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The Impacts and Challenges of the 2015 Sargassum Seaweed Invasion in the Caribbean

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ABSTRACT

Sargassum seaweed is a brown alga, comprising mainly of two species- *Sargassum natans* and *Sargassum fluitans* found in pelagic masses in the Atlantic Ocean. In 2015, large algal mats inundated American, Caribbean and African coastlines in unprecedented amounts, creating significant environmental and health impacts including to the small island developing state of Grenada. This paper reviews the environmental and health impacts caused by the 2015 invasion. Relevant literature was obtained using databases, namely EBSCO HOST and PubMed. Information was also obtained from special reports, newspaper articles and personal communication. The Prisma Method was adapted to aid in determining the inclusion and exclusion criteria for the study. Results found on the impacts and challenges of the Sargassum Seaweed during the year 2015 indicate that many countries were not prepared to deal with the issue especially due to the lack of early warning systems.

Key Words: Sargassum Seaweed; *Sargassum natans; Sargassum fluitans;* Environmental Impacts; Health Impacts.

INTRODUCTION

Nature of the Sargassum and Spatial Distribution

Seaweeds are categorized into three different classes; red (Rhodophyta), green (Chlorophyta) and brown (Ochrophyta) macro-algae (Seaweed Industry Association 2014). Sargassum is the genus named for brown seaweed in the order Fucales. As defined by the National Oceanic and Atmospheric Administration (NOAA 2014), Sargassum seaweed is an accumulation of one or more types of brown algae found in pelagic masses in the ocean and identified by pneumatocysts, which are berry-like floats that are a part of the Sargassum seaweed (Encyclopedia Britannica 2015). The two main species of Sargassum seaweed that characterize marine communities are *Sargassum natans* (Linn.) Gaillon and *Sargassum fluitans* (Børg.) Børgesen (Sargasso Sea Alliance 2014).

Sargassum seaweed has been around for ages; Christopher Columbus was documented as the first European to discover it while sailing in the year 1492 (Sargasso Sea Alliance 2011). It is a crucial part of marine ecosystems; a major provider of food, habitat, nursery, and a migration route for many marine organisms (Sargasso Sea Commission 2015). However, a problem has arisen due to the unprecedented (in living memory) amounts of the brown algae overwhelming coastal areas in many parts of the world (Caribbean Regional Fisheries Mechanism 2012, News Week 2015). It has been reported that proliferated amounts of seaweed on selected beaches were raising concerns among citizens (Barbados Today 2015). It was in 2011 that the seaweed started appearing in substantial amounts, lining coastal areas of the North Atlantic and the Caribbean region (Patrick 2015). In 2014, Doyle and Franks (2015) noted similar episodes occurring, with 2015 bringing heavy inundation, in various parts of the Eastern

Caribbean (Patrick 2015). Bloom (2015) reported that seaweed problems have apparently escalated in recent years.

Modern technologies including ocean current models and satellite imagery have improved scientists' capacity to track movement of Sargassum seaweed (Doyle and Franks 2015). A "one-way model" defined movements of Sargassum from its growth in the Gulf of Mexico to where it settled in the Sargasso Sea (Akumal Dive Shop 2015). In recent times, scientists discovered via satellite imagery, the escape of Sargassum seaweed from the Sargasso Sea (characterized by the pelagic Sargassum in the western Atlantic Ocean mainly consisting of the *S. natans and S. fluitans)* forming a "Sargassum Loop System" which consists of three different entry passages for Sargassum. Firstly, it goes between Cuba and Haiti (Akumal Dive Shop 2015). Secondly, between Dominican Republic and Puerto Rico (Akumal Dive Shop 2015). Lastly, between Saint Thomas and Anguilla (Akumal Dive Shop 2015). Additionally, the Sargassum finds its way to the Caribbean resulting from a weather condition known as the Azores High Pressure System (Akumal Dive Shop 2015). This system is located at the mouth of the "Sargassum Loop System" and contains the pressure needed to push the Sargassum throughout the loop (Texas A and M University 2010), resulting in invasion of a diversity of new areas. Satellite images from the Medium Resolution Imaging Spectrometer (MERIS) and the Moderate Resolution Imaging Spectro-radiometer (MODIS) are currently being used to track the seasonal patterns of the seaweed (Gower, Young and King 2013). The Sargassum Early Advisory System (SEAS) by the Texas A and M University in collaboration with the National Aeronautics and Space Administration (NASA), allows the authorities in Texas to predict seaweed movements up to16 days in advance. However, ideally, improvements are needed to foresee at least six months in advance (Texas A and M University 2010) to allow for effective management. The Texas A and M system uses satellite imagery, wind and current data from the Gulf of Mexico to track and predict directions of massive amounts of seaweed and times expected to hit the shores (Houston Texas 2015). The SEAS also generate alerts when Sargassum mats get close to the shore so that coastal managers can prepare (Houston Texas 2015). Moreover, there's a "base camp" online for real-time data sharing among all scientists in the region (https://basecamp.com/2965659/projects/9982511/messages/59042194#comment_435197557). At present, the geographic distribution of seaweed has been traced and found to be present in several countries; specifically, *S. natans* has been sighted in North and Central America, Australia, Asia, Africa, Europe, the Caribbean and the Atlantic Ocean (Szechy et al. 2012, The San Pedro Sun 2015). On the other hand, *S. fluitans* has a much restricted distribution as compared to that of *S. natans.* It has been found in North and Central America, Asia (southeast and southwest), the Caribbean and in varying parts of the Atlantic Ocean (Szechy et al. 2012).

