Béné, et al. 2012), as eluded to the in the definitions.

Figure 7. The three types of capacities; absorptive, adaptive and transformative that can lead to resilience (Béné, et al. 2012).

2.4.3 Resilience Framework

In this study, the socio-economic impacts of the *Sargassum* influx events were identified and examined as environmental phenomena, that affect the life of stakeholders in the fishery value chain in different ways. Environmental disruptions are said to affect different attributes of the groups involved in an SES. This is regarded as alterations in capital (Resilience Alliance 2007; 2010); perturbations or environmental disruptions affect the natural, financial, built, human, and social capital of stakeholders (Resilience Alliance 2007). This analysis also underlines the

interrelatedness among the various types of capital available to a stakeholder; and the snowball effect that a loss of capital, be it economic, social or otherwise, has on other actors within the domain; landscape; SES. The SES in this scenario was the fishery sector, and by extension the Barbadian public.

Impacts caused by the *Sargassum* events were categorised following Resilience Alliance (2007) as biological, economic, physical, social or policy. In this research, emphasis was placed on the social and economic impacts, however, it is noted that biological, physical and policy impacts, all contribute, precede, or add to these. The fishery value chain response to these impacts and overall adaptation to events was examined using a resiliency framework.

Figure 8 shows the steps involved in a resilience assessment framework, that were applied to the study. As the diagram illustrates this preliminary assessment identified the environmental shock or perturbation; described the changes to the system; identified the interactions involved at each scale; identified the role of the governmental institutions and networks; and made recommendations for addressing the impacts, at each scale. This analysis ties into the concepts mentioned previously of absorptive, adaptive and transformative capacity, and assessing the fishery sector of Barbados as an SES. This analysis assisted in the understanding of the impacts, the complexity of the system, and the changes in interactions created by the *Sargassum* influx, and ultimately generated recommendations for action and further study.

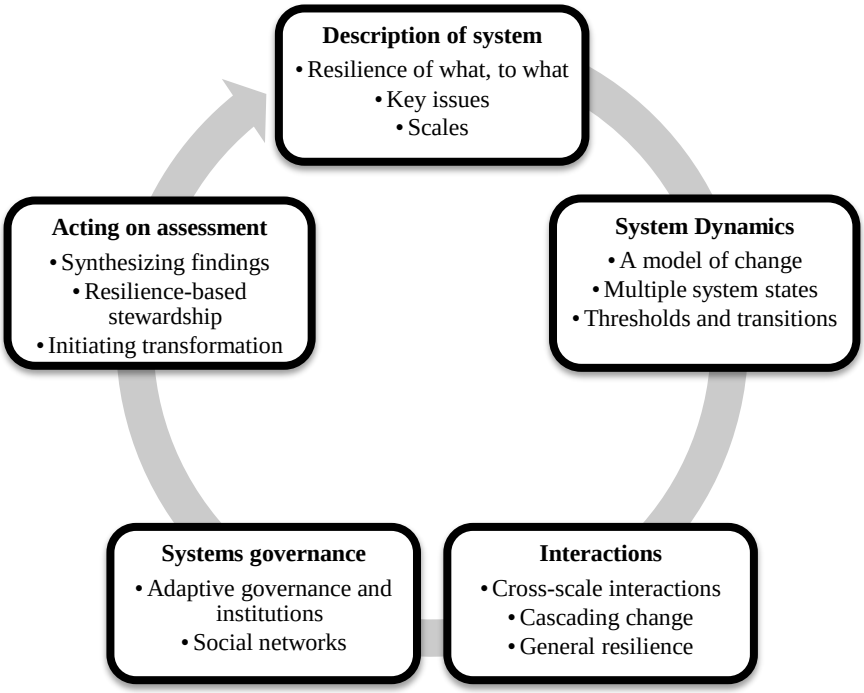

Figure 8. An illustration of the five stages of the resilience assessment framework. Adapted from Resilience Alliance (2010).

3 METHODOLOGY

3.1 Data Collection

Several qualitative methods were used in collecting data for this study. These were loosely based on methods used in socio-economic monitoring or SocMon (Bunce et al. 2000). This was done in an effort to maximise the quality and depth of information gathered in the limited data collection period: July to mid-September 2015. Different methods were used for different stakeholder groups in the fishery value chain of Barbados. The groups were fisherfolk (fishers, boat captains, boat owners, vendors, scalers, and boners), seafood processors, restaurant owners, and other organisations involved in the management of, or being affected by, the influx of *Sargassum.* Each method is explained further in the following subsections.

3.1.1 Key informant interviews

Key informant (KI) interviews (Bunce and Pomeroy 2003) were carried out with two governmental, and three non-governmental organisations involved in the management of the *Sargassum* influxes. These interviews were based on the impacts reported by each organisation, and the impacts on the organisation; how the organisations were responding, and their role in the management of the issue, and their plans for management of future events. Interviews were conducted with the Coastal Zone Management Unit (CZMU), the National Conservation Commission (NCC), Barbados National Union of Fisherfolk Organizations (BARNUFO), Barbados Game Fishing Association (BGFA), and the Caribbean Youth Environmental Network (CYEN) Barbados Chapter. These were conducted at the offices of the interviewees, at times convenient to them.

3.1.2 Landing site visits and interviews

Semi-structured and unstructured (informal) interviews (Bunce et al. 2000) were conducted at 13 fish landing sites on the east, west and south coasts of Barbados (Figure 9). Most interviews were semi-structured, guided by the following questions:

1. What are the differences between *Sargassum* events occurring in 2011, 2014 and 2015 (nature, intensity, impacts)?

2. What are the impacts (socio-economic and otherwise) of the events on you / your organisation?

3. How have you coped with or adapted to these impacts?

4. Can you make any recommendations for dealing with the issue, with respect to everyday practical measures, policy and management measures, and necessary research; in the event that the *Sargassum* stays?

5. Do you see *Sargassum* as a natural resource that can be potentially used by stakeholders to help mitigate income lost due to impacts of the seaweed?

These landing site visits targeted mainly boat owners, boat captains, crew, vendors, scalers, and boners. Forty-four persons participated in these interviews. The visits were conducted at various times to avoid peak activity hours of the landing site, or times when boats were coming in from a fishing trip. Interviews were conducted on evenings on the west coast, mornings to midday on the east coast, and afternoon to evenings on the south. Interviews at Pile Bay were conducted early Sunday mornings. An attempt was made to visit landing sites on multiple occasions, at similar times, to develop a working relationship with stakeholders. The "GCFI *Sargassum* Factsheet" (Doyle and Franks 2015) was distributed to interviewees, as a source of information (Appendix 2). The information gathered during landing site visits guided further data collection, and assisted in the planning and execution of the focus groups.

A map showing the location of all the landing sites present around the coasts of Barbados (Figure 9) was used to determine the landing sites where data collection would take place. Sites were chosen based on coast, reports of *Sargassum* present, level of activity, and by recommendations of Fisheries Division (FD) staff. Sites where data collection was conducted are indicated on the map.

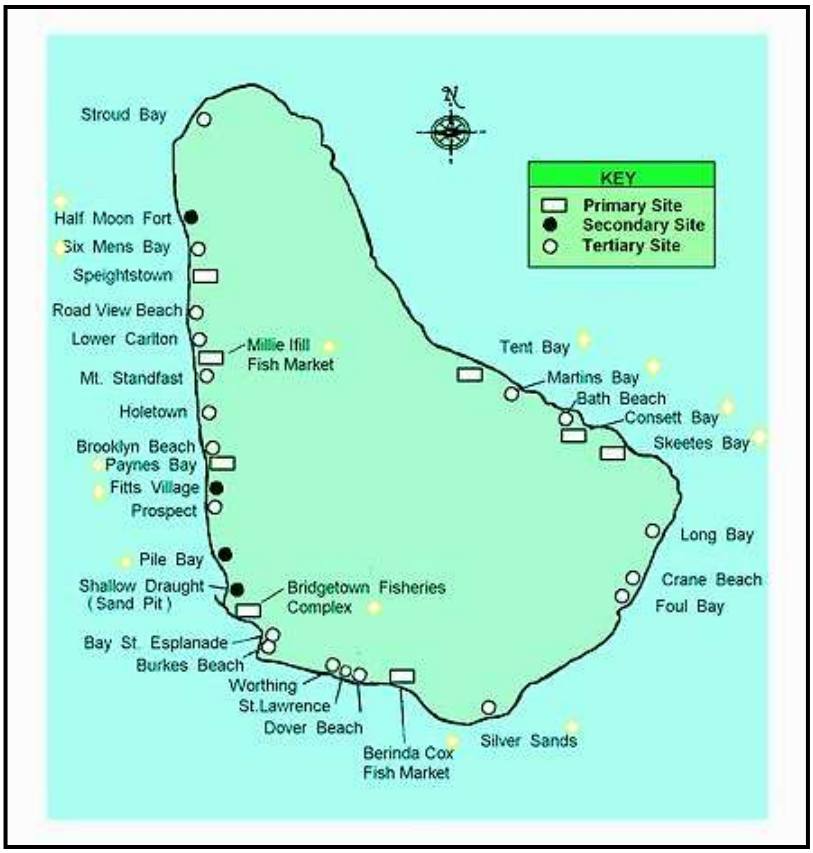

Figure 9. Map of primary, secondary and tertiary landed sites recognised by the Fisheries Division of Barbados (Franklin 2012). The yellow diamonds identify the 13 sites visited during the study.

3.1.3 Semi-structured interviews not at landing sites

The semi-structured interviews (Bunce et al. 2000), using the guiding questions as listed in Section 3.1.1, captured information from other actors in the fishery value chain that were not targeted with the landing site visits. Interviewees included recreational fishers (n=3), charter boat fishers (n=3), seafood processors (n=2), and restauranteurs (n=7). A total of 15 persons participated in these interviews. These were conducted at times convenient to interviewees, in person, or via telephone or email. Interviews conducted in person were the most effective of the three. Telephone interviews were not conducive to discussion, and in some instances there was no response to follow-up calls or emails. Interaction face-to-face allowed for more discussion than the other methods.

3.1.4 Group interview

A group interview was held, in the format of a half-day workshop, to review and discuss trends in fishery landing data. The landing data were provided by the fisheries biologist at the FD, with whom data trends were identified and examined in a previous meeting. The group interview was structured around seven objectives, listed below, aimed at soliciting expert opinion on the trends identified, and overall data collection and management processes at the FD. This was necessary to examine the ability of reported fisheries catch data to capture crucial information for *Sargassum* influx events, essential to making sound management decisions. The group interview guiding questions were as follows:

1. What trends can be identified in the reported fisheries catch data for the years 2010-2015, and can a "*Sargassum* signature" be identified?

2. What policy and decision-making process for fisheries management demands data, and how are such data collected?

3. What section(s) in the Draft Strategic Action Plan for the Fisheries Sector addresses *Sargassum* events?

4. What *Sargassum* related decisions would have to be made by the Fisheries Division (as it relates to adaptation), and what data would be required for this decision-making process?

5. What are the issues, if any, with the data collection, and data management systems currently in place?

6. What recommendations are there for improving data collection, data quality, and data management systems, for decision-making processes?

7. What recommendations do you have for improving the adaptive capacity of the Division to *Sargassum* events socio-economically, ecologically, physically, and how can the adaptive capacity and resilience of the fishery value chain be improved?

There were six participants, four of whom were from the Fisheries Division, one representative from Markets Division, and one from the Centre for Resource Management and Environmental Studies (CERMES), University of the West Indies.

3.1.5 Focus groups

Focus group meetings were held towards the end of the data collection process. The information collected from the other exercises was used to tailor the objectives and activities of the focus groups. There were three meetings held: on the west coast at Millie Ifil Fish Market (Weston), on the east coast at Consett Bay, and on the south coast at the Berinda Cox Fish Market (Oistins), respectively. These sites were chosen because of accessibility, facilities available and their central location on each coastline. Meetings were held on evenings, at 5:00 p.m. as this was suggested to be the time most likely to have a higher turnout.

The intention of the focus group meetings was to bring together the fishers, vendors, scalers, boners, boat captains, and boat owners, from along the coast to discuss the *Sargassum* events, and their experiences thus far. Persons met during the initial data collection stages, that is, during landing site visits, were invited to the meetings on their respective coasts, and encouraged to invite others who may be interested in attending. The focus groups were informal, but more structured than other data collection methods as they adhered to recommended focus group methods (Bunce et al. 2000).

A short presentation was used to review the agenda for the evening: objectives of the meeting, objectives of the project, status of the research, regional research, and the planned activity. For the activity, participants were encouraged to think about the different categories of impacts as mentioned in the analytical framework that is biological, physical, financial, social, and policy, which were described in the context of the *Sargassum* events. This fed into a condensed form of scenario planning. Figure 10 details the steps involved in the scenario planning exercise within the focus group (Waylen et al. 2015).

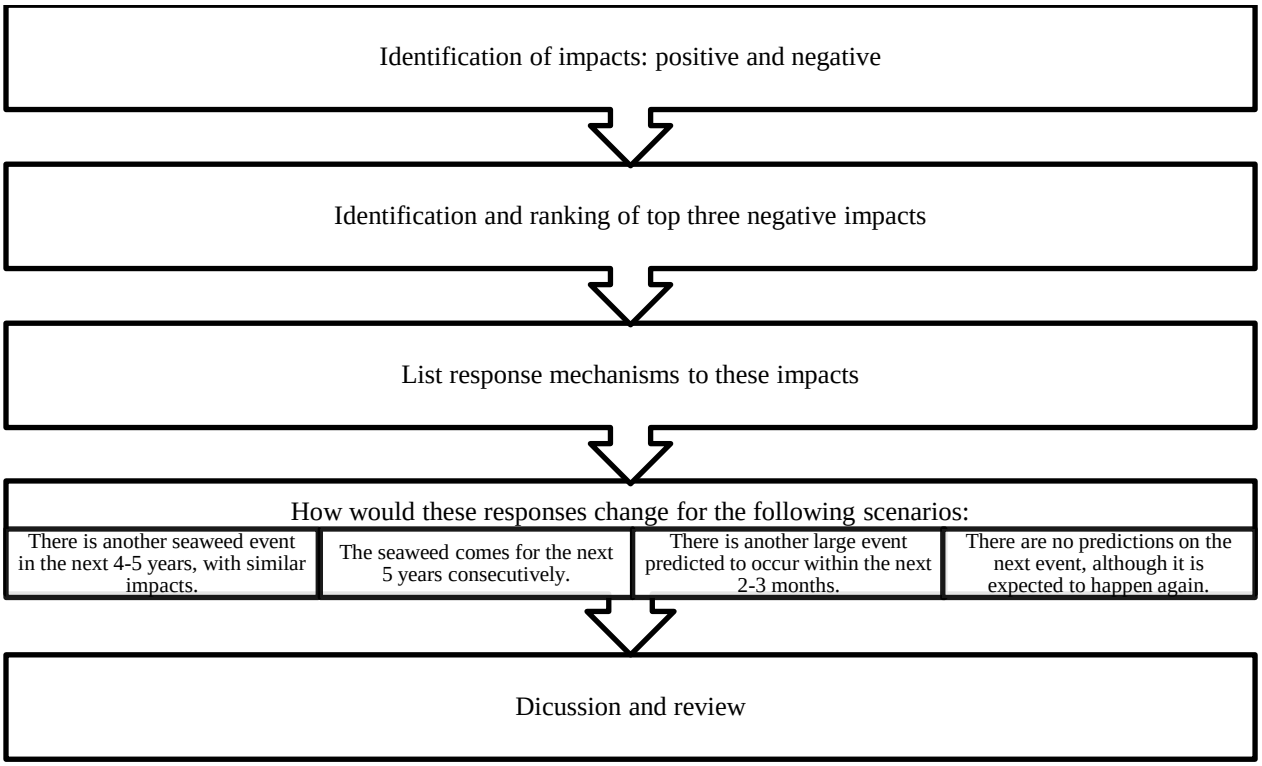

Figure 10. Scenario based exercise carried out at focus group meetings used to determine how fisherfolk are adapting, and how they would adapt in the future, if the *Sargassum* continues to come.

In each focus group, participants were asked to provide their basic demographic information. There were nine participants on the west coast, and five each on the east and south coasts. Educational literature was also shared, which included a hand-out on the research project, the "GCFI *Sargassum* Factsheet" (Doyle and Franks 2015) (Appendix 2), and a presentation given at the "*Sargassum* Symposium" held by the University of the West Indies, Cave Hill (Oxenford and Franks 2015). Thus, the focus group incorporated information exchange.

3.1.6 Investigating the role of climate change

The role of climate change in *Sargassum* events was investigated through secondary sources. Data collected on the fishery value chain coping mechanisms to the influxes were used to infer the stakeholders' ability to respond to climate change vulnerabilities. Information gathered in the group interview was also used to discuss the role of fishery policy in climate change adaptation for the sector.

3.2 Data analysis

Data analysis techniques are summarised in Table 1. The table depicts the various outputs generated in the results. The analysis also used techniques commonly associated with SocMon (Bunce et al. 2000), due to the qualitative nature of the results. Information gathered through various data collection methods have been combined in some instances, for a comprehensive representation of the results. The analytical framework as outlined previously was used to

interpret and synthesise the findings, as well as to generate recommendations, which are presented later in the report.

3.2.1 *Sargassum* information recording and compilation

Spreadsheets were set up to record all the data collected by the various methods used. These spreadsheets were then used to condense information for analysis and comparison by landing site, coast and stakeholder group. Data were updated on a continuous basis throughout the data collection period, and managed using a tracking worksheet.

3.2.2 Visualization techniques

Diagrams were employed to portray information on relationships between stakeholders, and their roles in the fishery value chain, impact analysis, decision-making processes for adaptation and mitigation. Visual techniques were also used to show trends identified in the landing data examined for the years 2010-2015. These techniques include: matrix timeline; fishbone or herring bone diagrams; network analysis; flow charts; and other simple diagrams. Tables, lists, and quotes were also used.

Table 1. Methods matrix developed for the study outlining the various qualitative data collection methods used and their respective output

Methods	Research Questions		
	Objective 1	**Objective 2**	**Objective 3**
	To identify socio-economic impacts of *Sargassum* events on the entire fishery value chain, using an ecosystem based approach.	To investigate actual and potential response mechanisms of the fishery value chain; potential uses andpolicy solutions.	To examine fish landing data to determine the extent to which it is able to capture information on *Sargassum* events, with recommendations for improved monitoring.
	Outputs		
Discussions at Landing Sites	• Spreadsheets of data condensed list by group • Visualization techniques	• Spreadsheets of data condensed list by groups • Tables	Not applicable
Focus Groups	• List of impacts- social, economic, physical, ecological • Ranked impacts	• Scenario building activity • Description of responses • Visualization technique • Network analysis	Not applicable
Group Interview	Not applicable	Not applicable	• Matrix timeline • Flow chart of decision-making process • List of adaptations and recommendations
Key Informant Interviews	• Summary spreadsheet of information • Network analysis • Quotes	• Summary spreadsheet of information • Network analysis • Quotes	Not applicable

Methods	Research Questions		
	Objective 1	**Objective 2**	**Objective 3**
Semi-Structured Interviews	• Spreadsheets of data, compiled with landing site discussions • Condensed list or responses • Visualisation technique	• Spreadsheets of data, compiled with landing site discussions • Condensed list of responses • Tables	Not applicable

4 RESULTS AND DISCUSSION

The results are organised and presented chronologically using the research objectives. For each objective condensed lists, summaries and comprehensive diagrams present the information. Although there are data gaps, the information gathered gave insight into how the sector was affected on various levels and scales. Also captured is information on how stakeholders were coping with the changing conditions of the environment in which they work and live.

4.1 Socioeconomic impacts of *Sargassum* influx events

This section reports on findings related to the first objective, which was to identify the socio-economic impacts of *Sargassum* events on the fishing industry of Barbados, examining the entire fisheries value chain, using an ecosystem-based approach, and taking climate change and variability into account.

4.1.1 *Sargassum* influx events timeline for Barbados

Sargassum influxes have led to several problems in the Eastern Caribbean islands, affecting sectors such as fisheries and tourism. The events were widely reported, receiving a lot of media attention. This attention increased considerably in 2015 due to the unprecedented large landings of seaweed. The impacts in Barbados were especially detrimental to the local flyingfish fishery. Using published literature, and landing data obtained from the Fisheries Division (discussed in more detail later), a timeline (Figure 11) was made of major events seen through the years 2010 to 2015.

Figure 11 depicts the first *Sargassum* influx event occurring in the year 2011. According to interviewees, in 2011, they were surprised by the occurrence of the *Sargassum* in such volumes, and they did experience negative impacts.

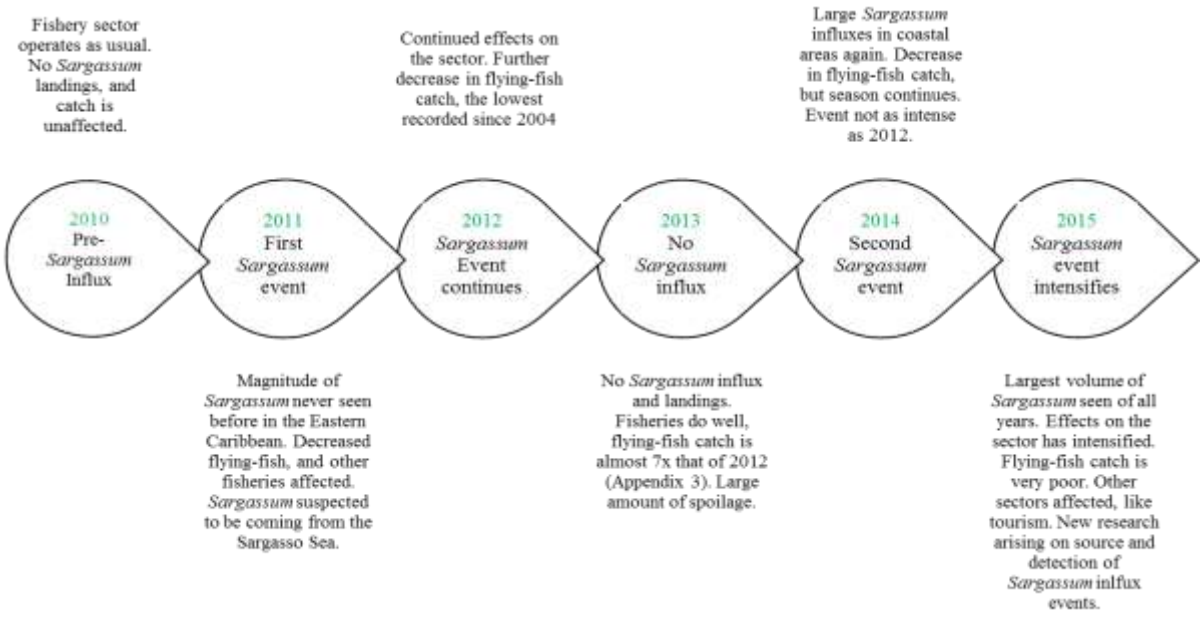

Figure 11. Timeline of sargassum influx and related events occurring over the past six years in Barbados and other islands of the Eastern Caribbean.

