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Impacts of Sargassum on marine resources in the region and utilization of initiatives

Introduction

1. This report provides a synopsis of the major impacts and challenges in the WECAFC region arising from the Sargassum blooms in the Atlantic Ocean and Caribbean Sea. The paper also looks briefly at some options for utilizing Sargassum.

2. Sargassum seaweed (*Sargassum natans and S. fluitans*) has been an issue of major concern in the Caribbean since 2011, when widespread blooms in the Atlantic Ocean and massive accumulations started affecting coastal and marine resources, ecosystems, beaches and communities in the Wider Caribbean and West Africa (Kershaw, 2017; Franks *et al*., 2016; Hinds *et al.,* 2016; Wang et al., 2019; Oxenford *et al.* 2021). The blooms and beaching are seasonal, usually occurring from March-April through August-September each year, although the season may start earlier and continue until November or December, as was the case in 2018 and 2019. Since 2011, the Sargassum phenomenon has been a topic of keen interest and the focus of several regional, national and local initiatives due to its recurring presence and concerns regarding its socio-economic, health and environmental impacts in the region. Several initiatives have also been implemented or proposed to utilize sargassum in various ways to generate value-added products and services as well as create employment and generate income.

3. In terms of geographical scales and biomass quantities, the recent influxes have been unprecedented for both the Caribbean and West African regions affected. The massive Sargassum blooms in the Atlantic Ocean and ensuing inundation of the coastal waters and beaches of Caribbean States have been overwhelming in many local communities, with significant impacts on the coastal and marine

ecosystems, tourism, fishing and recreational activities, and on the well-being of coastal communities of several WECAFC Members.

4. The recurring influxes of Sargassum have generates both interest and serious concerns among academics, planners, policymakers, coastal communities, civil society organizations and private sector operators in fisheries and tourism among others, across the Wider Caribbean region. The Small Island Developing States in the Caribbean have been especially concerned due to their fragile economies and limited capacities to cope and adapt given that the recurring blooms and influxes seem to be increasing over time and represent a 'new normal' due in part to climate change and variability and nutrient enrichment of the ocean. This has led to increased partnerships, networking, community-based actions, research, innovations and investments to better understand, adapt to, and manage the phenomenon.

5. At the global level, Smetacek and Zingone (2013), reported that there has been an overall increase in green and golden seaweed 'tides' within recent years. Dai *et al* (2023) also reported that coastal algal blooms have expanded and intensified over the past two decades. On the other hand, Hallegraeff *et al* (2021) conducted a statistical analysis on a global dataset on marine harmful algae bloom event spanning the period 1985–2018, to investigate temporal trends in the frequency and distribution of such blooms. They found that the perceived global increase in algal blooms is attributable to intensified monitoring and emerging bloom impacts.

6. The Sargassum blooms being experienced in the Caribbean are novel and unprecedented and seem to be increasing in magnitude over time (Wang et al., 2019; UNEP-Cep, 2021). They have affected national and regional economies through diversion of funds for clean-up and dumping, reduce profitability or loss of livelihoods and economic opportunities to fishers, hoteliers and related businesses.

Impact on Fisheries

7. Sargassum influxes have negatively impacted local and regional fisheries across the Caribbean region to varying extents. The floating mats can entangle fishing gear, making it difficult for fishermen to operate efficiently, including through gear entanglement and damage; impede fishing and other vessels at sea; reduce catches of key fisheries species such as flyingfish and adult dolphinfish; change the availability and distribution of coastal and pelagic fisheries resources; and disrupt coastal fishing communities and tourism activities. Moreover, some fish species may be deterred from their usual migration routes or breeding areas due to the presence of Sargassum, affecting fish abundance and densities and the livelihoods of fishing communities (CRFM, 2012; Hinds *et al*., 2016; Ramlogan *et al*., 2017; Oxenford *et al*., 2019; and JICA & CRFM, 2019).