Several hypotheses were introduced by scientists as possible reasons for the massive quantities of Sargassum in various regions. Among the suggested hypotheses, direct and indirect impacts of climate change and shifts in weather patterns were most commonly identified (USA Today 2014, Florida Today 2014, Caribbean Regional Fisheries Mechanism 2015, Inter Press Service 2015, Roffer's Ocean Fishing Forecasting Service 2015). Scientists continue to investigate possible sources and reasons for the emergence of these huge amounts of seaweed and are adding to the still limited data and information available on the phenomenon (Akumal Dive Shop 2015, International Business Times 2015).

Statement of the Problem

The unprecedented amounts of Sargassum seaweed received on the Tri-Island State of Grenada in 2015 created significant environmental and health impacts. The lack of early warning systems to detect the direction of the seaweed beforehand was a major contributor to the problems faced. Grenada, being a small island developing state (SIDS), lacked the necessary institutional, technical and financial capacity to mitigate the impacts. It is likely that similar algal invasions may occur in the future. Therefore, there is an urgent need to develop cost effective, culturally relevant and sustainable solutions for future Sargassum invasions in Grenada and other islands in the Caribbean that are heavily dependent upon their coastlines for tourism revenues and employment.

METHODOLOGY

Several sources were referred to for this research including: Academic journals, special reports, newspaper articles and personal communications.

A secondary literature review was conducted to focus on Sargassum Seaweed. Information on the

impacts and challenges related to the Sargassum Seaweed were derived from secondary sources including journal articles and peer reviewed journals, newspaper articles, special reports and key informants. To probe the objectives of this study, databases used included PubMed-NCBI and Ebscohost. A wide range of keywords and Boolean phrases were utilized to search for information relevant to the topic and included "Sargassum", "Seaweed", "Sargassum Seaweed", *"Sargassum natans", "Sargassum fluitans"*, "Environmental impacts of Sargassum", "Health impacts of Sargassum", "Reports on Sargassum", "Sargassum affecting the beaches", "Large quantities of Sargassum Seaweed", "Sargassum Seaweed affecting global countries", "Sargassum Seaweed problems in the Caribbean region", "Causes of the increase in Seaweed" and "Scientist predictions on Sargassum Seaweed". Information used was limited to a 10 years period, from 2005 to 2015 and any documents outside of this range were excluded. All information acquired was in one way or the other related to Sargassum Seaweed on a global, regional (the Caribbean) and local level (The Tri-Island State of Grenada). Also, documents not related to health or the environment were omitted from the review as well as laboratory-based studies which were deemed irrelevant to this research. To aid in determining the inclusion and exclusion criteria for this study, the Prisma method was adapted, and about 100 articles were retrieved. Those meeting the eligibility criteria were summarized and analysed.

RESULTS

Environmental Impacts

Table 1 lists the main environmental impacts and economic implications created by the Sargassum seaweed globally, including interruptions to fishing and boating activities, effects on wildlife, and coastal pollution/effects on recreation and tourism. The countries affected are also identified.

Health Impacts

The health impacts appeared to be related to the release of gases and odours during decomposition of the seaweed and the organic matter caught in the weed. The main gas released is hydrogen sulphide which gives off a foul smell and leads to acute symptoms such as breathing problems, headache, drowsiness, fatigue, loss of appetite, irritability, poor memory and dizziness and respiratory difficulties in persons with asthma. The Public Health Limit for exposure to hydrogen sulphide gas is 2 parts per million (ppm) for 30 minutes. This indicates that upon exceeding this limit, persons would experience the symptoms.