The influx events of *Sargassum* in 2014 and 2015 were also unexpected, however, interviewees expressed that they experienced the worst effects in 2015. In a key informant interview with a BARNUFO representative, it was said that in the first event most persons in the sector did not understand what was happening, but remained unperturbed by it. The event led to a shortened pelagic fishing season in 2012, as a result of poor flyingfish catch. However, 2015 was identified as the worst of of the two (2011/2012 and 2014/2015) events. One key informant expressed that the 2011/2012 event received less media attention than the 2014/2015 event, and thus persons were less aware of the 2011/2012 influx. In 2013, there was an absence of the *Sargassum* influx, which meant that fishing could take place as per usual. This led to increased landings of flyingfish, and other species such as dolphinfish and carangids. Unfortunately, according to the BARNUFO representative, a large amount of "dumping" of unsold or spoilt fish occurred that year.

Participants unanimously identified the second *Sargassum* influx event, especially the second year, 2015, as the worst since the *Sargassum* influx events first occurred. In another interview, a representative of the NCC whilst referring to 2015 as the worst year of the event, even suggested that there was "10-20 times" more seaweed, than previous years. He reported that in 2011, the seaweed was handled manually, whereas in 2014/2015 for the most part, only mechanical equipment could remove the vast quantities of seaweed. He said that there was more seaweed in 2014, than in 2011, and that the influx of seaweed became more frequent, and in greater volumes in 2015. From November 2014, until the time of the interview in August of 2015, there was seaweed constantly on east and south coast beaches.

According to the timeline recorded, each event lasted over a period of two years, that is, 2011 to 2012 and then again in 2014 to 2015, with a one year gap between the events. The fish landing data (Appendix 3) from the Fisheries Division also illustrates this pattern. In the first event,

2011/2012, the impacts appeared to be worse in year two, and similarly for 2014/2015, the worst impacts occurred in the second year, 2015.

Figure 11 shows the main impacts over time since the events first occurred, however the next subsection of results details the impacts reported by the different groups in the fishery value chain. The scale of the impacts differed among stakeholder groups in the fishery value chain, by coastline along which fisherfolk operate, and by type of fishery. These parameters will be further discussed in Section 5.

4.1.2 Impacts of *Sargassum* influx events on the fishery value chain

As mentioned in the analytical framework the study takes an ecosystem-based approach, looking at differences of impacts by scale, that is, over time, space, institutional management, and linkage (McConney and Parsam 2007). Information on the impacts by scale were examined by looking specifically at the fishery value chain of Barbados. The value chain primarily consists of the harvest and post-harvest sectors. For this study the value chain is divided into three groups; the first group: fishers, boat captains and boat owners comprise the harvest sector, while the post-harvest sector is represented by the second group (vendors, scalers, boners) and the third group (restauranteurs, seafood processors and regular customers) (see Figure 5).

Although the study was based primarily on the socio-economic impacts of the sector, other effects are also noted. Impacts were categorised as: biological, physical, economic, social, and policy. The fishbone diagrams (Figures 12–14) classify and list the various impacts according to these five categories: physical, biological, social, economic, and policy The results are presented for each of the three stakeholder groups in the fishery value chain. In some cases, positive and negative impacts were identified, as reported by participants in interviews and focus groups.

4.1.2.1 Impacts of the *Sargassum* influx events on the harvest sector

The harvest sector included boat owners, boat captains, and fishing crew. These groups of stakeholders were directly in contact and interacted with the seaweed off-shore and on-shore. Figure 12 organises the impacts according to the five categories as mentioned in the analytical framework. These impacts are a compiled list of all responses from each of the data collection methods. Note that both biological and ecological branches have positive and negative impacts.

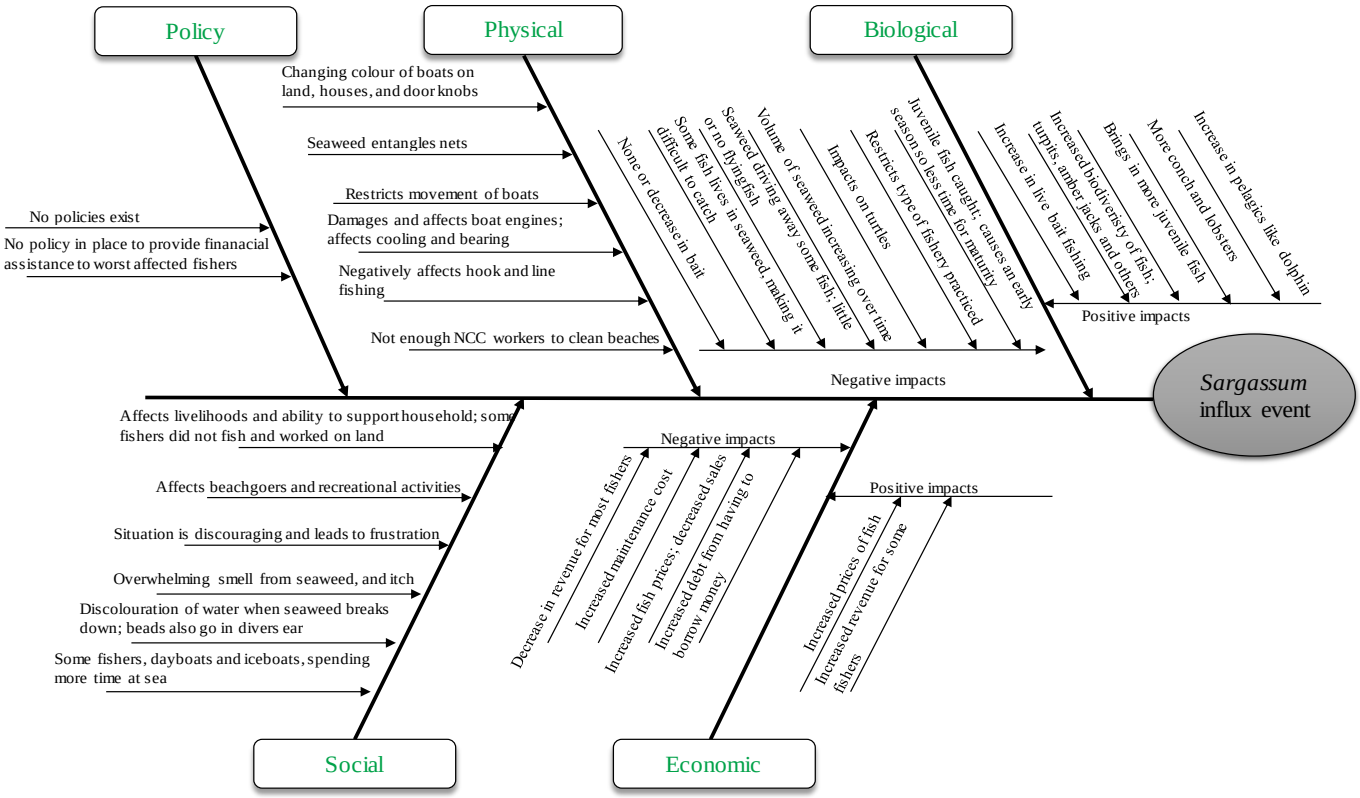

Figure 12. Impacts of the *Sargassum* seaweed influx events on the fisheries harvest sector of Barbados, showing responses of fisherfolk in the harvest sector (fishers, boat owners and boat

The fishbone diagram for the harvest sector is the most detailed of the three, as they were the most interviewed groups.There were both positive and negative effects given for biological and economic impacts. Biological impacts listed were associated with the increased abundance of some species of fish and in juvenile fishes, as reported by participants from the harvest sector. Some of these positive impacts also had negative repercussions. For instance, the increased number of juveniles following the seaweed also meant more juvenile fish were caught, sold and eaten, and less were available for replenishment of the stock. This was particularly so for dolphinfish where the *Sargassum* mats were bringing a large number of juveniles into Barbadian waters, which fishers reported seeing and catching in and around the mats. This will have impacts on the effectiveness of fishery policy; that is the ability of current policy measures to manage the catching of juvenile fish.

One key informant from the BGFA noted that because of the increased number of juvenile dolphinfish (weighing just 6-12 lb) being found in the summer, the fish was now available year round. He stated that in the past, the recreational fishing season for the large pelagics usually ran from January to May, with a larger average size of around 15-25 lb. He also noted that the wahoo that usually arrived around October or November, were absent in 2015.

For economic impacts, a few fishers said that the increased prices were able to compensate for the decrease in flyingfish caught. Others reported not having a large difference in income, compared to non-event years, and some even reported increased income. Most harvest sector individuals however, reported that even though the price of flyingfish increased, the catch was too poor to compensate for the deficit in income. They noted also that the increased prices also caused a change in the buying patterns of regular customers, who tended to purchase less, or seek alternatives. Fishers who only targeted flyingfish using gillnets reported that their gear was ineffective due to the seaweed. Nonetheless from the harvest sector responses received, most fishers resorted to changing their target, their gear, or catching whatever else was available.

4.1.2.2 Impacts of the *Sargassum* influx events on the post-harvest sector

The impacts on the post-harvest sector consisting of the intermediary group in the value chain: vendors, scalers, boners (considered fisherfolk, since their livelihoods, like the fishers, boat captains and boat owners are primarily dependent on fishery resources (Kher 2008)), and the third group: seafood processors, restauranteurs and the general consuming public are illustrated in Figures 13 and 14, respectively). Interestingly, many of the impacts reported by the post-harvest sector groups were similar to those reported by the harvest sector. This similarity was most pronounced between the harvest sector and the second group in the value chain (Figure 13). This was not altogether surprising, considering that these two groups generally shared a facility at all landing sites visited. The exception to this was the majority of recreational fishers and charter boat fishers, who do not operate out of these landing sites.

For the stakeholder groups in the post-harvest sector, especially the vendors, the increased variety of fish associated with *Sargassum* events was viewed positively, but also had negative consequences. According to vendors, while there were alternative species available, there was still a preference among customers for flyingfish, dolphinfish and other traditional pelagics such as swordfish. Vendors and scalers, particularly those interviewed on the west and south-west coasts, said they were able to cope with the impacts of the *Sargassum* influx events, and that they had no significant change of income. For others, the majority of whom worked on the east and south-east coast, they reported that the 2014/2015 fishing season was one of the most difficult for them, and that they had experienced a decrease in their income. Although fish retail prices increased, some vendors reported buying less fish (wholesale), since they could not afford to buy more and/or could not sell anymore at the higher prices. Vendors reported that the raised prices changed consumer buying patterns. One vendor noted local residents around the landing site; her regular customers, were buying less fish, or they bought smaller pelagics such as the jacks brought in by fishers, which were generally cheaper.

The poor catch and absence of flyingfish caused a change in the fishing season. The fishing season typically runs from November to July (Fisheries Division 2004), but according to the key informant from BARNUFO, as well as other vendors, the lack of flyingfish created a shorter season, since it finished earlier than usual. It was said that between December 2014 and January 2015 there were still some flyingfish, but this started to decrease after January. Although this affected all stages of the fishery value chain, the vendors, scalers and boners, whose jobs primarily depended upon flyingfish, were the worst affected. As the representative from

BARNUFO explained, the processing plant operating at Bridgetown processed solely flyingfish, but there was very little to process.

For the final group in the value chain, the seafood processors, restauranteurs and the general consuming public, the impacts reported were predominantly economic (Figure 14). The seafood processors interviewed did not sell large quantities of freshly caught fish, and mostly relied on imports and specialty items. They expressed that although the *Sargassum* was a problem, and reduced the fresh fish supply they bought, they were not adversely affected. It should be noted that there are seafood processors more reliant on the local fishery sector, with whom attempts for interviews were made. However, given the limited time and resources for data collection, they were not reached. The data presented nonetheless, were sufficient for proper analysis as a baseline or initial look at the socio-economic impacts on the industry.

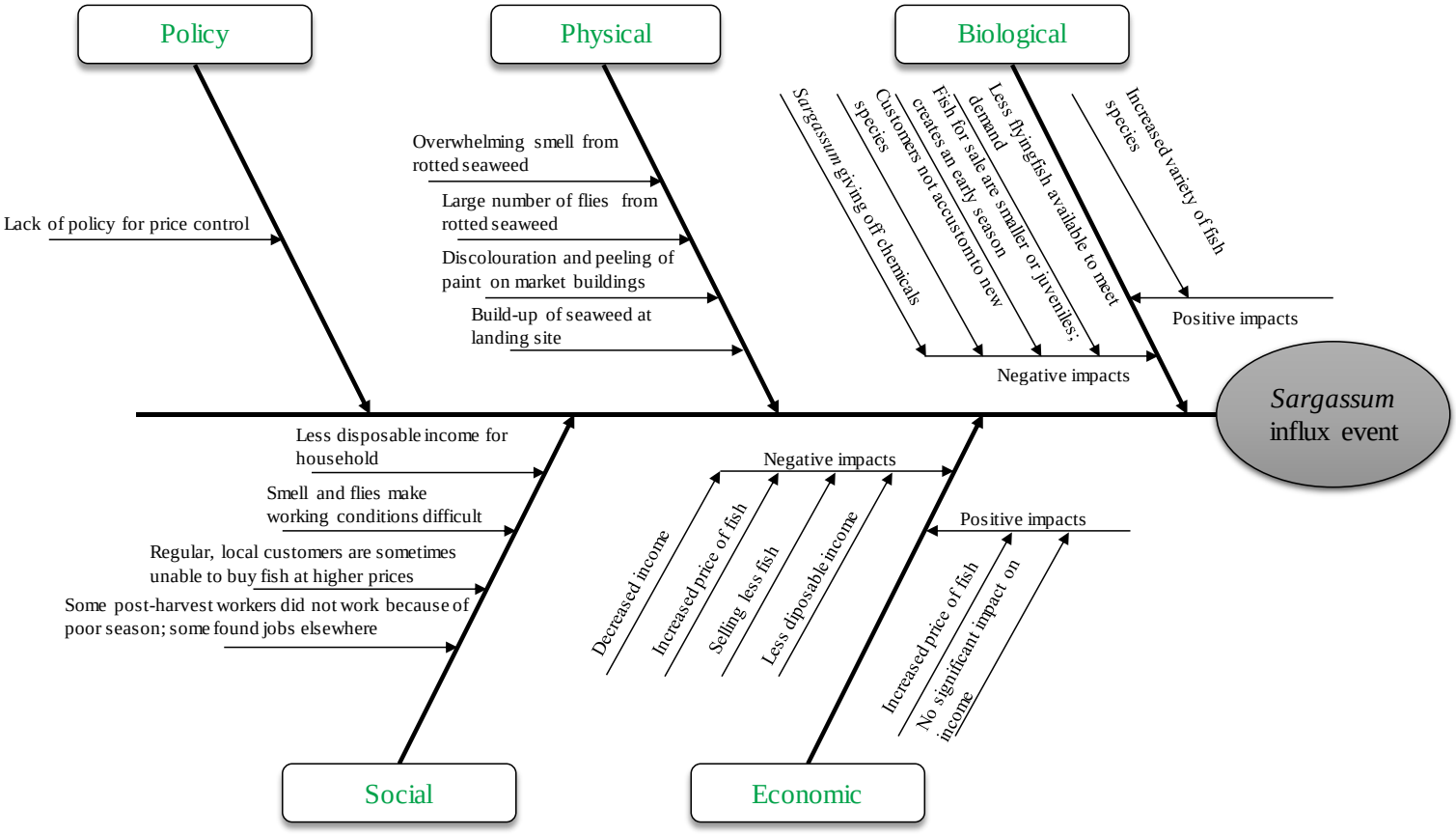

Figure 13. Impacts of the *Sargassum* seaweed influx events on the post-harvest fishery sector, showing responses from the intermediary group in the value chain (vendors, scalers and boners).

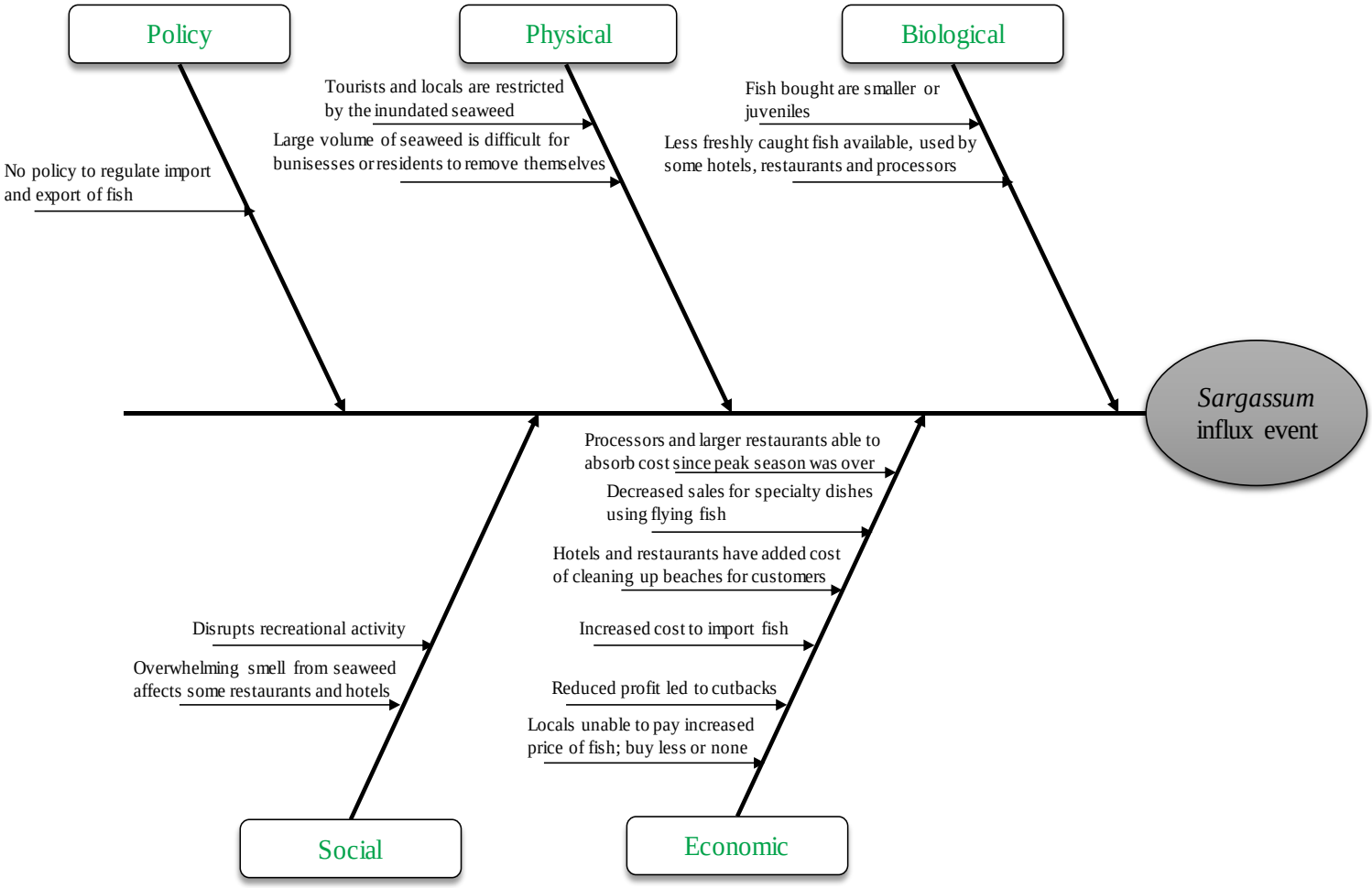

Figure 14. Impacts of the *Sargassum* seaweed influx events on the post-harvest sector, showing responses from private enterprises including seafood processors, hoteliers and restauranteurs, as well as the general public of Barbados.

Obtaining flyingfish was described as difficult and expensive. Larger restaurants and seafood processors said that they resorted to importing their seafood supplies which increased their expenses, but not so much that they were unable to absorb the cost. Smaller restaurants, such as those at Oistins, or others close to landing sites were impacted to varying degrees, depending on the type of fish on their menu. For example, two restaurants at Oistins served a variety of fish, and one specialised in snapper. One of the restaurant owners said that he started importing to meet the demands of his customers. Another restaurant at Martin's Bay served mainly snapper, along with other species, but said they were unaffected by the decreased supply of flyingfish. However, prices were increased for all the other species as well, so even though flyingfish was not served, restaurants still needed to pay more for other species of fish.

Although the general consuming public were not included in the data collection process, they are included in the fishery value chain for completeness in analysis. Information about impacts on

this group were garnered from other interviewees in the sampled population.The tourism industry, though affected by the decrease in flyingfish which is marketed as the Barbadian specialty, was more affected by the physicals impacts. The build-up of the *Sargassum* on-shore, and the inundation in the intertidal zone, was a nuisance. The seaweed covered the white sand beaches that tourists came to enjoy, made bathing uncomfortable or impossible, brought a lot of flies, and carried a scent of hydrogen sulphide (CAST 2015). As a result, the tourism sector stakeholders had to invest a considerable amount of resources on clean-up efforts. Interviewees also reported that locals were deterred from spending time at beaches because of the presence of the seaweed wracks on-shore, and suspended in the intertidal zone of many east coast and south coast beaches. Fortunately for west coast beaches, being on the leeward side of the island, the volume of seaweed was much less, and the mats did not generally strand on the beaches but tended to stay farther out to sea.

4.1.3 Comparison of impacts on different livelihoods in the fishery value chain

Here we compare the different categories of impact (biological, physical, economic,social or policy) among the different stakeholder groups in the fishery value chain.