8. The impacts of Sargassum on fisheries has been a regular item on the agenda of the annual meetings of the Ministerial Council of the CRFM. The issue was first discussed during the Sixth Meeting of the Council on 15 June 2012 (CRFM, 2012). Following extensive discussion on the new phenomenon that had severely impacted the fisheries across the Caribbean in 2011, the Council, *inter alia*:

   " ***Noted*** *that the large quantities of Sargassum observed in the coastal waters of several Eastern Caribbean States during mid- 2011 was an unusual and previously undocumented event;*
   Noted also *that the scientific investigations to date suggest that the source of the Sargassum was not the Sargasso Sea but possibly an area in the central Atlantic Ocean that may be only recently contributing to Sargassum growth;*
   Expressed concern *regarding the impact of the large quantities of Sargassum on the fisheries and livelihood of fishers and fishing communities;*

Supported *the need for further research to better understand the underlying causes of the phenomenon;*
Requested *the CRFM Secretariat to continue to monitor the situation in Member States regarding the Sargassum seaweed and to keep the Council updated on further developments*. "

9. The influxes have also been associated with an increase in the abundance and catches of juvenile dolphinfish (CRFM, 2016a; Monnereau and Oxenford, 2017). The practice of capturing large quantities of immature dolphinfish can seriously impair the long-term sustainability of the stocks by reducing spawning stock biomass and affecting the stock's ability to replenish itself, and ultimately compromise the economic and social benefit from the fisheries in future years. The 10th Meeting of the Ministerial Council of the CRFM, held in June 2016, on the recommendation of the 14th Meeting of the Caribbean Fisheries Forum, adopted model fisheries management regulations for the protection of juvenile dolphinfish by imposing minimum harvest size limits (CRFM, 2016a).

10. In November 2015, the CRFM in collaboration with CARICOM Representatives at the UN General Assembly session on sustainable fisheries introduced text for inclusion in the annual resolution to raise awareness and seek international support for action to address the impacts of Sargassum on fisheries and coastal communities. The text was accepted and included in Paragraph 179 of Resolution (A/RES/70/75) adopted by the General Assembly on 8 December 2015. The General Assembly:

> *" 179. Expresses concern about the recent massive influx of sargassum seaweed into the waters of the Caribbean and its impact on aquatic resources, fisheries, shorelines, waterways and tourism, and encourages States and relevant regional organizations to cooperate to better understand the causes and impacts of the influx, with a view to protecting the livelihoods of fishers and fishing communities and finding ways of beneficially utilizing the seaweed and environmentally friendly ways of disposing of sargassum washed up on shore;.."*

11. The impacts of Sargassum influxes on fisher livelihoods have not yet been fully analyzed and documented. For example, within the fisheries sector there has been a loss of fishing days, reduced catches of flyingfish, damage to fishers' engines, and increased operating costs. However, the economic losses associated with these events have not been quantified and calculated. Similarly, within the tourism sector, the economic impacts associated with the reduction in tourist arrivals or changes in their time spent in coastal communities due to Sargassum has not yet been quantified. Neither has the impacts on the physical and mental health and wellbeing of fishers and other residents and visitors in affected fishing and other communities including workers engages in clean-up activities, being evaluated.

Impacts on Marine Ecosystems

12. Sargassum influxes have also negatively impacted coastal and marine ecosystems and habitats. When the massive floating mats enter coastal waters and wash ashore, they can smother and disrupt important coastal ecological processes and habitats such as seagrass beds, mangrove swamps and coral reefs. These habitats serve as nurseries and feeding grounds for various marine species, and their degradation can have cascading effects on the entire ecosystem. The unpredictable timing, frequency, extent and severity of massive Sargassum influxes constitute a natural hazard with potential for disaster.

13. Sargassum mats and accumulation of decaying sargassum can prevent sunlight penetration from reaching seagrass beds and coral reefs reducing photosynthesis processes and causing rapid

degradation, fish kills and even coastal dead zones (Lopez et al., 2008). Furthermore, decomposing Sargassum can lead to alteration of water chemistry arising from the release of toxic hydrogen sulphide and ammonia gasses, which can cause oxygen depletion, increased acidity and eutrophication in coastal waters (ANSES, 2017). These events threaten the health of critical ecosystems such as coral reefs and seagrass beds, cause fish and invertebrate mortalities, affect sea turtle nesting and hatching, and impact human health. For example, the fish kills in San Pedro, Belize in 2018 (Carrias *et al*., 2018) and the mass die-off of seagrass beds in Mexico in 2015 (UNEP-CEP, 2021) have been linked to the presence of decaying Sargassum. Decomposing Sargassum also releases carbon dioxide, methane, and other greenhouse gases into the atmosphere contributing to climate change, global warming and ocean acidification.

