An aerial photograph showing a vast expanse of the ocean covered in a thick, yellowish-brown Sargassum seaweed bloom. The bloom is irregularly shaped, with some darker blue patches of open water visible. The overall scene is a stark contrast between the natural blue of the sea and the artificial-looking yellow of the seaweed.

SARGASSUM WHITE PAPER

Turning the crisis into an opportunity

2021

CREDITS AND ACKNOWLEDGEMENTS

Coordination: Cartagena Convention Secretariat, United Nations Environment CEP
(Ileana C. Lopez)

Lead authors: This Sargassum White Paper was prepared by Shelly-Ann Cox and A. Karima Degia for the United Nations Environment Programme - Caribbean Environment Programme (UNEP- CEP).

Contributing authors:
Ileana C. Lopez (UNEP-CEP)

Other contributors:
UNEP-CEP acknowledges the support and feedback from colleagues at UNEP, Nairobi and the Regional Activity Centre for the Protocol Concerning Specially Protected Areas and Wildlife for the Wider Caribbean Region (SPAW-RAC).

Financial Support:
The Secretariat gratefully acknowledges the Swedish Ministry of Environment for their support to the Regional Seas 2020 implementation in particular SPAW STAC-8 para 3 recommendation endorsed by COP-10 Roatan, Honduras.

Citation:
United Nations Environment Programme- Caribbean Environment Programme (2021). Sargassum White Paper – Turning the crisis into an opportunity. Ninth Meeting of the Scientific and Technical Advisory Committee (STAC) to the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region. Kingston, Jamaica.

Front page photo credit: Tony Rath – Drone photograph of a vast mat of sargassum near Silk Cayes, Belize, 4 Sept 2018

Disclaimer

All intellectual property rights, including copyright, are vested in the United Nations Environment Programme-Caribbean Environment Programme (UNEP-CEP). As customary in UNEP-CEP publications, the designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of UNEP-CEP concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by UNEP-CEP in preference to others of a similar nature that are not mentioned. The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of UNEP-CEP. This work is made available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO (CC BY-NC-SA 3.0 IGO).



The Ministry of the Environment is part of The Government Offices of Sweden. It is responsible for matters related to reduced climate emissions, a non-toxic everyday environment and strengthening biodiversity on land and in water. Sweden supports UNEP and wants to strengthen the UN's role in the environmental area and intergovernmental environmental cooperation.



Government Offices of Sweden
Ministry of the Environment

TABLE OF CONTENTS

| | |
|--|-----------|
| 1. Problem Statement | 4 |
| 2. Purpose and Scope of Paper | 6 |
| 3. Sargassum Background and Impacts | 7 |
| 3.1 Pelagic Sargassum: Benefits | 9 |
| 3.2 Sargassum Influx Events: Causes | 10 |
| 3.3 Impacts of Sargassum Influx Events | 11 |
| 3.3.1 Biophysical Impacts | 12 |
| 3.3.2 Socioeconomic Impacts | 13 |
| 3.4 Sargassum Coastal Influx Events – Hazard or Opportunity? | 14 |
| 4. Caribbean Regional situation | 17 |
| 5. Caribbean Sargassum Stakeholders | 20 |
| 6. Strategy Framework | 23 |
| 7. Interventions and Management Strategies | 25 |
| 8. Gap Analysis and Recommendations | 29 |
| 8.1 Forecasting | 29 |
| 8.2 Harvesting/collection and use | 30 |
| 8.3 Policy and Coordination | 32 |
| 9. Contribution of the Cartagena Convention to the strategy | 33 |
| 10. General Recommendations | 35 |
| 11. Conclusion | 36 |
| 12. Selected Reading | 37 |
| 13. Appendices | 43 |
| 13.1 Appendix I: Forecasting Initiatives | 43 |
| 13.2 Appendix II: Monitoring Initiatives | 45 |
| 13.3 Appendix III: Projects, Programmes and Initiatives | 48 |
| 13.4 Appendix IV: Sargassum management plans and strategies in the Caribbean | 55 |



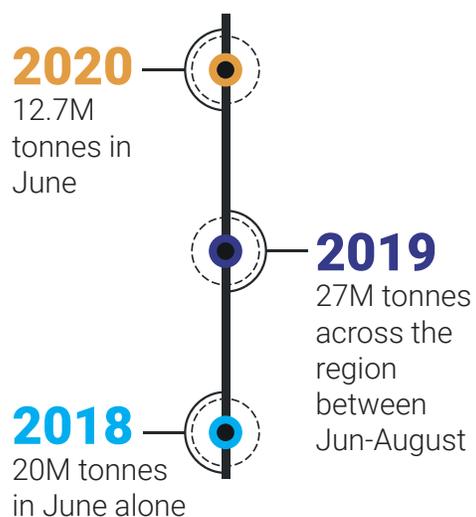
Photo credit: Hayden Billingsy

1

PROBLEM STATEMENT

Since 2011, Caribbean coastlines have been subject to unprecedented, massive, episodic influxes of floating sargassum seaweed. While 2020 was relatively mild in terms of sargassum volumes, and a global pandemic became the overarching worry, 2018 was record breaking in terms of sargassum volumes reaching Caribbean shores and 2019 was also significant.

Floating sargassum should not be construed as negative in and of itself – it is beneficial at sea, mainly as a unique pelagic habitat. However, the mass stranding of sargassum on coastlines has significant negative impacts (biophysical and socio-economic), particularly on coastal communities and livelihoods, public health, tourism and fisheries. This issue therefore represents an emerging hazard for a region that is already subject to numerous hazards. Indeed, various countries in the Caribbean have declared national states of emergency with respect to sargassum influxes (Desrochers *et al.* 2020).

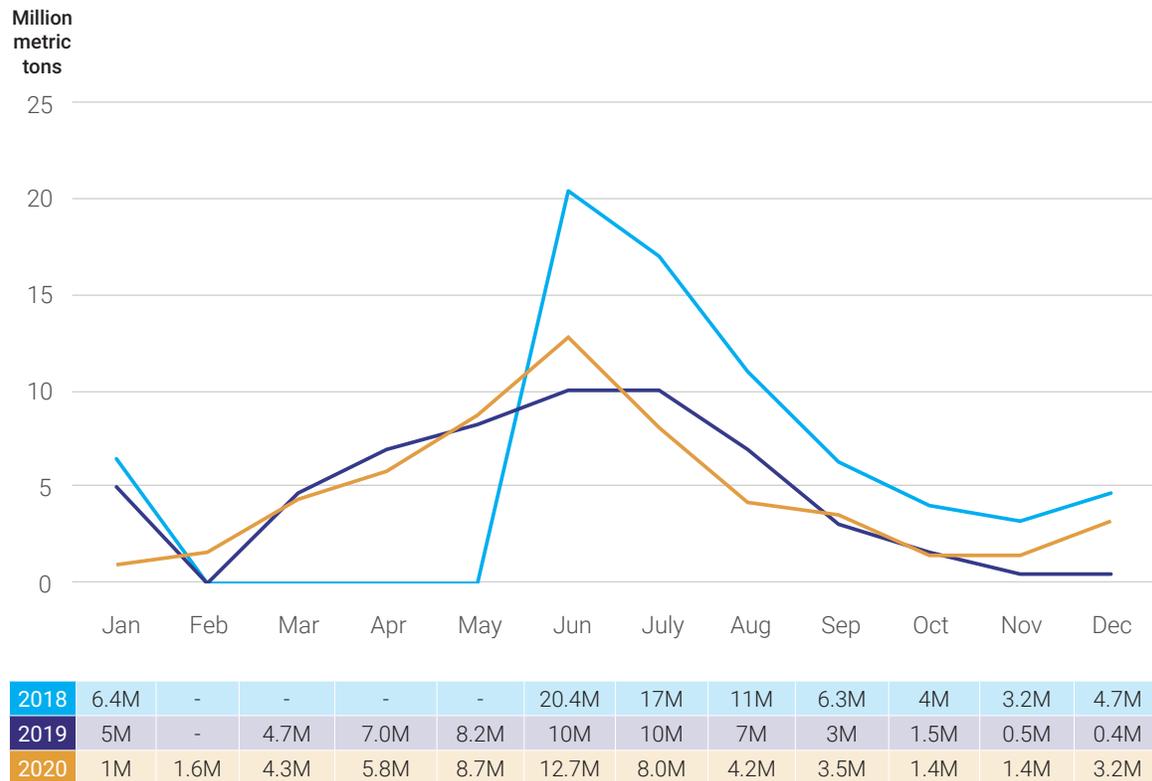


Initially, there was significant uncertainty as to the causes and expectations of recurrence of this new issue, and therefore also on the best response for impacted territories. Subsequently, in the ten (10) years since the first inundation episodes, it is generally accepted that the influxes are part

of a ‘new normal,’ and significant progress has been made in understanding this phenomenon and developing response strategies. Nonetheless, this is a still relatively new issue, and significant gaps remain in information and understanding, as well as effectiveness of response strategies. Significant seasonal and international variations in the influx timing and magnitude hinder accurate predictions, and periods of time when the issue is ‘out of sight, out of mind’ amidst myriad other issues (now including a global pandemic) can derail momentum. Furthermore, the challenges are compounded by the general complexity of Caribbean regional ocean governance. While there is general consensus that part of the response should consider influxes an economic opportunity as much as a threat, there remain many issues to be resolved before that is realised.

The issue is however not confined to the Caribbean, but it extends across the Tropical Atlantic, including equatorial Brazil as well as coastal West Africa from Sierra Leone through the Gulf of Guinea. Sargassum influxes are very much a multi-regional transboundary issue, demanding coordination and collaboration within and across impacted regions.

FIGURE 1: Estimated total amount (million metric tons) of sargassum in the tropical Atlantic (2018 – 2020)



Source: USF Outlook Bulletin



Photo credit: Hayden Billingsy

2

PURPOSE AND SCOPE OF PAPER

The overall purpose of this white paper is to compile background information for a strategic status update and critical situational analysis that informs and elicits feedback from key regional stakeholders. It will also form the basis for development of a draft Concept Note for a UNEP Cartagena Convention-led project targeting key issues identified. The paper is not an exhaustive review of all available knowledge on the issue. It focuses on influxes in the Caribbean, with reference to other impacted regions as appropriate.

This paper is a living document intended to be regularly updated so that it remains current and relevant. This most recent update is the first revision following the original version presented during the Eighth Meeting of the Scientific and Technical Advisory Committee (STAC-8) to the Protocol Concerning Specially Protected Areas and Wildlife (SPA) in the Wider Caribbean Region held in Panama City, 5–7 December 2018.

The original white paper drew upon desktop research and the results of a survey disseminated to UNEP CEP National Focal points in 2018. This update relies entirely on desktop research and review of recent literature. It includes information on new initiatives, proposes a strategy framework and concludes with a section that lists useful resources.

This paper also builds on immense interest on this topic, with over 2,500 registrations to the 4 webinars hosted by UNEP in 2020. This was a joint effort between the GPA Global Partnership on Nutrient Management, UNEP's Science Division, the Cartagena and Abidjan Convention Secretariats of the Regional Seas Programmes, and UNESCO-IOC Harmful Algal Blooms Programme.

The target audience of this paper is diverse, potentially including researchers, policy makers, impacted sectors, and parties interested in sargassum as a commodity, and therefore encompassing both technical and nontechnical readers. Hence, the paper deliberately uses simplified technical language while making reference to technical sources for those interested in further reading.



Photo credit: Hayden Billingsy

3

SARGASSUM BACKGROUND AND IMPACTS

Sargassum is a genus or family of brown *macroalgae* or seaweed that includes over 300 species distributed across the world in both temperate and tropical oceans. Many species are *pelagic*, forming large floating rafts or mats, but most have a benthic (bottom-attached) phase of their life cycle.

A few species, thought only to occur in the Atlantic, are '*holopelagic*,' meaning that they spend their entire life cycle afloat, transported by ocean currents with influence from surface winds. While individuals of these species may occasionally float alone, they more often tangle together to form communities of many individuals, which can take the form of large mats or rafts, or sometimes long lines called windrows. These species are thought to reproduce only vegetatively through growth and fragmentation. Knowledge of growth and mortality rates is limited, although it is known that it can increase its biomass very quickly under the right conditions, and that growth rates are affected by nutrients, salinity and temperature (Desrochers et al. 2020).

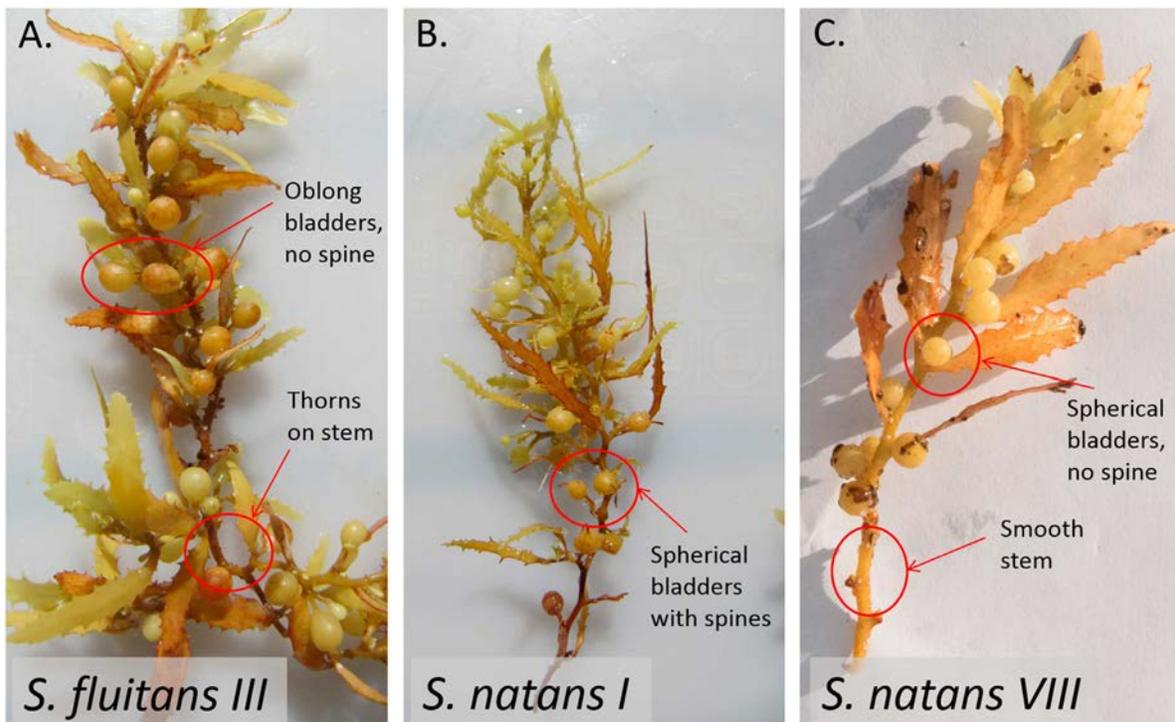
Holopelagic sargassum occurs naturally in the North Atlantic, where massive quantities contained by circulating currents form the Sargasso Sea. It is also common in the Gulf of Mexico where it blooms in the spring and supplies the Sargasso Sea population via the Gulf Stream current, and it has been known to occur occasionally in the Caribbean (Wang et al. 2019). Research into the causes of the recent massive influxes of sargassum in the Caribbean and West Africa has led to the identification of a new 'consolidation region' in the Tropical Atlantic, between the Gulf of Guinea and the north coast of Brazil that is generally agreed to be the source of the influxes to the Caribbean and West Africa.