4.1.3.1 Biological

Collectively, there were numerous biological impacts listed by stakeholders along the entire fisheries value chain. However, the most commonly reported impact by interviewees and focus groups was the decrease in availability of flyingfish, and the change in catch composition for pelagic fishing trips. In comparing the three fishbone diagrams (Figures 12, 13 and 14), the harvest sector listed the most biological impacts. Furthermore those biological impacts listed by both post-harvest groups (Figures 13,14) were very similar to those listed by the harvest sector (Figure 12).

Fishers reported that they were not catching flyingfish, but that there were more turpits, jacks, and dolphinfish due to the presence of the *Sargassum*. As a result, they targeted these species, or as often expressed, they caught whatever they could. This finding was corroborated by the FD landings data which showed a large decrease in flyingfish landed during the most serious influx event (2015); 277.9 tonnes landed from January-June in 2015 compared with 981.3 tonnes landed over the same months in 2014. This large decrease in the quantity of flying-fish caught resulted in less being available for the post-harvest sector, as voiced by the vendors interviewed, and the key informant from BARNUFO. The lack of locally available flyingfish also affected the hospitality sector, with restaurant owners and seafood processors stating that there were fewer flyingfish available and therefore they were unable to meet the demand of their businesses for this species, resulting in them seeking alternatives.

As the key informant from the CZMU, and staff at the FD expressed that the change in species also had subsequent biological impacts such as a change in the ecology of the nearshore system with an increase in species that were not there before, or were there in smaller numbers at different times of the year. They also suggested that there was the possibility of uncommon or non-native species being transported by the *Sargassum* into the nearshore environment, as well as the creation of anoxic conditions on coral reef systems when *Sargassum* was trapped in the

nearshore, and subsequently sunk and began decomposing. A point raised by thekey informantfrom the CZMU was that at first the *Sargassum* was viewed as just a natural entity, coming into Barbadian waters in large volumes. However, when it began to decay, it actually posed a completely different threat. The breakdown of the seaweed created an issue with water quality in the nearshore environment, which at the time of the interview was not being monitored. There was still no biological research conducted to investigate ecosystem impacts of the *Sargassum* influx events, however, the FD, CZMU and experts at CERMES identified the need and intention for conducting these studies.

There were also reported increases in the abundance of species that were previously known to have diminishing stocks. Lobsters, conch and sea eggs (urchins) were reported by some divers to have increased. These observations, however, are not seen in the landings data provided by the FD for the months of January to July (refer to Appendix 3). This is not particularly surprising, since the sea egg harvest season remained closed during this period, and landings of the other species (conch and lobster) are not well monitored, since they are generally not landed at government fishery facilities. Although there have been no conclusive studies to validate these observations, the FD, under strict regulation, was able to reopen the sea egg fishery for one month in 2015 (October 1st - 30th) for the first time in many years, as there was deemed to be sufficient sea eggs at this time to support a short harvest period. Divers were required to obtained permits from the FD, valid only for this one-month period, to legally harvest the sea eggs (Slinger 2015). The key informant from the BGFA also indicated that a 'new' species, the almaco jack, not usually seen in Barbadian waters, was now being caught, along with amberjacks.

The biological effects had ramifications on all livelihoods, although there were differences in the extent of the impacts among the livelihoods. Fishers, boat captains, and boat owners described effects on the species they targeted, and the fishing methods and gear employed. They reported that fishing trips were generally less successful; even though there were other fish coming in with the seaweed, there was still a decrease in catch altogether. Vendors, scalers, and boners primarily involved in the flyingfish fishery reported to be greatly affected by the decrease in flyingfish caught. This was more apparent through information gathered at south coast landing sites, Bridgetown and Oistins. Some charter boat fishers reported that although the *Sargassum* did become a nuisance and entangled lines, in some cases it made it easier to catch fish using lines. One charter boat fisher expressed that if a trip was proving to be unsuccessful he would try fishing around the seaweed mats using the same fishing gear. The charter boats fished around the mats so that customers were almost guaranteed to catch a fish, which in most cases were reported to be dolphinfish. Seafood processors interviewed reported having little impact from the decrease in flyingfish or the presence of different species, while restaurants did admit to having to find alternative sources, not just for flyingfish, but other larger pelagics. For the public (as reported by other interviewees), they were affected by the decreased supply of flyingfish, and the increased variety of pelagics available, which is discussed further in other sections.

4.1.3.2 Physical

There were differences in quantities of *Sargassum* experienced across coasts and landing sites. The massive mats and inundation of the nearshore area by *Sargassum* appeared to be more

common at the east and south coast landing sites. Some south-west and west coast landing sites did not get any seaweed on shore, due mainly to the direction of the prevailing wind and sea surface currents, according to fisherfolk.

The large mounds of stranded seaweed not only congested landing sites but also inundated beaches such as the case at Enterprise Beach on the south coast, where the volume of seaweed was decribed as "inconceivable". According to the key informant from the NCC the seaweed from this beach was transported into Oistins and beyond by waves and currents. The key informant from NCC explained that in Oistins, because of the shape of the bay, the seaweed was less likely to move out of the system by wave action; hence, heavy equipment was required to move the compacted seaweed off the beaches.

He said that the NCC focussed a lot of their resources on clearing the beach, and that vendors, beach goers, and locals also contributed to the effort, since this beach has been a favourite beach of both tourists and locals. He described an instance where at Enterprise Beach there were piles of *Sargassum*, approximately two to three metres tall, and four to five metres wide. A lot of financial resources, heavy machinery and workers were used to move the *Sargassum* from the beach. However, he explained that removal was difficult because the NCC did not have the "requisite equipment". The equipment was rented from a private company, for use by the NCC. The use of the machinery in the intertidal zone meant the company had to repair any machinery damaged by the saltwater.

On the east coast, the Skeetes Bay Fishing Complex was closed for the rest of the 2015 fishing season because it was inoperable due to the volume of seaweed, the profuse hydrogen-sulphide odour, and the inaccessibility to boats, as indicated by the security guard on site. According to the key informant from the NCC, the slipway for boat launching was blocked by *Sargassum*. According to the security guard, fishers resorted to operating out of the Bridgetown Fishing Complex on the leeward side of the island. They also reported that the east coast Consett Bay Fishing Complex was heavily covered in the seaweed, but the water column did not have as much seaweed suspended in it as nearby Skeetes Bay. Fishers, however, reported that there were difficulties in accessing a channel they used to bring their boats to the jetty, especially on occasions when larger volumes of seaweed were coming to shore.

Figure 15 was taken at Skeetes Bay on the east coast of Barbados in August 2015, when the entire bay was completely inundated by the seaweed. The *Sargassum* appeared to be thick in the water column, as waves were loaded with seaweed coming in to shore. The figure also shows the coastline to the right of the fishing jetty at Skeetes Bay, where the seaweed has completely inundated the shoreline.

Figure 15 A thick layer fresh golden yellow *Sargassum* seaweed suspended in the nearshore (top) and mounds of older darker *Sargassum* piled up along the shoreline (bottom), compacting with sand, and forming towers of *Sargassum* at Skeetes Bay, east coast, Barbados.

Sargassum also affected fishers offshore. The large mats and patchy windrows occurred offshore island-wide, making it difficult for fishers to operate their boats and fishing gear, especially the flyingfish gillnets. Fishers reported that the *Sargassum* mats not only covered a large surface area, but were also several metres deep. One longline boat captain reported that the floating *Sargassum* mats were generally1-2 m thick, and even thicker for the larger mats further offshore. As a result, flyingfish fishers were unable to successfully set and retrieve their gillnets, and the sheer weight of the entangled *Sargassum* also damaged the nets. Problems with setting and retrieval of sub-surface gear were also reported by some longliners, and surface hook and line fishing was also affected as the line gathered *Sargassum* which then became entangled on the hook, rendering it ineffective for catching fish. This affected shore fishers (Figure 16) as well as those surface trolling from a boat. These fishers reported that the line became taut, as if they had caught a fish, but it was seaweed entangled on the hook or line. The weight of the seaweed sometimes led to the line breaking when fishers attempted to pull or reel it in, which resulted in the loss of line, as well as the lure, hook and sinker. Commercial fishers, charter boat fishers and recreational fishers who utilise lines for fishing, all reported this problem. Charter boat fishers in particular reported the seaweed as being a nuisance, and cumbersome to their trips by entangling and breaking lines.

Figure 16. Photographs showing *Sargassum* seaweed caught on a recreational fisher's line cast from the shore at Bathsheba, east coast, Barbados

All fishers, boat captains and boat owners also reported that the seaweed often became stuck in the engine of the boat. This included: getting tangled in the engine's propeller, causing the engine to lose power, steerage and even stall; and/or getting stuck in the impeller, blocking the intake of water and resulting in the engine overheating. This proved to be an issue for all fisherfolk regardless of the coast they operated from or the type of engine (inboard or outboard) they had. They reported that they were most likely to get seaweed in their engines when passing through patches or windrows of the seaweed. This was almost impossible to avoid because the weed was so pervasive that fishers often had no choice but to drive through it. Some fishers said that they preferred the *Sargassum* in larger mats, rather than the small, wispy lines, as it was easier to see and drive around. Fishers on the windward east coast and to some extent those on the south coast, also had to manoeuvre their boats in and out of *Sargassum* inundated waters at their landing sites. On the leeward west coast, there was much less *Sargassum* on the shore at landing sites.

Fishers were also asked how day-boat fishers were affected in comparison with ice-boat fishers. Most persons said that there was no significant difference, and that all fishers were affected the same. Some said ice-boat fishers were more severely affected, since some have resorted to staying out longer on trips, and required more fuel and more groceries to maintain the boat. Others argued that day-boats were the worst affected, because they spent less time at sea due to the 'moss', and had to make the trip in and out everyday.

On the east coast particularly, there were reports of the stranded *Sargassum* along shorelines causing discolouration of the paint on 'dry-docked' boats, on the fishing facility building, and even on homes nearby. Some also mentioned the darkening of jewellery. Figure 17 shows a boat at Skeetes Bay with a black discolouration. Although it was not known at the time of the interviews, it is now understood that these impacts result from the release of the corrosive

hydrogen sulphide gas emitted by rotting wet *Sargassum*. Interestingly, one boat owner and fisher at Consett Bay reported that the floating *Sargassum* around his boat helps to clean the hull (Figure 18).

Figure 17. Black coloration on the paintwork of a 'dry-docked' fishing boats at Skeetes Bay, east coast, Barbados

Figure 18. Some *Sargassum* seaweed suspended in the water at Conset Bay, east coast, Barbados, which the boat owner contends helps to keep his boat hull clean

4.1.3.3 Socio-economic

Due to the similarities in the social and economic impacts, they were combined for this analysis and discussion. The different livelihoods in the fishery value chain were affected to different degrees by the *Sargassum* influx events, economically. According to interviewees, the harvest sector suffered from a decreased income, particularly for those primarily targeting flyingfish. Most fishers described the flyingfish season of 2014/2015 as the worst yet, with some even expressing that it was "non-existent". As such, the majority of fishers said that their income had decreased, and that it was difficult to make ends meet. However, most reported that they did not have to resort to borrowing money, and that in most instances they made enough to cover expenses for each fishing trip.

Not every fisher however had the same experience. A few fishers expressed that they had an increase in income. For example, one fisher on the west coast believed that incoming *Sargassum* was good, allowing fish stocks to replenish, and expressed that he had had a good season. Differences in reported economic impacts appeared to be related, among other things, to the type of species targeted and the gear used since the seaweed affected species and gear-type differently (see Section 4.1.3.2). Fishers who targeted flyingfish used surface gillnets which were badly affected by the floating *Sargassum;* those catching demersal species used fish traps (pots) that were not affected, and those fishing larger pelagics used lines which were somewhat affected. Most fishers who targeted flyingfish said that the seaweed adversely affected their incomes. A few others at Oistins reported that although there was a decrease in the volume of flyingfish caught, the increase in prices compensated for it, and their income was more or less the same.

Line fishing and traps were less affected. Although costs were incurred to replace lines, in most cases it was reported as being minimal, and most fishers who were unsuccessful with catching flyingfish switched to other species and fishing methods to supplement their income. However, for recreational fishers who in most instances were line fishers, and were not selling their catch, there was the extra cost of replacing lines and sinkers. As one recreational fisher explained, he spent approximately BBD $150 to replace the amount of line and sinkers lost due to entanglement with *Sargassum*. This was in addition to the money spent on fuel, with very little or no fish being caught. In the case of this recreational fisher, he sold some of his catch, mainly the bigger pelagic species, like dolphinfish and barracuda, to some of the restaurants to cover the cost of his extra boat expenses. In light of the *Sargassum* present, less fish was available for selling and for personal use, and the entire experience had become frustrating. On the contrary, the key informant from the BGFA said that the association members were not affected financially or otherwise. The presence of the *Sargassum* did not deter membership or interest in game fishing or taking part in the association's fishing competitions.

Charter boats, expressed frustration with line fishing (trolling) when *Sargassum* was present, but reported that the cost of replacing lines was considered minimal, and their income remained largely intact, except for the case of one fisher whose engine was damaged because of the *Sargassum*, and needed to be repaired. Divers who target demersal and benthic species said they were unaffected, and gave reports of increased abundance of benthic species. Some said they actually benefitted from the presence of the *Sargassum*. Most fishers were able to switch from nets, to trap fishing or other methods less affected by the seaweed mats. As some fishers indicated in the focus groups, the early end to the flyingfish season, because of the mats of seaweed, meant an early start and longer season for pelagics and pot fishing. In the key informant interview with the BARNUFO representative it was expressed that fishers were still able to sustain themselves while some employed in the post-harvest sector were not. If there were no flyingfish, then there was no work, particularly for those employed in the processing plants, which only process flyingfish.

Apart from affecting the income of groups in the fishery value chain, another important impact was the increase in the price of fish. One seafood processor said that the price of flyingfish increased drastically, resulting in the highest prices seen for some time, both ex-vessel and retail. For example, the ex-vessel price of 100 flyingfish went from a 'normal' range of BBD $25-50 to a range of BBD $80-150. Another fisher quoted the price as going from between BBD $0.75-

1.00 to BBD $2.50-2.75 per flyingfish, while larger species such as dolphinfish and snapper were raised to prices higher than BBD$10.00 per pound.

Fish such as marlin doubled and tripled in price according to a seafood processor, explaining that the lightweight (without bone) price was BBD $18.00 per pound, and bone weight (with bone) went to BBD $9.00 per pound from just BBD $3.00 per pound. The processor also stated that flyingfish increased from around BBD $0.90 to $2.00 per fish. The seafood processor went on to say that the company was able to absorb the increased purchase costs and wholesale customers were therefore able to pay for the fish they needed. However, retail and "walk-in" customers were the most affected by the prices, and "only certain persons could afford the processed fish". Restauranteurs also said they were able to bare the costs for the increased fish prices, or for importing fish to meet demands, without increasing the prices of meals. However, they did express that it was an issue they needed to further address if there were future events.

There was also an economic impact at the management level, where there was a substantial cost to cleaning the beaches. As the key informant from the NCC suggested there were issues with the time for procurement of equipment, and the rental of heavy machinery which used up a significant amount of the NCC's resources. This was not limited to money, but included a change in their normal focus, time and effort of the NCC staff, equipment and heavy machinery (rented). According to the NCC representative interviewed, they had to prioritise which areas required attention the most. The BHTA reported that the tourism sector also had to place a considerable amount of capital into cleaning the beachfront of hotels and restaurants (CAST 2015).

For most of the harvest and post-harvest sector, it was expressed that the poor flyingfish season meant there was less money available for supporting the household and less money for leisure activity. Some fishers expressed frustration caused by unsuccessful fishing trips; and their worry about what the *Sargassum* influx events might mean long-term for their livelihoods. Other groups, such as seafood processors and restauranteurs were less affected socially, and it was essentially 'business-as-usual'.

The smell of the decaying seaweed was also reported by interviewees to have affected vendors at landing sites, beach users, and restaurants close to the beach. The presence of flies (Figure 19), which increased due to the decomposition of the *Sargassum*, was also reported to be a nuisance by vendors and restauranteurs on the east coast, namely Martin's Bay, and the south coast at Oistins. Fishers also reported that the *Sargassum* causes itching, and this makes it difficult to attend to boats in the intertidal zones. The presence of the seaweed, mainly the stranded seaweed on-shore, significantly lowered the quality of experience for tourist visitors and locals, and made working conditions for vendors and fishers unpleasant.

Figure 19. Flies covering the wall in the Oistins fish cleaning facility which were associated with the presence of decaying *Sargassum* nearby.

Other groups were also affected by the presence of the seaweed, as reported in the interview with the NCC representative. Wind surfing and other watersport enthusiasts were affected by the mats and windrows of *Sargassum* offshore. He also said that beaches such as Enterprise Beach which is usually frequented by a fair number of returning nationals who use the beach daily were impacted by an inability to swim there, and that the stranded *Sargassum* also impacted a number of vendors and small businesses on these beaches. The impact on the tourism sector was reiterated, as he said that efforts of the NCC had to be consolidated, and resources were focussed on areas were tourism was most affected.

4.1.3.4 Social Capital

Social capital refers to the social organisation of a community and the networks formed within it. Members of the community share values, behaviours, information, and resources (McConney, Pomeroy and Mahon 2003). For the fishery value chain, the *Sargassum* influx events did not appear to negatively affect social capital. The relationships in place before the events between members of the harvest sector, and between fishers and vendors were maintained. The "social unit" (OECD n.d.) at landing sites, such as in Consett Bay, Weston, Paynes Bay and Pile Bay were stable and functioned as they usually would.

However, the formation of linkages with other organisation outside of the fishery value chain, have increased the social capital. Fisherfolk had to form new or reinforce old relationships with organisations such as the FD and the NCC, which they were dependent on for assistance in the cleaning of landing sites. At the same time, some fishers expressed disappointment with how these organisations were coping with the impacts, such as the timely cleaning of the landing site, or the lack of financial or other assistance by the FD. One fisher also expressed that more should be done by fisherfolk organisations such as BARNUFO to assist fisherfolk. There was also a lack of information shared between the FD and the fisherfolk. Although the FD did undertake a socio-economic survey, the lack of information about the *Sargassum* influx events was evident from

the people interviewed in the current study. An event such as this should facilitate sharing of information between the fishery value chain and the regulatory body, building social capital for the sector.

4.1.3.5 Policy

The impact on policy, of all other impacts outlined in the analysis, were more difficult to pinpoint. Although interviewees are aware of other regulatory policy pertinent to the sector, they were unsure of suggestions for the management of the *Sargassum* influx events using policy. Most fishers have eluded to, and expressed their opinion on what the role of the FD, NCC and other state agencies are, and should have been. In a lot of cases fishers were not aware of any specific policy or legislation to specifically tackle an issue like the *Sargassum* influx events. Some said that there was no policy present to manage such events.

At focus group meetings, however, fishers were given the opportunity to further discuss policy involved in managing environmental issues. They did recognise that there was a need to develop minimum size restrictions for fish caught, particularly for the dolphinfish since small juveniles were now being caught in association with the *Sargassum*. They expressed that in the absence of regulations and because of the difficulty they now face with the absence of flyingfish, that they would make the most of the surge in availability of juvenile dolphinfish and other smaller pelagics such as jacks. They reiterated that they would sell whatever was caught, since they needed to at least try to make back the expenses of the boat and were less likely to let fish go even if they were clearly juveniles.

Many fishers also identified areas in which government agencies and fisherfolk groups lacked policy to support the sector. They noted that there was no policy or guidelines for assisting fisherfolk, such as a system in place to help boats stuck in seaweed, or financial aid to fishers severely affected. Fishers also suggested that the sea egg fishery be opened. Fishers saw this as an opportunity to supplement their income by harvesting urchins, and to ensure they can fairly partake of the increased stock, before they were all harvested illegally. In this regard, the FD eventually opened the sea urchin fishery for one month.

In the group interview with the Fisheries Divison, the lack of clear policy was the largest issue identified, for the FD to deal with the *Sargassum* influx events. Although there are draft documents with sections under which these events were be addressed, there was still a lack of specific policy to manage fishery stocks in years of plenty and years of scarcity. This is further discussed in Section 4.3. In this group interview, the lack of policy for price control was identified as attributing to the unchecked rise in prices of fish. The representative from Markets Division also indicated that there was no policy in place to regulate the import and export of fish in Barbados.

4.1.4 Ranked impacts of the *Sargassum* influx events

Although there are other stakeholders in the fishery value chain, the focus groups were targeted towards fisherfolk. As part of the focus group exercises, fisherfolk were asked to rank the impacts identified, giving the top three impacts that affected their livelihoods the most (Table 2).

Table 2. Top three impacts ranked by fisherfolk on the West, East and South Coasts of Barbados. 1 represents the top ranking issue.

Rank of impact	Coast		
	West	East	South
1	Restricted movement of boats, affected engines and access to boats	Financial issues borrowing money to purchase a boat with lower income and increased debt	Negatively affected income
2	Decreased revenue for some fishers	Decreased flyingfish catch	Decrease in flyingfish; work is slow
3	Restricted the type of fishery that was done	Lack of policy to assist worst affected fishers	Boats affected by the seaweed; movement is restricted

The impacts listed in the top three were more or less the same for all focus group meetings, with the exception of the third ranked impact on the east coast; the lack of policy to assist fishers affected. Although there were some differences in the ranking, the responses were similar. Decreased income, decrease in flyingfish catch, and restricted movement of boats were the most prevalent answers, not just in the focus group meetings, but in interviews as well. The ranked impacts were used to focus the coping and adaptation mechanisms suggested during the scenario based exercises. It was also important in identifying the impacts most affecting the livelihoods of fisherfolk, for identifying recommendations, and devising management strategies for future events.

4.2 Coping and adaptive mechanisms to *Sargassum* influx events

This section reports on findings related to the second objective, which was to investigate actual and potential response mechanisms of the fisheries value chain, and recommend climate-smart action for reducing the negative impacts, inclusive of potential uses and possible policy solutions.

4.2.1 Adaptations to impacts of the *Sargassum* influx events

As the analytical framework suggested the impacts of the *Sargassum* influx events were categorised according to the assets, which they affect: biological, physical, economic, social and policy impacts, as stated by the Resilience Alliance (2007). All the impacts affected the capital of stakeholders (actors in the fishery value chain) used to make and maintain a livelihood.

Another step in the resilience framework was the identification of the mode of change. In this case, the mode of change in behaviour of stakeholders in response to the environmental perturbation or shock, caused by the *Sargassum* influx events. The following subsections list the adaptations to impacts faced by each group in both harvest and post-harvest sectors of the value chain.