14. In removing Sargassum, beaches may also be compacted by heavy machinery and inadvertent sand removal may lead to depletion and possible shoreline instability (Kershaw, 2017). These types of regime shifts can have substantial impacts on ecosystem services and human well-being but are typically difficult to predict and costly to reverse (Hastings and Wysham, 2010). It is therefore imperative to determine at what points (thresholds of unacceptable change) Sargassum becomes a hazard due to its abundance. Anecdotal evidence of beach erosion is available in some Member States where people have observed significant changes in the beach slope after removal of Sargassum e.g., Barbados. Proliferation of algae in nearshore waters, and increased sedimentation have also been observed after Sargassum influxes (JICA & CRFM, 2019). However, these impacts need to be fully investigated and quantified over time.

Impacts on human health

15. While Sargassum is a natural part of marine ecosystems and can provide valuable habitats for various marine species, excessive accumulations in the coastal waters, bays and on beaches adjacent to local communities can have several potential impacts on human health and wellbeing in coastal communities. The decomposition of Sargassum produces hydrogen sulfide gas and ammonia, both of which can be harmful to human health when inhaled in large quantities. Additionally, rotting Sargassum on beaches may attract pests and cause skin irritation or respiratory issues for residents and beachgoers.

16. Hydrogen sulfide and ammonia can cause severe pulmonary, neurological, and cardiovascular damage as well as skin rashes, nausea, headaches, respiratory irritation, and imbalance in persons who are exposed to the gases. Fishers, and other residents and visitors to coastal communities with exposure to decaying Sargassum for extended periods are at risk. With a few exceptions, the health hazards posed by decomposing sargassum have not received the same level of attention and public discussion as the threats to the tourist sector and recreational activities on the beaches (Anses, 2017; Resiere *et al.,* 2018).

17. The French authorities and academics have been studying the health impacts on people in coastal communities by monitoring the concentration of harmful gases and presence of heavy metals. The French Agency for Food, Environmental and Occupational Health and Safety (ANSES) conducted an expert assessment on gaseous fumes emitted by decaying Sargassum (Anses, 2017). The Agency recommended preventive measures for exposure to hydrogen sulphide such as regular collection of accumulated Sargassum; informing the public of health risks; wearing personal protective clothing and equipment, and use of hydrogen sulphide detectors for workers; mechanical means of collection whenever possible; and implementation of a traceability system for exposed workers. The assessment also revealed that Sargassum can accumulate heavy metals such as arsenic and cadmium which may pose a risk to human health and to the environment. Therefore, the Agency recommended prohibiting

any possible food or feed uses until more in-depth studies could be conducted (ANSES, 2017; Resiere *et al*., 2021; Resiere *et al.,* 2023).

18. According to Resiere *et al* (2023) toxic exposure to hydrogen sulfide from Sargassum typically happens during decomposition, approximately 48 hours after it washes ashore. Significant exposures (50-400 ppm) may cause difficulty in breathing, agitation, confusion, nausea and vomiting, elevated blood pressure, and loss of consciousness. At higher concentrations, hydrogen sulfide rapidly causes myocardial infarction, unconsciousness, seizures, acidosis, and death (Resiere *et al.*, 2021).

19. Resiere *at al.* (2023) argue that governments in the Caribbean must invest more in sargassum management from a health perspective, and more collaboration across agencies and sectors (government, Caribbean Public Health Agency (CARPHA), Organization of the Eastern Caribbean States (OECS), civil society, research, United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Caribbean Community (CARICOM) needs to take place. Collaboration across countries can enhance faster progress and reduce consequences and deaths due to sargassum.

20. The health impacts of Sargassum are not limited to the physical impacts. Frequent and significant Sargassum influxes can create emotional, mental and psychological stress among fishers, coastal residents and workers involved in cleaning the beaches of Sargassum. The unpleasant odor, the deterioration of their environment, lack of access to the beaches for relaxation, uncertainty about the future, increase in physical ailments such as respiratory illness and skin rashes, and concerns about other potential health risks, among other things, will naturally affect mental health. The mantal health impact seems apparent from just casual interaction with fishers and residents in affected coastal communities.