FIGURE 2: Schematic illustrating new sargassum source region



Source: Adapted from Oxenford, H. A. 2020

The influxes to the Caribbean have been found to consist predominantly of two species of holopelagic sargassum, *S. natans* and *S. fluitans*. There are various morphotypes of these species and some debate as to whether there may be third additional distinct species. (Desrochers et al. 2020)



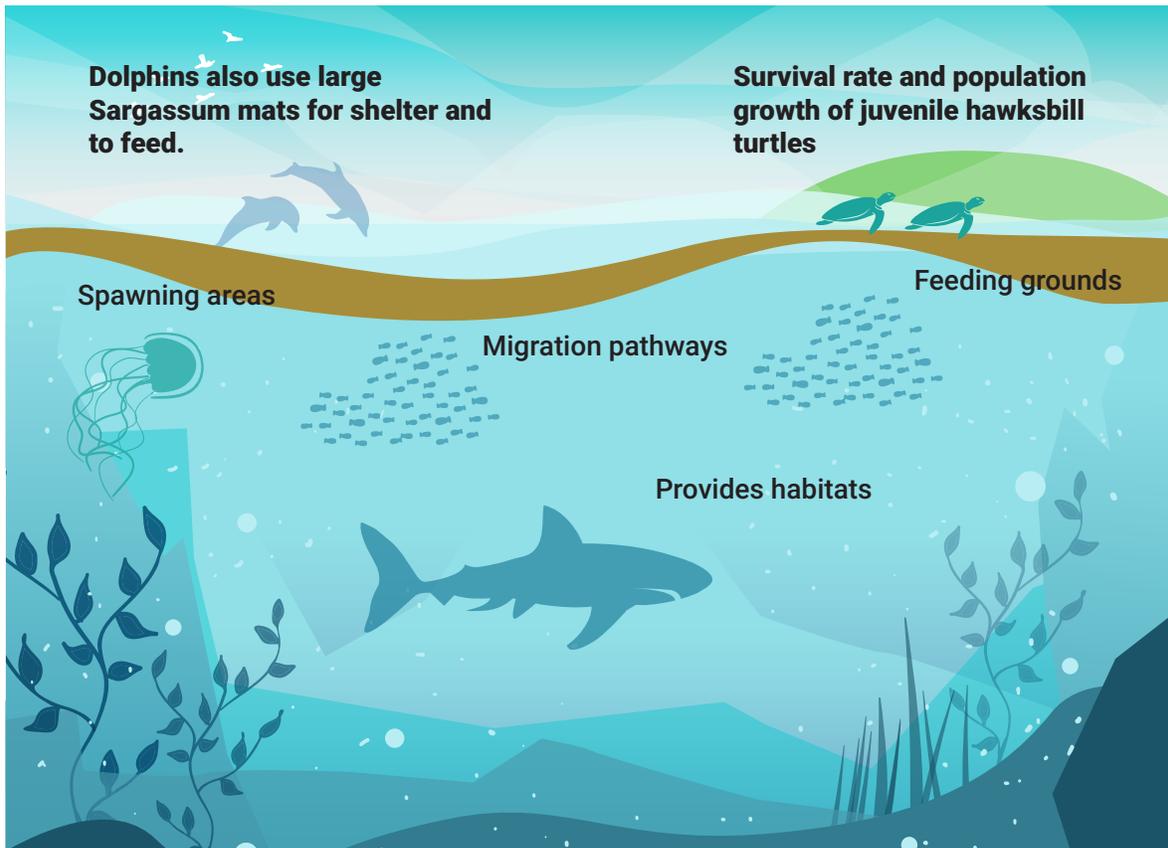
Source: DOI: 10.7717/peerj.7814/fig-1

3.1 Pelagic Sargassum: Benefits

Holopelagic sargassum in the open ocean is generally beneficial. The Sargasso Sea in the North Atlantic, named for the seaweed, is formed by circulating currents around the North-Atlantic subtropical gyre supporting a large community/ population of holopelagic sargassum that is the basis for a unique open-ocean ecosystem sometimes referred to as a 'golden floating rainforest.' According to the Sargasso Sea Commission, the 'Sargasso Sea provides habitats, spawning areas, migration pathways and feeding grounds to a diverse assortment of flora and fauna, including endemic, endangered, and commercially important species.' Similar benefits obtain from free-floating sargassum are common in the Gulf of Mexico.

Pelagic Sargassum in the Tropical Atlantic, though relatively new in such quantities, does have some positive impacts in terms of habitat for marine species. Hawksbill turtles, in particular, are said to be benefiting from increased large Sargassum mats. In Jamaica, scientists have observed an increase in survival rate and population growth of juvenile hawksbill turtles during times of Sargassum infestation. The large sargassum mats provide shelter and food, and thus greater chances of survival. Dolphins also use large Sargassum mats for shelter and to feed on fish.¹

FIGURE 3: Sargassum benefits



¹ The Gleaner. Sun, Sea and Sargassum. Available at: <http://jamaica-gleaner.com/article/news/20190707/sun-sea-and-sargassum>

3.2 Sargassum Influx Events: Causes

Identifying the causes of the sargassum influxes is fundamental and critical to any future effort to mitigate the issue, as well as efforts to predict the influxes that would support planning adaptive response and management measures. This is therefore an active area of research. This phenomenon does not stem from a single or simple cause, but rather from complex combination of causal factors that may be visualised as causal pathway or set of causal mechanisms. A key step in understanding this causal pathway was identifying the new consolidation region that is the source of these influxes. The existence of this was confirmed through remote sensing since 2013 (Gower, Young and King 2013). With this knowledge, it is possible to frame an outline causal pathway as follows:

FIGURE 4: Causal Pathway



Within the framework of this causal pathway, there remains much that is uncertain or unknown about the details of processes and mechanisms. There is much debate, with numerous hypotheses advanced, as to the establishment of the new consolidation region, i.e. how/why sargassum was transferred there, and how/why it persists/proliferates there.

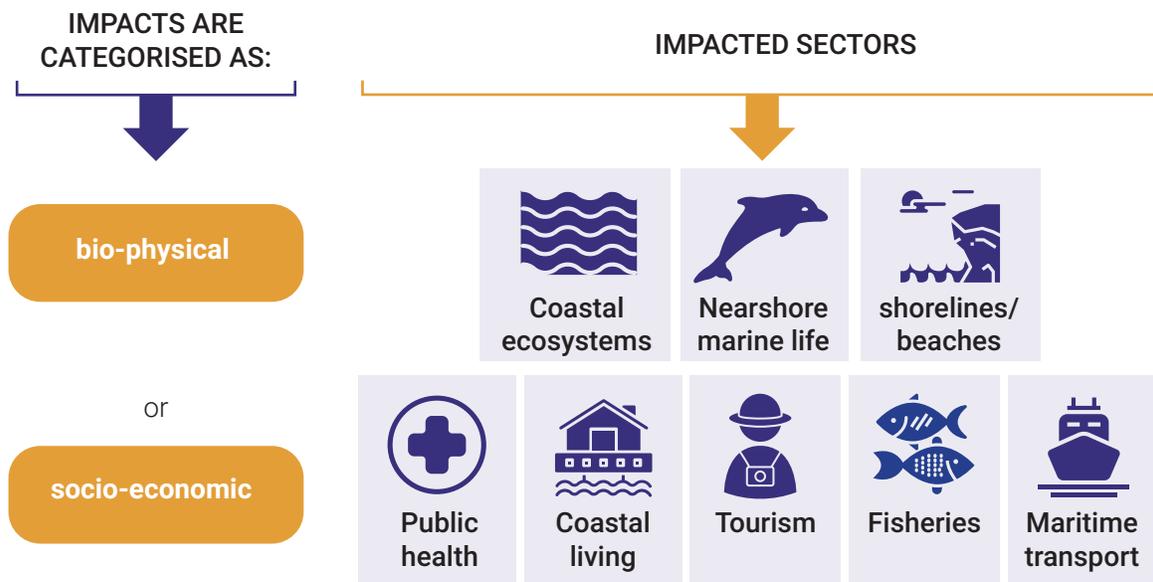
The immediate proximal factors involved are likely linked to broader underlying issues like general ocean eutrophication (land-based nutrient pollution) and climate change (Table 2). Given the existence of the new consolidation region, there is also general agreement that sargassum influxes may be expected to continue as part of the ‘new normal’ until/unless mitigation may be achieved, i.e. the issue is unlikely to resolve itself without intervention.

TABLE 1: Proximal Factors and supporting empirical evidence

| Causal Pathway | Factors | Empirical evidence |
|---|---|---|
| Sargassum exists elsewhere | Wind anomaly | Gower, Young and King 2013 Johns et al. 2020 |
| Transfer to new consolidation region | North Equatorial Current North Equatorial Counter Current | Putman et al. 2020 Johnson et al. 2020 Wang et al. 2019 |
| Persistence/ Proliferation in new consolidation region | Nutrient enrichment African biomass Sea surface temperatures | Fulton et al. 2014; LaPointe 1995, 2019; LaPointe et al. 2014 Barkley et al. 2019 Djakouré et al. 2017 |
| Separation and transport to Caribbean | North Brazil/Guiana Current North Brazil Current Rings North Equatorial Counter Current North and South Equatorial Currents | Lumpkin and Garzoli 2005 Gower et al. 2013 Franks et al. 2016 Putman et al. 2018 Putman et al. 2020 |

3.3 Impacts of Sargassum Influx Events

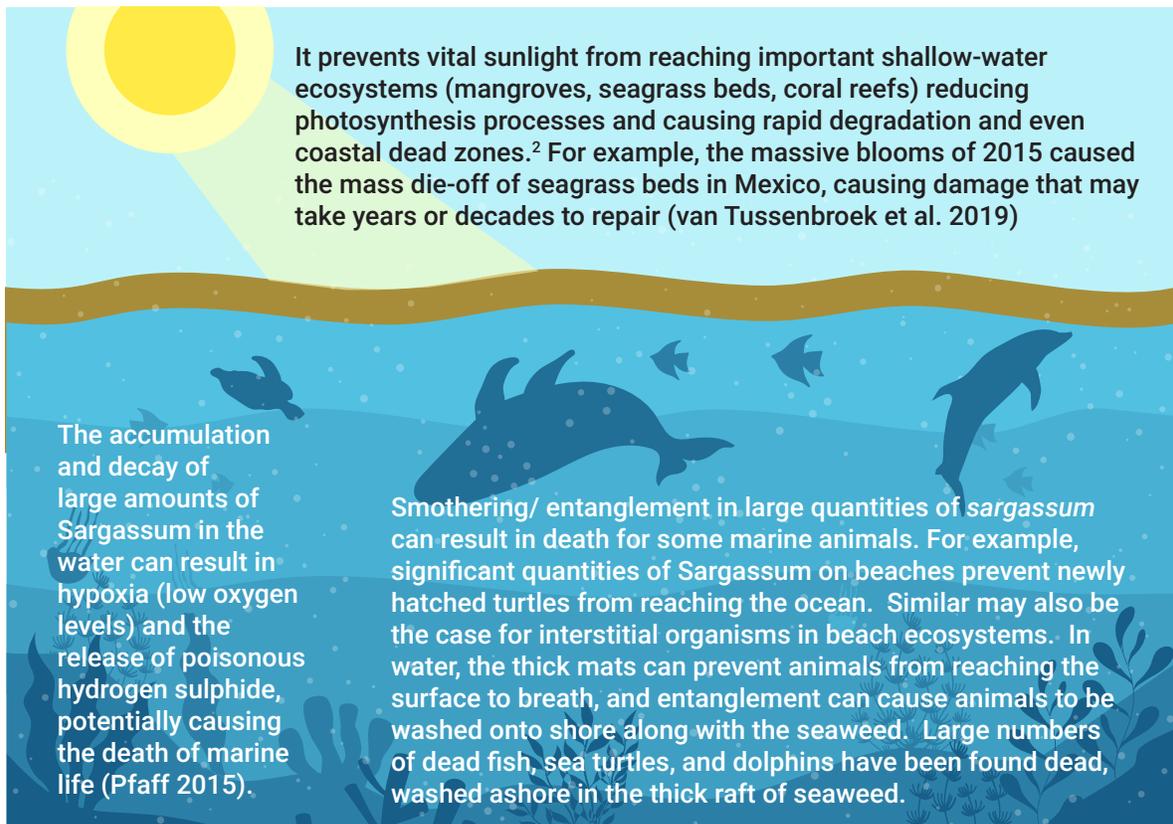
This section outlines the impacts of sargassum influxes in general, with some specific examples.



It should be understood that the types and severity of impacts and feasibility of responses all vary spatially across the Caribbean according to several factors, including: coastline position (level of exposure to sargassum influxes), geomorphology and coastal dynamics of the impacted coastline, and presence/absence/proximity of vulnerable resources, activities and operations along the impacted coastline. This is discussed further in Section 7.

3.3.1 Biophysical Impacts

Stranding on coastlines negatively impacts the sargassum itself (a potentially beneficial habitat at sea) as it dies and subsequently decays. Also in that process, the sustained presence of large quantities of decaying biomass negatively impacts coastal and nearshore marine life through a number of mechanisms:



A secondary, avoidable negative impact of the influxes relates to the use of heavy machinery to remove massive Sargassum landings, which impacts beach habitats and tend to worsen the environmental harm. The use of heavy machinery causes compaction of beaches and kills organisms that live in the sand, such as ghost crabs and other sea creatures that keep a beach healthy by creating hundreds of holes that keep the beach ventilated. Driving with heavy equipment will not only crush them, but also kills any potential sea turtles' nests.³ Another impact is the removal of vast quantities of sand, resulting in unintentional sand mining, and ends up affecting the entire beach ecosystem.

Sargassum washing ashore can in some cases yield a positive impact, wherein the seaweed aids in stabilising the beach. This benefit is likely lost with large quantities that overwhelm a beach or bay, and would often be offset by major negative impacts depending on the resources present and uses of the beach.

² Hakai Magazine. The Eastern Caribbean is Swamped by a Surge of Seaweed. Available at: <https://www.hakaimagazine.com/news/the-eastern-caribbean-is-swamped-by-a-surge-of-seaweed/>

³ The Gleaner. Sun, Sea and Sargassum. Available at: <http://jamaica-gleaner.com/article/news/20190707/sun-sea-and-sargassum>.

3.3.2 Socioeconomic Impacts

Sargassum influxes negatively impact human well-being, activities, and livelihoods as well as major sectors of Caribbean Economies. Key sectors impacted include: coastal living and livelihoods, marine transport/ navigation, public health, fisheries and tourism. These impacts are inter-related, with many stemming from one of the key drivers of biophysical impacts – the decay of the sargassum biomass.

The production of hydrogen sulphide negatively impacts air quality, results in very unpleasant odours, and prolonged exposure is unhealthy, especially for persons with underlying respiratory conditions. This is detrimental for coastal residents and beach users, whether local or visitors. Beach users who live elsewhere have the option to avoid impacted locations, while residents may be unable to avoid prolonged exposure.

Large quantities of sargassum also spoil the aesthetic appeal of Caribbean beaches, and inhibit access to nearshore waters. Both issues affect residents, local beach users and tourists, while the latter particularly impacts those whose livelihoods rely on the sea, such as fishers who may need to access the water to access their equipment and/or livelihood.

Specific sectoral impacts are outlined in Table 3 below, with specific examples where available.