It was noted that although for some impacts, groups and in some instances individuals may have had specific response mechanisms, in a large part, groups had similar strategies for coping. The

general trend was that most groups, and even government agencies, were caught off-guard. According to most interviewees, the strategies evolved from dealing with issues as they arose, day by day, and were modified as conditions or problems changed.

4.2.1.1 Biological

Although the biological impacts were reported by fishers to be one of the first effects to be felt, as a result of the Sargassum mats offshore, and stranded Sargassum onshore, there was little that fishers were able to do solve these problems. As expressed by many fishers, the Sargassum influx events "cannot be stopped and will continue to come". Nonetheless, fishers reported addressing impacts by adopting short-term coping mechanisms. As seen in Table 3, stakeholder behaviour for both positive and negative impacts were listed. In reference to the impacts represented in the fishbone diagrams in Section 4.1, not all of the impacts had coping strategies, and these were not discussed. The list here represents all of the adaptations reported by fishers from landing site visits, focus groups, and all other semi-structured interviews.

Table 3. Coping mechanisms stated by interviewees of the fishery value chain for biological impacts of *Sargassum* influx events

	BIOLOGICAL IMPACTS	ADAPTATIONS
Positive	Increased live bait fishing	• Switched from other fisheries, namely gillnet/flyingfish fishery • Even though trolling with hook and line was affected by the thickness of the seaweed, fishers still attempted to fish around or close to *Sargassum* mats which tended to have pelagics like the dolphinfish in and around them.
	Increased biodiversity of fish	• Other fish, which were more plentiful, were sold; whatever was caught was sold or eaten.
	Brought in more juvenile fish	• Juvenile dolphinfish were caught and sold, however, some fishers contend it was another smaller-sized species of dolphinfish. • Fishers and vendors said that customers preferred the smaller dolphinfish.
	Increased pelagics like dolphinfish and amber jacks	• Fishers preferred to catch dolphinfish, since customers preferred the smaller dolphinfish and they fetched a higher price than some other pelagics.
	No significant impact	• Stakeholders who remained largely unaffected, for example divers, continued to operate as per usual.
Negative	Restricted type of fisheries	• Switched gear, fishing method or target species e.g. switched to potfishing, or switched from targeting flyingfish to snappers
	Impacted turtles	• NCC cleaned turtle nesting beaches by marking nests beforehand, however, some areas where the *Sargassum* was very thick, the eggs were lost. There was still the issue of the seaweed suspended in the water, which in some cases, was several feet thick, and resulted in numerous reported deaths of turtles.
	Seaweed drove away some fish	• Changed fishing grounds and moved around coast(s) or went further out to sea, to avoid *Sargassum* mats.
	Some fish lived in seaweed, making it difficult to catch	• Fishers tried to fish around mats for larger, pelagic species such as dolphinfish and jacks, which appeared to have travelled with the floating mats of seaweed.
	Juvenile fish were caught; early season so less time for maturity	• Some switched to hook and line, pot fishing, diving, or a combination of these when season is over.
	Customers were not accustomed to new species or different species	• Customers who are accustomed to using the new species buy it; they were cheaper; or fishers would use it themselves
	Fish for sale were smaller or juveniles; which created an early season	• In post-harvest sector, persons sought jobs in other areas, since they were unable to work for the season. • In the case of dolphinfish, which were plentiful, customers were reported to prefer the smaller sized fish. • The BGFA asked members to desist from catching dolphinfish less than 6 pounds.

BIOLOGICAL IMPACTS	ADAPTATIONS
Less flying-fish were available to meet demand	• Changes in fishing effort either in number of days fishing or hours spent per trip, depending on the catch. Some fishers increase days, while others decrease due to fuel expenses. • Vendors import fish to meet demand.
Less freshly caught fish available used by some hotels, restaurants and processors	• Vendors buy more fish at a time, when fresh fish is available. • Some vendors stockpile fish. • Fish also sold by orders, so that there is no wastage, and all fish were sold. • Flyingfish and in some cases alternatives to pelagics are imported by restaurants and seafood processors.

Fishers responses make up the majority of the adaptations listed and as such, most of the adaptations listed were for those in the harvest sector. The table shows that the coping mechanisms were simple, everyday changes in behaviour and operational practices. The fishers did acknowledge the changing conditions brought by the seaweed, and noted that the fishing industry was itself changing in state over the years. These changes were more gradual and less obvious compared to the *Sargassum* event.

Some older, more experienced fishers indicated that the flyingfish catch has been declining over the years, due to reasons unrelated to the *Sargassum.* Several fishers also suggested that they have observed a change in the currents around Barbados, saying that it has changed direction and/or became stronger. The key informant from the BGFA suggested that there was a change in ocean currents, with a consistent current coming from the southern and western quadrants (south-west, west, and north-west) and travelling to the north. He believes that these currents are different from the usual currents coming in from the eastern quadrants (north-east, east and south-east), from the Atlantic.

A few persons, including fishers and vendors said there was nothing they could do, and that they have not made any changes to cope with the influxes. Others suggested that the events were "blessings in disguise" which allowed the nearshore ecosystems and fish stocks to recover and replenish. The general approach to dealing with the issues was to come up with short-term solutions. A general sentiment shared by fishers was that fishing itself is a temperamental livelihood, affected by different factors. Some days the catch is good, and other days very little, or nothing is caught. Therefore, they would deal with the *Sargassum* influx similarly, and tackle issues as they arise.

4.2.1.2 Physical

Coping mechanisms to physical impacts were numerous and simple, focussed again on the harvest sector. Some adaptations were listed for the post-harvest sector mainly concerning the removal of seaweed from the shoreline, to allow activities, both for tourists and locals.

For the physical impacts, a large role was played by government agencies such as the NCC, and the FD. According to the key informant from the NCC, they were responsible for maintaining and removing the large piles of *Sargassum* from beaches used for recreational activity, as well as landing sites. He also said that NCC at the time had limited resources with which to clean the massive volume of seaweed onshore. As a result, areas were prioritised according to the worst

affected, and where the most persons were affected. The NCC also had to determine what should be done with the seaweed after it was removed. Some measures taken by the NCC also included the opening of storm drains, to help push the seaweed out to sea. They used excavators to clear the *Sargassum* off beaches, and rakes to collect seaweed in the intertidal zone. The collected seaweed was either trucked to the Sustainable Barbados Recycling Centre (SBRC) for making fertiliser, or used to renurish the back beach, sand dunes and replanting of *Chrysobalanus icaco* or "fat pork". This was done at Bath Beach (Figure 20), Cattlewash, Silver Sands and Long Beach, as reported by the key informant.

Figure 20. Photograph showing piles of *Sargassum* seaweed with sand dumped on the backshore at Bath beach, east coast, Barbados

A vendor at Enterprise Beach reported raking up disintegrated seaweed into small heaps, which were then moved using a wheelbarrow to the back beach. The vendor, who sold at the beach every day, said that he usually tries to keep the area in front of his business (the white tent in the picture) clean, in preparation for the day (Figure 21).

Figure 21. Beachwear vendor at Enterprise Beach, south coast Barbados, raking heaps of seaweed for removal from the shore

Nonetheless, given the unpredictability of the event, the government agencies involved, as well as the stakeholders of the fishery value chain coped, and after time adapted to the changed coastal environment in which they operated, as deduced by the responses compiled. Table 4 lists all responses for various physical issues arising out of the *Sargassum* influx events. Some strategies were ubiquitous while other were more specific. For example, driving through and around the seaweed mats, and reversing to get the stuck seaweed out of the propellor, were strategies that are more common in the harvest sector, as opposed to modifying the engine using strainers, to keep the *Sargassum* out of the impellors.

Table 4. Coping mechanisms reported by interviewees of the fishery value chain for physical impacts of *Sargassum* influx events

PHYSICAL IMPACTS	ADAPTATIONS
Colour of boats on land, houses, and doorknobs blackened.	• There was no coping mechanism undertaken at time of data collection. Blackening persisted. .
Seaweed entangled nets.	• Net fishers avoided fishing around *Sargassum* mats or fished around them using other gear types.
Restricted movement of boats.	• Fishers and boat captains drove around the *Sargassum* mats or through them in cases where they could not be avoided, such as the windrows. • Some fishers turned around and headed back to shore when the seaweed was too thick. • Some fishers, especially longliners, have used satellite imagery from internet sources to determine fishing grounds. • Radio communication also used to find out and inform others about locations to avoid or locations clear of seaweed mats.
Affected and damaged boat engines	• Used radio to warn other fishers of *Sargassum* mats. • When it is stuck in propellor: stop, reverse and get 'moss' out. • If the seaweed gets thick, it cuts off engine. Outboard engine is raised and propellor cleaned, if the moss is sparse, it chops it up. • If the bearing is damaged (because of blocked impellor and subsequent overheating) the parts needs to be bought. If the local agent for the particular boat engine does not have them, they are imported. • Some fishers have begun using strainers over the engine's intake, however most interviewed have made no modifications to their engine.
Negatively affected hook and line	• Although it affected hook and line, fishers still use this method, commercially and recreationally, since the number of pelagics have increased due to the *Sargassum.* • They fish around the seaweed, rather than in it,to avoid lines snagging the weed. • Once the line caught seaweed, fishers manually removed the seaweed from the lines, since it made the line heavy and more difficult to use, or it covered the hook. • If the line breaks, they replace it, and buy new line and sinkers if they are lost. For game fishers, it has been reported that since trolling had become difficult, they had resorted to spending more time searching visually for fish.
Large mounds of seaweed on beaches and not enough NCC workers to clean them	• On the west coast where a smaller volume of seaweed was beached, fishers and residents bury seaweed in holes they dug along the shore. • On the south coast at Oistins, fishers have attempted to dig trenches through the mounds to allow waves to carry out some of the seaweed. • At some locations on the east coast, along with selected beaches on the south and southeast coasts the NCC has used machinery to clean the beaches, where there was too much seaweed for fishers and residents to remove manually. • There was one contracting company cleaning beaches, as reported by the NCC official.
Overwhelming smell from rotted seaweed	• Some of the beaches and landing sites were cleaned, or attempts were made to remove the seaweed by the NCC and Fisheries Division, and it was given to agricultural companies to use and sell as fertilizer, or it was mixed and buried in sand in the backshore.
Large number of flies from rotting seaweed	• Similar to adaptations for the smell, the seaweed was removed, or enough was removed for the functioning of the landing site or for swimming. The rest was left to be taken out during high tide. • Windows of houses were left closed to keep flies out.
Discolouration and peeling of paint on market buildings	• Not much was done as most buildings were left as they were up until time of data collection.

PHYSICAL IMPACTS	ADAPTATIONS
Tourists and locals are restricted by the seaweed inundation	• NCC were using heavy equipment, carrying out beach clean-ups with the public and NGO groups to clean heavily affected beaches, especially those that were frequented by tourists and locals. • In some instances such as on Enterprise beach vendors also cleaned the beach sections in the which they operated. • BARNUFO also assisted in cleaning some of the south coast beaches as part of a collaborative effort with NCC. • BHTA also hired private contractors to clean beaches near hotels, restaurants, and other business affected. • Some hotels have taken their own clean-up measures. For example,The Crane Beach Hotel on the southeast coast continuously cleaned the tideline with a bobcat and by hand raking, and they also attempted to deploy a seaweed boom nearshore to deflect weed away from their shoreline.

The physical impacts allowed for more innovative and creative approaches for fishers to deal with the *Sargassum*, such as modifying gear, or targeting different species, with different gear types, as reported by harvest sector interviewees. It also introduced the opportunity for fishers to utilize technology for communicating information about the seaweed mats, and sharing locations with each other. A large number of fishers indicated that they used the radio to find out about or warn other fishers about conditions and the presence of mats. One longline boat captain explained that he used satellite imagery, from the internet, to decide on areas to set lines (see Appendix 3 for image). He explained that using the current speed and direction, he would determine where to go. The fisher normally operated where the currents were not as strong, knowing that fish were more likely to aggregate there. However, given the presence of the seaweed, he fished in areas with stronger currents, since it was less likely for mats of *Sargassum* to occur there, and therefore avoided getting his longline entangled. Fishers also reported digging trenches in the stranded heaps of Sargassum to help waves come in behind the weed and wash it out (Figure 22).

Figure 22. Trenches dug by fishers to help waves carry out *Sargassum* built up on the beach at Oistins Bay

4.2.1.3 Socio-economic

As a result of the similarities, the social and economic coping strategies were combined here. Adaptation strategies for economic difficulties introduced by the *Sargassum* influx events were primarily focused around raising the prices of fish caught. Flyingfish, which was the fishery most negatively affected by the events, and for which there was a large demand, incurred drastically increased prices, as reported by the interviewees. This resulted in a change in buying patterns of customers (Section 4.1). The list of socio-economic coping strategies are listed in Table 5.

Table 5. Coping mechanisms reported by interviewees of the fishery value chain for socio-economic impacts of *Sargassum* influx events

	SOCIO-ECONOMIC IMPACTS	ADAPTATIONS
Positive or neutral	Increased prices of fish	• Flyingfish sold at a centralized price; price of fish determined at Bridgetown Fish Market, as with most fish. • Vendors paid higher prices for fish from fishers, and in turn sold fish for higher prices to consumers. • Consumers bought less fish at once, or less frequently, than they did normally. • Locals, especially older customers, bought less fish because they could not afford to buy the amount they would normally have done.
	Increased revenue for some fishers	• For live bait fishers, pot fishers, and trollers the season improved around August-September, a time of year which is normally considered the low season or off-season for most fishing. • There was an increased number of snapper caught. • Increased number of fishers switched to pot fishing, even before the traditional start of the pot fishing season.
	No significant impact on income	• Some vendors, processors, restaurants, and a few fishers said they had no impact or minimal impact on income, and operated with a 'business as usual' manner. • Charter fishers had no significant impact on income, but proved the events to be a nuisance. However, some fished around the *Sargassum* mats because of the increased likelihood of catching dolphinfish. • For most restaurants, the cost of fish remained the same. • Ice-boats and day-boats increased efforts by staying out longer on trips
Negative	Decrease in revenue for most fishers	• Some found jobs on land such as security guards, in gas stations, in construction, and in other areas outside of the fishery sector • For others there was no alternative income, just fishing. • Some said they would continue to fish because it was the only way of life they knew, while others have said if the *Sargassum* continues to come, they will stop fishing.
	Affects livelihoods and ability to support household	• Some interviewees said they budgeted more, and spent more carefully; only bought the essentials to ensure they live comfortably. • Some in the harvest sector reported that they borrowed money to maintain boats.
	Increased maintenance cost.	• Some fishers increased effort by spending more days out fishing (iceboats) or more hours fishing (day-boats) to compensate for higher costs. • Some boats spent less days, and time fishing to avoid wastage of gas, groceries, time and effort.
	Regular, local customers are sometimes unable to buy fish at higher prices	• The general consuming public bought less fish at a time, or bought less frequently. • Some have also started buying the jacks, which were sold at cheaper prices than the larger pelagics. • Those who were able to afford it, continued to buy the fish available at the raised prices.
	Increased debt from having to borrow money	• Some fisherfolk were more cautious and aware of spending.
	Less disposable income	• Boat owners took half of the boat earnings, and divided the rest in 2,. altering the usual division of earnings among crew to ensure fishers did not have a large decrease in income. • Costs were balanced; catch less fish, fish less, less grocery and other costs, therefore more money to split. • Some vendors had no alternative income, and relied solely on continuing to sell fish.
	Some post-harvest workers did not work because of poor	• Some did not work for the season, and found jobs elsewhere.

SOCIO-ECONOMIC IMPACTS	ADAPTATIONS
season	
Decreased sales for specialty dishes using flyingfish	• Fish was imported from other countries such as Trinidad and Tobago to compensate for the deficit. • Some restaurants used alternatives, especially for freshly caught fish; if it was not available, another fish of similar quality was used. • Changes or revisions were made to the menu.
Increased cost to buy fish	• Most restaurants were able to absorb costs associated with increased prices of fish, locally caught or imported. • If the situation worsens, some reported that there will have to be cutbacks in staff and other expenditure, alternatives would be introduced to the menus, and there will be a small increase in the price of meals. • Some businesses may have to consider closing, until season improves. • At the time of data collection the tourism season had already slowed so most restaurants did not have to resort to those measures. • Processors were able to absorb costs since they did not sell a lot of fresh caught fish.
Situation is discouraging and leads to frustration	• Many fishers reported that they became frustrated and disheartened at times because of the lack of fish. As a result, they fished fewer days to save on wasted gas money, time and effort. • Turned around and headed back to shore when there was too much seaweed. • Continued fishing, drove around or through it; and hoped that the situation improved the next day.
Affects beachgoers and recreational activities	• NCC involved in the clean-up of beaches using heavy equipment. • Some persons continued to go to the beaches, and opted for beaches with less seaweed.
Overwhelming smell and flies around seaweed	• Beaches were cleared by removal of seaweed, or left for the high tide to take it out. • There was not much else done, apart from removal, to cope with the smell or flies.

To mitigate the decreased income and effects on livelihoods, fishers said that they changed their normal fishing patterns by targeting other species, fishing fewer days, or more days but using different fishing methods and changing fishing spots. Some fishers however, developed theories on where were the best places to fish according to observations made. An example of this was one fisher from the east coast who suggested fishing on the northern side of the net, since he noticed fish tend to aggregate there. Fishers, who did not already work part-time on land, said they would seek additional income, if needed. One charter fisher said that he also used fish caught in a catering business to supplement his income, even before the arrival of the *Sargassum*. However, most fishers continued to fish, and changed little, operating as they usually would and hoped that their luck improved.

Vendors were more innovative in how they stabilized their income. Interviewed vendors reported selling what they could afford to buy from the fisher, at a higher price. One vendor explained that in order to ensure she had enough fish to sell; she would buy smaller quantities from various fishers to make up the volume she wanted, instead of buying exclusively from a single fisher and ending up with too much or too little. This way she got just as much as she needed, while helping more fishers to sell their catch. She also stockpiled her fish to ensure that if there were slow fishing days, she still had fish to sell. The vendor also sold by orders. Although there were still walk-in customers, the majority of her fish were sold to regular customers, most of whom ordered their fish beforehand, which she would weigh out and prepare for collection. This ensured that very little fish was wasted, and she only bought as much as she knew she could sell. She explained that this has helped her to maintain a relatively steady income. The key informant

from BARNUFO, also employed in the post-harvest sector, said that given the seasonal nature of the job, she planned, and transitioned into another job at the end of the season. Hence, even though the sector was suffering as a whole, she had already put measures in place to ensure that her income was steady.

Other actors in the post-harvest sector did not raise prices like fishers, and vendors, however they did indicate that they would consider doing so in the future if the *Sargassum* continues to be an issue. When asked if they had attempted to make money from the events by offering *Sargassum* based products, such as developing meals or drinks from the seaweed for menus, most said they did not yet attempt this. The larger, upscale restaurants said they would be open to it, once they were sure that it was safe for consumption.

Overall, though some stakeholder group incomes remained the same, the majority of persons interviewed said that their livelihoods and incomes were negatively affected. However, the mechanisms put in place to maintain their livelihoods were temporary, and developed to deal with the situation as they occurred. There was no long-term planning suggested by interviewees, although they did agree that there should be. As thekey informantfrom BARNUFO pointed out, there was also no information on fisherfolk skills and education, to assist persons in transitioning to other work, in the instance that fishing became unprofitable to them, and they had no choice but to seek alternative livelihoods.

The *Sargassum* influx events also impacted the Barbadian public. As mentioned in the focus group on the west coast, events affected leisure time at the beach, where locals would normally spend free time and weekends. It also marred the white sand and clear blue water that are synonymous with Barbados beaches. Beach goers and tourists changed their behaviour, by going to the beach less, or going to beaches with less seaweed. For example, it was reported by the CYEN key informant that instead of using east coast or south coast beaches, persons went to west and south-west coast beaches. Some even bathed from the beaches with *Sargassum*, where it was not too overwhelming, or went out beyond the seaweed. The way of life for many individuals living near to the coast, especially on the east and south coasts was disrupted, as well as for the fishers, whose livelihoods were at stake. Fish, which is a staple for Barbadian households, was now unaffordable and unavailable for some. These events not only affected incomes and physical assets, but also in a large part disrupted Barbadian living, especially for coastal villages, where fishing and landing sites are integral to the community.

4.2.1.4 Social capital

As mentioned before social capital did not seem to be impacted, as fishers did not change the relationships they shared, and operated as they normally would. Fishers expressed that they shared information on conditions of the sea, and areas where fish was present; information they shared even before the presence of the *Sargassum*. The only difference was they now shared information about the location of *Sargassum* mats.

In some instances fishers would come together collectively to deal with an impact. For example, the fishers at Weston would come together and clean the beaches of the seaweed; at Oistins some fishers tried making trenches in the seaweed to aid in its removal. Through observations made

during landing site visits, there is a sense of community, where not just fishers, but boat owners, boat captains, vendors, scalers, and local residents are involved at the landing site. As observed, these behaviours were still intact. The lack of government assistance, as stated by some fishers, lead to collective action at some landing sites to mitigate impacts brought about by *Sargassum*. Fishing community social networks were maintained and values were maintained.

4.2.1.5 Policy

As highlighted in Section 4.1.2 there are no policy measures in place to manage *Sargassum* influx events directly. The impacts and response mechanisms listed demonstrated that stakeholders, and Barbados as a whole, would have benefitted from clearer policy for environmental events of this magnitude. Unfortunately, as stated before, the events were unpredicted and unprecedented. However, the relevant government bodies, and the academic community has realised the need for more defined and thorough policy for environmental issues, and vulnerabilities. The need for incorporating vulnerability and risk policy, and overall climate-related policy into existing Barbados legislation, has been identified in the group interview discussed further in Section 4.2.4.

Table 6. Coping and adaptive mechanisms noted over the course of discussions and the group interview with the Fisheries Division on the policy impacts of the *Sargassum* influx events.