21. To date, very little seems to have been done in the health sector across the Wider Caribbean to monitor and address the management of the hydrogen sulfide and ammonia, or to ascertain the scale of the toxins released during the decomposition of Sargassum or the impacts these may be having on fishers, fishing communities and other persons with significant exposure to Sargassum. Given the serious health issues that can arise and the significant time and exposure of some fishers and residents of coastal communities to decaying Sargassum, more attention needs to be given to the potential health concerns, including those that may arise of the heavy metal content.

Heavy metals and Sargassum

22. There is a growing body of evidence supporting the proposition that Sargassum has a high capacity to absorb and accumulate heavy metals from the surrounding seawater (Anses, 2017; Rodríguez-Martínez *et al.,* 2020; Desrochers *et al*., 2020; López-Contreras, 2021; Bam *et al.*, 2022; PRF & CRFM, 2022). These heavy metals include toxic elements such as cadmium, arsenic, lead, mercury, and others. As the Sargassum grows, they can accumulate heavy metals, leading to potential toxicity issues.

23. Jaishankar *et al* (2014) conducted a review of heavy metals and their toxicity mechanisms, along with their health effects in people. They concluded that heavy metal toxicity has proven to be a major threat and there are several health risks associated with it. Heavy metals, they reported, are required in small amounts for maintaining good health in people but in larger amounts they can become toxic or dangerous. Furthermore, the metals accumulate in the body. Heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidney, liver, blood composition and other important organs. Long-term exposure can lead to gradually progressing physical, muscular, and neurological degenerative processes that imitate diseases such as multiple sclerosis, Parkinson's disease, Alzheimer's disease and muscular dystrophy. Repeated long-term exposure to some metals and

their compounds may even cause cancer. The toxicity level of a few heavy metals can be just above the background concentrations that are present naturally in the environment.

24. The heavy metals present in Sargassum is a major concern when considering harvesting, handling, processing and utilizing Sargassum biomass for any purpose. High levels of metals in seaweed used as fertilizer may lead to accumulation of metals in agricultural soils and even in crops. Metals from Sargassum-based fertilizers may be transferred to crops and eventually to consumers. Arsenic in seaweed exists in different species, organic or inorganic. Inorganic arsenic is more toxic than organic arsenic species (López-Contreras *et al.,* 2021).

25. Since 2020, the CRFM and Plant and Food Research Limited of New Zealand (PFR) have been working together to implement a regional project entitled, "Sargassum Products for Climate Resilience" which aims to mitigate the environmental and economic impacts of Sargassum in the region through the creation of technologies and value chains from the biomass. The CRFM and PFR established partnerships with local universities, research organizations, fisherfolk and government ministries to assist with the sampling and drying of Sargassum collected from the coastal waters of Barbados, Belize, Dominican Republic and Jamaica during 2021 and 2022 for heavy metal testing. The study found variable but elevated levels of cadmium and arsenic, including the more toxic inorganic form of arsenic, present in the sargassum samples. These results are consistent with reports from other studies in the Wider Caribbean region. The concentration of heavy metals found in the samples were found to be higher than the maximum allowable limits for human consumption, animal feed or aquaculture or for use in agricultural soil. The dumping of Sargassum on land, or use of pure Sargassum or soil enhancers made from Sargassum carries the risk of transfer and accumulation of toxic heavy metals in the soil, ground water, crops and eventually the chain, potentially putting people's health at risk.

26. Monitoring the heavy metal content in Sargassum and assessing their potential impacts on marine ecosystems, on land where Sargassum may be dumped or applied as fertilizer, and on human health can be challenging. Very little seems to have been done to determine if heavy metals are being transferred from Sargassum to other marine organisms including fish and shellfish associated with the Sargassum ecosystems and targeted by fisheries. Furthermore, the presence of heavy metals appears to vary depending on the location, season, and environmental conditions. The methodologies used for testing heavy metals may also be a challenge. The CRFM-PFR team had to rely on laboratories in the United States to do the required tests due to limitations of the laboratories available in the Caribbean region, e.g., with respect to speciation of arsenic. It is nevertheless essential to continue and strengthen research on the accumulation and effects of heavy metals in Sargassum, as well as implement effective monitoring plans and laboratory testing capability to help mitigate the negative impacts on both marine ecosystems and human populations that rely on coastal environments for their livelihoods and well-being.