Table 1. Reported Environmental Impacts of the Sargassum seaweed

Environmental Impacts	Implications	Countries Affected
Interruptions in fishing and boating activities	Inability to access fisheries' resources Spoilt fishing gears, entanglement of boats, damage to propellers and boat engines Unable to launch boats Affects livelihood	Barbados, St. Lucia, Carriacou, Trinidad and Tobago, Antigua, St. Martin, Ghana
Effects on Wildlife	Suffocation of turtles e.g, Death of 42 turtles in Barbados Increase in invasive species eg.. Lionfish	USA, Belize, Trinidad, Grenada
Coastal Pollution/ Effects on Recreation and Tourism	Debris endangers human health and wildlife Un-aesthetic and deters potential tourists Navigation hazards for ships Deterioration of one's physical, mental and social well-being Forced foreclosure of hotels and resorts Devalued beaches	California, St. Martin, Antigua and Barbuda, Barbados

DISCUSSION

Magnitude of the Problem: Environmental Impacts

The seaweed invasion in 2015 was a widespread threat which compromised the ability of countries to recover in a speedy and timely fashion from its impact (Beckles 2015). Sargassum seaweed was washed up on the beaches of many African countries including Ghana, areas of Central America, Australia, the United States and the Caribbean (Szechy et al. 2012) (Figures 1, 2 and 3). In Ghana for instance, the seaweed got as high as 10 feet (Bloom 2015). Similarly, large dunes of seaweed, as high as four feet were reported in Antigua (Bloom 2015) and Grenada (Now Grenada 2015) and five feet in Barbados (The New York Times 2015). The major environmental impacts reported in the literature from accumulations of seaweed on shorelines included: Interruptions in fishing and boating; effects on wildlife and coastal pollution/effects on recreation and tourism.

Figure 1. Sargassum on the East Coast, Grenada (Roberts Caribbean, 2015)

Figure 2. Sargassum on beach, Windward, Carriacou (Rawle Paterson 2015)

Figure 3. Sargassum on beach, Windward, Carriacou (Rawle Paterson, 2015)

Interruption of Fishing and Boating Activities

Interruptions in fishing and boating activities were reported in Ghana (Joy Online 2015), Belize (The San Pedro Sun News 2015), Florida (Florida Today 2014) and Texas (Houston Chronicle 2014). This was due to the accumulation of seaweed, preventing access to fishing areas leading to discontinuation of fishing activities (Florida Today 2014, Inter Press Service 2015). Similarly, access to fishing resources and ports was a major problem in Barbados, Saint Lucia (Caribbean Regional Fisheries Mechanism (CRFM) 2015) and Carriacou (Cox, Personal Communication 2015). For instance, in Carriacou, the marketing sites for buying and selling of fish were significantly disrupted in the summer of 2015 (Cox, Personal Communication 2015).

In addition, boating related issues were reported in Antigua, Saint Lucia, St. Martin, Trinidad and Tobago (CRFM 2015) and Carriacou (Cox, Personal Communication 2015). Some of the impacts included entanglement of boats, damage to propellers and spoilt fishing gears, found evident in Tobago (Bloom 2015) as well as failure to start boat engines (Cox, Personal Communication 2015) (Figure 4).

The high influx of seaweed created major problems for those trying to make a living from the coastal zone (Algae World News 2015). It affected the livelihoods of persons especially those dependent on fishing activities as a major source of revenue. In fact, in 2012, an interview conducted within a small fishing village of 100 persons in Ghana concerning the seaweed problem revealed that villagers were suffering, due to discontinuation of fishing related activities resulting in starvation and inability to provide for their families

(Inter Press Service 2015). The fishing sector is known for its immense contribution to food and nutrition security, poverty reduction, employment and trade (Martini and Lindberg 2013). For example, in 2010, fisheries and aquaculture were major sources of revenue for about more than seven percent of African countries including Ghana (Martini and Lindberg 2013).

Figure 4. Sargassum posing danger to boating activities, Windward, Carriacou (Rawle Paterson, 2015)

Effects on Wildlife

Effects on Turtles

Sea turtles that came ashore to lay eggs were at risk of suffocation and death by high mounds of seaweed within their nesting locations (The San Pedro Sun News 2015, Bloom 2015). This was of major concern due to the significant role turtles play in maintaining health in marine ecosystems; therefore, if they become extinct, these systems will suffer (Sea Turtle Conservancy 2015). Belize (The San Pedro Sun News 2015) reported suffocation of baby sea turtles and other wild life; Barbados reported the death of 42 turtles including adult and baby hawksbill (*Eretmochelys imbricata),* leather-back *(Dermochelys coriacea)* and green turtles *(Cheloni amydes)* in 2015 attributable to the presence of the seaweed (Bloom 2015, Mcfadden 2015), Trinidad Nature Seekers Tour Coordinator reported return of turtles to the sea upon failure to reach their designated nesting grounds (Trinidad and Tobago News Day 2015); and in Grenada, Levera Beach, well known for the nesting of the Leather Back turtles was under seaweed attack and threatened the survival of the turtle population (Now Grenada 2015).