POLICY IMPACTS	ADAPTATIONS
No policy exists Lack of policy on the provision of financial assistance to worst affected fishers Lack of policy for price control; Lack of policy to regulate import and export of fish	• Fisheries Division undertook a survey in which they recorded the observations and found out the impacts of the *Sargassum* events on fisherfolk livelihoods. • Several meetings were held by various stakeholder groups to discuss the impacts of the events and to come up with solutions to the problems posed. • Discussions held between various ministries and relevant agencies on best practices when dealing with landed seaweed, and other issues in the marine environment. • Regionally a lot of research and information exchange has been undertaken to address the issue throughout the Caribbean. One example is the establishment of UNEP SPAW-RAC internet-based communication and information network focussed on the *Sargassum* issue. • There was no specific legislation or policy put in place to address *Sargassum* events particularly, however the Strategic Action Plan for Fisheries has sections relevant to vulnerabilities. • This current socio-economic study was also undertaken in response to the need for documentation of knowledge on the issue for use in developing tools for policy implementation.

4.2.2 *Sargassum* as an alternative livelihood

Participants in the interviews were asked their view on the use of *Sargassum* by the sector as an additional source of income. The majority of fishers said they were open to the idea; however, they would only get involved in the initiative if there were an established system, and a role outlined for them, where they were paid for their services. For example if businesses or other stakeholders required *Sargassum*, they would "fish for the seaweed", collecting it and bringing it to the business. Others expressed that if the seaweed was being bought at decent prices, they would definitely collect the seaweed and sell it to whomever wanted to buy it. One fisher said that one business was buying the seaweed, but at a very low price, so none of them (the fishers) considered it feasible. Some fishers went on to say that collection would be the extent of their involvement, because they would not have time to invest otherwise.

The key informant representing BARNUFO said *Sargassum* should be looked at as an alternative source of income, however, it should not be the only choice provided for fisherfolk seeking alternative or additional income. She expressed that other skills training should be provided so that fishers can still have a steady income, even when there is a slow or short season.

According to the key informant from the NCC, there were persons at the time working with the seaweed to develop uses in the agricultural sector. Some fishers used it in home gardens (Figure 23), but did not utilise it commercially. He informed that the Caribbean Agricultural Research and Development Institute (CARDI) was conducting research on the *Sargassum*, as well as a teacher at the St. Georges Secondary school, along with a few other institutions. This research was largely based on the use of the *Sargassum* as a fertiliser. There are some individuals and groups of the view that other uses of *Sargassum* should be explored, such as biofuel.

Another interviewee from the CYEN Barbados chapter suggested that persons whose livelihoods have been disrupted by the influx of seaweed, such as fisherfolk, should be involved in the initiatives to harvest the *Sargassum* for making *Sargassum*-based products. At a *Sargassum* Symposium held at the UWI, Cave Hill on the 17th September 2015, a number of presenters highlighted products for which the *Sargassum* can be used, in Barbados and the region. Speakers expressed the opportunity for Barbados to become a leader in *Sargassum* research, and product manufacturing, suggesting it provides a way to utilise the seaweed, and stimulate economic growth.

Figure 23. *Sargassum* seaweed collected by a charter boat fisher for use in his home garden

However, the key informant from the BGFA suggested that while there should be exploration on uses of *Sargassum*, such as "animal feed, fertiliser, food and cosmetics", there should be consideration for the possible negative impacts of harvesting the *Sargassum* on marine life and the ecosystems it supports.

4.2.3 Scenario-based planning exercise for future events

In the focus groups, participants were asked to discuss how they would deal with the top three ranked impacts in the following scenarios:

- There is another seaweed event in the next 4-5 years, with similar impacts.
- The seaweed comes for the next 5 years consecutively.
- There is another large event predicted to occur within the next 2-3 months.
- There are no predictions on the next event, although it is expected to happen again.

This exercise was aimed at providing more insight into fisherfolk ability to cope and adapt to environmental disturbances, such as the *Sargassum* influx event, that affect their livelihood and way of life.

4.2.3.1 Scenario responses from West Coast focus group

At the west coast focus group meeting (Figure 24), there were nine participants, all male, and over the age of 35. These fishers were mainly from Weston, with one fisher from Six Men's Bay. Several of them had multiple roles in the fishery value chain, being boat owners, boat captains, and two were also vendors. The west coast focus group's top three impacts were presented in Table 2. In the scenario-based exercise, the fishers were asked to suggest how they would cope with each of these top ranked issues, for each of the scenarios given.

Figure 24. Focus group meeting conducted at the Millie Ifil Fishing Facility at Weston, west coast, Barbados.

For scenario one, where the event takes place in a four to five year cycle fishers agreed that they would cope the same way they did for the last event. In the instance of restricted access and engine damage, one fisher suggested a collection system, where some boats are used to corral larger mats and removing it using a barge. They suggested trapping the seaweed or diverting it away from the island. Suggestions were also made that relevant agencies needed to work together and utilise satellite imagery to find out more about the events, and to research uses of the *Sargassum*. However, they reiterated that adaptations by fishers would be the same as they are now, coping with the seaweed day by day.

In scenario two, for five consecutive years of *Sargassum* influxes, fishers suggested because of the restrictions to the type of fish being caught, they would switch to another type of fishery, such as pot fishing. To address the issue of decreased income, which was identified as the second most important impact, some fishers agreed they would be willing to collect the seaweed once they were paid, if uses were found for the *Sargassum*, and an arrangement was made with the harvest sector. Some participants conceded that fishers needed to start putting measures in place for "hard times". Some contend that they are minimum wage earners, and as such this does not allow saving. Some say they may have to "moonlight" in order to make additional income. When asked they thought fish stocks, such as the dolphinfish would need to be more strictly regulated, they agreed that restrictions would have to be put in place. One fisher described it as a "double-edged sword", where the *Sargassum* is bringing in increased numbers of juvenile dolphinfish, but catching the juveniles would negatively affect the stock. They agreed that some middle ground would have to be found.

In scenario three, if it were to occur again in about two to three months, the answer was similar to the first, where they would continue dealing with issues on a day-to-day basis, coping with problems as they come along. Most fishers however, said that they would be more prepared now to deal with those challenges, than when the *Sargassum* first started to arrive. It was said that even though there might be need for the introduction of restrictions on the catching juvenile

dolphinfish, most fishers are mainly concerned with making money, and the implementation of this would be difficult. The same can be said for the last scenario, which describes the current situation; not knowing when the next *Sargassum* influx event will occur. Most fishers said they would cope the same way, and deal with it whenever it occurs, and hope a solution comes.

4.2.3.2 Scenario responses from East Coast focus group

At the east coast focus group meeting (Figure 25), there were six participants, all of whom were male, above the age of 40. They operated out of several coasts including Consett Bay, Bridgetown, with some saying multiple sites. Most of the participants were boat owners, and held other roles such as boat builder, diver, vendor, and one participant and boat owner, was the Consett Bay Fishing Complex keeper. On the east coast, the focus group discussions brought about some similar sentiments as the west coast fishers. The fishers said that if the seaweed were to come in the next four to five years, their coping mechanisms would be similar to what they did for the last event.

For their largest impact, decreased income, they said that they would have lifestyle changes, be more budget-conscious, raise the prices of fish, and continue fishing. For their second largest impact, decreased volume of flyingfish, they would look for jobs outside of fishing, and continue to fish around the seaweed mats for species like turpits. They would also try to find areas where the seaweed is absent and would not affect fishing. For the third most important impact, lack of policy to assist fishers, they will again continue with the coping mechanisms adapted for the last event. They will avoid going out if the seaweed is too thick, fish less days to save on maintenance costs, get jobs outside of fishing. Boat owners, who have bank loans, may have to find jobs on land, since some of the boat owners are not fishers, and do not have alternative income other than the earnings of the boat.

Figure 25. Focus group meeting conducted at Consett Bay, east coast, Barbados.

For the second scenario, the fishers explained that the coping mechanisms would again be similar; they will try to deal with the seaweed as it comes and "ride it out". Although very few persons have attempted any modifications to their boat engines, such as using the strainers, they agreed that they would have to start adapting these methods or others if the *Sargassum* comes

continuously. They suggested that fishers could be used to set up a sighting system for monitoring oncoming mats of seaweed. The fishers also stated that if the frequency of the *Sargassum* continues to increase there should be more ease of access to funding for those most affected. They also suggested that they would have to look for new fishing grounds if the old ones have seaweed, and devise new techniques for determining areas to catch fish. For example, look for clear areas, look for bait, or use lines to determine where it might be clear or not. Some of them also said they would wait until they get news of increased catch and then go out. There was also the proposal of using new types of nets that maybe better fitted to the *Sargassum* conditions.

For the third scenario, fishers again suggested that they would employ the same measures used along the course of the year, 2015. They said depending on the time of the year, and the tides, they can cope with the seaweed, and they have learnt how to fish and manoeuvre around it, for bigger fishes such as kingfish. One of the fishers suggested that spearfishing should be banned. Again, for the final scenario, the responses were the same. They would not do much differently, except adapt and deal with issues as they come.

4.2.3.3 Scenario responses from South Coast focus group

At the south coast focus group meeting, there were five participants, four males and one female, of ages 42 and above. Four participants operated at Oistins, and one at Bridgetown. There were two boat captains, one boat owner, and two vendors. For this focus group on the south coast similar responses to the other focus groups were given. For the first scenario, one fisher suggested that measures should be put in place for the next event, and times of financial instability. For the decrease in flyingfish, it was stated that it would cost too much for storing or stockpiling fish, and other measures need to be developed. For the third most important impact, restricted boat access, the use of satellite imagery was suggested to determine the position of *Sargassum* mats.

The suggestions for five years of continuous seaweed were to target other fish stocks, that were less exploited, but not fishing those with eggs. They said they will continue to manoeuvre around the seaweed, and one participant suggested that there should be some negotiation and agreement between Caribbean governments, for some free movement between islands for fishing. Participants also suggested there should be information shared through the local television Channel 8 and the Barbados Government Information Service (BGIS).

For the third scenario, fishers agreed that they would be more prepared to deal with problems brought about by the *Sargassum* if it comes again within the following two to three months. Fishers will continue to cope and hope for the best in the following season. The same can be said for the last scenario where the same measures will be undertaken, if and when another event occurs. There were some suggestions from the focus group on how the situation should be dealt with in the future, such as: associations having funds set aside for instances like the *Sargassum* events; putting restrictions in place for the size of fish caught, for instance the fish should not be less than two to three pounds. It was also suggested that fisherfolk education on the issue should be improved, with workshops and lectures held to inform fishers about the *Sargassum* influx events and there should be more research being done on the events. There was also the

suggestion of training fishers to use satellite imagery from internet sources, and resources such as the *Sargassum* Early Advisory System (SEAS).

4.2.3.4 Summary of responses to scenario planning exercises

The main responses received from fisherfolk at each of the focus group meetings for the scenario exercises is shown in Figure 26.

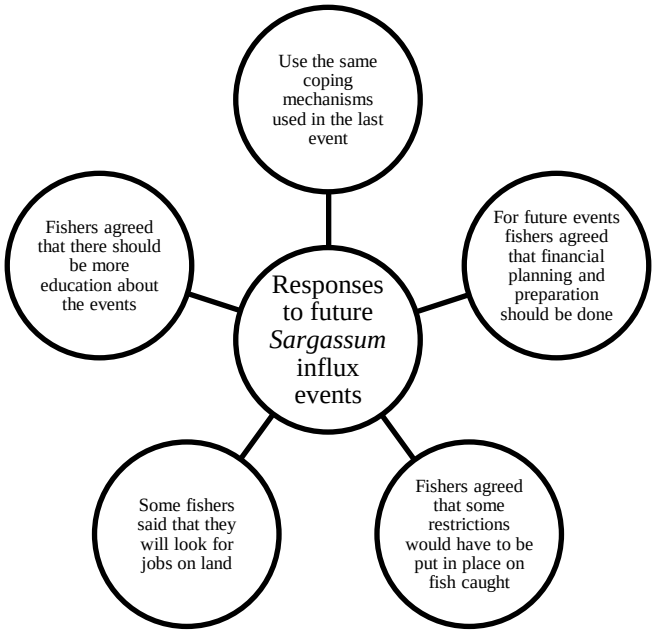

Figure 26. Diagram summarising fisherfolk response mechanisms to future *Sargassum* influx events based on their suggestions at focus group meetings around Barbados.

While there were some differences among fisherfolk from different coasts, fishers generally agreed on the most important impacts affecting their livelihoods, and had similar approaches to dealing with the problems brought about by the influx of seaweed, although the extent of impacts varied among coasts.

4.2.4 Fishery sector organisations responses to *Sargassum* influx events

In the previous section, the response mechanisms adopted within the fishery value chain were described, along with fisherfolk opinions on how they would react long-term, if there were a reoccurrence of the events. In this section, coping response mechanisms at the sector level are examined.

The management of the *Sargassum* issues fell within the jurisdiction of two ministries: the Ministry of Agriculture, and the Ministry of Environment and Drainage. The FD is a regulatory body under the purview of the Ministry of Agriculture, while the CZMU and the NCC are part of the Ministry of Environment and Drainage.

The role of the FD was to ensure that landing sites were maintained, find out how fisherfolk livelihoods were affected, and monitor and ensure that fish stocks were not further affected. The FD were also responsible for carrying out research to investigate the *Sargassum* influx events and the effect on fishers and fish. This type of research will inform decision-making processes and help to develop programmes and policies to minimize impacts (Fisheries Division 2004).

As an example, the FD and NCC worked together on clearing the worst affected landing sites. The FD also worked with fisherfolk, conducting a survey to determine the various impacts experienced along the various landing sites, as mentioned in discussions and the group interview with FD staff. They also worked closely with the Markets Division (MD) for data collection and operations of the larger landing sites or fish markets, such as the Bridgetown Fisheries Complex and the Berinda Cox Fish Market at Oistins (see Fisheries Division 2004).

The NCC interacted with several organizations and groups in tacking the *Sargassum* wracks, as discussed with the key informant from the NCC. This was because the NCC was largely responsible for mitigating the physical impacts of *Sargassum* through the removal of *Sargassum* from beaches, and its disposal. The NCC collaborated with the Fisheries Division, the Barbados Hotel and Tourism Association, as well as other private and public sector groups.

It was reported in interviews that members of the public and non-governmental organisations (NGOs) such as BARNUFO and the CYEN Barbados, assisted the NCC in beach cleanups. According to the key informant from the CZMU, this unit provided technical guidance to the NCC. They assisted in the development of a response guide on how beaches should be cleaned, and what should be done to minimize harm to the beach environment, such as the removal of sediment from the beach system. The Barbados Sea Turtle Project (BSTP) also worked with the NCC in an attempt to reduce effects of heavy machinery on turtle nesting beaches, and through the marking of turtle nests along beaches. According to a representative from the NCC, they also received assistance from groups such as the Friends of Enterprise and Oistins, schools, churches, as well as from the Government's Environmental Protection Department (EPD), the police, and the defense force. However, there was little assistance received from fisherfolk in some heavily affected areas.

The CZMU plays the role of the research body in this regard, providing expert knowledge on the *Sargassum* influx events, along with the University of the West Indies, Cave Hill and the Centre for Resource Management and Environmental Studies (CERMES).

The role of NGOs in the *Sargassum* influx events was sharing information, and education of the public on the issue. In an interview with a representative of CYEN Barbados, it was stated that main role of the group was the education of youth, and by extension, the Barbadian public on all the issues related to climate change. They were also the coordinators for the International Coastal Cleanup (ICC) events in Barbados. They saw the *Sargassum* influx events as an opportunity to educate persons more about the effects of climate change. As the group also sits on the National Climate Change Committee, their role can also be seen as lobbyists for introducing climate-smart policy, and encouraging civil society to participate in these discussions. Other groups such as the "*Sargassum* Hack", an initiative from the Caribbean Sustainability Collective, sought to

encourage entrepreneurship, and small enterprise development in Barbados, using *Sargassum* as a raw material. However, it is unsure whether this group is still functioning.

A simple network diagram, which indicates the interaction and flow of information in the sector, constructed from information gathered throughout the data collection process is shown in Figure 27. The diagram illustrates the coping mechanisms undertaken at an organisational level. At this level, the *Sargassum* influx events were viewed as national issues, not isolated solely to the fisheries sector. There are other organisations outside of the fishery sector, which also play an important role in the decision-making process in the management of the influx events. It also shows that there is more preparation needed for the management of the issue, so that organisations such as the NCC are not overburdened, with limited resources, and that they receive the necessary support from other relevant organisations.

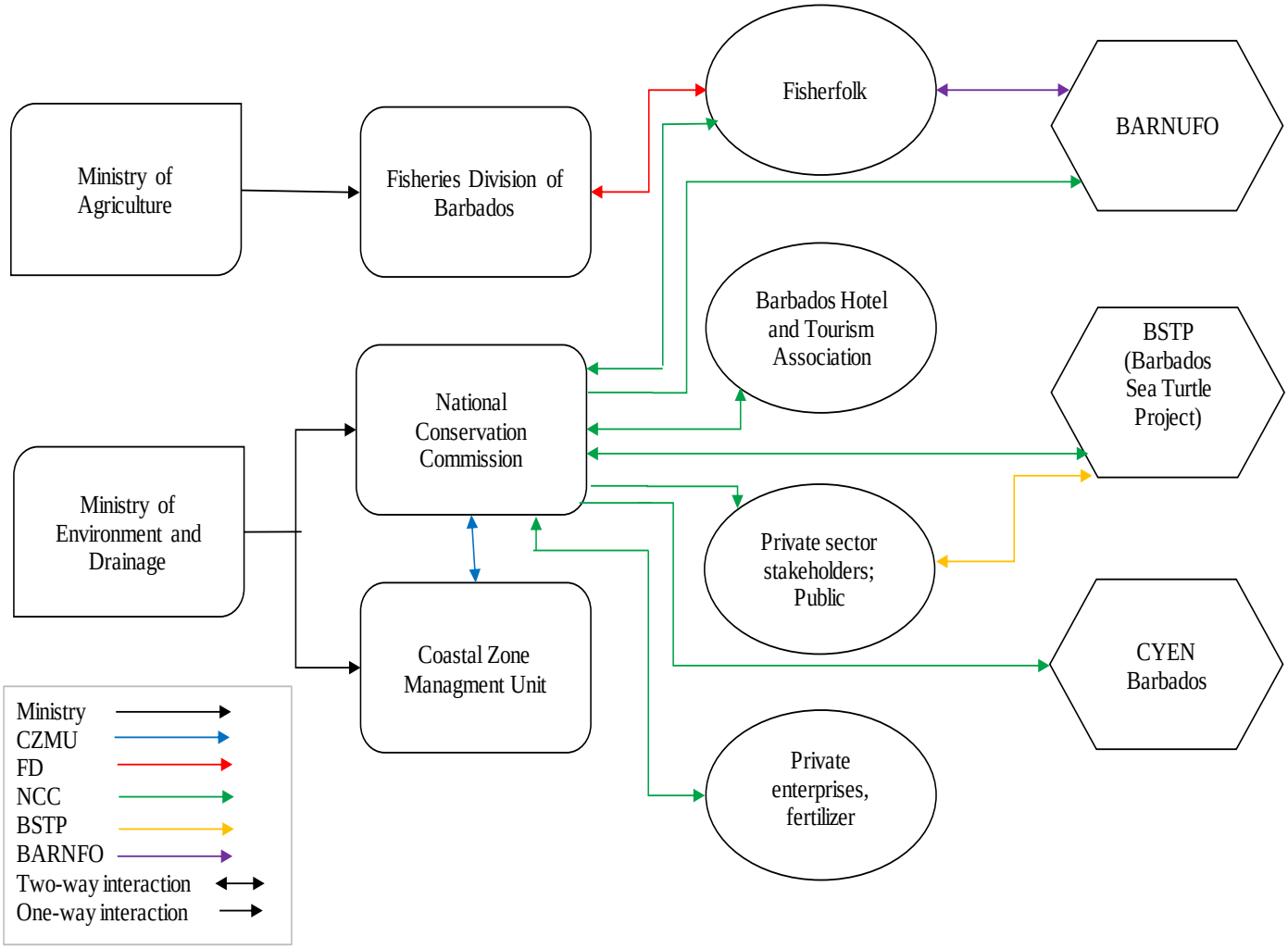

Figure 27. Diagram showing the relationships between stakeholders at different levels, in the management of the *Sargassum* influx in Barbados, as deduced from the data collection process

4.3 Fish landing data and *Sargassum* influx events

This section reports on findings related to the third objective which was to examine official fish landing statistics to determine the extent to which they capture information on *Sargassum* influx events in Barbados, and make recommendations for improving monitoring.

Fish landing data obtained from the FD were used to identify *Sargassum* event years and associated trends in the data for those years, and the years proceeding. These trends, fisheries data collection systems, and the role of the FD were discussed in-depth with staff, and other involved parties, in a group interview held at the FD. The group interview was centred on a list of guiding questions, the results for which are presented hereafter.

4.3.1 The examination of fish landing data and the identification of a "*Sargassum* signature"

The first objective identified and reviewed the trends in the catch data, as well as suggested plausible explanations for the trends seen. These main trends were identified in a simple matrix showing the two *Sargassum* events (Table 7). In examining the timeseries of landings data for the first seven months of each year (Jan-July; termed here as the 'fishing season') from 2004-2015 (Appendix 3), it is seen that the *Sargassum* events are reflected by changes in catches of several species. For example the 2011/12 *Sargassum* event affected the 2012 fishing season drastically, being the lowest seasonal catch since 2004. Likewise the 2014/15 *Sargassum* influx resulted in very poor catches in those years, and corroborating with fishers' perception that the 2015 season was virtually 'non-existent'.

Table 7. Trends seen in fisheries landing data for *Sargassum* influx events

Category	*Sargassum* event 2011/2012	*Sargassum* event 2014/2015	Discussion of trend
Carangids	Increase	Increase	Predatory fish, which may be following *Sargassum* or flyingfish.
Dolphinfish	Increase	Increase	Dolphinfish fishery does well. The *Sargassum* brings dolphinfish, but at smaller sizes.
Potfish	Increase	Increase	Potfish also seem to be attracted to the *Sargassum*, especially juveniles.
Small tunas	Increase	Increase	Predatory fish numbers increased with the influx of *Sargassum*. They follow prey.
Swordfish	Increase	Increase	Predatory fish which maybe following *Sargassum* or flyingfish.
Flyingfish	Decrease	Decrease	Flyingfish has been difficult to catch, the seaweed has reduced catchability.
Turpit	Decrease	Decrease	Smaller fish, therefore catch recorded by weight does not represent the number caught. Also sometimes lumped into "any other varieties" (AOV).
Wahoo	No significant change in catch	Decrease	Peculiarity, which needs to be further assessed. *Sargassum* may have some impact, but may not be the singular reason for decreased catch.
Tunas	Steady increase	Steady increase	Catch maybe be increasing due to global trends, and not associated with *Sargassum*.