UTILIZATION OF SARGASSUM

27. Sargassum is a naturally occurring marine living resource that can be used in a variety of ways to benefit society. It can be harvested, processed, transformed into a variety of products, and commercialized to benefit the Caribbean countries and local communities. In this regard it is like the wide variety of other marine living resources available in the waters of Caribbean States, such as, bony fishes, shrimps, lobsters and crabs, cephalopods, gastropods, bivalves, and other marine algae that have already been commercialized and are contributing to global economic activity. Sargassum is a complex marine alga that contains hundreds of elements and compounds. For this reason, detailed understanding of its biochemical composition is necessary to inform requirements for harvesting, transportation, and storage

and to guide utilization and valorization initiatives. See Rodríguez-Martínez *et al (*2020) and Desrochers *et al* (2020) for reviews of the biochemical composition of Sargassum.

28. The Centre for Resource Management and Environmental Studies (CERMES), University of the West Indies, released in 2020, a Sargassum Uses Guide intended for use by researchers, entrepreneurs and policy makers in the Caribbean (Desrochers *et al.,* 2020). The manual provides a general overview of Sargassum including its basic biology, ecology and chemical composition to guide the development of uses of sargassum biomass. It provides detailed technical explanations and examples of the demonstrated or potential use of Sargassum in fifteen different sectors ranging from agriculture to food and beverages, biofuels, fashion, cosmetics, paper, bioplastics, construction, pharmaceutical, electrochemical, water and air purification, and environmental remediation, *inter alia*.

Sargassum for Carbon Sequestration

29. Sargassum absorbs carbon dioxide from the ocean surface water and can therefore function as a carbon sink instead of a source of greenhouse gases (e.g., carbon dioxide and methane) entering the atmosphere when it decomposes in the coastal waters and on land. Sargassum may be collected from the coastal waters, transported to deeper water and sunk to a depth of about 150 - 200 meters where the swim bladder will collapse due to the pressure, making it negatively buoyant (Gray, *et al.,* 2021). The Sargassum will thus slowly sink to the deep ocean floor where the carbon would be sequestered for hundreds or thousands of years as it breaks down very slowly and is gradually dispersed into the water over geological timescales.

30. This represents a potential method of reducing the amount of carbon dioxide and other greenhouse gases in the atmosphere with the goal of reducing climate change (Gray *et al*., 2021). This method of managing and using Sargassum further offers the potential to generate carbon credit for Caribbean States and private sector enterprises. Carbon credits can be a source of income, generate employment and livelihood opportunities in coastal communities, as well as contribute to healthy and resilient coastal ecosystems and communities.

31. Sargassum Ocean Sequestration of Carbon (SOS Carbon), an organization with a presence in the Dominican Republic, has been working on Sargassum since 2018. According to their website (https://soscarbon.com/) they are "*a spinoff organization from the Mechanical Engineering department at the Massachusetts Institute of Technology (MIT).*" Their website goes on to say they were, "*…founded on the technology for sequestering sargassum in the deep ocean and turning the problem into an opportunity for carbon offsetting*." SOS Carbon have developed a low-cost device that can be used on small-scale and artisanal fishing vessels for harvesting Sargassum at Sea. The Sargassum harvested can either be taken onshore for processing or to the deep ocean for carbon sequestration.

Main Approach to Handling Sargassum

32. Notwithstanding the potential for commercialization mentioned above, to date, the main approaches to managing Sargassum influxes and mitigating the negative impacts on coastal communities and on economic sectors are firstly, by manual or mechanical clean up and removal of Sargassum from the beaches. And secondly, deployment of physical barriers in the coastal waters to deflect and reduce the beaching of Sargassum or the amount in the adjacent coastal waters used by visitors. Beach clean-ups are done using labourers with wheelbarrows, rakes, shovels or even heavier mechanical equipment and trucks to collect and transport the Sargassum to landfill or other disposal sites (CRFM, 2014; CRFM,

2016; Hinds *et al.,* 2016; and Gray *et al.,* 2021). These management measures are primarily focused on coastlines and beaches that support tourism activities, and may be financed by the private sector, government authorities, or both in a collaborative manner.