Increase in Invasive Species

In recent years, South Eastern United States and the Caribbean reported a rapid spread of the *Pterois volitans* (Lionfish) (World Resources Institute 2011). Authorities in Belize have claimed that the invasiveness of lionfish populations is attributed in part to high influx of Sargassum from other marine jurisdictions (The San Pedro Sun News 2015). According to Albins and Hixon (2008), the invasion of the Lionfish is recognized globally as one of the most severe conservation issues (Randall and Schram 2011). The National Oceanic and Atmospheric Administration (NOAA) (2012) stated that invasive species are a principal threat to coastal ecosystems, generating severe impacts on local economies, fisheries, ecosystems, and human health. For instance, the United States reports billions of dollars in economic damage each year from invasive species (US Fish and Wildlife Service 2012).

Effects on Recreation and Tourism

Coastal Pollution:

Coastal pollution was another major problem caused by the washing ashore of large amounts of seaweed, affecting many countries globally. Seaweed is usually entwined with non-biodegradable debris such as plastic bags, bottles and other waste materials collected in the ocean **(**Inter Press Service 2015). These are referred to as "ocean trash", ranked as a major pollution predicament (Ocean Conservancy 2015). "Ocean trash" is un-aesthetic, and detracts from the cultural ecosystem services provided by the beaches. In addition, ocean debris may contain chemicals and sharp objects such as nails, glass and syringes that can be hazardous to human health (Ocean Conservancy 2015, California Coastal Commission 2015). Reports indicate that the above-mentioned debris was found on beaches affected by seaweed, in the United States (The Coastal Star 2015), and many other countries experienced the same issue. Further to this, severe harm to wildlife such as difficulty eating, breathing and swimming was possible if debris were ingested or if marine organisms got caught in the seaweed (Ocean Conservancy 2015, California Coastal Commission 2015). In addition, the seaweed with its entangled debris can create navigation hazards for ships by getting trapped in propellers causing them to drift from their original route (Ocean Conservancy 2015, California Coastal Commission 2015). Furthermore, this

can lead to a decrease in a country's economy by driving away potential tourists (Ocean Conservancy 2015, California Coastal Commission 2015).

Coastal Recreation

The impact on coastal recreation was also highlighted as a major concern due to the seaweed phenomenon (Joy Online 2015). In St. Marten, swimming on some beaches was prohibited due to fear of persons drowning from entanglement of seaweed (The New York Times 2011). Coastal recreation is considered a necessity in many countries, especially where most persons reside near coastal areas. For instance, in Australia it is noted that over 80 percent of the population reside within100km of the coast (Cox et al. n.d.). This is due to the vital role the coastal areas play in enhancing the social well-being of individuals, providing much needed benefits to physical and mental health, self-identity, skill development and learning, spirituality, social cohesion and community satisfaction (Cox et al. n.d.). In addition, they found that high stress levels, feelings of marginalization, lower self-esteem, hopeless and helpless feelings, lower levels of problem solving and support seeking are all consequences of a wounded coastal environment.

Tourism

The Sargassum seaweed invasion had a major effect on the tourism industry in the Caribbean in 2015. Sir Hilary Beckles, Vice Chancellor of the University of the West Indies describes it as "The single biggest threat to tourism in the region" (Caribbean360 2015). This is particularly troubling, when one takes into consideration the importance of the sector to the region's development. Tourism accounts for over 16 percent of the economic output in Caribbean countries (Economic Commission for Latin America and the Caribbean (ECLAC 2011). In St. Lucia, tourism is responsible for more than 31 percent of its Gross Domestic Product (GDP), while in the Bahamas and Antigua and Barbuda it is accountable for about 29 percent of their GDP (ECLAC 2011). Zappino (2005) stated that the Caribbean Tourism Organization (CTO) estimated that tourism directly and indirectly provides over 800,000 jobs in the Caribbean. The influx of the Sargassum has led to many of the most popular tourist destinations such as Barbados, St. Martin and Antigua and Barbuda temporarily closing operations of their high amenity hotels and resorts (Inter Press Service 2015). For example, Antigua reported one month forced closure of one of its most prominent resorts, St. James's Club and Villas, to remove the seaweed from the beaches; in September 2011, 10,000 tonnes of seaweed were removed (The New York Times 2011). The popular beaches on French St. Martin including Orient Bay and L'Galion were affected by the seaweed; on the Dutch side, beaches such as Guana Bay Beach was out of use for months (The New York Times 2011). Barbados reported one of its most prestigious beaches, the Crane, marked as one in the world's top ten beaches, as being devalued by the Sargassum outburst (The Empire Remains 2015). Indeed, the Owner and Managing Director of the Crane Hotel in Barbados reported early check-outs of tourists, cancellations and even a decline in bookings, all due to the unsightly deposits of seaweed (Loop News Barbados 2015).