Category	*Sargassum* event 2011/2012	*Sargassum* event 2014/2015	Discussion of trend
Total fish landed	Significant decrease	Significant decrease	The total landed fish greatly decreased since the main fishery of Barbados; the flyingfish fishery, was the most affected.

Although Table 7 represents only a portion of the species of fish caught, the particular fishery species highlighted are those with the most notable changes during *Sargassum* event years. An increase in Carangids (jacks), concurs with the observations made by the fishers participating in the survey. This is also true for dolphinfish, all tunas, and other large pelagics. According to participants of the group interview. The main reason for this, as identified in Table 7, was that these fish are predatory, and in some cases migratory (dolphinfish, tunas and swordfish). Hence, these types of fish may follow the *Sargassum*, as it provides a functional moving habitat for smaller, prey fish. It was also suggested that the conditions during *Sargassum* events lead to increased fishing effort for these species, due to the poor flyingfish season. As mentioned previously fishers changed their fishery, or target species depending on what was being caught by others, or what gear was less affected by the thick layers of seaweed offshore. A lot of these larger pelagics are mainly targeted by longliners, for example the tunas and swordfish (Fisheries Division 2004), whilst dolphinfish are caught by boats which utilize lines for trolling (day-boats, ice-boats, sports fishing vessels).

Regarding flyingfish, the *Sargassum* years showed the lowest landings for the 12 year period (2004-2015). In 2011 landings for flyingfish (681.1 mt) decreased dramatically from those recorded in 2010 (1652.9 mt), and decreased further to 262.9 mt in 2012 (Appendix 3). For turpit, the recorded landings fluctuate markedly over the 12-year time period with no obvious '*Sargassum*-signature', although landings were relatively low in both 2012 and 2015, contrary to reports given by fishers, who claimed that they had an increase in turpit catch (Appendix 3). For wahoo again there was no obvious pattern of landings associated with the *Sargassum* events.

Of note were significant increases in the total recorded landings of fish (including barracuda, congalee (tripletail), dolphinfish, flyingfish, turpit, sharks and billfish) in 2013, the year following the first *Sargassum* influx event of 2011/2012. It was suggested that this might be as a direct result of the seaweed moving out of the system, improving the catchability of some species. It may also indicate that the influx of seaweed allows replenishment of stocks, and thus the abundance available for catch is greater following successful recruitment in heavy *Sargassum* years. This was highlighted as an important area of research for the management of fish stocks as it relates to the *Sargassum* influx events.

A '*Sargassum* signature' was therefore apparent in the landings data as evidenced by the trends highlighted. This was especially obvious in Barbados' two largest fisheries: flyingfish and dolphinfish, which showed antagonistic responses. That is, during *Sargassum* influxes flyingfish catch was severely diminished or disrupted, while the dolphinfish catch increased. As stated by FD staff, the change in environment favours the capture of larger pelagics, while smaller fishes or bait fish, cannot be caught. Although the trend is quite evident, it was pointed out in the group interview that there are issues with the data collection and data quality. Also, only data for the first seven months of the year were made available for review. As such, further analsysis for the

full dataset is recommended in order to confirm the existence of the apparent *Sargassum* signature seen. These recommended steps are discussed later on. It should be noted that attempts were also made to access price data from the Markets Division, but these data were only available in hand-written ledgers at the Bridgetown market, and were not available electronically at the time of this study.

4.3.2 Fisheries data management review and decision-making

Data are collected to serve the mandate of the regulating body, as per the legislation governing fisheries in Barbados. The legislation defines the managing role of a body, and describes objectives for which they are responsible. Management of a resource such as fisheries requires scientific data which is used to guide decision-making processes. The management hierarchy of the FD, and the levels at which data influences decision making, as it relates to the *Sargassum* influx are modeled here in a flow diagram (Figure 28). The model was based on information gathered through key informant interviews, and the group interview with staff at the FD.

The diagram attempts to illustrate the factors influencing decision making within the FD. The sequence was based on the questions asked in the group interview. It identifies (in level two) the legislative and policy frameworks governing the fishery sector of Barbados. This influences the vision, mission, values, goals, and strategies of the strategic action plan (SAP) for fisheries; a tool designed to outline the management of the sector in detail. Although the SAP is still a working draft, the sections most relevant to the *Sargassum* issue were identified. These sections referred to in Figure 28 are:

- Section 5.2:
    - Goal 1- “To effectively manage and utilize the fisheries resources as sustainable sources of nutritious food, provider of employment, economic benefits and social well-being, without negatively impacting on the sustainability of the resources or destroying the habitats.”
    - Strategy 3- “Collaborate and cooperate with others”
- Section 7:
    - Goal 7. “To minimize the impact of disasters on livelihood assets and governance systems by building the capacity of institutions, communities and individuals to anticipate, adapt, cope with and recover quickly from the impact of vulnerabilities.”
    - Strategy 3- “Investigate vulnerabilities”

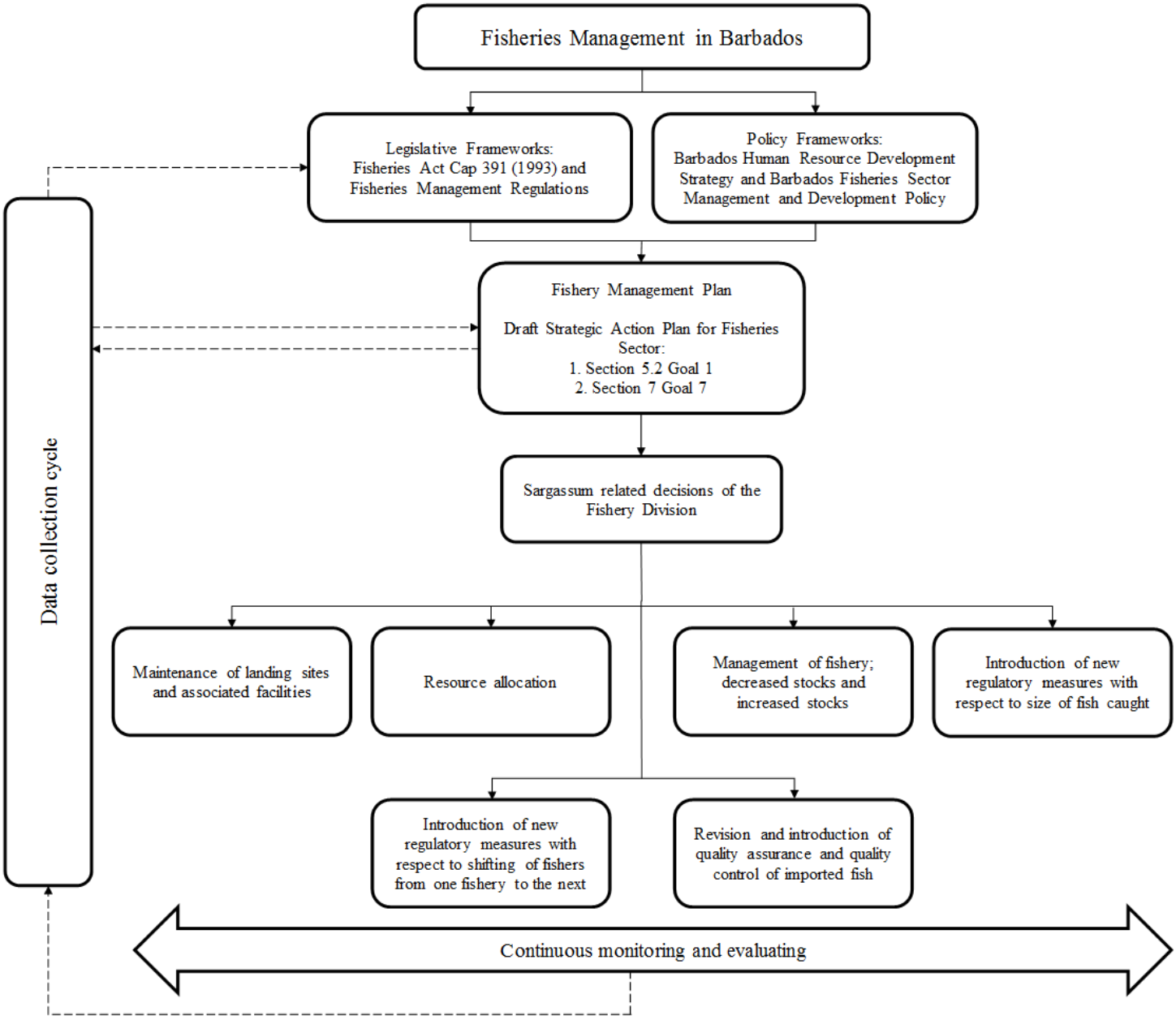

Figure 28. Model of the management system in the Fisheries Division of Barbados showing the flow of data inputs and the outcome actions as it relates to *Sargassum* influxes.

4.3.3 The *Sargassum* related decisions of the Fisheries Division

These quoted sections from the Draft SAP were included to address the management of environmental or natural disasters that may affect Barbados's fishery sector, as stated by FD staff. It was said that these are the sections that will be used to tackle the issues brought about due to the *Sargassum* invasion in the offshore and nearshore marine environment of Barbados, and the effects on physical (e.g. landing sites and boats), and biological (commercial species) assets, as well as the socio-economic consequences. As such, there were specific decisions to be made by the Fisheries Division to deal with these impacts. These *Sargassum* related decisions (outcome actions) are presented in Figure 28.

Sargassum related decisions would in turn influence the type of data collected, and the data collected influences the decision-making process. The *Sargassum* management decision, according to interviewees, should be continuously monitored and evaluated, for improvement of decision-making processes. This is an ideal model for all decisions made by the Fisheries Division, where the specific *Sargassum* related decisions are replaced by everyday protocols of the Division, to deal with any environmental phenomena, or the more overarching issue of climate change.

In Figure 28 data collected are used to make decisions at the legislative level, policy level and every day management level. The data collected should also be used to inform and improve the Draft SAP, and the Draft SAP in turn, should direct the data collection process. The data collected influences the introduction of new policy or legislation in response to changing conditions of the sector, including fish stocks and the environment.

Other *Sargassum* related decisions may also include the regulation of regionally and internationally shared stocks, areas of research necessary for understanding and dealing with the *Sargassum* influxes, information dissemination and education of fisherfolk, as well as fisherfolk relief and outreach. These however, are determined and/or influenced by decisions already listed in Figure 28.

4.3.4 The issues with data management systems

For this to work, and for informed decision-making, monitoring and evaluation, interviewees pointed out that reliable and fairly accurate data are necessary. However, a major area of contention is the quality of data received. This was an issue discussed during the group interview, which has also been documented in other studies. In the study by Staskiewicz et al. (2008) several issues were identified with the Fisheries Information System (FIS) and the CARICOM Fisheries Information System (CARIFIS).

The perceived short falls in the data management and data collection system of the FD, as it relates to reporting, collecting, recording, managing, and analysing data are summarised in Figure 29. As stated in the group interview, these issues ultimately affect what the data can be used for, with a certain degree of confidence. Consequentially, the data cannot be used confidently for decision-making, policy implementation, and finding solutions to issues, such as those posed by the *Sargassum* influxes.

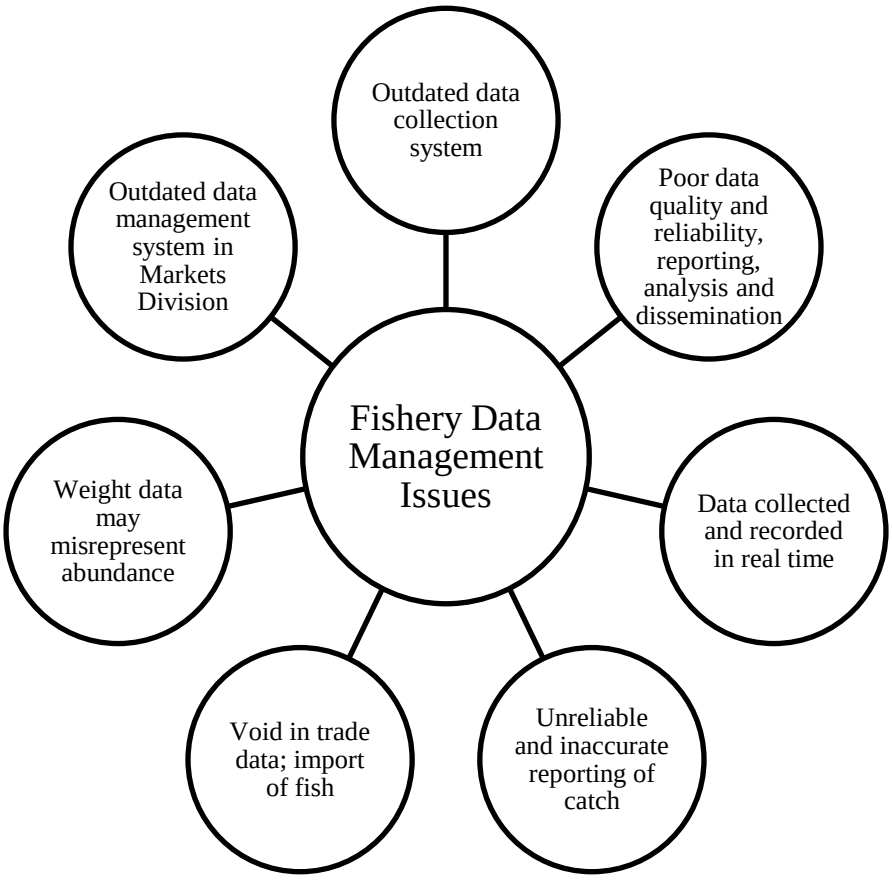

Figure 29. Issues with data quality and data management identified during the group interview

4.3.5 Other issues in managing the impacts of the *Sargassum* influx events

Other issues identified as part of the group interview, as it pertains to the *Sargassum* influxes, include:

- There was a lack of clear, structured, and comprehensive policy to address the *Sargassum* invasion.
- There was an overlap of responsibilities between different governmental organisations dealing with the problems resulting from the *Sargassum* influx events, with little collaboration and cohesion of efforts.
- There was limited or an absence of technical capacity in some governmental agencies and limited experience throughout, in dealing with the *Sargassum.*
- There was limited research that could be used to answer many questions surrounding the effect of *Sargassum* on Barbadian fisheries. For example:
    - whether the poor flyingfish catch was due to reduced catchability, or the complete absence of the fish, with the "running away" of the flyingfish by the seaweed;

    - if the small dolphinfish caught around *Sargassum* are juveniles of the same species, or another 'small-sized' species as some fishers suggest;
    - if there is any effect on potfish, especially at the larval and juvenile stages;
    - and whether it has a positive effect on benthic species, as is attributed to the increased sea egg population over the last season.
- The apparent livelihood issue, resulting from the poor flyingfish season, versus the issue of overfishing, or over-capitalization of the fishery to meet livelihood needs.
- There was a lack of policy in place for management of years of abundant flyingfish catches, where a high degree of spoilage resulted. There are also no provisions in place to effectively manage years of scarcity.
- There was limited price control, and the price of fish rose unchecked.
- The current management system allows for leakages within the system. Some of the fish caught goes unaccounted for ("dinner fish"), while others avoid the recording system and the associated tolls paid on landings
- Landing tolls are too low to assist in management costs and have not been changed since 1995. Market fees paid by hawkers renting stalls are also inadequate to cover the stall maintenance costs, with hawkers being charged just BBD $0.75 per day.

Two other objectives of the group interview looked at the recommendations for improving data management, and improving the adaptability of the Fisheries Division, and the sector by extension. These objectives were presented in the Section 6 of the report.

5 SYNTHESIS

In Section 4, a thorough description and discussion of the results was presented, for impacts of the *Sargassum* influx events on the fishery sector, and adaptions to these events. Many of the main trends and changes of the sector were presented according to the information gathered from numerous interviews. In this synthesis, the analytical framework outlined in Section 2 was applied to the results, to examine the resilience and capacity of groups in the fishery value chain.

This synthesis first reviews the fishery sector of Barbados as an SES, identifying the characteristics of SES within the sector. Next, the fishery value chain's capacity is assessed using the three categories of capacity: absorptive, adaptive and transformative. The results of the study were extensive and contained crucial qualitative data necessary for further qualitative and quantitative research.

5.1 The fishery sector of Barbados as a social-ecological system

The fishery sector of Barbados represents a social-ecological system (SES) as defined by Folke (2006) where the groups in the fishery value chain, harvest and post-harvest sectors, as well as other stakeholder groups such as the FD, BARNUFO, BGFA, Markets Division *inter alia*, are the individuals making up the human component of the system. These groups are dependent on, manage, regulate, protect, and interact with the marine and coastal ecosystem of Barbados

(considering the marine environment of Barbados as a whole). These groups of actors are a part of the SES, and their actions within it, impact and create change in the SES (see Folke 2006).

These groups within the fishery sector have different characteristics and roles in the sector. For example, the harvest sector catches and supplies the fish to the post-harvest sector, which ultimately contributes to the food security of Barbados. The FD acts as the regulatory body, managing the fish stocks and fishers, to ensure that the fish are harvested sustainably. Although there were similarities among groups, in income, in roles, education and other characteristics; no two groups or individuals in the sector are the same. This meant there is non-linearity within the system. This diversity creates a robust system. Each group has a function, and works in tandem with each other to allow the functioning of the entire system.

There is also a certain degree of integration among groups, where they work together and are dependent on each other for their livelihoods. For instance, most fishers are dependent on vendors to buy their fish. If they had to catch and sell their fish, they would have to wait until all their fish from the first catch sold before they could fish again, which may lead to spoilage, and decreased income. Vendors rely on fishers to get fish for retail; if fishers sold their own fish, then vendors would be displaced, and have no income from the fishery value chain. Similar comparisons can be made for scalers and boners, who also play an important role in the fishery value chain. Without customers, hotels, restaurants and seafood processors, there would not be any local demand for fish. Therefore, there was connectivity and interactions between stakeholder groups, and integration was seen within the sector. The various roles of each group in the fishery value chain, as well as, the number of groups within the sector, created a complex system.

The SES in this study, the fishery sector was viewed as a landscape, comprising domains acting and reacting to the environment, and the each other. This landscape is subject to thresholds, that is, the fishery sector operates under certain conditions. These conditions may vary slightly from time to time, but not so much that the landscape and its domains are destabilized. These create an ongoing, continuous change in the environment. For example, the effects of climate change have been occurring over time, such as sea-level rise and increased global temperatures, and the marine ecosystem and the SES have remained relatively stable. The same can be said for overcapitalisation of the sector, which has been increasing over the years, even though there are still negative impacts, the fisheries of Barbados still remain largely intact, with the exception of the sea egg resource.

The thresholds in this study can be regarded as the number of fishers targeting a particular species, or the number of boats utilised by the industry. For the *Sargassum* events, the threshold was the volume of seaweed coming into the marine environment of Barbados. If the amount of seaweed stays within a particular range, or volume, the system will retain its stability, and will not have destructive impacts.

However, when there is an unexpected shock or perturbation to the landscape, it causes a shift from the normal state of stability. This was what occurred when the large mats of *Sargassum* continued to come into the nearshore ecosystem, and inundate the shoreline. The threshold of seaweed that was manageable by the environment and the fishery sector, was crossed. The

frequency, and volume at which the seaweed came into Barbadian waters, did not allow time for the fishery sector, and the landscape in which they operate, time to settle back into a stable state. As the landscape or fishery sector is disturbed. The domains, such as the harvest and post-harvest sectors were also affected, and the connectivity and integration between groups have new conditions or variables with which to cope. The *Sargassum* influx events created a regime shift, from a state with little to no seaweed, to one which has now experienced large-scale inundations of seaweed, twice in a few years. Due to this environmental perturbation, the *Sargassum* influx events, the fishery value chain and other stakeholder groups within the fishery landscape must now cope with the changed variables. They must adapt to the conditions of the changed landscape, so that stability in this new state; that is the presence of the *Sargassum* in the marine off-shore and coastal nearshore environment, can be achieved.

For assessing whether these groups in the SES have been able to regain stability, a resilience framework must be applied, to determine stakeholder capacity to cope with these changes in the environment in which they work and live.

5.2 Assessment of capacity and resilience of fishery value chain of Barbados

As identified in the analytical framework, Armitage (2005) identified four characteristics for assessing adaptive capacity. The ability of the system, or individual to learn to accept change, to be able to integrate and use different types of knowledge about the change, to encourage the use of creative measures to reorganise the system, so that stability is restored, and lastly to recognise new opportunities arising from the changed conditions, and take advantage of them. The analysis was taken a step further by identifying the types of capacity of groups, that is, its absorptive, adaptive, or transformative capacity (OECD 2014).

5.2.1 Resilience of fishery value chain actors

In the fishery value chain, the groups of livelihoods were divided into three stages. Stage one of the fishery value chain contained the fishers, boat owners and boat captains, collectively known as the harvest sector. There were differences in ability to adopt coping mechanisms between these groups, and even between individuals within these groups For the three groups at this stage, the ability to learn and use knowledge to adapt to the changing conditions were relatively the same. This was expected to some degree since fishers who comprise the crew, and boat captains work together and are subjected to the same changes. The boat captains may have a slight advantage since they often get a larger cut of the boat earnings, and are more prone to utilising information and seeking information about the seaweed, using the radio to find out the daily conditions, or seeking satellite imagery.

However, in many of the cases, interviewees were boat captains, and boat owners, which meant expenses for maintenance of the boat, income for crew, and repairs to boat, even when there is little fish caught, is his/ her responsibility. It is important to note that each individual in the fishery value chain has a different background and circumstances that determine their ability to utilise the four aspects outlined by Armitage (2005). Each individual will cope with the *Sargassum* influx events differently, using their experience and knowledge. Within the harvest sector, there were other reported characteristics of fishers, which would also determine how they

coped. Some fishers were also carpenters, auto mechanics and involved in agriculture. For part-time fishers, they already have additional income from jobs on land. This will increase their ability to cope socio-economically with the changed conditions.

Education level, age and exposure to technology play interesting roles in determining one's ability to adapt. Although, these characteristics were not investigated fully, it was noted that most of the fishers attending the focus group meetings had a secondary school education. Their willingness to participate in the focus groups, and seek information on the *Sargassum* influx events, indicated the capacity to learn, and openness to receiving and sharing knowledge.