33. Several Caribbean countries have developed Sargassum Management Plans to guide policy and operational actions by government authorities, private sector, and local communities to manage the manage Sargassum accumulation and minimize the negative impacts. Several CRFM States used the "Model Protocol for the Management of Extreme Accumulations of Sargassum on the Coasts of CRFM Member States" which was developed by the CRFM and approved by the CRFM Ministerial Council in 2016 (CRFM, 2016) as the basis for preparation of their National Sargassum Management Plans. Several eastern Caribbean countries have received funding and technical support from the FAO/GEF Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) project to prepare their national Management plans for Sargassum. However, not many are adequately funded or implemented. The reality is that in most areas, particularly in poor communities, including fishing communities, there is little or government or private sector funded programme aimed at managing the Sargassum accumulation and the resulting negative impacts on coastal communities and ecosystems (Gray *et al*., 2021).

Potential Commercial Uses of Sargassum

34. The approach of collecting and dumping Sargassum in landfills or deflecting it from landing on local beaches is neither a long-term solution nor the best way of managing this natural marine resource. Sargassum, like many other species of seaweed, can be utilized in a variety of beneficial ways due to its bio-chemical composition and properties and potential benefits to society. For example, it can be used as an organic fertilizer or soil conditioner to enrich soil quality and promote plant growth; building material for low-cost housing; a source of renewable bio-energy for electricity generation; a source of carbon sequestration; it is high in cellulose and hemicellulose, which are raw materials used in manufacturing paper product; it contains alginic acid, which can be used as a thickener and emulsifier in the food industry; and the genetic material may hold potential for biotechnological research and applications.

35. A recent study by Transparency Market Research (2021) estimated the global value of the algae market at USD$20.16 billion in 2021, and they expect it to grow at a compound annual growth rate of 10.9% per year between 2022 -2031, to USD$55.67 billion by the end of 2031. It is therefore not surprising that regional governments, regional and international development partners, entrepreneurs, and local farmers have been exploring ways of taking advantage of the Sargassum blooms to develop products, generate income and generate jobs.

36. Given the recurring blooms and large biomass available in the coastal waters, the valorization of Sargassum biomass is an option for management and generation of economic activity that should be fully explored. From the beginning of the recent large influxes in the region entrepreneurs and other entities have been viewing the blooms as an opportunity for entrepreneurship and have been exploring potential ways of creating innovative products and value chains and generating jobs and income from the Sargassum. For example, at the Sixth Meeting of the Ministerial Council of the CRFM, which was held in June 2012, a year after the start of the large influxes, the representative of Antigua and Barbuda (Minister Hilson Baptiste) at the meeting,

" *…informed the meeting of his experience in trying to convert the Sargassum seaweed to fertilizer, based on information that this could be done. He advised that the salt content of the seaweed was too high, which resulted in the destruction of the vegetables on which the seaweed was tested*."

37. On the other hand, Algas Organics, a small St. Lucian enterprise, has made significant strides. The company has been manufacturing organic fertilizers from Sargassum seaweed since 2015, for lawn and garden and general agricultural crops use. The company's website (https://www.algasorganics.com/) identifies it as the "*Caribbean first Indigenous Agriculture Biotech Company*." The enterprise has been featured in the public media regionally and internationally, including the prestigious Forbes Business Magazine (Ewing-Chow, 2019), https://www.forbes.com/) and from all indications they appear to be doing well in producing and marketing products derived from Sargassum.

38. The general situation in developing the business potential and valorizing Sargassum is however more challenging and complex. Oxenford *et al.* (2021) conducted a comprehensive study of the challenges encountered by entrepreneurs and innovators in valorizing Sargassum. They reported that despite the many potential opportunities for valorizing sargassum in the Caribbean, stakeholders have encountered many impediments that continue to challenge start-up businesses, and present barriers for the expansion and scaling-up of existing sargassum-based ventures. They identified and analyzed five key areas of concern including: (1) the uncertainty surrounding supply of Sargassum; (2) insufficient knowledge of the chemical components including micro-pollutants and their variability; (3) challenges with harvesting, transport and storage; (4) inadequate governance including uncertain regulatory frameworks; and (5) significant funding constraints for research and development, and for supporting innovation (see also Desrochers et al., 2020). Another very important issue that may be added to this list is identifying which of the potential products that could be made from Sargassum are best suited for commercialization, that is, marketing and generating adequate monetary benefits within the context of the business environment in the Caribbean countries.