Health Impacts

Robert Webster, a Texas Agricultural and Mechanical Research Scientist and Sargassum expert stated that, once Sargassum seaweed gets to the seashores, it undergoes instant death thus terminating the role it plays in feeding and protecting certain marine species. It then starts decomposing and Environmental Resources Management Specialist Dalrymple noted that the decomposition of the seaweed encourages vermin such as flies, and the fetid scent produced can lead to serious health conditions (Inter Press Service 2015). The fetid scent is associated with the production of gases from the breakdown of the sulphates, for example, hydrogen sulphide. In addition, the EPA is concerned about the sensitivity of some members of the populace, for example in Ghana, to the sulphide gases released from seaweed decomposition; vulnerable populations such as persons with asthma and other respiratory problems, the elderly, pregnant women and babies (Joy Online 2015, Ambergris Today 2015). The concentration of these gases increases in high temperatures, emitting a foul smell like a "ton of rotten eggs" (Ambergris Today 2015). This was not only found to be an issue in Ghana but also in Belize and the Caribbean islands including Grenada (The San Pedro Sun News 2015, Government of Grenada 2015).

The United States Occupational Safety and Health Administration (OSHA) states that persons exposed to hydrogen sulphide for long periods may experience acute symptoms including: problems breathing, drowsiness, fatigue, loss of appetite, headache, irritability, poor memory and dizziness (OSHA 2015). For example, in Nigeria, fishermen found that handling the seaweed resulted in irritations of the eye and skin and concluded

that it is due to the chemicals released during decomposition (Oyesiku and Egunyomi 2014). In fact, Lapointe stated that the decomposing seaweed in water may cause skin irritations from the bacteria and microbes produced (San Pedro Sun News 2015). Additionally, persons suffering from asthma may experience respiratory difficulties (OSHA 2015). If exposed to very high concentrations, death can be the result (OSHA 2015).

Furthermore, in 2009, the Health Department of Australia reported evidence of the hydrogen sulphide gas endangering human lives on the coastline of the western part of the country due to the breakdown of accumulated Sargassum over the years (Government of Western Australia Department of Health 2009). The two most common health symptoms found to be present among individuals were breathing problems and headaches (Government of Western Australia Department of Health 2009). Air sampling techniques defined by the World Health Organisation (WHO) guidelines indicated that emission of the gas exceeded the public health limit of two parts per million (ppm) for 30 minutes (Government of Western Australia Department of Health 2009). In addition, it was discovered that Hydrogen Sulfide takes approximately three days to break down after which it is dispersed via the wind into the atmosphere (Government of Western Australia Department of Health 2009). Moreover, an ongoing availability of the gas from the constant exposure to the Sargassum poses a major threat to the health of those affected (Government of Western Australia Department of Health 2009).

CONCLUSION

Grenada and its neighbouring Caribbean islands have been impacted by invasions of Sargassum since 2011 and particularly in 2015. The cause of the recent proliferation of the algae in the Caribbean is still unclear. Therefore, it would be prudent to assume that future invasions are likely. Small island states like Grenada will require management solutions that are culturally and economically sustainable in the future.

Given the severity of the environmental and health impacts highlighted in this research, it is important for small island states to develop cost effective and culturally relevant plans within the context of their limited resources and capacity. If the 2015 invasion of Sargassum into the Caribbean Sea was a harbinger of further events, the governments, non-governmental organisations and coastal communities of the region can ill afford to be caught as unprepared and as poorly equipped as was the case in 2015.

In the future, rather than solely rely on cash-strapped national government to mobilise a response to the next algal invasion, it may be prudent to train local communities and incentivise the private sector to treat the nutrient-rich biomass as a resource. There are numerous examples cited in the literature on potential end uses for harvested Sargassum which will be the subject of another research paper (Dhargalkar and Pereira 2005, Jadhav 2009, Lavine 2015). Training of coastal communities, public and private sector workers on how to remove the biomass from the shoreline without significantly damaging the beach profile, particularly with heavy equipment, will also be necessary.

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