TABLE 2: Sectoral impacts and examples

| | |
|---|--|
|  | <p>IMPACT There have been reports of respiratory problems, nausea, headaches and irritation of the eyes believed to be caused by exposure to high concentrations of hydrogen sulphide in the air. Furthermore, direct contact with Sargassum may cause skin rashes and/or irritation, not likely from the seaweed itself but because of some tiny organisms that live in the Sargassum (Resiere et al. 2018).</p> |
| <p>Public health</p> | <p>Example(s) Reports in St. Lucia suggest that both residents and tourists have experienced higher incidences of respiratory problems since the sargassum influxes began. Other complaints include nausea, headaches, and skin rashes⁴.</p> |
|  | <p>IMPACT Residents are unable to obtain relief from poor air quality, health impacts, and unpleasant odours by simply avoiding the area. Beach use that may have been a part of their lives will also be negatively impacted. It has also been reported that decomposing Sargassum causes corrosion of electrical appliances and equipment in the near vicinity (Mendez-Tejeda and Rosado Jiménez 2019).</p> |
| <p>Coastal living</p> | <p>Example(s) In the Dominican Republic, coastal residents have reported that sargassum causes the corrosion of metal infrastructure and boats, which is likely associated with the effects of hydrogen sulphide. These effects dissipate as exposure decreases.</p> |

⁴ <https://eos.org/articles/saint-lucia-works-to-release-itself-from-sargassums-stranglehold>



Tourism

IMPACT

Spoiled aesthetics, unpleasant odours, difficult access to the beach/sea, and potential health risks all diminish or destroy the 'sun-sand-and sea' appeal of Caribbean tourism. As a result, some areas of the Caribbean have witnessed large declines in tourism. This has significant impacts on the overall national economy, as well as direct impacts on those across income levels who make their livelihoods through tourism. Waterfront hotels may incur costs of beach clean-ups to alleviate the issue on their frontage (see below). Watersports operators would be directly impacted both through reduced visitor numbers and similar access issues as fishers (below).

Example(s)

Mexico experienced 35% drop in tourism during the first quarter of 2018 attributed to sargassum influxes.



Fisheries

IMPACT

Sargassum blooms also result in reduced access to fishing grounds and disrupted fishing operations when, in worst case scenarios, fisheries cannot take their boats out to sea (Solarin et al. 2014). Fisheries and aquaculture may also be severely impacted by the mortality of fish and other marine life (Pfaff 2015), resulting in reduced and/or altered fish catches (Fogarty 2018).

Example(s)

In Barbados, the arrival of massive amounts of Sargassum have coincided with a dramatic decrease in flyingfish landings from 981 tons in 2014, to 278 tons in 2015. This represented a 72 percent decline in one of the island's most important fisheries (Oxenford et al. 2019).



Maritime Shipping/Navigation

IMPACT

Ships and boats may find it difficult to navigate through thick mats of sargassum which affects the engines.

Example(s)

Transatlantic sailors have reported that thicker clumps of sargassum slowed down their boats significantly. The biggest problem is caused by seaweed snagging on spade rudders and bulb keels creating drag.⁵



Direct costs

IMPACT

In addition to economic and livelihoods losses as outlined above, especially tourism and fisheries, there are direct costs associated with alleviation measures such as beach cleaning. Depending on the location, these direct costs may be borne by government or hotels or both.

Example(s)

Mexico has spent USD\$17 million to remove Sargassum from over 1,000 km (621 miles) of Mexican beaches through 2019. From May to August 2019, 69,606.1 tons of Sargassum was collected and 13,527 people were employed to clean up beaches.

⁵ <https://www.yachtingworld.com/sailing-across-atlantic/sargassum-weed-increasing-problem-transatlantic-sailors-125971>

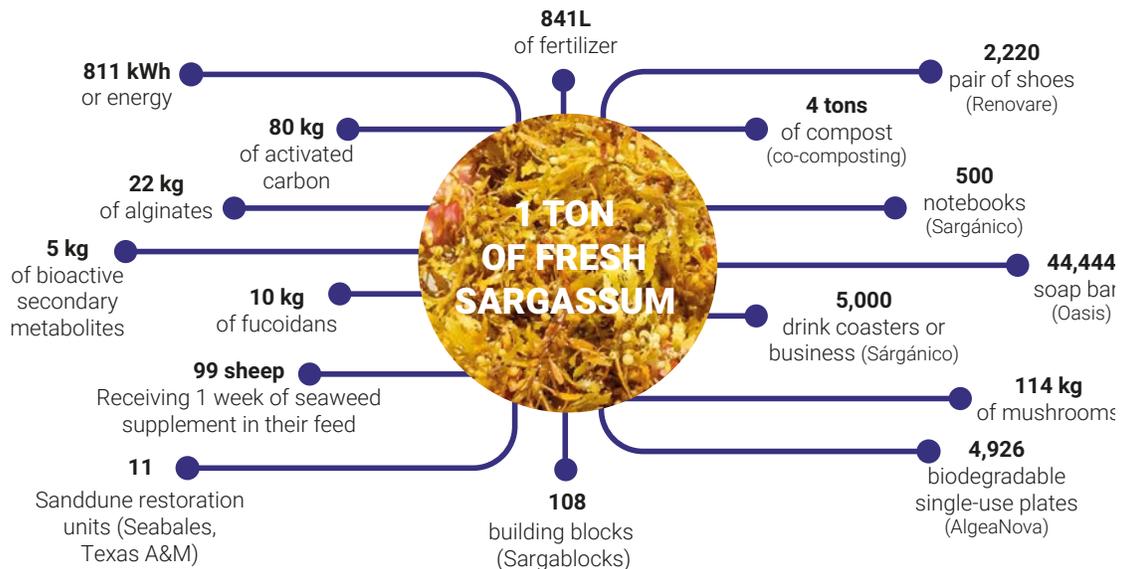
3.4 Sargassum Coastal Influx Events – Hazard or Opportunity?

It is important to make a clear distinction between floating sargassum on the high seas and floating sargassum that has been transported to and stranded in nearshore coastal areas in large quantities. The former is generally beneficial as outlined above. It is the latter that generates the significant negative impacts prompting this paper. When stranded in coastal areas, the sargassum itself dies, and many of the negative impacts originate with its decay. Given the scale and extent of the negative impacts these influx events may be characterized as a recurring hazard. The unprecedented scale of the Sargassum influxes also led to declaration of emergency conditions in several Caribbean countries e.g. Tobago in 2015, Barbados in 2018, and Mexico in 2019 (Chavez et al. 2020).

Sargassum has also been identified as a potential resource that may be commoditised. There is potential for a variety of uses including agriculture, bioenergy, bioplastics, bioremediation and purification, construction and cosmetic among others (Desrochers et al. 2020). As such, its transport in large quantities by natural processes to the Caribbean may represent an opportunity for economic development. At the same time, the Sargasso Sea Commission has identified the future harvesting of sargassum as a potential threat to the Sargasso Sea⁶. Harvesting Sargassum in the tropical Atlantic that would otherwise be stranded with the attendant negative impacts to supply that demand may have the co-benefit of helping to mitigate that risk to the Sargasso Sea.

This is however contingent on several factors that remain uncertain or unresolved on both the supply and demand sides. These include the capacity and costs required to efficiently harvest, store and transport sargassum for processing, as well as requirements for or preclusions from various potential end uses, e.g. some end uses may achieve a better yield with only certain types of sargassum, some processes may require fresh versus dried sargassum, or the presence of heavy metal or contaminants may preclude its use for certain applications. Another factor is the relative product yields based on a specific volume of fresh sargassum (Figure 5). Countries

FIGURE 5: Relative product yields that could potentially be produced from one metric ton (1000 kg) of fresh sargassum



Source: Adapted from Desrochers et al. 2020

⁶ <http://www.sargassoseacommission.org/about-the-sargasso-sea>

may want to explore uses that require larger volumes of sargassum and simple processing techniques to support cost-recovery initiatives.

On the last point, there are concerns regarding potential health implications with the consumption or utilization of Sargassum as fertilizer because of the potential harmful contents and the possibility that some crops may take up the contents of the seaweed. The French Research laboratory Institut Technique Tropical (IT²), along with the Agency of the Environment and Energy (ADEME) have produced an extensive study to warn about the utilization of sargassum as a soil fertilizer for two main reasons: the high risk of salinization of soils as well as the relative low results (based on cucumber, lettuce, sweet potato, bananas and sugar cane exploitations). Further research in this area is important to define the exact toxins and concentration levels to determine potential safe utilization purposes.

At this stage, while efforts to explore the potential opportunity are underway, the reality is that sargassum influxes remain more of a hazard than a benefit until key issues are resolved.



Photo credit: Ulises Jauregui



Photo credit: Hayden Billings

4

CARIBBEAN REGIONAL SITUATION

The Wider Caribbean Region (WCR) is geopolitically diverse and complex (Mahon et al. 2013, Debels et al. 2017); indeed it is the most diverse and complex among the Regional Seas Programmes. There are numerous political entities, vast differences in size, and varying levels of development (Debels et al. 2017). The region contains numerous small island developing states (SIDS), with the well-known associated sustainable development challenges – the WCR contains the largest number of SIDS of any region globally, and by extension the largest number in any of the Regional Seas Programmes. While there are many commonalities and valid generalisations, the region is less homogenous and more variable than many realise. This has implications for both how sargassum impacts countries and territories of the region, as well as the suitability of responses.



Source: The CLME+Project

There are numerous ways to categorise the countries and territories in this complex region. For the purposes of this discussion, consider two broad categories/subsets outlined in Table 3. Note these are broad generalisations to make certain key points, and there will be some exceptions.

TABLE 3: | Categorisation of countries and territories in the Caribbean

| Category | The Island Chain (The Lesser Antilles, Greater Antilles and the outlying Lucayan Archipelago, i.e. the Bahamas plus Turks and Caicos) | Continental landmass of South and Central America |
|------------------------------------|--|--|
| Type of land mass/ position | Fragmented land mass that forms the ‘front line’ or outer boundary of the Caribbean Sea, with various inter-island channels through which water flows along with all that it conveys including Sargassum | Continuous continental landmass that forms the southern and western borders of the Caribbean Sea |
| Exposure | More exposed to high energy sea conditions directly off the Atlantic | Less exposed to high energy sea conditions, sheltered by the outer barrier of the island chain |
| Development | Mostly SIDS, along with small island overseas territories of developed countries (US, UK, France and the Netherlands) that share some similar small island challenges | Continental countries, mostly classified as developing, albeit at varying levels, and including three (3) small countries categorised as SIDS based on shared challenges |
| Language | Mostly English speaking, with several exceptions (French, Dutch and Spanish) | Largely Spanish speaking with few exceptions |

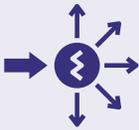
The impacts of sargassum influxes are outlined in general in Section 3. However, it is important to understand that impacts are not uniform across the region, or even across each territory. This heterogeneity also has implications for management and response strategies, in particular collection/ harvesting logistics. Key examples are outlined below:



The impacts of sargassum stranding and the suitability of the responses are influenced by coastline morphology and dynamics (shape, orientation, physical features, processes like waves/currents). A key distinction is that long beaches on continental landmasses will receive larger quantities of sargassum in a continuous stretch, whereas small beaches on a small island will receive smaller, fragmented amounts of sargassum. On islands where there are numerous pocket beaches, such as Barbados and Antigua, this fragmentation of the sargassum ‘supply’ is even more pronounced.



Specific coastlines, typically those that are windward/ Atlantic facing are impacted the most. For the islands of the Eastern Caribbean in particular, this is typically the most rugged and exposed coastline, with the most difficult sea conditions, often remote from urban centres and sometimes with difficult access.



Secondary impacts of sargassum influxes depend on the assets/ resources present at that coastline, e.g. tourism impacts are limited if that is not an important tourism site, similarly impacts on coral reefs / seagrasses are not relevant if those systems are not present at that site.



Capacity to respond varies significantly as well. SIDS and less developed countries already struggle to mobilise resources to address environmental issues and hazards.

Consequently, a blanket approach for the region is not suitable, as approaches and technologies that work well in one location may nor may not be transferrable to another. Critical analysis of the specific situation is required to identify and prioritise specific impacts, determine the appropriate course of action, and efficiently allocate resources. A hazard exposure and vulnerability assessment framework is outlined in Section 8 as a recommended approach for each territory.

While it is agreed that sargassum influxes represent a major transboundary issue requiring regional cooperation, it is also understood that regional ocean governance arrangements are complex, reflecting the overall complexity of the region as described above. Key issues such as weakness in regional natural resources governance, limited human capacity and financial resources, and external dependency have been identified as root causes of environmental degradation in the WCR (Mahon et. al 2013). It should be expected that associated challenges will also manifest in efforts to coordinate sargassum response regionally. Management and governance at the regional level for sargassum influxes are discussed/ described in detail in Section 6.

As things stand, there is significant variability in the uptake and various technologies in predicting, monitoring, collecting/harvesting, or sargassum and little in the way of consistent application across monitoring programmes. "Regional" projects are often targeted at a specific groups of beneficiary countries rather than the region as a whole. The multiple languages in the region can lead to language barriers that hinder transboundary collaboration, as cited by a recent paper on coral reef restoration (Bayraktarov, et al. 2020). Fortunately, numerous collaborations on sargassum issues have cut-across language barriers (e.g. Sarg'COOP, Appendix III), and some key publications including this white paper will be produced in English, Spanish and French.



Photo credit: Gary Marshall

5

CARIBBEAN SARGASSUM STAKEHOLDERS

Since the impacts of sargassum influxes are multi-sectoral, there is correspondingly a wide range of stakeholders. Stakeholder dynamics, interrelationships and interests are also often complex, again reflecting the general regional circumstances and governance arrangements as above. In order to identify stakeholders at the regional level with reasonable representation across sectors and interests, a stakeholder map has been developed (Table 4). The map is structured around three broad categories, namely:

- Stakeholders responding to sargassum influxes as a hazard requiring management, mitigation or adaptation;
- Stakeholders responding to sargassum as a resource/ commodity/ opportunity; and
- Stakeholders with broad interests in sargassum both in terms of both hazard management and potential opportunity.

Each of these broad categories is further sub-divided into sectors, e.g. tourism, fisheries etc., and stakeholder organisations in each category/sector are identified across the public and private sector as well as the NGO/CSO community. Several actors working at the marine science-policy interface in the Caribbean are featured in the stakeholder map. Of notable mention is the UNEP-CEP's Specially Protected Areas and Wildlife (SPA-W)- Regional Activity Centre's (RAC) role in engaging regional stakeholders and facilitating networking opportunities related to sargassum management and research. Many of these initiatives and partners are featured in the regional sargassum activities illustration (Section 6) and in the appendices. Section 8 outlines the contribution of the SPA-W protocol to the regional sargassum management strategy in more detail.