Fisherfolk attitudes towards the events also determined the strategies they used. For some divers, especially on the west and south-west coasts, who were not affected by the events, they were not as concerned about the events as others. Some fishers expressed that it was the nature of the job where events such as these happen, where "one day you'll get a big catch, and the next day, nothing", and therefore went about fishing as they normally would. In some instances religion was used to explain the influxes, which to the interviewee meant not much could be done except to carry on fishing, and wait to see what the future would bring. Another observation, made through the interviewing process, and at the focus group meetings, was that older fishers, generally were more knowledgeable about the changes in fishing throughout the years. They appeared to have a greater understanding of the ocean, and used their observations to create coping mechanisms. The younger fishers were more likely to increase effort, to catch fish.

Most fishers showed a genuine interest in the issue when interviewed, and took the opportunity to ask questions, and share their observations. A lot of fishers said that they had limited access to technology, some even saying they had GPS but did not use it. However, quite a few said that they would research the issue when they had chance, or said they would ask their children to do some research on their behalf. Only one fisher mentioned using the SEAS forecasting on incoming *Sargassum.* However, as the same fisher suggested, if persons were trained on its use or the information from the forecasts were shared with them, it may allow them to be more prepared.

In looking at the four attributes, it can be said that fishers have displayed an ability to learn from the events, most have even said they know it will come again, and they are more prepared to deal with it. Fishers tended to use mainly traditional knowledge, however, a few have also used scientific knowledge. For most fishers, the GCFI hand-out (Appendix 2) was the first piece of scientific information they had since the *Sargassum* became an issue. The fishers to an extent have recognised the opportunity to re-organise, and utilise new opportunities, that is, targeting new species coming into the system, and changing their fishery and gear types, and fishing spots. For instance, catching the new jacks coming in with the seaweed, and the younger dolphinfish, as well as moving to other fishery species that they would not have normally exploited, such as the demersal reef fish.

For the post-harvest sector there were large differences in the ability to cope, as identified in results. It makes up two stages in the fishery value chain, and comprised vendors, scalers, boners, seafood processors, restauranteurs, and the general consuming public. The post-harvest sector is reported to make up the bulk of the fishery sector (Fisheries Division 2004). As explained for the

harvest-sector, individuals in the post-harvest sector also have differences among groups and individuals, which meant that their livelihoods are impacted differently, and their ability to cope would also be different. For example, some vendors said their income remained steady, or that even though there was a decrease they were not affected badly, because it was the nature of the job, and they were able to budget efficiently. Others said they were drastically affected. The difference in responses can be as result of the individual ability to learn from past experiences in the sector, and preparing for the seasonality of the Barbadian fisheries.

However, this event has been unlike anything fisherfolk have had to deal with previously, and the effect on fisheries was unforeseen. Those solely employed in the flyingfish fishery were vulnerable to decreased incomes due to the lack of flyingfish, such as those employed in the processing plants. Their ability to adapt would therefore depend on whether they had access to other sources of income, or whether they can transition into another type of fishery. For those working in the plants, switching to another fishery would not have been possible, as mentioned by the BARNUFO representative, the Bridgetown plant only processes flyingfish. This fishery is itself already seasonal, and some persons employed there would already have alternatives. The shorter season however, would have had repercussions in their incomes, and they may have had to seek other employment earlier than usual. Seafood processors and restaurants, as reported in interviews, were able to learn, and use the knowledge provided to cope with the changing conditions brought about by the seaweed. Since their livelihoods were not as affected as others, their income remained steady. For smaller restaurants, however, the increased prices of fish took a large part out of the profits. Some restaurants used alternative local species, while some used imported fish to meet their needs. As such, they demonstrated the ability to accept the changes and come up with alternatives

In the fishery value chain, the harvest sector, and those from the post-harvest sector, whose jobs are based solely on the flyingfish were the most affected. All groups or stakeholders displayed some degree of adaptation to the events, some more than others did. Fishers and boat captains displayed the most creativity in terms and seeking new opportunities from the events, especially through line fishing and pot fishing. Some vendors also showed creativity, in coping with the deceased supply of fish.

Both the harvest and post- harvest sector exhibit absorptive and adaptive capacities. Most of the strategies or mechanisms put in place are short-term, and already in use. However, through discussions, especially in focus group meetings, fishers have expressed the need for longer-term adaptation. This is seen in the scenario-based planning, where most fishers agreed that they will continue using the same methods of response, but that research, technology, and revised policy should be used to make the sector more resilient in the long-term.

5.2.2 Resilience of coasts

As mentioned in the discussion on the resilience of the fishery value chain, there are various degrees of resiliency among the various stakeholder groups depending on the roles and characteristics of each group. Another factor contributing to this difference was the coast on which persons operated. This is most pronounced for the harvest sector, and some members of the post-harvest sector.

Of the three coasts included in the study, the west coast fishers appear to be the most adapted. They have exhibited the attributes outlined byArmitage (2005) in one way or another, to cope with their situation, learn from it, and benefit from it as best as possible. West coast fishers demonstrated more of a community management approach to the issue and were easily adapted to the changing conditions. The fishers here took initiative cleaning the beach of seaweed if necessary, and most reported sharing information on conditions for the day prior to heading out. However, it should be said that the fishers on the west coast did not have to deal with the large volume of seaweed found on the east and south coasts. If there was any seaweed, fishers said that it was usually taken back to sea the next day, by the waves. In addition, fishers were able to manoeuvre around the *Sargassum* mats offshore more easily, which allowed fishers the opportunity to fish around them for pelagics such as dolphinfish.

East coast fishers also seem to have figured out how to deal with the main issues, even though the approach is a slightly less systematic "deal with it as it comes" approach. Unlike the fishers on the west coast, they had to deal with the seaweed offshore and inshore as well as inundating their landing site. Skeetes Bay Fishing Complex ended up being abandoned by fisherfolk and closed for the remainder of the season in 2015. However, fishers at other east coast sites such as Tent Bay, Consett Bay and Martin's Bay were still able to operate. This was due in part to the physical nature of the bays. Skeetes Bay is the most enclosed of all bays, and even though attempts to remove the piles of *Sargassum* were made, it was still difficult to clear the area, before another influx of seaweed came into the shore. High energy waves were unable to come in and take the seaweed offshore.

At the other sites visited, wave action was able to clear the shore of large volumes of the *Sargassum,* although it took a slightly longer time for the seaweed to be removed from Consett Bay, than west coast beaches, it was reported that under very high-energy conditions the seaweed is naturally removed. Therefore, although the fisherfolk on the east coast appeared to be a little less organised than on the west, this may be largely due to the magnitude of seaweed present on the east coast, and the inundation of landing sites. The presence of more *Sargassum* windrows, are also more difficult to navigate, compared to the large mats more often seen on the west coast.

The south coast also showed some ability to cope with the events, but showed the least resilience of the three coasts, in terms of the attributes of adaptive capacity (Armitage 2005). Though fishers and other groups found ways to cope, it seemed that they were not taking any active measures in dealing with issues, but depended on the FD and other agencies to clear the seaweed at the landing site. It should be noted that the larger landing sites were on the south coast, and would have needed the intervention of government agencies, especially at Oistins where the entire bay was inundated. The nature of the beach, according to the NCC official, did not allow high-energy waves to take out the *Sargassum.* The volume of the *Sargassum* required heavy machinery to remove the seaweed, as was the case at the east coast sites of Skeetes Bay and Consett Bay. There was some attempt to remove the seaweed, by digging trenches to allow the water to take the seaweed off-shore. Unfortunately, there was so much sand trapped in the piles of *Sargassum,* compacted by the waves, it was almost impossible for the waves to move the heavy seaweed back out. This was similar to the scene at Skeetes Bay.

Fisherfolk at each of the sites displayed both absorptive and adaptive capacity, as evidenced by interviews and focus groups. Although the west coast is more organised, the east coast and the south coast also showed attributes of learning from their experiences, and adapting.

5.2.3 Resilience of organisations

Institutional capacity to adapt to the changing domain state, due to the introduction of massive amounts of *Sargassum* to the system, was not as high as was necessary to avoid significant disruption. Although the phenomenon occurred in 2011, interviewees said, its unpredictability rendered Barbados completely unprepared for the management of the impacts on the marine environment and the fishing industry, according to some KIs. There was no response plan in place; one was only developed after the *Sargassum* started to inundate shorelines. The NCC was ill-equipped to deal with the magnitude of *Sargassum* landing on the beaches around Barbados, lacking the required machinery and man-power. There was limited national research initiated since the last event in 2011, to understand the cause, impacts, or solutions to the issue. There was a clear lack of policy to guide the management of the issue and regulate the fishery, especially the flyingfish and dolphinfish fisheries, in *Sargassum* years, as indicated in the group interview. Even though *Sargassum* influx events are relatively new to the eastern Caribbean, interviewees pointed out that policy should be in place to manage stocks, and regulations to ensure sustainable fishing should already be established, so that the sector can still thrive in years of gluts.

Nonetheless, organizations such as the NCC, CZMU, FD, and Markets Division to a lesser extent were able to cope with the events and initiate plans for long-term adaptations. Discussions on the introduction of climate-smart policy, which encompasses *Sargassum* influx events, were also started. It can be said therefore, that the measures adapted by institutions were largely coping mechanisms, but, these will then be the starting points of longer-term adaptive strategies. The success of the implementation of these long-term adaptive strategies will however be determined by the priority the issue is given, access to resources necessary for proper management and the timely implementation of new policy geared towards managing future events. Organizations involved in the management of the *Sargassum* influx events can be said to have absorptive capacity, preparing for renewed influxes throughout the season by utilising the same measures. It also exhibits some degree of adaptive capacity; trying to adjust management measures and fisheries policy to keep the fishery sector as stable as possible, while using the opportunity to directly deal with the lack of climate-change policy and legislation. The institutional resilience of Barbados was largely persistence, with incremental adjustments made, as the phenomenon was more understood.

5.2.4 Resilience of sector

Looking at sector resilience to the *Sargassum* influx events, it can be said that there was overall an ability to cope with the event, given its unpredictability. The sector showed absorptive capacity, using the same short-term coping mechanisms, which would have been used in the first event, in 2011. The government agencies, NGO groups, and other civil society organisations also showed adaptive capacity, as there was a conscious recognition for the need for both short-term and long-term measures to be put in place. It also called to question the usefulness of pre-established systems in events such as this, and the need for modifications, adopting of new

technologies, creating new technologies, introducing new policy, and/or revising the old to include environmental events such as the *Sargassum* influx events.

Calls have also been made for not just the fishery sector, but for the government of Barbados, and research institutions, such as the UWI, to look at potential uses of the *Sargassum* seaweed. Initiatives such as the *Sargassum* Hack, are viewing this an opportunity to create small business, with *Sargassum* being the raw material. Although it is not clear whether this initiative is still active, local entrepreneurs have started experimenting with using the *Sargassum.* Discussions have brought about the idea of making Barbados one of the major producers of *Sargassum* - based products. Persons have already started processing it and selling it as fertilizer. Though more exploration and research needs to be done on the biochemical make-up, and its feasibility as a raw material, since it is unpredictable, the interest in using the *Sargassum* will create a new domain or landscape, for stakeholders within the fishery value chain, or outside of it, to participate. The interest in the seaweed for new products, though not necessarily stemming from fisherfolk, may lead to the formation of new interactions, as fishers could perhaps be included in harvesting the seaweed, or taught to make *Sargassum* based products themselves, as additional or alternative income, outside of the fishing season. In this way, the sector is becoming transformative.

6 RECOMMENDATIONS AND CONCLUSION

6.1 Recommendations

The recommendations listed here are a compilation of all those made throughout the research. They include recommendations made by both harvest and post-harvest sector individuals participating in the semi-structured, key informants and group interviews, and focus group meetings. Some of these recommendations have already come to fruition, or plans for implementation were made. These recommendations have been organised into categories corresponding to the impacts and adaptations presented. The recommendations do not target a specific body or organisation; however, it presents recommendations for the entire fishery value chain, the fishery sector, and other sectors of Barbados.

Recommendations were also listed for improved data management systems within the FD, as discussed in the group interview. These solutions were aimed primarily at improving data collection systems, and policy within the FD, in collaboration with other governmental agencies, such as the Market Division. Researcher's recommendations are also included, and are based on the interviews, discussions, participation in meetings in Barbados, and abroad. The recommendation would reflect those which seem to be the most pressing, given the research done.

6.1.1 Recommendations for biological impacts

Short-term

- Local or collaborative research on the origin, cause, effects, and potential uses of *Sargassum*.

- Use of trends identified in the landing data for further investigation of trends in catch and effort data to establish more conclusively a "*Sargassum* signature", to implement management strategies for fisheries in years prior to *Sargassum* events, years of *Sargassum* events, and years proceeding *Sargassum* events.
- Looking at ICCAT (International Commission for the Conservation of Atlantic Tunas) reports, and other international bodies, for the global trends of fisheries and investigate trends seen, for species such as billfish, tuna, and shark. Comparison with local statistics, to examine changes in catch of larger pelagics.
- Planning and implementation of research on the effect of the *Sargassum* on water quality in the nearshore environment, and the effect on reefs.
- Research should also be done on the human health impacts associated with the *Sargassum*.

Long-term

- Development and implementation of minimum size limits is needed to regulate the fishing of the small-sized dolphinfish, which would likely require financial input for increased monitoring personnel.
- Initiation and continuation of research covering various areas such as:
  - introduction of exotic species,
  - nearshore water quality associated with *Sargassum* trapped in the nearshore,
  - predicting *Sargassum* influxes and beach stranding,
  - food chain repercussions
  - biochemical assays to inform potential for extraction of commercially valuable compounds for pharmaceutical development, fertilizers, animal feed, human consumption, *inter alia*.
- Licenses should be introduced to regulate switching between species and gear type, and prevent overfishing of more vulnerable labile species, such as reef species. This would control the fishing pressure on the various types of fisheries in Barbados, and limit unsystematic switching between fisheries and target species.

6.1.2 Recommendations for physical impacts

Short- term

- Implementation of "*Sargassum* Task Force" for dealing with beached seaweed, following models such as Grenada, Guadeloupe and Martinique.
- Coordinated response between the NCC and other agencies that can provide support in the safe physical removal of the seaweed from the beaches, with minimal damage from the use of heavy equipment.
- Use *Sargassum* for beach building in other areas where coastal erosion is becoming more prevalent.
- Encourage schools, NGOs, and more businesses to assist in the cleaning process, with opportunity for education on the *Sargassum* influx events. Marketing, promotions, and competitions can be used to garner public support.

- Education and training of fishers on how to use internet resources such as the *Sargassum* Early Advisory System (SEAS) for monitoring of *Sargassum* for predicted landings and movement of seaweed. This can assist them in determining fishing spot, and avoiding areas with a lot of seaweed.

Long-term

- The development of a long-term response plan for *Sargassum* events, and similar events.
- Consider these events in future design and operation of landing sites, and other shoreline infrastructure.
- Development of specialised equipment for cleaning *Sargassum* off beaches, with minimal damage to the beach ecosystem. Innovative ideas, and designs for equipment for removal of *Sargassum* off-shore, or to deter the seaweed from coming in, which minimises negative impacts on marine life.

6.1.3 Recommendations for socio-economic impacts

Short- term

- The FD should look at the impacts of the *Sargassum* influxes on consumers, and investigate how they are adapting to the difference in species availability, and the price increases.
- Educational outreach with fisherfolk about research being done on *Sargassum* and encouraging innovation and entrepreneurship amongst fisherfolk and the wider public for *Sargassum* products.
- The publishing of more public service announcements (PSAs) using local newspapers, social media networks, radio and, local channel to inform public about the seaweed, its importance, predicted landings, any management measures put in place, and other vital information.
- Developing a *Sargassum* monitoring system, with fisherfolk being instrumental in reporting *Sargassum* sightings to the FD, with *Sargassum* Forecasts Bulletins broadcasted to fishers via radio and phone applications.
- More effort should be placed on sharing information and making it more accessible to fisherfolk. It is important to foster a sense of ownership of the data in fisherfolk, and thus the data must be readily accessible to fishers, so that they can better understand the impacts on the fish stocks, and their own potential roles in assisting and dealing with efforts to reduce the impacts.
- The FD should gather information on adaptation measures taken by fishers, and share this with other fishers, from other landing sites. The Division will act as a repository for collection, storing, and disseminating information.

Long-term

- Markets Division price data should be reviewed and used for further analysis of socio-economic impacts. This can also be used to monitor and regulate fluctuations in prices, particularly during shortages.
- Socio-economic monitoring of the fisheries sector, by the FD, should be improved. This can be used to further inform strategic action plans for fisheries in which there is an increased emphasis on livelihoods.
- Implementation of a National Insurance Scheme (NIS) for fisherfolk, which acts as a financial safety net for fishers, long term.
- Fisherfolk forums to understand how events have affected them, how they are coping financially, and provide training on financial planning. Provide information to fishers on how they can reduce money lost due to the seaweed, such as the use of the satellite imagery.
- Classes and training seminars for alternative livelihoods, so that fishers can obtain training outside of the fishery sector.
- Investment in public education programmes by public and private sector, as seen in Galveston by SEAS, where *Sargassum* wracks are used as an opportunity for education of beach goers on the importance of the seaweed, and the animals and other creatures found in the seaweed, and the relationships between each.
- A system should be put in place to monitor and record adaptations, or lack of adaptations of fisherfolk, over time, for various environmental and social perturbations which fisherfolk may face.
- An outreach programme can be developed by the FD to share information with fishers, engage fisherfolk in creating solutions, not just to the problems brought about by the *Sargassum*, but all other issues affecting the sector. These meetings can be held once a month, changing locations, and targeting current issues or events in the fishery sector.
- The opportunity can also be used to educate fisherfolk, schools, and the public about climate change and climate variability. It can be used to foster discussions about vulnerability, and to inform persons about lifestyle changes that can reduce negative effects of climate change. The opportunity can also be used to engage more youth in environmental initiatives.

6.1.4 Recommendations for policy impacts

Short- term

- There should be improved collaboration and integration between FD and other government agencies involved in the management of the *Sargassum* landings, and its effects on the marine environment. This will ensure a multifaceted approach to management, and should be guided by policy.
- Goal 7 of the Strategic Action Plan for the Fisheries Sector should be expanded. Specific objectives for research and the use of technology should be included.

Long-term

- Developing policy for improved fishery data collection, analysis and storage and streamlining management plans to include provisions for gluts and shortages.
- Revise and introduce more strict management schemes for fishers through use of restrictive, species-specific and gear-specific, fisher licenses (e.g. require special permits for pot fishing, for diving (spear fishing) etc).
- Introduce penalties in the form of fines for fishing without a particular permit.
- Development of policy that can regulate fisheries in years of plenty, to anticipate years of shortages. For example policy that may address an action plan for stockpiling of flyingfish in years of abundance, to help in following years where there are shortages in the flyingfish season.
- The fishing industry needs to also be viewed in terms of food security, as well as the livelihoods it provides. Policy should be built around these factors.
- Policy should also make recommendations for the FD to lead the sector in research into adaptive measures, introduction of new fishing technology, and gear modifications. This policy should also provide recommendations for creating incentives for fisherfolk innovation and problem-solving capabilities, when occurrences like the *Sargassum* influxes take place.
- Policy and standards need to be introduced for quality control and quality assurance of fish imported into Barbados.
- For improved regulation of imported fish, enforcement efforts of regulations also need to be improved, to minimise any illegal trade and ensure that fish coming into Barbados maintain the minimum standards set. Frequent inspections and the implementation of monetary management tools such as fines are important for encouraging compliance.

6.1.5 Recommendation for data collection

Short-term

- Review of data collection process to ensure more accurate data are collected.
- Consistent monitoring of data quality and "data cleaning".
- Continuously clean up data. The effort must be increased to ensure the database has a level of accuracy to allow data sharing, and for use in decision-making processes.
- Training of data collectors in identifying the different species coming in to landing sites would assist in breakdown of the data more accurately into the different species.

Long-term

- Technology used in the data collection process must be updated to adapt to the new challenges faced by the industry, and to make data collection processes more efficient and improve on reliability and accuracy.
- A standardised reporting system for data should also be put in place, to reduce errors in the data, and reduce hesitation of sharing data, due to these inaccuracies. This will allow data to be shared more freely.

- Concessions can be introduced as a way to encourage fishers to report on catch, where in order to receive the set predetermined concession (reward) the fisher has to cooperate by providing relevant reports.
- Create a database for receipts from markets. This can be used for verification of data.
- Introduction of technology and software to improve the accuracy of data recording, storage and management. This aids with real time data gathering and recording, and could allow automatic uploading to databases. This also allows interfacing with technologies such as SmartStream (SmartStreams Technologies ltd. 2016).

6.1.6 Recommendations of researcher

Short-term

- A fisheries educational outreach programme should be established, using the *Sargassum* event as the first initiative under the programme. This should be used to educate fishers about the *Sargassum* events, informing them of where it is coming from, and why, and other current research. This recommendation is made because of the high level of misinformation encountered during the data collection process. This should not be restricted to the harvest sector, but also include post-harvest sector individuals, and members of the public who are interested in learning more about the events.
- Fishers should be trained to use the SEAS website to keep updated on forecasts, and using other satellite imagery to assist in determining where and when *Sargassum* mats may be coming into Barbadian waters. Fisherfolk organisations can be recruited to disseminate this information, posting notices at landing sites, or making announcements via boat radios.
- Public service announcements, via television and radio should be increased, informative documentaries and other videos should be shown, to inform and educate the public on the issue.
- The use of fisheries catch and effort data to establish a definitive "*Sargassum* signature" which can be used to implement management strategies of fish stock for *Sargassum* event, and non-event years.
- There should be revision of the Draft Fisheries SAP to include more comprehensive guidelines and management strategies for the fishery sector during *Sargassum* events, and other environmental events.
- There should be the establishment of a task force especially for dealing with the physical impacts of *Sargassum.* This task force should be comprised of persons from relevant government agencies, NGO, CSO and private sector groups, so that all interests are represented.
- There should be research initiatives started on several aspects of the *Sargassum* influxes, establishing Barbados as the Caribbean leader in research and innovation surrounding *Sargassum*. The research should include:
    - The change in ecology of the nearshore and the impacts on marine life.
    - The potential uses of *Sargassum* feasible for small business aswell as larger companies*Sargassum.*

- The innovation and development for beach and turtle-friendly machinery for cleaning *Sargassum*, on-shore and off-shore, and technology for improving detection, and the use of ICT in *Sargassum* monitoring.
- The FD, in collaboration with the fishery value chain, should investigate the development and use of new gear types adapted to the conditions presented by *Sargassum* events.