PFR/CRFM Sargassum Project

39. The information in this section is drawn largely from unpublished internal project reports and notes regarding project activities under the regional project entitled, "Sargassum Products for Climate Resilience".

40. As indicated previously, since 2020, the CRFM and Plant and Food Research of New Zealand have been working together to implement the "Sargassum Products for Climate Resilience" project which aims to mitigate the environmental and economic impacts of Sargassum in the region through the creation of technologies and value chains from the biomass. The project which is funded by the New Zealand Ministry of Foreign Affairs and Trade (MFAT) has four main components as follows: (1) raw material safety testing and harvest operations review; (2) product and process Development; (3) product commercialization strategy development; and (4) outreach and supply chain development. The basic approach of the project is to collect fresh Sargassum at sea and use it as raw material for innovative products based on the circular economy concept, with the aim of total utilization and recycling of the Sargassum, thus reducing waste to a minimum. The Sargassum and any residue remaining after processing will neither be left to decompose and release toxic gases, nor will other toxic elements such as arsenic and cadmium be reintroduced into the environment – all will be utilized in a safe manner.

41. One of the early activities undertaken by the Project was collecting and analyzing Sargassum from across the region to determine its biochemical composition and suitability as a raw material in the manufacture of product(s) with special focus on the presence and toxicity of heavy metals to address knowledge gaps identified in previous studies. A total of 65 samples were collected in 2021 and 2022 from four countries, each representing a specific geographic region across the Caribbean (Barbados in the eastern Caribbean, Belize the western Caribbean, Dominican Republic (north coast) in the north central Caribbean, and Jamaica in the central Caribbean). This is to account for the geographic variability in the species and morphotypes and determine the concentrations of heavy metals in Sargassum around the region. An additional 11 samples were collected in Barbados in 2023, during the commencement of the experimental trials to produce safe and effective liquid fertilizers using samples of Sargassum collected from the coastal waters.

42. The concentrations of Arsenic including inorganic Arsenic, Cadmium, and Mercury in the Sargassum samples collected and analyzed were found to be at levels that would preclude certain potential uses due to safety concerns. The concentration of Arsenic and Cadmium were at or above the Maximum Allowable Limits (MAL) for use in food or animal feed products for livestock or aquaculture. The results suggest that Sargassum in its pure form is not suitable for use as a soil enhancer by adding to soil. This is because it would result in heavy metal contamination of the soil over time.

43. Determining which of the many potential products are most suitable for commercialization is another important step in the process towards commercialization. The CRFM/PFR project used a two-staged approach to determine a shortlist of potential Sargassum-based products to pursue during the process and product development phase of the project and which are deemed suitable for eventual commercialization in the region.

44. The first stage (Stage 1) entailed an initial pre-screening of a range of potential products that could be produced from Sargassum. The process was designed to address both technical and commercial risks. The initial list was put together from literature review, brainstorming sessions, market information gathering, and a patent landscape analysis where 336 patents relating to Sargassum derived products were identified and reviewed. Each option on the list was assessed and screened using four criteria - product value, technological complexity and investment required for harvesting and product development, competitive intensity, and whether the end-product depends on regulatory standards concerning the concentration of heavy metals.

45. The second stage screening was a more detailed analysis, primarily based on publicly available online data on market size, challenges commonly faced by the industry, and key commercialization and product development risks. Many potential product options were eliminated during the Stage 1 screening due to technological complex requirements for harvesting and product development, market competitiveness, and regulatory requirements, related, for example, to heavy metal concentrations. The concentrations of heavy metals render Sargassum an unsuitable raw material for cosmetics, pharmaceuticals, nutraceuticals, and functional foods. Other product options such as paper production, anti-fouling and bioplastics were eliminated due to competitive markets with multiple low-cost competitive raw materials available for their production.