TABLE 4: Regional Sectoral Stakeholder Map

| Sector/ Category | CARICOM/ CARIFORUM | Other Inter-governmental | Private Sector | NGO/CSO/ "Third Sector" |
|---|---|---|--|---|
| Broad interests in sargassum both in terms of hazard management/adaptation as well as a potential opportunity | University of the West Indies, University of Guyana | International Atomic Energy Agency | Several private companies in R&D e.g. Punta Cana Foundation, Dominican Republic to be listed | Greater Antilles: DR - Universidad Autonoma de Santo Domingo CIBIMA; PR - Universidad de Puerto Rico French Caribbean - Université des Antilles Central America: UNAM (Mexico); University of Belize Environmental Research Institute USA Universities: FIU, USF, USM |
| Broad interests in sargassum both in terms of hazard management/adaptation as well as a potential opportunity | | US National Oceanographic and Atmospheric Association (NOAA) | | |
| Broad interests in sargassum both in terms of hazard management/adaptation as well as a potential opportunity | Caribbean Meteorological Organisation (CMO) Caribbean Institute for Meteorology and Hydrology (CIMH) | Caribbean Sea Commission of the Association of Caribbean States UNEP-Caribbean Environment Programme (Regional Seas Programme) IOC Sub-Commission for the Caribbean and Adjacent Regions (IOCARIBE) | | |
| Broad interests in sargassum both in terms of hazard management/adaptation as well as a potential opportunity | | Economic Commission for Latin America and the Caribbean (UNECLAC) | | |
| Broad interests in sargassum both in terms of hazard management/adaptation as well as a potential opportunity | Caribbean Development Bank (CDB) Caribbean Tourism Organisation (CTO) | IDB, World Bank, UNEP, UNDP, FAO, Sida, KfW, USAID, Interegg Europe | Caribbean Hotel & Tourism Association | The Nature Conservancy (TNC) |
| Broad interests in sargassum both in terms of hazard management/adaptation as well as a potential opportunity | | | | |
| Stakeholders responding to sargassum as a risk or hazard requiring management, mitigation or adaptation | Caribbean Regional Fisheries Mechanism (CRFM) | FAO/WECAFC | Caribbean Network of Fisherfolk Organisations (CNFO) | Gulf and Caribbean Fisheries Institute (GCFI) |
| Stakeholders responding to sargassum as a risk or hazard requiring management, mitigation or adaptation | | | | |

| | Sector/ Category | CARICOM/ CARIFORUM | Other Inter-governmental | Private Sector | NGO/CSO/ "Third Sector" |
|---|---|--|--|--|---|
| Stakeholders responding to sargassum as a risk or hazard requiring management, mitigation or adaptation | Agriculture (terrestrial, i.e. not fisheries) | Caribbean Agricultural Research and Development Institute Caribbean Public Health Agency (CARPHA) | Food and Agriculture Organisation (FAO) Pan American Health Organisation (PAHO) | | |
| | Public health | | UNEP-Caribbean Environment Programme (Regional Seas Programme), CLME+ Interim Coordination Mechanism (ICM) | | Caribbean Natural Resources Institute (CANARI) The Nature Conservancy (TNC) Waitt Institute |
| | Coastal ecosystems management/ conservation | | | | Caribbean Water and Wastewater Association |
| | Marine pollution | | THE BASEL CONVENTION REGIONAL CENTRE-CARIBBEAN | | |
| | (Solid) Waste management | | | | |
| | Climate Change | Caribbean Community Climate Change Centre (CCCCC) | | | |
| | Port services/ maritime transport | | International Maritime Organization (IMO) | Port Management Association of the Caribbean Caribbean Shipping Association | |
| | Marine Protected Areas management Marine surveillance/ patrol | | CampPAM, BioPAMA Regional Security System | | |
| | Emergency management/ Response | Caribbean Disaster Emergency Management Agency (CDEMA) | Caribbean Catastrophe Risk Insurance Facility (CCRIF) | | |
| | Small business/ SME affairs | Caribbean Export Development Agency | | Regional network of Small Business Development Centres (SBDCs) | |
| Energy (renewable) | Caribbean Center for Renewable Energy and Energy Efficiency (CCREEE) TBD | | The Caribbean Electric Utility Services Corporation (CARILEC) | | |
| Harvesting - nearshore (national) vs offshore regional cooperation | | TBD | | TBD | |
| Uses - post harvest production | | TBD | | TBD | |
| Mitigation, cleanup, barriers (collection vessels, booms etc) | | Fragmented - various national operations | | Numerous e.g. AlgaeNova, EnergyAlgae | TBD |
| Stakeholders responding to sargassum as resource/ commodity/ opportunity | | | | | |



Photo credit: Hayden Billings

6

STRATEGY FRAMEWORK

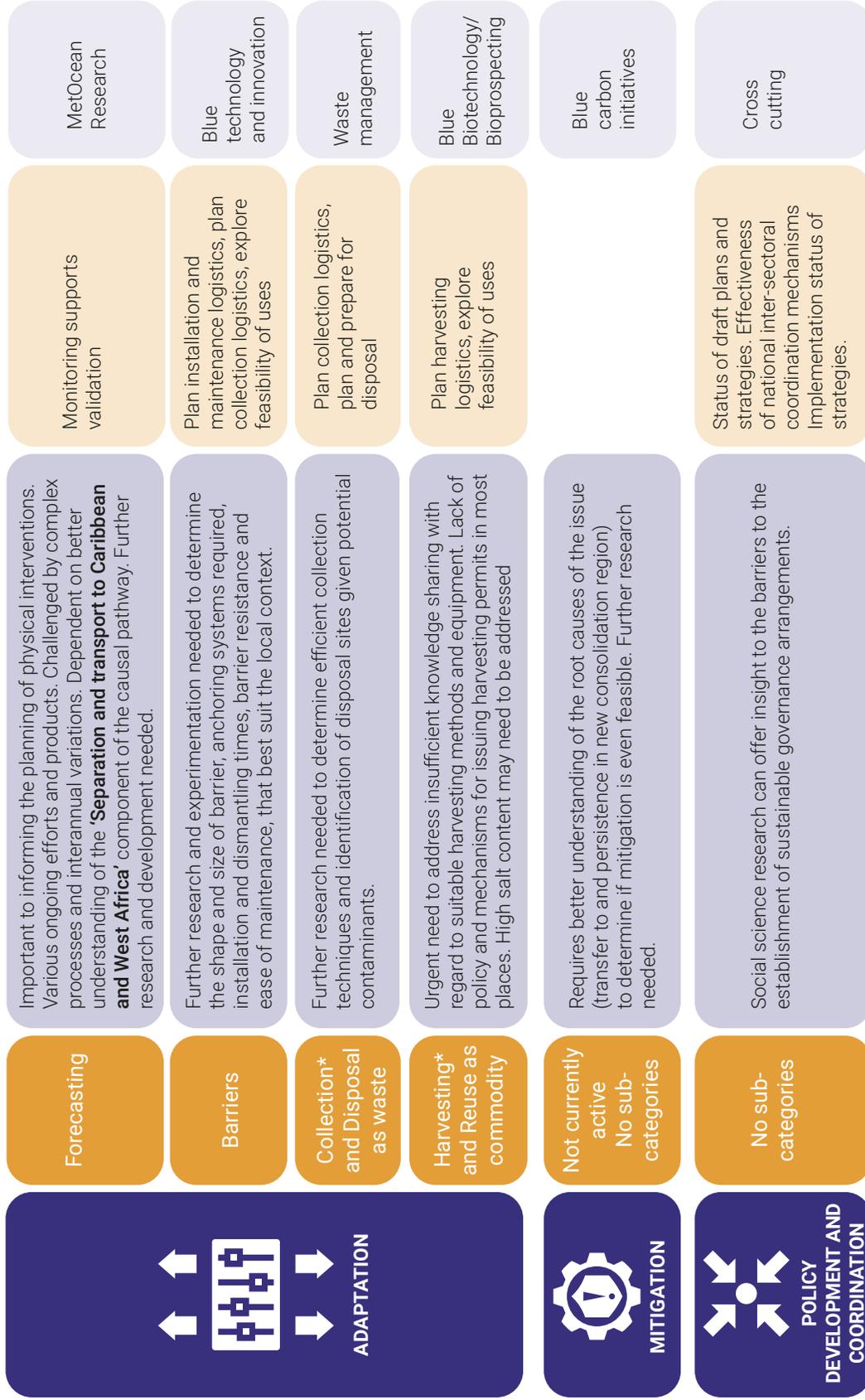
The range of possible interventions and management strategies may be broadly categorised as either adaptation or mitigation (meaning mitigation of the sargassum issue as distinct from climate change mitigation). Adaptation responses may be further categorised as efforts in forecasting, collection, disposal, or harvesting and reuse. Mitigation options are not well developed and require additional information on the root causes of the issue for further advancement. Policy development and coordination is also critical, and this will enable both adaptive and mitigative interventions. This strategy framework, presented in Table 5, will be used to identify gaps in coverage and make specific recommendations.

Some types of interventions are dependent on understanding the causal pathways/ and mechanisms of this issue. Efforts in mitigation and prediction have differing needs out of the causal analysis (Section 3.2). In the context of the causal framework, key questions in exploring mitigation include: *'how/ why does sargassum proliferate in the new consolidation region?' (leading to 'can it be stopped/ reduced?'), and 'was the incident that transferred sargassum to the new source region a one-time occurrence, or is there some means of recurrence or exchange between the new consolidation region and the original source?'* (the latter would stymie mitigation). Prediction is more considered with the process by which sargassum detaches from the main consolidation region and is transported to the Caribbean.

A key activity required as part or in support of these interventions is monitoring and quantifying sargassum influxes. This is needed to help validate forecasts, plan collection/harvesting logistics, plan and prepare for disposal, and explore use/ commoditisation opportunities.

Some of the adaptation intervention categories have clear links with Blue Economy development, and should be explored further in that context and in coordination with various regional blue economy initiatives.

FIGURE 6: | Strategy framework



* Note that 'collection' and 'harvesting' here overlap significantly, the difference is in the next step, whether disposal or putting the material to use.



Photo credit: Hayden Billingy

7

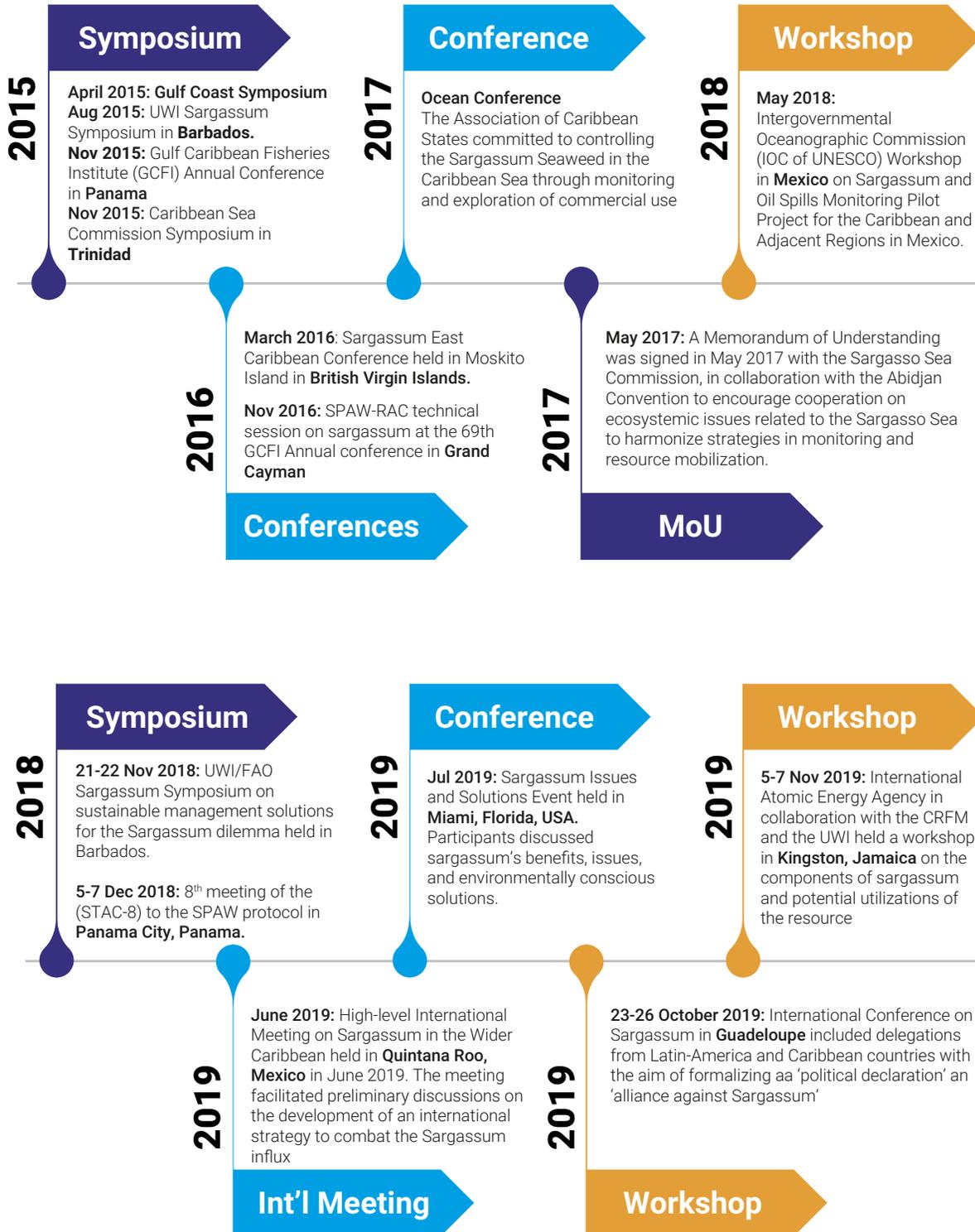
INTERVENTIONS AND MANAGEMENT STRATEGIES

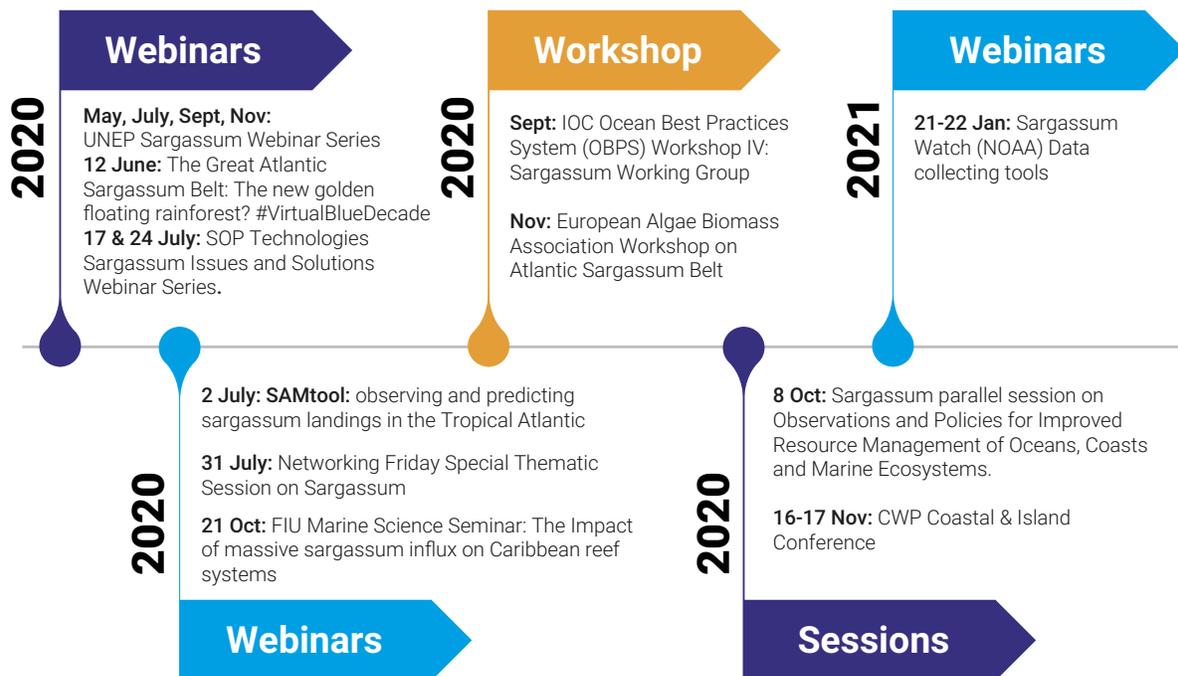
This section provides a review of existing and ongoing interventions and management strategies, including regional sargassum activities (meetings, symposia, workshops, conferences, grass roots activities etc), formal projects, programmes and initiatives, and governance arrangements. The presentation of this review is organised along the same lines as the overall strategy framework outlined in the previous section, in order to elucidate gaps in coverage and support subsequent recommendations.

Figure 7 below illustrates notable regional sargassum activities from 2015-2021.

Other activities not highlighted in the figure include the creation of numerous sargassum Facebook groups to promote information exchange, beach clean ups organised by community groups and art advocacy initiatives to inspire solutions.