Long-term

- The FD, along with fisherfolk should explore using fish stocks that are less exploited, or not targeted at all, and investigate the feasibility of starting a new fishery.
- Spatial (GIS) data should be incorporated into FD data analysis and recording. This can be used to map *Sargassum* influx events over-time, and may help identify trends in movement of mats, and the change in currents reported.
- Establishment of an in-house *Sargassum* monitoring system at the FD, involving the use of fisherfolk live reports, which can then be broadcast to all fishers via radio.
- The improvement and updating of data collection systems of the FD and Markets Division to allow for improved data quality, and to better inform decision-making processes.

6.2 Conclusion

In the analytical framework, the resilience framework was outlined, in a five-step process (Figure 8). The objectives of this research project, tackled each of the stages outlined. The key impacts of the events were investigated, the coping mechanisms and extent of impacts on different livelihoods were assessed, the interactions between groups in the value chain, and in the sector were discussed, and the governance and management issues were reported on. The last stage; acting on assessment, was addressed to the extent of the provision of lists of recommendations, which regulatory organisations, such as the Fisheries Division can use to guide further action, and initiate transformation of the sector to be prepared for future *Sargassum* influx events, and other vulnerabilities.

From the review of fishery landings data, it was seen that *Sargassum* influxes do appear to have a '*Sargassum* signature'. This can be defined as a sharp decline in the landings of the major fishery, flyingfish, in *Sargassum* years, and an increase in dolphinfish (albeit comprising juveniles). Further, based on data only for the first event, the years directly after an event show a large increase in the catch of flyingfish, and some other pelagic species. However, the exact causes of the trends seen in the '*Sargassum* signature' need to be determined through further research. The Fisheries Division identified data management and data quality as one of the biggest issues affecting management decisions, and the lack of clear policy to directly address the impacts of *Sargassum.*

The largest impacts on the sector were found to be the decreased flyingfish catch, the decrease in income, and the physical impacts on boats and landing sites. The worst affected groups included those in the harvest sector, and those from the post-harvest sector directly employed in the flyingfish industry. The volume of the seaweed at landing sites also played a large role in

determining the ability of fishers to cope. It also highlights that other parameters such as coasts, nature of bays, ocean currents, socio-economic background such as education, access to and knowledge of technology and demographic characteristics like age plays a part in how a group or individual reacts. An important point was that sites with more community effort and organisation, coped better.

In the synthesis of the results, it was found that most stakeholders used short-term coping mechanisms, showing absorptive capacity and on the spectrum of resilience, they were persistent. There was also some evidence of adaptive capacity as some fishers said they were now better prepared for future events, some fishers have begun to modify boat engines, and seek alternative or new ways to operate in *Sargassum*, showing incremental adjustments to the changes brought about by the seaweed. Transformative capacity is occurring, however, not necessarily within the fishery sector, as other groups, businessmen and entrepreneurs, are looking towards creating a *Sargassum* product industry.

The short-term measures will, over time, become the long-term measures, as the likely responses employed in any future events. Fisherfolk will continue to use coping mechanisms they have developed, until action by organisations, such as the Fisheries Division, develop sustainable measures. If there is no long-term measures adopted through improved fisheries policy and the introduction of climate-smart legislation, the fishery value chain, and by extension, the fishery sector will be left vulnerable to future *Sargassum* influx events.

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8 APPENDICES

Appendix 1: Potential uses of *Sargassum*

Beach building and dune nourishment

Sargassum spp., which have landed in large quantities in the Gulf of Mexico, primarily in areas such as Galveston, Texas, have been used for beach building purposes. Williams and Feagin (2010) conducted a study in which the benefits of subsidising beach dune ecosystems with beach wracks were investigated. In Galveston, these wracks comprised mainly *S. fluitans* and *S. natans*, and the study showed that dune vegetation had benefited through increased access to more nutrients such as nitrogen, phosphorus and potassium. A recommendation was made to incorporate the seaweed at the base of existing dunes to nurture the growth of "embryonic dune systems". This is useful for shoreline stability, and would help to mitigate costs associated with coastal protection and maintenance (Williams and Feagin 2010).

Agricultural uses

There is substantial evidence for the use of seaweed for soil enhancement and use in the agricultural industry as mulch and fertiliser. Seaweeds, including *Sargassum* spp. have been used as a peat moss additive, and used in composting. Seaweeds can also be used to hold moisture in soil, provide anchorage and stability in plant growth, and to shade the soil, as mulch. It was recommended that for use as mulch, the seaweed should be rinsed thoroughly to remove the salt. The seaweed has also been used in "green manuring" to create soil, with a mixture of natural soil components and fertilizer (UF IFAS Extension 2003). The use of seaweeds in agriculture is well documented in the case of Bermuda (Stovell 2012) where the phenomenon of stranded seaweed is not a novelty. *Sargassum* is also being made in to a meal for animal feed production in places such as Philippines and Indonesia (McHugh 2003). In the last few years, experimenting with the use of the pelagic *Sargassum* spp. in agriculture has become more popular in affected Caribbean countries.

Pharmaceuticals and other chemicals

Research has also been geared towards discovering pharmaceutical and nutraceutical uses of *Sargassum* spp. (Mohapatra 2015). It has been used for many years in traditional Chinese medicine (; Oyesiku and Egunyomi 2014). It has been documented as being used by in Japan and China for treating glandular illnesses (Kolanjinathan, Ganesh and Saranraj 2014). Several researchers have shown that seaweeds generally are rich sources of minerals, trace elements, vitamins, protein, and iodine. *Sargassum* spp., along with other genera of seaweed contain antioxidants, phytochemicals and polyunsaturated fatty acids (PUFA) (Yende, Harle and Chaugule 2014; Kolanjinathan, Ganesh and Saranraj 2014; Mohapatra 2015).

The *Sargassum* genus has been already been identified as demonstrating antioxidant, antiviral, anit-allergic, anti-infammatory, anti-cancer, anti-coagulant and analgesic properties. It has also been used for treatment of long-term mental disorders such as Parkinson's disease, Alzheimer's disease, and Myasthenia gravis (Yende, Harle and Chaugule 2014; Mohapatra 2015).

Food based uses

Sargassum and other seaweed types are consumed in many Asian countries, as a result of being rich in proteins. It is known to be used in dishes such as salads, soups and curry. In some instances, it is also eaten dried. Macroalgae such as these are known to contain essential amino acids, not available it vegetables. Seaweeds can also be prepared as jellies, sauces, ice cream and various other edible products (Kolanjinathan, Ganesh and Saranraj 2014). Although the *Sargassum* seaweed is not customarily used for food in the Caribbean, there has been the suggestion for it to be used in "Asian-inspired dishes" (CAST 2015). There is still more research required however, on the biochemical properties of the *Sargassum* coming into the Caribbean, in particular because of the seaweed's biosorbent properties and thus the potential for heavy metal content, before its use in culinary dishes and even animal food is explored further.

Alginate extraction

The extraction of *Sargassum* alginate holds the potential for the future industrial exploitation of the seaweed, apart from the production of pharmaceutical products. Alginates can be used in animal feed such as fishmeal; in cosmetics; in textiles; in a range of processed food; and even in welding rods (Mohapatra 2015). Texas A & M University, Galveston is already making some headway in the areas of fish food, and creating a sargassum drink using yeast (SEAS n.d.). However, when compared with other species of seaweed belonging to the Phaeophyceae class, the alginate content and quality in *Sargassum* is a lot lower, and for alginate producing countries is often used as a last resort (McHugh 2003).

Bioremediation

Sargassum also has potential for use in bioremediation of polluted water, having bioabsorbent properties for heavy metals.

Appendix 2: GCFI *Sargassum* Fact Sheet

July, 2015

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GULF AND CARIBBEAN FISHERIES INSTITUTE, INC.

Pelagic Sargasssum Fact Sheet

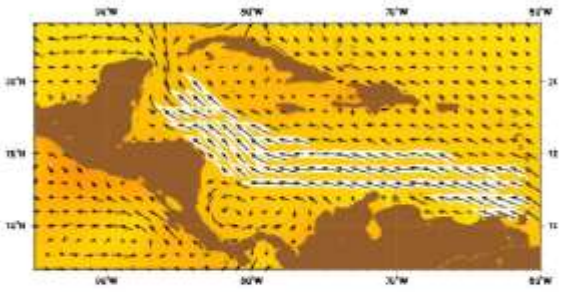
Have you noticed an occurrence of greater than normal amounts of sargassum on your beaches in recent years? Has it caused problems for you or local communities? Are other people in your country or island talking about sargassum?

Sargassum is an emerging issue on the coasts of the Wider Caribbean

During 2011, massive quantities of pelagic sargassum occurred throughout the Caribbean, impacting aquatic resources, fisheries, shorelines, waterways, and tourism. A similar event occurred in 2014 and continues in 2015. This Fact Sheet seeks to share the state of knowledge about the sargassum influx and to promote the adoption of best management practices. Some of the questions that we're frequently asked are:

What is it? Pelagic sargassum is a brown alga, or seaweed that floats free in the ocean and never attaches to the ocean floor. These free-floating forms are only found in the Atlantic Ocean. Sargassum provides refuge for migratory species and essential habitat for some 120 species of fish and more than 120 species of invertebrates. It's an important nursery habitat that provides shelter and food for endangered species such as sea turtles and for commercially important species of fish such as tunas. There are two species of sargassum involved in the sargassum influx: *Sargassum natans* and *Sargassum fluitans*.

Left: *Sargassum natans;* **Right:** *Sargassum fluitans*
Photo: H. Oxenford



http://oceancurrents.rsmas.miami.edu/

Where does it come from? Sargassum travels on ocean currents. Scientists are able to determine where the sargassum comes from by back-tracking from its stranding location using ocean models and data on movements of satellite trackers that are deployed at sea. It is believed that the recent influxes are related to massive sargassum blooms occurring in particular areas of the Atlantic, not directly associated with the Sargasso Sea, where nutrients are available and temperatures are high. The sargassum consolidates into large mats and windrows and is transported by ocean currents towards and throughout the Caribbean.

Will the sargassum influx occur every year? We don't know for sure if it will happen every year, but currently proposed efforts to develop prediction and alert systems would help answer this important question. Signs from the Eastern Caribbean so far this year are that we'll be seeing sargassum in the region periodically throughout 2015. Some scientists associate the cause of sargassum with higher than normal temperatures and low winds, both of which influence ocean currents, and they draw links to global climate change.

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Will the influx happen all year round? The sargassum does not necessarily affect the same location in the Caribbean all year. As it's transported on currents it progressively affects different locations across the region. At any one time of the year there are multiple locations that can be affected.

Is it a problem to leave it to rot on the beach? Sargassum occurs naturally on beaches, albeit in smaller quantities. It plays a role in beach nourishment and is an important element of shoreline stability. Sand dune plants need nutrients from the sargassum and sea birds, for example, depend on the sea life carried in the sargassum for food. During decomposition there will inevitably be a smell and insects around. The experience in locations that have left the sargassum on the beach is that it will eventually get washed away or buried in the next storm, with rain easing the smell. Leaving sargassum on the beach has proven to be the simplest and lowest cost approach, also helping to nourish the beach and stabilize the shoreline.

Photo: Les Fruits de Mer

Sargassum natans
- Pods usually tipped with a spike
- Leaves long-stalked and narrow

Sargassum fluitans
- Pods usually not tipped with spike
- Leaves short-stalked and broad

Illustrations by Julia S. Child (Schneider and Searles, 1991)

What's that smell? When sargassum accumulates and decomposes in large quantities, the smell of rotten egg gas can occur. This is hydrogen sulfide gas and is given off as part of natural decomposition. The US Occupational Safety and Health Administration lists that when the smell is described as 'more offensive' (3-5 parts per million) then prolonged exposure may cause effects such as nausea, tearing of the eyes, headaches and loss of sleep. Asthma sufferers may experience airway problems. Full details are at https://www.osha.gov/SLTC/hydrogensulfide/hazards.html. Tarnishing of metals has been reported in areas affected by the sargassum influx and is likely associated with hydrogen sulphide, with the effect improving when exposure eases.

Are there any uses for sargassum? The species of pelagic sargassum involved in the influx are different from those grown as sea moss in the Caribbean and sometimes used in food and drinks. Sargassum can be used as mulch or compost – allow salt to wash out in the rain and mix with manure and soil. Collected sargassum can also be usefully redistributed in areas affected by beach erosion. But care is needed in how this is done so as to avoid damaging sand dunes and to avoid impacting sea turtle nesting and bird nesting habitat. The Coastal and Wetlands Ecology Laboratory of Texas A&M University Galveston Campus is testing compacting sargassum in bales, burying them in eroded areas and planting dune vegetation on top. New uses for sargassum collected from beach strandings are being developed – as biofuel, fertilizer and livestock feed or fish food, for example.

Photo: N. Cazaubon

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Photos: E.Doyle

What about fishers and impacts of the sargassum influx? Since the influx of sargassum is a relatively new topic there is only limited experience in relation to its management, especially in dealing with impacts on fishers and interactions with boats and fishing gear. Fishers might consider the following:

- The sargassum influx does not necessarily affect the same location in the Caribbean all year, so there will likely be periods when a particular fishing area is less affected by sargassum;
- Impacts are being seen on different types of fisheries, sometimes with a prevalence of juvenile fish which are vulnerable to over-fishing;
- Sargassum has impacts on fishing gear and motors. Fishers are coming up with devices to free rudders of weed, to back up engines to free propellers, and are using strainers across the water intakes to prevent blockage and engine over-heating;
- Those heading to sea need to be prepared to deal with gear complications plus possible loss of power or steering, and plan for the safety implications of this, especially when fishing at night;
- Having a set of oars, or in shallow areas a pole, may help with maneuvering small fishing boats through some accumulations of sargassum;
- Fishers may prefer to keep their boats in less affected bays, where these exist, eg. on the leeward side of islands;
- Researchers who are working to track causes and transport pathways, as well as develop prediction and alert systems, welcome reports of sargassum from fishers and boaters. Researchers also welcome observations from fishers about the impact of sargassum on their catch, and how their catch differs from years without sargassum influx. Please use the reporting site **http://www.usm.edu/gcrl/sargassum/sargassum.observation.form.php**.

What can we do about the sargassum influx? Attempts at local management mostly focus on dealing with the large quantities of sargassum washed up on beaches. Coastal managers agree on the need to balance the importance of sargassum for natural processes and as life-giving nourishment for beaches and seabirds, with pressure to address negative impacts on communities. In parts of the Atlantic, pelagic sargassum is considered Essential Habitat and protected accordingly. Be aware that:

- Collection from the sea is difficult in practical terms and threatens the living ecosystem in the floating sargassum;
- Applying any chemicals to sargassum makes things worse, is hugely damaging to reefs and fish and is illegal;
- Typically the law does not require agencies to remove sargassum since it's not marine debris but is natural;
- Where capacity exists to clean beaches, it's essential to establish clear policies about where, when and how to clean beaches so as to avoid detrimental impacts such as worsened erosion from the use of machinery for beach cleaning.

Photos: L to R: H. Oxenford, E. Castro, S. Ward

What are some good practices to apply if removing sargassum from beaches? A review of experiences from beaches affected by sargassum in the Gulf of Mexico at the 2015 Sargassum Symposium hosted by Texas A&M University Galveston Campus, NASA Stennis Space Center and Galveston Island Park Board of Trustees highlighted that:

- Beach cleaning should be done only in the presence of monitors who check for wildlife prior to any cleaning, and operators must respect no-go areas such as sea turtle or bird nests;
- Patience is required, and be aware that it's not necessarily desirable to clean beaches that are already facing a precarious erosion situation, that are essential habitat for sea turtle nesting or where grooming will increase wind-blown sand and worsen erosion;
- Removal of sargassum should be from and to agreed areas only, and equipment should use the same route on to and off the beach to prevent harming dunes, destroying dune vegetation and turtle or bird nests;
- There is a difference between achieving a naturally clean beach and an over-sanitized beach - constant grooming of the beach for regular maintenance or for aesthetic purposes is discouraged due to very real risks of worsened beach erosion from physical damage of machinery and unintended removal of sand;
- Least intrusive practices are preferred - hand raking is preferable to machinery, beach raking equipment with a perforated conveyor belt is preferable to heavy construction equipment, and heavy tracked equipment like road graders are prohibited. Front loaders must utilize a bucket level control indicator/float mechanism to prevent gouging of the beach;
- A mechanized beach rake can remove moderate quantities of sargassum on dry sand. When exceptional amounts occur (ie. in excess of 3 feet deep) then removal of just the upper layers of sargassum first with a front loader, without touching sand, can be followed by mechanized beach raking in order to reduce sand loss;
- Cleaning should always occur at low tide and heavy equipment should stay on wet sand in the tidal zone. Adjust cleaning schedules to when wind and storms are less likely to immediately bring new influxes;
- Consider public safety and avoid mechanical beach cleaning in the presence of fishers or beach goers;
- In embracing the challenge of sargassum, good communications between agencies and the private sector, with the press, and with locals and visitors is essential. Make sure everyone knows where clean or less-affected beaches can be found.

We can't keep our heads in the sand about sargassum!

To report sargassum please go to **http://www.usm.edu/gcrl/sargassum/sargassum.observation.form.php**
For more information contact sargassum@gcfi.org

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Appendix 3: Fishery Division landings data for the period January-July each year from 2004 to 2015. AOV – represents 'any other variety' and is used to record species not otherwise listed.

1st 7 months – Jan – July

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Date	AOV	Barracuda	Billfish	Carangids	Conch	Congalee	Dolphin	Flying fish	Lionfish	Lobster	Potfish	Sharks	Small tunas	Snappers	Swordfish	Tunas	Turpit	Wahoo	Grand To
2004	12654	642	30948	13394			366435	883042			5139	5274	384	2539	10446	124842	69007	30817	15555
2005	18655	603	59893	9194			284912	780674		85	7721	6678	720	1710	19200	164291	51610	15069	14210
2006	24600	247	47277	1938			375989	658744		83	7647	6053	664	1941	16182	107036	31998	27016	13074
2007	9240	503	27796	1310		1006	549646	892119		20	11201	5387	1080	3753	11276	86553	29739	22337	16529
2008	7184	899	44133	4193		0	334416	1710691		188	10725	5965	802	1922	13947	99317	35773	19020	22891
2009	9361	656	12561	149	9	287	688815	1669528		24	9765	3753	1484	1512	7172	36913	47468	13472	25029
2010	6199	417	14002	7650		1003	359106	1652929		94	7551	3930	974	5345	5191	76923	29513	18972	21897
2011	6134	832	21994	1533	118	1002	381628	681077		131	14897	4777	529	2441	11635	69961	25992	15723	12203
2012	8114	1237	18515	15257	64	369	361021	262898		312	21581	7543	1911	1509	10265	97882	28450	18151	8550
2013	9754	3339	21403	1459	19	4402	408627	1421156		176	11534	5354	124	1828	7078	123444	67266	15998	21029
2014	14479	1658	21999	1207	304	2854	179193	981274		275	10043	4999	183	1400	6510	137847	67454	14545	14462
2015	16973	1933	38912	16307	12	1813	[illegible]	277929	590	211	18075	10389	1913	1623	14831	156585	33213	7040	8571
Total	143347	12966	359433	72591	526	12736	4529472	11872061	590	1599	135879	70102	10768	27523	133733	1281594	517483	218160	194005

Tonne

Date	AOV	Barracuda	Billfish	Carangids	Conch	Congalee	Dolphin	Flying fish	Lionfish	Lobster	Potfish	Sharks	Small tunas	Snappers	Swordfish	Tunas	Turpit	Wahoo	Grand Tot
2004	12.7	0.6	30.9	13.4	0.0	0.0	366.4	883.0	0.0	0.0	5.1	5.3	0.4	2.5	10.4	124.8	69.0	30.8	1555
2005	18.7	0.6	59.9	9.2	0.0	0.0	284.9	780.7	0.0	0.1	7.7	6.7	0.7	1.7	19.2	164.3	51.6	15.1	1421
2006	24.6	0.2	47.3	1.9	0.0	0.0	376.0	658.7	0.0	0.1	7.6	6.1	0.7	1.9	16.2	107.0	32.0	27.0	1307
2007	9.2	0.5	27.8	1.3	0.0	1.0	549.6	892.1	0.0	0.0	11.2	5.4	1.1	3.8	11.3	86.6	29.7	22.3	1653
2008	7.2	0.9	44.1	4.2	0.0	0.0	334.4	1710.7	0.0	0.2	10.7	6.0	0.8	1.9	13.9	99.3	35.8	19.0	2289
2009	9.4	0.7	12.6	0.1	0.0	0.3	688.8	1669.5	0.0	0.0	9.8	3.8	1.5	1.5	7.2	36.9	47.5	13.5	2502
2010	6.2	0.4	14.0	7.7	0.0	1.0	359.1	1652.9	0.0	0.1	7.6	3.9	1.0	5.3	5.2	76.9	29.5	19.0	2189
2011	6.1	0.8	22.0	1.5	0.1	1.0	381.5	681.1	0.0	0.1	14.9	4.8	0.5	2.4	11.6	70.0	26.0	15.7	1220
2012	8.1	1.2	18.5	15.3	0.1	0.4	361.0	262.9	0.0	0.3	21.6	7.5	1.9	1.5	10.3	97.9	[illegible]	18.2	855
2013	9.8	3.3	21.4	1.5	0.0	4.4	408.6	1421.2	0.0	0.2	11.5	5.4	0.1	1.8	7.1	123.4	67.3	16.0	2103
2014	14.5	1.7	22.0	1.2	0.3	2.9	179.2	981.3	0.0	0.3	10.0	5.0	0.2	1.4	6.5	137.8	67.5	14.5	1446
2015	17.0	1.9	38.9	15.3	0.0	1.8	289.8	277.9	0.6	0.2	18.1	10.4	1.9	1.6	14.8	156.6	[illegible]	7.0	857
Total	143.3	13.0	359.4	72.6	0.5	12.7	4529.5	11872.1	0.6	1.6	135.9	70.1	10.8	27.5	133.7	1281.6	517.5	218.2	19400

Appendix 4: Example of satellite imagery used by a longliner boat captain