46. While bioenergy/renewable energy represent an attractive medium to high value market with only a few competing solutions. However, the PFR/CRFM concluded that the technological requirements and complexities to harvest and process Sargassum into bioenergy raw material presented a significant product development hurdle and were also relatively expensive either in terms of equipment needed or energy required for producing the required end products.

47. The screening process used by PFR and the CRFM identified three potential types of products that offer the best chance of producing commercially viable Sargassum derived end-products in the Caribbean based on the four screening criteria applied. Firstly, sustainable building material made from Sargassum represents an attractive opportunity due to its medium to high product value and low technological requirement for harvesting and processing. The competitor landscape appears to be clear with only one infant Sargassum-based solution.

48. A second attractive market is using Sargassum as a raw material for sustainable footwear production. Although this is a lower value product, harvesting and processing Sargassum into sustainable footwear material does not require complex methods and costly equipment and investment. Heavy metal contents are not regulated and enforced in footwear production so the concentrations in the Sargassum would not pose a product development challenge.

49. The third attractive market segment is the production of crop enhancers that promote plant growth, health, and productivity or provide other direct or indirect benefits that support plant development. This is another commercially viable market for Sargassum. Crop production enhancer is a broad category of products with each product ranging in market value from medium to high. What makes this market attractive is the growing market size and demand from both developed and developing countries, and the possibility of diluting the heavy metals to address potential regulatory hurdles.

50. The Phase 2 activities, i.e., Process and Product Development commenced during the first half of 2023 with the aim of producing sample liquid fertilizers that would effectively be free of heavy metals or have only low concentration. The liquid fertilizer samples would then be tested on crops in Greenhouse trials to evaluate their safety and efficacy. These trials are expected to commence in early September 2023. The Sargassum residue remaining following production of the liquid fertilizer will be diluted to reduce the heavy metal concentration well below the MAL and used in the formulation of compost and possibly also construction material in keeping with the circular economy principle.

51. As noted earlier, utilizing Sargassum for commercial purposes needs to consider the spatial and temporal variability in supply across the region and across each territory. In order to ensure a steady supply for production purposes, Sargassum could be harvested, preserved, stored and stockpiles during the peak season between March and September and used whenever required during the year.

52. Priority is being given to working with local fishers to harvest Sargassum for product development, to ensure they are recognized as key stakeholders in the commercialization of Sargassum. There are already harvesting methods that can be used to collect fresh Sargassum from the coastal water such as the device developed by SOS Carbon which can be attached to small-scale fishing boats. In addition, since 2021, the CRFM/PFR team has been working with local fishers to assist with the harvesting of fresh Sargassum from the coastal waters using their own collecting devices. Further collaboration with local fishers will continue to improve the harvesting techniques and efficiency as well as build capacity among fishers.

53. Solar drying and ensiling are considered both viable options for the preservation of Sargassum in the Caribbean. Solar drying is an effective and low-cost technology that is considered suitable in the Caribbean as a method of preservation with minimal temperature fluctuation and environmental impact. PFR/CRFM project will be reviewing and evaluating available solar drying systems with the goal of having an effective system to manage large volumes of Sargassum needed to produce fertilizers, compost and other products outside the Sargassum season.

CONCLUSION

54. Much progress has been made in understanding and utilizing Sargassum in the region since 2011 when the large blooms started. Studies have confirmed that Sargassum is an important and complex marine alga that contains hundreds of elements and compounds and therefore has potential for commercialization if certain challenges can be surmounted.

55. The fact is that valorization and commercialization of Sargassum or other marine living resources that have not traditionally been utilized or studied, is not a simple process. It requires significant investments in research and technology, process and product development, marketing, and development of appropriate policy and legal frameworks to regulate and manage the value chains. Careful research and studies are needed to better understand Sargassum's biology, ecology, and chemical composition to inform the strategies and requirements for harvesting, handling, transportation, storage, processing, product development and transformation to guide valorization and commercialization initiatives. Given the capacity of Sargassum to absorb toxic heavy metals from the sea water and release toxic gases during decomposition, a strong precautionary approach should be adopted in pursuing the development of Sargassum value chains. This is necessary for the protection of environmental health, and more so, for the protection of human health.

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