FIGURE 7: Regional sargassum activities timeline (2015-2021)





For more information: <https://sargassumhub.org/events/>

Both the science and the management of this entirely new phenomenon were relatively slow to get going and are still 'playing catch-up' in what has now become a fast-moving and dynamic area of research and development. Some strides have been made albeit rather slowly in the development of forecasting and monitoring initiatives. We outline the most noteworthy in **Appendix I** and **II**. **Appendix III** highlights 27 ongoing projects, programmes and initiatives that are being implemented in the Caribbean region and in West Africa in some cases.

Several countries in the Caribbean region have established or are in the process of setting up multi-agency/multi-sectoral Taskforces or National Committees to provide support and coordination in addressing sargassum influxes. However, in many cases, the ability of these Taskforces/Committees to function has been limited by funding. In addition, draft sargassum management plans or strategies (**Appendix IV**) that have been or are being developed for some countries lack approval from cabinet or other competent authorities and resources to support implementation.

As part of the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) project (Appendix III), CERMES, FAO and other regional partners are collaborating on several sargassum related initiatives including the development of draft national sargassum plans for four countries (Grenada, St. Kitts and Nevis, St. Lucia and St. Vincent and the Grenadines) in the Eastern Caribbean. These drafts build upon national level activities implemented under CC4FISH and other initiatives that seek to address sargassum influx events as a hazard and an opportunity. Principles of disaster risk management are being employed to address the threat aspect, while strategies for encouraging investment in innovation and entrepreneurship are provided to take advantage of the opportunity. Developing uses will require consideration by governments to update policies and regulations to allow expansion of sargassum enterprises. For example, governments will need to permit feed-in tariffs to allow the sale of electricity onto the grid and support companies in getting the necessary accreditation.

The plans are primarily a practical action, or operational plan, or an adaptive management strategy meant to be a framework for frequently updated content. Short, medium and long-term strategies are included with local strategies tailored to country and stranding site contexts. Special emphasis is placed on the importance of multi-level planning and management through intersectoral collaboration (Cox et al. 2019). National inter-sectoral coordination mechanisms (NICS) such as ocean governance committees (OGC) or fisheries advisory committees (FAC) are recommended for overseeing the implementation of the plans – as opposed to new sargassum-dedicated committees. These mechanisms can also provide a governance structure with a view of building resilience through adaptive capacity.

It has been recommended that these plans would be best placed as an annex to updated fisheries management plans (where applicable) and be operationalised as a set of webpages and links rather than remaining a static document unless it is regularly updated (every quarter, for example). Sargassum research, management and uses are all very dynamic; information is soon outdated or contested, but typically both with high uncertainty.



Photo credit: Hayden Billingy

8

GAP ANALYSIS AND RECOMMENDATIONS

The review of background information and ongoing interventions presented above was used to make an assessment of remaining gaps – in information and understanding, and in response. The gaps identified are outlined here, and then used to make recommendations. This section is organised to follow the strategy framework (Section 6).

8.1 Forecasting

Forecasting efforts, though much progress has been made, still provide only relatively low precision. Influxes do not follow a regular pattern, there are significant interannual variations. Key constraints to be addressed include:



limited optical satellite coverage in the cloud-covered sargassum source regions;



relatively low satellite image resolution and optical 'noise' (e.g. sun glint, Sahara dust, atmospheric moisture);



lack of information on the growth and mortality rates of floating sargassum as it travels through different environments;



lack of validation of regional wind induced slippage added in the predictive models versus actual movement of sargassum mats in situ; and



lack of consistent national and site-level monitoring of sargassum strandings, especially the quantity (as volume or weight) and the location, constrains the ability to validate predictive models.

Addressing the gaps in forecasting will require costly high precision imagery and radar that could help in observing movements of sargassum nearshore and support local predictions of strandings. This imagery can also address the uncertainty in the accuracy of open ocean current models over long-distance paths through this complex and dynamic ocean region. Research collaborations with meteorologists and radar specialists may offer an opportunity to explore this recommendation.

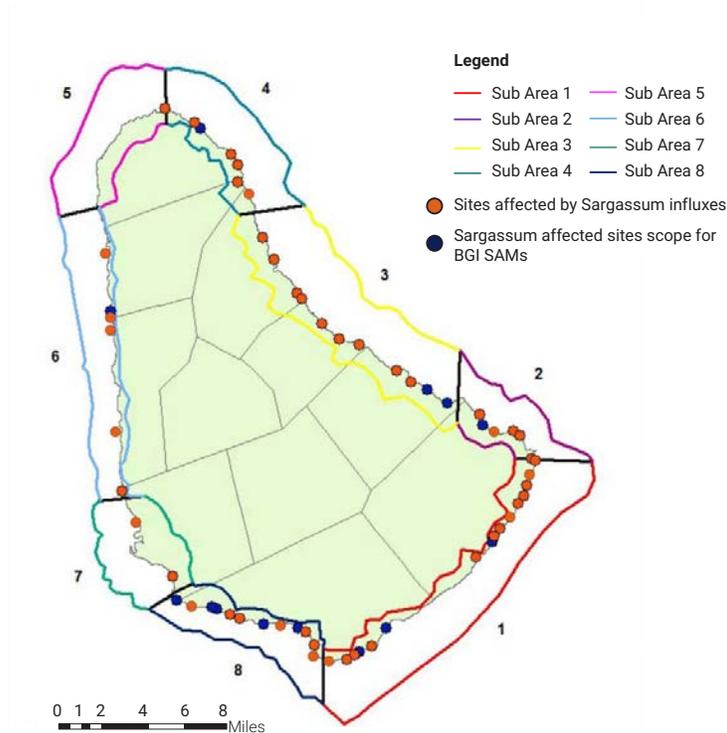
8.2 Harvesting/collection and use

With regard to the variation across the region outlined in Section 4, effective adaptive planning requires additional resolution at the level of the specific territories being affected. There is a need to acknowledge variation in impacts and systematically identify specific impacts and their spatial distribution, along with capacity and logistics within country/territory into order to effectively direct interventions to priority locations.

In order to evaluate country specific dimensions to sargassum impacts and responses, a coordinated programme of consistent spatially explicit hazard exposure and vulnerability assessments at the national level is recommended. This, or the information needed to support it, may exist to varying degrees in some locations. This would involve the following:

1. Mapping the spatial distribution of sargassum influxes (exposure)
2. Assessing exposed sites, mapping/ identifying the assets/ resources / activities / resources within/ near the exposure zones and identifying the specific impacts at the site
3. Assessing the vulnerability of the impacted assets/ resources / activities/ operations

FIGURE 8: Spatial Distribution of sargassum affected locations within the Barbados Integrated Coastal Zone Management (ICZM) sub areas



Source: CERMES and MMABE 2021

This assessment would be used to:

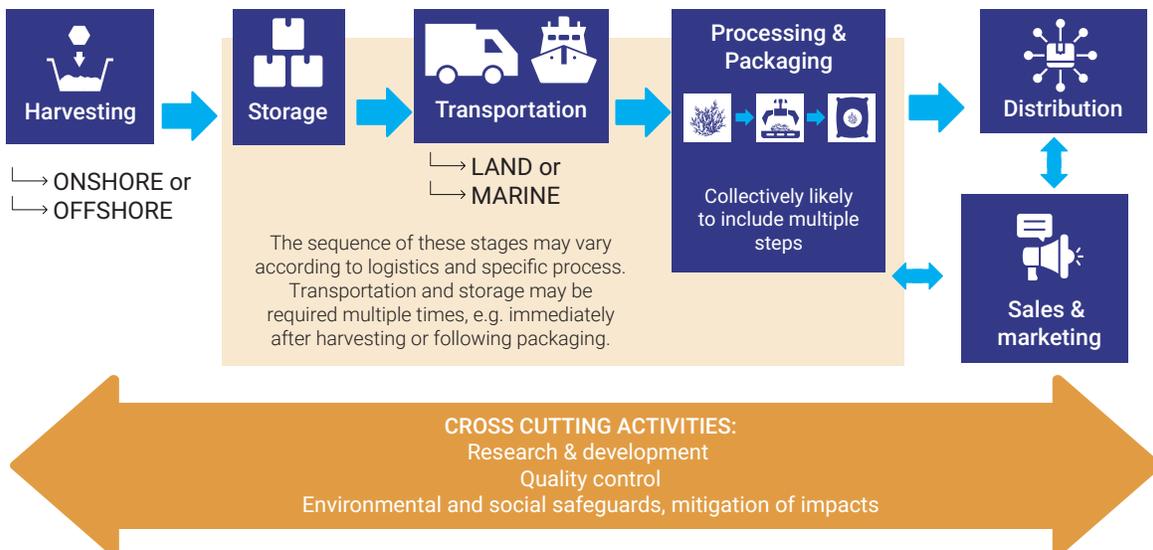


Interventions thus far focus on adaptation to intermittent sargassum influxes as a hazard, because direct mitigation of the issue is currently not possible. This in turn is because the root causes (transfer to and persistence in the new consolidation region, Section 3.2) are not well enough understood to effectively target them. This requires further research and development that would require substantial human and financial resources and the establishment of a regional governance framework given the fact that these root causes are transboundary issues.

A key question as part of this would be, was the transfer a one-off occurrence, or was there a continuous, possibly recurring process of transfer (one-way) or even exchange (two-ways)?

While there has been and continues to be work looking at the feasibility and marketability of sargassum uses and products, making the shift from hazard to opportunity requires more attention to potential value chains. This would involve assessing the locations where sargassum is available for collection, volumes available (including the inherent variability), the logistics of harvesting both in-water and onshore, the logistics of transfer to storage and/or use/production site, and finally the distribution of products to end users, and the costs and resources needed at each step. Such an analysis is needed for effective business planning at a scale significant enough to remove enough sargassum to begin to reduce the negative impacts. End use requirements – such as specific types of sargassum, fresh versus dry, absence of additional materials that may be mixed with sargassum - also need to be considered in the value chain to promote efficient production.

FIGURE 9: Sargassum value chain schematic



The potential commoditisation of sargassum also raises issues around ownership and rights to the 'resource.' There is some research into this issue, but beyond research, policy development work is required to address this, recognising that similar to other natural resources, this may be handled differently in different countries/ territories in the context of existing policy/legal frameworks.

The Caribbean is in the process of exploring the concept of the Blue Economy and developing strategies at the regional and national levels for Blue Economy development. There are opportunities for sargassum innovations to be considered as blue growth initiatives which can be integrated into blue economy strategic frameworks and road maps. This can support economic diversification and resilience to reduce economic vulnerability and reliance on a small number of sectors.

8.3 Policy and Coordination

No regional governance framework specific to the pelagic sargassum phenomenon exists to guide appropriate responses in the Caribbean. There is a lack of policy and management plans/ strategies to deal with strandings, and many of those that exist have not been officially endorsed or implemented. In addition, there is also a lack of regulations to support harvesting, transport and production standard. This has led to a poor environment for encouraging investment in large-scale solutions.

The general lack of governance arrangements (policies, management plans and regulations), applicable to sargassum harvesting and use, needs to be addressed. Government policies and programmes need to present a more attractive and enabling environment that fosters innovation and supports the expansion of existing enterprises and the development of new industries. Protocols and standards need to be developed to prevent environmental damage and ensure the safety of products for consumptive or contact uses.

There are significant deficiencies in coordination and integration that relate to underlying deficiencies in regional ocean governance as outlined previously (Section 4). The response to sargassum influxes is a dynamic arena - there is no shortage of initiatives. This has reached the point of almost being problematic, creating information overload and difficulty in tracking related work. Too often, new initiatives are pursued rather than linking or building on existing ones.



For this reason, it is recommended that the CLME+ Strategic Action Programme (SAP) Interim Coordination Mechanism (ICM) should be leveraged to promote interactive governance of the sargassum issue in the region. The objectives of the ICM align with the recommendations outlined in previous sections that aim to enhance regional coordination and collaboration and support oversight.

Beyond the Caribbean, the need for transatlantic collaboration, including impacted countries/ territories from both the Caribbean and West Africa has been highlighted in numerous meetings, conferences and webinars. While there are some collaborations that have begun, this remains an area in need of strengthening.



Photo credit: Hayden Billingy

9

CONTRIBUTION OF THE CARTAGENA CONVENTION TO THE STRATEGY



COOPERATION: Facilitate regional cooperation and guide national action to protect and sustainably manage ecosystems and species of national and regional concern: that may be affected by the Sargassum influx. This can be achieved through the CLME+ Strategic Action Programme (SAP) Interim Coordination Mechanism.



DATA: Ongoing cooperation with the IOCARIBE Oil Spills and Sargassum EWS, USF, Texas A&M University, CONABIO, NOAA-AOML, USM and UWI-CERMES for Sargassum early prediction systems.



PLANNING AND POLICY: Emphasis on ecosystem-management approach, linked primarily via the EBM Italian Project, the CLME+ project and UN Decades on Ecosystem Restoration and Ocean Science.



Provide guidance to implement provisions of related and broader agreements.



CAPACITY BUILDING AND OUTREACH: Emphasis on capacity building, public education and awareness, community participation, scientific information specifically through the Sargasso Forum and Parties participation in the Scientific and Technical Advisory Committee (STAC).



Active Working Group on Sargassum to advise regional decision makers by preparing Scientific and Technical Advisory Committee (STAC) documents to be endorsed politically at the COP.



Link with the Abidjan Convention to coordinate a Transatlantic action.



ONE UN approach aiming to build synergies and promote coordination and efficient use of resources.



Photo credit: Shelly-Ann Cox

10

GENERAL RECOMMENDATIONS

The use of the term 'sargassum influx' is recommended when addressing the challenges and impacts posed by large landings of sargassum. This terminology adequately reflects massive inundations and avoids erroneously characterising the genus *Sargassum* itself as an undesirable group of species.

The CEP Secretariat should increase collaboration and joint programming between the SPAW and LBS Protocols, particularly in the context of the SPAW Sargassum Working Group. The Secretariat is well positioned to promote regional cooperation on ocean governance and ensure ecologically friendly management interventions given the ecological and socio-economic implications of sargassum influxes for the entire area under the Cartagena Convention (UNEP-CEP 2019).

The SPAW Protocol should develop further cooperation with relevant organisations and initiatives in order to minimise duplication and enhance SPAW programme delivery. Collaboration with the Abidjan Convention (West Africa) and others such as the GEO-BluePlanet (Sargassum Information Hub) and Florida International University (SargNet) is encouraged with the objective of consolidating a common platform for Sargassum management in the Wider Caribbean and West Africa.

The CLME+ Strategic Action Programme (SAP) Interim Coordination Mechanism (ICM) should be leveraged to promote interactive governance of the sargassum issue in the region.



Photo credit: Joseph Weekes

11

CONCLUSION

Significant progress has been made in the last 10 years since sargassum influxes first emerged in the region. However, responses to addressing the issue have generally been reactive rather than proactive resulting in environmental degradation, inefficient use of resources and poor governance. There also has been significant research and business interest in exploiting sargassum as a commodity, or exploiting those desperate to be rid of sargassum. The arena is now very dynamic with the entry of many players with varying, sometimes competing interests. There are numerous projects and initiatives at national, multi-country and sub-regional levels that are sometimes very similar in nature, yet no formal attempt has been made to explore opportunities for promoting synergies to avoid unnecessary duplication.

This complexity is consistent with and reflective of the complexity and character of the region, but adds to the challenge of mounting a coherent response. With so much going on, while coordination and collaboration are much spoken of, there are inevitably fragmentation, disconnects and gaps. Effort and resources are not being applied efficiently or optimally. This situation has needed a systematic and strategic big picture review to consider what is being done, identify gaps and devise a strategy to better coordinate and apply effort and resources, fill gaps, recover costs, and promote synergies between existing initiatives. This white paper update seeks to begin that process through the provision of recommendations that will be validated through regional stakeholder input. Next steps include the development of a concept note to operationalise this strategy in an effort to reduce vulnerability and increase resilience to this issue, while seeking to explore emerging opportunity potential.

12

SELECTED READING

The documents listed below have either been cited in the preceding text of this white paper or provide additional information on many aspects of the sargassum issue. The list is not exhaustive.

- Arellano-Verdejo, J., H. E. Lazcano. 2020. Crowdsourcing for Sargassum Monitoring Along the Beaches in Quintana Roo. Springer. 1276, pp. 49-62
- Arellano-Verdejo, J, H.E. Lazcano-Hernandez, and N. Cabanillas-Terán. 2019. ERISNet: deep neural network for Sargassum detection along the coastline of the Mexican Caribbean. PeerJ, 7:e6842 DOI: <http://doi.org/10.7717/peerj.6842>
- Barkley, A. E., Prospero, J. M., Mahowald, N., Hamilton, D. S., Pependorf, K. J., Oehlert, A. M., ... & Gaston, C. J. 2019. African biomass burning is a substantial source of phosphorus deposition to the Amazon, Tropical Atlantic Ocean, and Southern Ocean. *Proceedings of the National Academy of Sciences*, 116(33), 16216-16221.
- Bayraktarov, E., A. Banaszak, P. Montoya Maya, J. Kleypas, J. Arias-González, M. Blanco et al. 2020. Coral reef restoration efforts in Latin American countries and territories. bioRxiv. doi: 10.1101/2020.02.16.950998
- Beron-Vera, F.J., M. J. Olascoaga, P. Miron. 2019. Building a Maxey–Riley framework for surface ocean inertial particle dynamics, *Physics of Fluids*, 10.1063/1.5110731, 31, 9, (096602)
- Berline, L., A. Ody, J Jouanno, C. Chevalier, Jean-Michel André, et al. 2020. Hindcasting the 2017 dispersal of Sargassum algae in the Tropical North Atlantic. *Marine Pollution Bulletin*, Elsevier, 158, pp.111431.
- Brooks, M. T., V. J. Coles, W. C. Coles. 2019. Inertia influences pelagic sargassum advection and distribution. *Geophysical Research Letters* 46 (5) 2610-2618
- Cabanillas-Terán N, Hernández-Arana HA, Ruiz-Zárate M, Vega-Zepeda A, Sanchez- Gonzalez A. 2019. Sargassum blooms in the Caribbean alter the trophic structure of the sea urchin *Diadema antillarum*. PeerJ 7:e7589 <https://doi.org/10.7717/peerj.7589>
- CAST-CHTA. 2015. Sargassum: a resource guide for the Caribbean. Caribbean Alliance for Sustainable Tourism, Caribbean Hotel and Tourism Association, Coral Gables, Miami, FL, USA, 14pp.
- CERMES and MMABE. 2021. Draft Barbados Sargassum Adaptive Management Strategy. Volume 2: Action Appendices. Draft co-developed by the Centre for Resource Management and Environmental Studies (CERMES) and the Ministry of Maritime Affairs and Blue Economy (MMABE): Bridgetown, Barbados. 123pp
- Chávez, Valeria; Uribe-Martínez, Abigail; Cuevas, Eduardo; Rodríguez-Martínez, Rosa E.; van Tussenbroek, Brigitta I.; Francisco, Vanessa; Estévez, Miriam; Celis, Lourdes B.; Monroy-Velázquez, L. V.; Leal-Bautista, Rosa; Álvarez-Filip, Lorenzo; García-Sánchez, Marta; Masia, Luis; Silva, Rodolfo. 2020. Massive Influx of Pelagic Sargassum spp. on the Coasts of the Mexican Caribbean 2014–2020: Challenges and Opportunities. *Water* 12, no. 10: 2908.
- Chereau, E. 2019. Monitoring and evaluation of Sargassum collection operations – Summary report. 15MAG007. ADEME, SAFEGE and SUEZ. 227 pp.

- Cox, S. and H.A. Oxenford. 2019. Summary report on the development of the sub-regional sargassum outlook bulletin for the Eastern Caribbean. Report prepared for the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) Project of the Food and Agriculture Organization (FAO) and the Global Environment Facility (GEF). Centre for Resource Management and Environmental Studies, University of the West Indies, Cave Hill, Barbados. 13 pp.
- Cox, S., H.A. Oxenford and P. McConney. 2019. Summary report on the review of draft national sargassum plans for four countries Eastern Caribbean. Report prepared for the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) Project of the Food and Agriculture Organization (FAO) and the Global Environment Facility (GEF). Centre for Resource Management and Environmental Studies, University of the West Indies, Cave Hill Campus, Barbados. 20 pp
- CRFM, 2016. Model Protocol for the Management of Extreme Accumulations of Sargassum on the Coasts of CRFM Member States. Technical & Advisory Document, No. 2016. 15pp.
- Debels, P., L. Fanning, R. Mahon, P. McConney, L. Walker, T. Bahri, M. Haughton, K. McDonald, M. Perez, S. Singh-Renton, C. Toro, R. Van Anrooy, A. Vanzella Khouri, P. Whalley. 2017. The CLME+ Strategic Action Programme: An ecosystems approach for assessing and managing the Caribbean Sea and North Brazil Shelf Large Marine Ecosystems, Environmental Development, Volume 22: 191-205. <https://doi.org/10.1016/j.envdev.2016.10.004>.
- Daniel, C. et al. In press. Sargassum: From Horror to Hope. Proceedings of the Gulf & Caribbean Fisheries Institute 71.
- Desrochers, A., S-A. Cox, H.A. Oxenford and B. van Tussenbroek. 2020. Sargassum uses guide: a resource for Caribbean researchers, entrepreneurs and policy makers. Report funded by and prepared for the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) Project of the Food and Agriculture Organization (FAO). Centre for Resource Management and Environmental Studies (CERMES), University of the West Indies, Cave Hill Campus. Bridgetown: Barbados. CERMES Technical Report No. 97, 172 pp.
- Devault, D.A., E. Modestin, V. Cottreau, F. Védie, V. Stiger-Pouvreau, R. Pierre, A. Coynel, F. Dolique. 2021. The silent spring of Sargassum. Environmental Science and Pollution Research <https://doi.org/10.1007/s11356-020-12216-7>
- Djakouré, S., M. Araujo, A. Hounsou-Gbo, C. Noriega, and B. Bourlès. 2017. On the potential causes of the recent Pelagic Sargassum blooms events in the tropical North Atlantic Ocean, Biogeosciences Discuss. <https://doi.org/10.5194/bg-2017-346>
- Doyle, E. and J. Franks. 2015. Sargassum Fact Sheet. Gulf and Caribbean Fisheries Institute.
- Edwards, B. 2020. Turning seaweed into big business. Sustainable Business, Raconteur reports. 0648: 26-27.
- Fogarty, P. 2018. Sargassum: The seaweed deluge hitting Caribbean shores. BBC News, August 6th 2018. Accessed September 20th 2018. Available at: <https://www.bbc.com/news/world-latin-america-45044513>.
- Franks, J.S., D.R. Johnson and D.-S. Ko. 2016. Pelagic Sargassum in the Tropical North Atlantic. Gulf and Caribbean Research 27: SC6-SC11.
- Fulton, C.F., M. Depczynski, T.H. Holmes, M.M. Noble, B. Radford, T. Wernberg & S.K. Wilson. 2014. Sea temperature shapes seasonal fluctuations in seaweed biomass within the Ningaloo coral reef ecosystem. Limnology and Oceanography, 59: 156-166. doi:10.4319/lo.2014.59.01.0156
- García-Sánchez, M., C. Graham, E. Vera, E. Escalante-Mancera, L. Álvarez-Filip & B. I. van Tussenbroek. 2020. Temporal changes in the composition and biomass of beached pelagic Sargassum species in the Mexican Caribbean. Aquatic Botany 167. doi: 10.1016/j.aquabot.2020.103275.
- Gower, J. and S. King. 2019. The distribution of pelagic Sargassum observed with OLCI. International Journal of Remote Sensing, 41(15), 5669-5679.
- Gower, J., E. Young and S. King. 2013. Satellite images suggest a new Sargassum source region in 2011. Remote Sensing Letters, 4: 764-773.

- Gower J. and S. King. 2011. Distribution of floating Sargassum in the Gulf of Mexico and the Atlantic Ocean mapped using MERIS. *International Journal of Remote Sensing*, 32, 1917–1929
- González-Nieto, D., M.C. Oliveira, M. L. Núñez Resendiz, K.M. Dreckmann, L. E. Mateo-Cid, A. Sentís. 2020. Molecular assessment of the genus *Sargassum* (Fucales, Phaeophyceae) from the Mexican coasts of the Gulf of Mexico and Caribbean, with the description of *S. xochitlae* sp. nov. *Phytotaxa*, [S.I.], v. 461, n. 4, p. 254–274
- Hardy, R. F., C. Hu, B. Witherington, B. Lapointe, A. Meylan, E. Peebles, L. Meirose, & S. Hiram. 2018. Characterizing a Sea Turtle Developmental Habitat Using Landsat Observations of Surface-Pelagic Drift Communities in the Eastern Gulf of Mexico. *IEEE J. Selected Topics in Applied Earth Observations and Remote Sensing*, 11:3646-3659.
- Hinds, C., H.A. Oxenford, J. Cumberbatch, F. Fardin, E. Doyle, and A. Cashman. 2016. *Golden Tides: Management Best Practices for Influxes of Sargassum in the Caribbean with a Focus on Clean-up*. Centre for Resource Management and Environmental Studies (CERMES), The University of the West Indies, Cave Hill Campus, Barbados. 17 pp.
- Hu, C., B. Murch, B. B. Barnes, M. Wang, J-P. Marechal, J. Franks, D. Johnson, B. Lapointe, D. S. Goodwin, J. M. Schell, and A. N. S. Siuda. 2016. Sargassum watch warns of incoming seaweed, *Eos*, 97(22):10-15.
- Hu, C. 2009. A novel ocean color index to detect floating algae in the global oceans. *Remote Sens. Environ.* 113(10), 2118–29. <https://doi.org/10.1016/j.rse.2009.05.012>
- Johns, E. M., R. Lumpkin, N. F. Putman, R.H. Smith, F. E. Muller-Karger, Digna T. Rueda-Roa, Chuanmin Hu, Mengqiu Wang, Maureen T. Brooks, Lewis, J. Gramer, Francisco E. Werner. 2020. The establishment of a pelagic Sargassum population in the tropical Atlantic: Biological consequences of a basin-scale long distance dispersal event. *Progress in Oceanography*, Volume 182: 102269.
- Johnson, D. R., J. S. Franks, H. A. Oxenford and S. L. Cox. 2020. Pelagic Sargassum Prediction and Marine Connectivity in the Tropical Atlantic. *Gulf and Caribbean Research* 31 (1): GCFI20-GCFI30.
- Johnson, D., J. Franks, H. A. Oxenford and S-A. Cox. 2020. Pelagic Sargassum blooms and marine connectivity of the north tropical Atlantic. Extended Abstract, Proceedings of the Gulf & Caribbean Fisheries Institute 72: 255-256.
- Johnson, D. and J. Franks. 2019. Final Report on Prediction of Pelagic Sargassum Incursions: Model Development. Report prepared for the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) Project of the Food and Agriculture Organization (FAO) and the Global Environment Facility (GEF). Center for Fisheries Research and Development, The University of Southern Mississippi, School of Ocean Science and Engineering, Gulf Coast Research Laboratory, Ocean Springs, Mississippi, USA. 13 pp.
- Johnson, D.R., H.A. Oxenford, S-A. Cox and J.S. Franks. In press. Holopelagic sargassum and the complexities of predicting influxes and impacts on pelagic fisheries of the Lesser Antilles. *Proceedings of the Gulf & Caribbean Fisheries Institute* 71.
- Jouanno, J., Benshila, R., Berline, L., Soulié, A., Radenac, M.-H., Morvan, G., Diaz, F., Sheinbaum, J., Chevalier, C., Thibaut, T., Changeux, T., Menard, F., Berthet, S., Aumont, O., Ethé, C., Nabat, P., and Mallet, M. 2002. A NEMO-based model of Sargassum distribution in the Tropical Atlantic: description of the model and sensitivity analysis (NEMO-Sarg1.0), *Geosci. Model Dev. Discuss.* [preprint], <https://doi.org/10.5194/gmd-2020-383>, in review, 2020.
- Langin, K. 2018. Seaweed masses assault Caribbean islands. *Science*, 360(6394), 1157-1158.
- Lapointe, B.E. 2019. Chasing nutrients and algal blooms in Gulf and Caribbean waters: A personal story. *Gulf and Caribbean Research* 30 (1), xvi-xxx
- Lapointe, B.E. 2019. Huge algal mat spanning an ocean is visible from space. *Nature* 571(7764)
- Lapointe, B. E., L. E. West, T. T. Sutton, and C. Hu. 2014. Ryther revisited: nutrient excretions by fishes enhance productivity of pelagic Sargassum in the western North Atlantic Ocean. *Journal of experimental marine biology and ecology*, 458, 46-56.
- Lapointe, B. E. 1995. A comparison of nutrient-limited productivity in Sargassum natans from neritic vs. oceanic waters of the western North Atlantic Ocean, *Limnology and Oceanography*, 40(3), 625-633.

- Lavine, G. 2015. Sargassum seaweed and extracts: evaluation of their potential use in crop production systems in Barbados. [Barbados: Ministry of Agriculture] http://www.agriculture.gov.bb/agri/images/Seaweed/seaweed_review.pdf
- Lee Lum, L. 2015. Changing the status quo on Sargassum seaweed. Port of Spain, Trinidad and Tobago: Institute of Marine Affairs. <http://www.ima.gov.tt/home/what-new/253-changing-the-status-quo-on-sargassum-seaweed-.html>
- Lopez, P.J., V. Hervé, J. Lambourdière, M. René-Trouillefou, d. Devault. 2020. From the sea to the land: Dynamic of the Sargassum tide holobiont in the Caribbean Islands. <https://doi.org/10.21203/rs.3.rs-33861/v1>
- López-Sosa, Luis B.; Alvarado-Flores, José J.; Corral-Huacuz, Juan C.; Aguilera-Mandujano, Arturo; Rodríguez-Martínez, Rosa E.; Guevara-Martínez, Santiago J.; Alcaraz-Vera, Jorge V.; Rutiaga-Quiñones, José G.; Zárate-Medina, Juan; Ávalos-Rodríguez, María L.; Morales-Máximo, Mario. 2020. "A Prospective Study of the Exploitation of Pelagic Sargassum spp. as a Solid Biofuel Energy Source" *Appl. Sci.* 10, no. 23: 8706. <https://doi.org/10.3390/app10238706>
- Lumpkin, R., & S. L. Garzoli. 2005. Near-surface circulation in the Tropical Atlantic Ocean. *Deep Sea Research Part I: Oceanographic Research Papers*, 52(3), 495–518. doi:10.1016/j.dsr.2004.09.001
- Maréchal, J.-P., C. Hellio & C. Hu. 2017. A simple, fast, and reliable method to predict Sargassum washing ashore in the Lesser Antilles. *Remote Sensing Applications: Society and Environment*, 5: 54-63.
- Marx, U.C., J. Roles and B. Hankamer. 2021. Sargassum blooms in the Atlantic Ocean- From a burden to an asset. *Algal Research* 54:102188. <https://doi.org/10.1016/j.algal.2021.102188>.
- McConney, P and H. A. Oxenford. 2020 "Caribbean Sargassum Phenomenon: Complexities of Communicating." *Journal of Caribbean Environmental Sciences and Renewable Energy* 3: 10-14.
- Mendez-Tejeda, Rafael, and Rosado Jiménez, Gladys A. 2019 . "Influence of climatic factors on Sargassum arrivals to the coasts of the Dominican Republic." *Journal of Oceanography and Marine Science* 10, no. 2: 22-32
- Michotey, V., A. Blanfuné, C. Chevalier, M. Garel, F. Diaz, L. Berline, L. Le Grand, F. Armougom, S. Guasco, S. Ruitton, T. Changeux, B. Belloni, J. Blanchot, F. Ménard, T. Thibaut. 2020. In situ observations and modelling revealed environmental factors favouring occurrence of *Vibrio* in microbiome of the pelagic Sargassum responsible for strandings, *Science of The Total Environment*, Volume 748: 141216. <https://doi.org/10.1016/j.scitotenv.2020.141216>.
- Milledge, J.J., S. Maneein, E. Arribas López, and D. Bartlett. 2020. Sargassum Inundations in Turks and Caicos: Methane Potential and Proximate, Ultimate, Lipid, Amino Acid, Metal and Metalloid Analyses. *Energies* 2020, 13, 1523.
- Milledge, J.J., B.V. Nielsen, M.S. Sadek, P.J. Harvey. 2018. Effect of freshwater washing pretreatment on Sargassum muticum as a feedstock for biogas production. *Energies* 11, 1771.
- Milledge, J. J. and J. P. Harvey. 2016. "Golden Tides: Problem or Golden Opportunity? The Valorisation of Sargassum from Beach Inundations." *Journal of Marine Science and Engineering* 4(3).
- Miron, P. M. J. Olascoaga, F. J. Beron-Vera, N. F. Putman, J. Triñanes, R. Lumpkin, G. J. Goni. 2020. Clustering of Marine-Debris- and Sargassum-Like Drifters Explained by Inertial Particle Dynamics. *Geophysical Research Letters*, 10.1029/2020GL089874, 47, 19.
- Monroy-Velázquez, L. V., R. E. Rodríguez-Martínez, B. I. van Tussenbroek, T. Aguiar, V. Solís-Weiss, and P. Briones-Fourzán. 2019. Motile macrofauna associated with pelagic Sargassum in a Mexican reef lagoon. *Journal of Environmental Management*, 252, 109650
- Ody, A., T. Thibaut, L. Berline, T. Changeux, J.M. André, C. Chevalier, A. Blanfuné, J. Blanchot, S. Ruitton, V. Stiger-Pouvreau, and S. Connan. 2019. From In Situ to satellite observations of pelagic Sargassum distribution and aggregation in the Tropical North Atlantic Ocean. *PloS one*, 14(9).
- Ofori, R. O. and M. D. Rouleau. 2020. Willingness to pay for invasive seaweed management: Understanding how high and low income households differ in Ghana. *Ocean & Coastal Management*, 192, 105224.

- Olascoaga, M. J., F. J. Beron-Vera, P. Miron, J. Triñanes, N. F. Putman, R. Lumpkin, G. J. Goni. 2020. Observation and quantification of inertial effects on the drift of floating objects at the ocean surface, *Physics of Fluids*, 10.1063/1.5139045, 32, 2, (026601)
- Oviatt, Candace A., Kristin Huizenga, Caroline S. Rogers, W. Jeff Miller. 2019. What nutrient sources support anomalous growth and the recent sargassum mass stranding on Caribbean beaches? A review. *Marine Pollution Bulletin*, 145: 517-525, <https://doi.org/10.1016/j.marpolbul.2019.06.049>
- Oxenford, H.A., D. Johnson, S-A. Cox and J. Franks. 2019. Report on the Relationships between Sargassum Events, Oceanic variables and Dolphinfish and Flyingfish Fisheries. Centre for Resource Management and Environmental Studies, University of the West Indies, Cave Hill Campus. Bridgetown: Barbados. 32 pp.
- Pfaff, M. 2015 Key scientific questions addressing environmental drivers and effects of periodic mass deposits of a brown seaweed (golden tides) along the Sierra Leone coast. Draft report for Oceans and Coastal Research, Directorate: Biodiversity and Coastal Research.
- Ponce RLR, del Barrio AGC, Spengler SI, et al. Evaluation of the antiviral activity of the brown alga *Sargassum fluitans* against Echovirus 9. *Rev Cubana Med Trop*. 2018;70(2).
- Putman, N.F., R. Lumpkin, M. J. Olascoaga, J. Trinanes, G. J. Goni. 2020. Improving transport predictions of pelagic Sargassum, *Journal of Experimental Marine Biology and Ecology*, Volume 529: 151398. <https://doi.org/10.1016/j.jembe.2020.151398>.
- Putman, N.F., G.J. Goni, L.J. Gramer, C. Hu, E.M. Johns, J. Trinanes & M. Wang. 2018. Simulating transport pathways of pelagic Sargassum from the Equatorial T Atlantic into the Caribbean Sea. *Progress in Oceanography*, 165: 205-214.
- Ramlogan, N., P. McConney, and H.A. Oxenford. 2017. Socio-economic impacts of Sargassum influx events on the fishery sector of Barbados. CERMES Technical Report 81: 86pp.
- Resiere, Dabor, Hossein Mehdaoui, Jonathan Florentin, Papa Gueye, Thierry Lebrun, Alain Blateau, Jerome Viguier, Ruddy Valentino, Yannick Brouste, Hatem Kallel, Bruno Megarbane, André Cabié, Rishika Banydeen & Remi Neviere. 2020. Sargassum seaweed health menace in the Caribbean: clinical characteristics of a population exposed to hydrogen sulfide during the 2018 massive stranding, *Clinical Toxicology*, DOI: 10.1080/15563650.2020.1789162
- Resiere, D., R. Valentino, R. Nevière, R. Banydeen, P. Gueye, J. Florentin, A. Cabié, T. Lebrun, B. Mégarbane, G. Guerrier and H. Mehdaoui. 2018. Sargassum seaweed on Caribbean islands: an international public health concern. *The Lancet*, 392(10165), 2691.
- Rodríguez-Martínez R.E., P.D. Roy, N. Torrescano-Valle, N. Cabanillas-Terán, S. Carrillo-Domínguez, L. Collado-Vides, M. García-Sánchez, B.I. van Tussenbroek. 2020. Element concentrations in pelagic Sargassum along the Mexican Caribbean coast in 2018-2019. *PeerJ* 8:e8667 <https://doi.org/10.7717/peerj.8667>
- Rodríguez-Martínez R.E., A.E. Medina-Valmaseda, P. Blanchon, L. V. Monroy-Velazquez, A. Almazan-Becerril, B. Delgado-Pech, L. Vasquez-Yeomans, V. Francisco, M. C. Garcia-Rivas. 2019. Faunal mortality associated with massive beaching and decomposition of pelagic Sargassum. *Marine Pollution Bulletin* 146:201-205.
- Rooker, J. R., J. P. Turner and S. A. Holt. 2006. Trophic ecology of Sargassum-associated fishes in the Gulf of Mexico determined from stable isotopes and fatty acids. *Marine Ecology Progress Series*, 313, 249-259.
- Schell, J. M., D. S. Goodwin, and A. N. Siuda. 2015. Recent Sargassum inundation events in the Caribbean: Shipboard observations reveal dominance of a previously rare form. *Oceanography*, 28(3), 8-11.
- Speede, R.F. 2018. Best practices for Caribbean fishers coping with sargassum influx events. MSc Research Paper, Centre for Resource Management and Environmental Studies, the University of the West Indies, Cave Hill, Barbados, 86pp.
- Speede, R.F., Cox, S-A. and H.A. Oxenford. 2019. Best practices for Caribbean fishers coping with sargassum. Centre for Resource Management and Environmental Studies, the University of the West Indies, Cave Hill, Barbados, 23pp.

- Smetacek, V. and A. Zingone, A. 2013. Green and golden seaweed tides on the rise. *Nature*, 504(7478), 84-88.
- Thompson, T.M., B.R. Young, S. Baroutian. 2020. Pelagic Sargassum for energy and fertiliser production in the Caribbean: A case study on Barbados. *Renewable and Sustainable Energy Reviews* 118:109564. <https://doi.org/10.1016/j.rser.2019.109564>
- Trinanes, J., N.F. Putman, G. Goni, C. Hu and M. Wang. 2021. Monitoring pelagic Sargassum inundation potential for coastal communities, *Journal of Operational Oceanography*, DOI: 10.1080/1755876X.2021.1902682
- UNEP. 2018. Sargassum White Paper - Sargassum Outbreak in the Caribbean: Challenges, Opportunities and Regional Situation. Eighth Meeting of the Scientific and Technical Advisory Committee (STAC) to the Protocol Concerning Specially Protected Areas and Wildlife (SPA) in the Wider Caribbean Region (Panama City, Panama).
- UNEP-CEP. 2019. State of the Cartagena Convention Area Report: An Assessment of Marine Pollution from Land-Based Sources and Activities in the Wider Caribbean Region. Fourth Meeting of the Contracting Parties (COP) to the Protocol Concerning Pollution from Land-Based Sources and Activities (LBS) in the Wider Caribbean Region. Roatan, Honduras.
- van Tussenbroek, B.I., H.A. Hernández-Arana, R.E. Rodríguez-Martínez, J. Espinoza-Avalos, H.M. Canizales-Flores, C.E. González-Godoy, M.G. Barba-Santos, A. Vega-Zepeda & L. Collado-Vides. 2017. Severe impacts of brown tides caused by Sargassum spp. on near-shore Caribbean seagrass communities. *Marine Pollution Bulletin*, 122: 272-281.
- Wang, M., C. Hu, B. B. Barnes, G. Mitchum, B. Lapointe and J. P. Montoya. 2019. The great Atlantic Sargassum belt. *Science* 365(6448): 83.
- Wang, M., C. Hu, J. Cannizzaro, D. English, X. Han, D. Naar, B. Lapointe, R. Brewton & F. Hernandez. 2018. Remote sensing of Sargassum biomass, nutrients, and pigments. *Geophysical Research Letters*, 45(22), 12-359.
- Wang, M. and C. Hu. 2017. Predicting Sargassum blooms in the Caribbean Sea from MODIS observations. *Geophysical Research Letters*, 44: 3265-3273. doi: 10.1002/2017GL072932.
- Wang, M. and C. Hu. 2016. Mapping and quantifying Sargassum distribution and coverage in the Central West Atlantic using MODIS observations. *Remote Sensing of the Environment* 183: 356-367.
- Webster, R. K., and T. Linton. 2013. Development and implementation of Sargassum early advisory system (SEAS). *Shore & Beach*, 81(3), 1.
- Weekes, J., H. Oxenford and K. Baldwin. 2019. Application of Drone Technologies in Quantifying Stranded Sargassum. 39th AMLC Scientific Meeting. Punta Cana, Dominican Republic.

13

APPENDICES

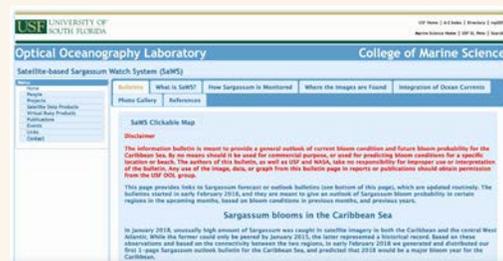
13.1. Appendix I: Forecasting Initiatives

SARGASSUM WATCH SYSTEM (SAWS)

Description: A portal developed by the Optical Oceanography Laboratory, USF. It provides open access to processed satellite images showing sargassum, and outlooks of sargassum blooms monthly for the entire Gulf of Mexico, Caribbean and the Tropical Atlantic.

Organisation/Agency: University of South Florida (USF)

Useful link: <https://optics.marine.usf.edu/projects/saws.html>



SARGASSUM EARLY ADVISORY SYSTEM (SEAS)

Description: Inactive experimental platform that provided visual processing of Landsat 8 images to draw the outline of the sargassum mats near the coasts, in about 30 small areas in the Gulf of Mexico and the Caribbean. Bulletins were also issued when the platform was operational.

Organisation/Agency: University of Texas A&M at Galveston (TAMUG)

Useful link: <http://seas-forecast.com>



SARGASSUM SUB-REGIONAL OUTLOOK BULLETIN

Description: Bi-monthly outlook bulletin presenting 3-month sargassum influx forecasts and implications to socio-economic sectors. Useful resources, recent publications and info on sargassum uses are also included.

Organisation/Agency: Centre for Resource Management and Environmental Studies (UWI-CERMES), University of Southern Mississippi (USM).

Useful link: <https://www.cavehill.uwi.edu/cermes/projects/sargassum/outlook-bulletin.aspx>



The development of this information product has benefited from the generous support of the Food and Agriculture (FAO) / Global Environment Fund (GEF) project 'Climate Change Adaptation in the Eastern Caribbean Fisheries Sector' (CC4FISH), and the Caribbean Biodiversity Fund (CBF) project 'Adapting to a new reality: managing responses to influxes of sargassum seaweed in the Eastern Caribbean (SargAdapt)', co-financed by the International Climate Initiative (IKI) of the German Federal Ministry for Environment, Nature Conservation, and Nuclear Safety through KfW.

SARGASSUM SURVEILLANCE BULLETIN FOR GUADELOUPE

Description: Weekly sargassum outlook bulletin for local authorities and government departments. Bulletins present a simple cartography of the coasts concerned, with a risk index in 4 colors, a forecast confidence index (linked to cloud cover), a forecast for the next 4 days, a trend over 2 weeks, over 2 months.

Organisation/Agency: Météo France, CLS and Nova Blue Environment (NBE)

Useful link: <http://bit.ly/MFWklyBulletin>



SAMTOOL

Description: Web-based sargassum detection and monitoring visualization platform. SAMTool allows the visualization of diverse information on a 30-day sliding time scale: cloud cover, daily sargassum identification layers, a weekly synthesis, drift predictions as well as area statistics, and detection level statistics (NFAI analysis).

Organisation/Agency: CLS

Useful link: <https://datastore.cls.fr/products/sargassum/>



SARGASSUM ALERT SYSTEM (SATSUM)

Description: Web-based maritime/coastal information and analysis system. SATSum is a sargassum monitoring and detection platform. There is also a site that presents sargassum observations on beaches with a density level, based on citizen observations.

Organisation/Agency: CONABIO (*Comisión Nacional para el Conocimiento y Uso de la Biodiversidad /National Commission for the Knowledge and Use of Biodiversity*)

Useful link: <https://simar.conabio.gob.mx>



EXPERIMENTAL WEEKLY SARGASSUM INUNDATION REPORT (SIR V1.2)

Description: Experimental Sargassum Inundation Reports (SIR) provide an overview of the risk of sargassum coastal inundation in the Caribbean and Gulf of Mexico regions. Risk is classified into three categories: low (blue), medium (orange) and high (red). In black are areas with not enough data.

Organisation/Agency: NOAA

Useful link: https://www.aoml.noaa.gov/phod/sargassum_inundation_report/

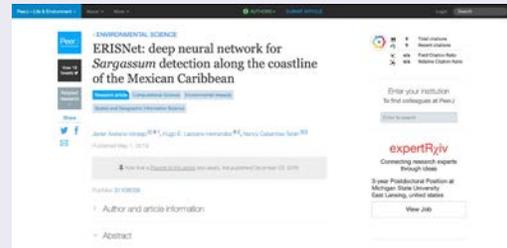


ERISNET

Description: Satellite detection platform using Artificial Intelligence to support sargassum detection along the coastline of the Mexican Caribbean.

Organisation/Agency: CONACYT (National Council for Science and Technology)

Useful link: <https://peerj.com/articles/6842/>



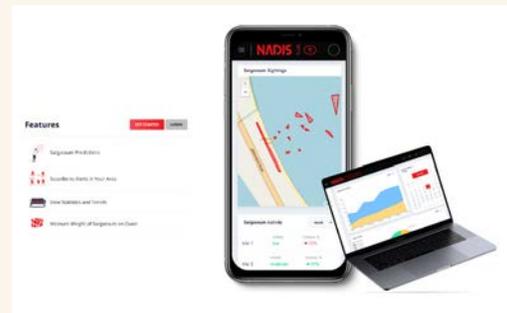
13.2. Appendix II: Monitoring Initiatives

NADIS APP

Description: Natural Disturbance Information Systems (NADIS) designs and builds proactive solutions to the effects of Natural Disturbances in the Caribbean including sargassum influxes. Satellite Imagery and Remote Sensing powers a modern Dashboard and App for users to receive Alerts of incoming Sargassum in their area and visualise data and analytics.

Company: NADIS Software

Useful link: <https://nadis.app>

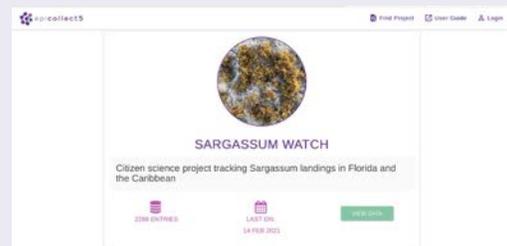


SARGASSUM WATCH ON EPICOLLECT 5

Description: Citizen science project coordinated by MMRL-FIU. Platform allows submissions of reports accompanied by photos.

Organisation/Agency: Marine Macroalgae Research Lab at the Florida International University (MMRL-FIU)

Useful link: <https://five.epicollect.net/project/sargassum-watch>

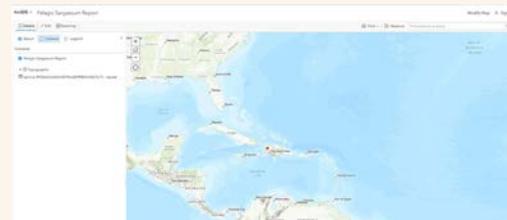


CARIBBEAN PELAGIC SARGASSUM REPORT

Description: Reporting website created with the core objective of creating a publicly available database that could be used to validate satellite and forecast products.

Organisation/Agency: CoastWatch Caribbean and Gulf of Mexico region node at NOAA/AOML

Useful link: <https://www.arcgis.com/home/item.html?id=e60a66e557a1483e-8427fe9c28157592>



OCEANVIEWER

Description: GeoServer platform that allows users to view satellite data including processed satellite images produced by USF, and in situ observations

Organisation/Agency: NOAA/AOML

Useful link: <https://cwgom.aoml.noaa.gov/cgom/OceanViewer/>

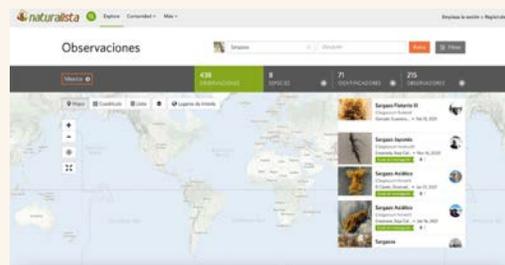


CONABIO'S MEXICAN ATLANTIC MONITORING PROJECT ON THE 'NATURALISTA' PLATFORM

Description: Citizen science platform that allows observations and close up and/or panoramic photographs of sargassum to be submitted and visualised.

Organisation/Agency: CONABIO

Useful link: https://www.naturalista.mx/observations?taxon_id=130178



UNIVERSITY OF SOUTHERN MISSISSIPPI (USM) REPORTING SITE

Description: This website serves as a data collection centre to accommodate reports of large quantities of pelagic sargassum observed within the region.

Organisation/Agency: USM

Useful link: <https://gcrl.usm.edu/sargassum/sargassum.observation.form.php>



SARGASSUM MONITORING WEBSITE

Description: Website that features maps created by reports of sargassum strandings using social media posts with the hashtag #sargassum. Photos/videos are provided for each impacted location.

Useful link: <http://sargassummonitoring.com>



LOCAL ENVIRONMENTAL OBSERVER (LEO) NETWORK SARGASSUM REPORTING SITE

Description: Reporting site that allows the LEO network of local observers and topic experts to record observations of sargassum strandings.

Organisation/Agency: LEO Network

Useful link: <http://bit.ly/LEONetwork>



SARGASSUM SIGHTINGS FORM

Description: Reporting form that allows users to submit sargassum strandings using the KoBo Toolbox platform

Organisation/Agency: UNEP-CEP

Useful link: <https://ee.kobotoolbox.org/x/uEYhY0nZ>

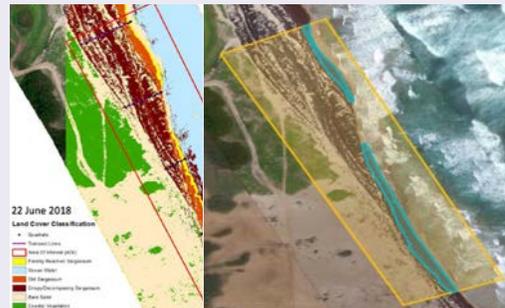


THE SARGADAPT DRONE MONITORING PROTOCOL

Description: This Protocol aims to develop the use of recreational drones, with UAS software & spatial analyses, to map, classify, & quantify the abundance of stranded sargassum. Field studies in Barbados have yielded successful results. Future work involves refinement and replication in other countries. Read more [here](#)

Organisation/Agency: UWI-CERMES, Marine Spatial Information Solutions, DroneDeploy's Drones for Good initiative, Center for Geospatial Analytics at North Carolina State University (NCSU) Capstone Community Partnerships Program

Useful link: <https://www.cavehill.uwi.edu/cermes/projects/sargassum/sargadapt.aspx>



12.3 Appendix III: Projects, Programmes and Initiatives

SARGASSUM HUB

Description: Website that integrates information from multiple sources. Items featured include monitoring systems, in-situ observations, bulletins issued and best practices for management & use.

Organisation/Agency: Geoplanet, IOCaribe, Atlantos, Air Centre

Year Established: 2015

Useful link: <https://sargassumhub.org>



SARGNET

Description: A listserv and online network of sargassum stakeholders hosted by Florida International University (FIU).

Organisation/Agency: FIU

Year Established: 2019

Useful link: <https://listserv.fiu.edu/cgi-bin/wa?SUBED1=SARGNET&A=1>



SPAW-RAC/UNEP-CEP SARGASSUM ON-LINE FORUM

Description: Online forum that provides easy access to relevant documents on awareness, management and research about the Sargassum influx, as well as direct exchanges between stakeholders to share their experiences.

Organisation/Agency: UNEP-CEP

Year Established: 2015

Useful link: <https://www.car-spaw-rac.org/?Sargassum-on-line-forum>



CARIBBEAN COOPERATION PROGRAMME AGAINST SARGASSUM (SARG'COOP)

Description: The Caribbean cooperation programme for the monitoring of sargassum seaweed' is bringing together regional partners to share knowledge and expertise and foster collaboration across language barriers.

Organisation/Agency: Regional Council of Guadeloupe

Year Established: 2019



SARGADAPT (Adapting to a new reality: Managing responses to influxes of sargassum seaweed in the Eastern Caribbean as ecosystem hazards and opportunities)

Description: The ultimate goal of SargAdapt is to reduce the impacts of and improve adaptation to sargassum influxes in the Eastern Caribbean with emphasis on converting a climate-linked ecosystem hazard into an asset that supports opportunities for socio-economic development.

Organisation/Agency: UWI-CERMES, Caribbean Natural Resources Institute (CANARI)

Year Established: 2019 - 2022

Useful link: <https://www.cavehill.uwi.edu/cermes/projects/sargassum/sargadapt.aspx>



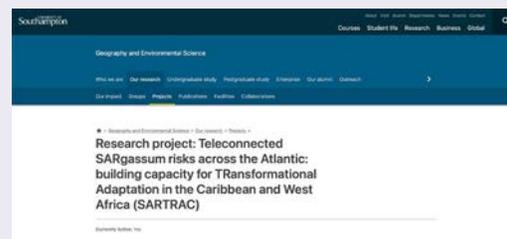
SARTRAC (Teleconnected SARGassum risks across the Atlantic: building capacity for TRansformational adaptation in the Caribbean and West Africa)

Description: SARTRAC identifies new transformational developmental opportunities that build resilience equitably, for people affected by changing biomes/ ecosystems in developing countries.

Organisation/Agency: University of Southampton, UWI-CERMES, University of Ghana, University of York

Year Established: 2019 - 2022

Useful link: <https://www.southampton.ac.uk/geography/research/projects/teleconnected-sargassum.page>



Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) Sargassum Subproject

Description: This sub-project aims to increase resilience and reduce vulnerability to climate change impacts including sargassum influx events in the Eastern Caribbean fisheries sector.

Organisation/Agency: FAO, UWI-CERMES, USM

Year Established: 2017-2021

Useful link: <http://www.fao.org/in-action/climate-change-adaptation-eastern-caribbean-fisheries/en/>



SASAMS (SATellite SARGassum Monitoring System)

Description: This project aims to develop a near real-time service for monitoring pelagic sargassum seaweed beaching, initially aimed at Mexico's Caribbean Coast.

Organisation/Agency: University of Nottingham, Specto Natura Ltd, Triple Line Consulting Ltd. CONABIO, UNAM, CentroGeo, Planet Inc.

Year Established: 2020

Useful link: <http://www.sasams.org>



SARGASSUM PRODUCTS FOR CLIMATE RESILIENCE IN THE CARIBBEAN

Description: The overall aim of the project is to mitigate the environmental and economic impacts of Sargassum seaweed influxes in affected Caribbean countries through the creation of inclusive value chains for Sargassum seaweed.

Organisation/Agency: CRFM, Plant and Food Research, New Zealand Crown Research Institute

Year Established: 2020 - 2023

Useful link: http://www.crfm.int/index.php?option=com_k2&view=item&id=667:sargassum-products-for-climate-resilience-in-the-caribbean&Itemid=175



ACTIVATED CARBON: A SUCCESSFUL MULTI-LATERAL AND MULTI-NATIONAL RESEARCH PROJECT

Description: This research project is investigating different activation methods and different pyrolysis temperatures (600 – 900°C) to obtain activated carbon using sargassum.

Organisation/Agency: Université des Antilles (Guadeloupe) (COVACHIMM2E laboratory), Instituto Tecnológico de Santo Domingo (INTEC) (Dominican Republic), Institut National de la Recherche Agronomique (INRA) (Guadeloupe & Nancy, France), Queen Mary University (UK), Instituto Superior de Tecnologías y Ciencias Aplicadas (InSTEC) (Cuba), Centre Inter-universitaire de Recherche et d'Ingénierie des Matériaux (CIRIMAT) (Toulouse, France), Université d'État d'Haïti (Haïti), Université Quisqueya, NBC (French Guiana), TECMALAB (Dominican Republic), NUM SMO Technologies (NST) and Phytobokaz (Guadeloupe)

Year Established: 2019

Useful link: <https://anr.fr/Project-ANR-19-SARG-0005>



CORSAIR (Atmospheric and marine corrosions)

Description: The main aim of this project to investigate the corrosion rate of exposure sites and modelling the phenomenon of corrosion and its natural inhibitory solution. It also seeks to characterize of biofilms and compile legal tools

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.slideshare.net/CRGuadeloupe/corsair-c-roos-l3ma-universit-des-antilles>



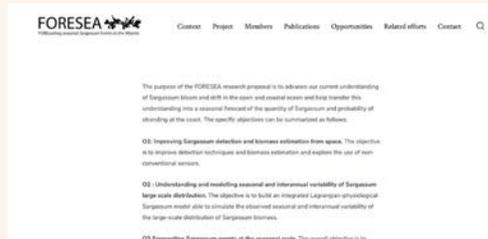
FORESEA (Forecasting of sargassum stranding in the Tropical Atlantic)

Description: The purpose of the FORESEA research proposal is to advance the current understanding of Sargassum bloom and drift in the open and coastal ocean and help transfer this understanding into a seasonal forecast of the quantity of Sargassum and probability of stranding at the coast.

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://sargassum-foresea.cnrs.fr/la-recherche/>



PYROSAR (Valorisation of sargassum by pyrolysis-application for food safety)

Description: This project aims to optimize the production of biochar and activated carbon from sargassum at laboratory and industrial scale using the solar microwave process of NST

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>



SARG AS CLD (Environmental impacts of sargassum leachate due to arsenic and chlordecone: quantification)

Description: The initiative seeks to improve knowledge on sargassum contamination by arsenic (marine origin) and chlordecone (terrestrial origin).

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SARGACARE (Human health effects of chronic exposure to gaseous fumes from decomposing brown algae in the French West Indies)

Description: Goal: Conduct a detailed study of the clinical, biological, functional and socio-anthropological consequences of gaseous emissions produced by decomposing sargassum

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SARGASSUM ORIGINS (Identity and origins of pelagic sargassum)

Description: This project aims to identify sargassum species growing in the North Atlantic (co-occurrence) by studying the connectivity of sargassum at the Atlantic scale.

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SARGOOD (Holistic approach to sargassum valorisation)

Description: The project will conduct an assessment of the sargassum life cycle and develop innovative materials and technologies.

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SARGSCREEN (Pharmaco-toxicological screening of molecules extracted from Caribbean sargassum: highlighting their impact on certain pathologies widespread in the Caribbean)

Description: The project aims to detect pharmacological potential of sargassum extracts against pathologies spread over the Caribbean.

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SARTRIB (Tribological and electrochemical valorisation of sargassum)

Description: Aim: Valorisation of vacuum pyrolysis by-products of sargassum: electrodes for lithium batteries and new generation of lubricant.

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SAVE (Sargassum agricultural valorisation and energy production)

Description: This project seeks to identify non-destructive sargassum harvest methods and develop a social and environmental approach to integrating the treatment of sargassum and local bio wastes.

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

SAVE-C (Study of holopelagic sargassum responsible of massive beachings: valorisation and ecology on Caribbean Coasts)

Description: This project aims to better understand the diversity and the functioning of pelagic sargassum, from the drifting rafts until their beaching

Organisation/Agency: Coordinator and collaborators can be found [here](#)

Year Established: 2019

Useful link: <https://www.regionguadeloupe.fr/actualites-et-agendas/toute-lactualite/detail/actualites/presentation-des-resultats-de-lappel-a-projet-sargasse/#>

DEVELOPING A SUSTAINABLE SARGASSUM VALUE CHAIN

Description: Research project seeking to identify sustainable business opportunities utilizing sargassum seaweed that could lead to the development of a sustainable sargassum value chain, easy to replicate and scaled- up in other areas or countries

Organisation/Agency: Polytechnic University in Quintana Roo (UPQRoo)

Year Established: 2019

SOS (Sargassum Ocean Sequestration) of Carbon

Description: This project supports the production of a specialized machine used as an alternative way to manage pelagic sargassum strandings. The machine pumps sargassum to a critical depth where it becomes negatively buoyant. Also exploring carbon credit or carbon trading opportunities.

Organisation/Agency: Massachusetts Institute of Technology (MIT)

Year Established: 2019

Useful link: <https://soscarbon.com>



ENERGYALGAE

Description: Multi-sectoral and multi-national initiative developing sustainable sargassum uses with a focus on bioenergy.

Organisation/Agency: AlgaeNova, Grupo Puntacana, University APEC (UNAPEC), Y.A. MAOF Holdings & Management Ltd.

Year Established: 2019

Useful link: <https://www.energy-algae.com>



CLOSING THE CIRCLE PROGRAMME

Description: Exploring challenges and advancing potential solutions to marine debris, Sargassum threats and marine spatial planning in Small Island Developing States with a particular focus on the Eastern Caribbean region.

Organisation/Agency: World Maritime University

Year Established: 2020

Useful link: <https://closing-the-circle.wmu.se>



SARGASSUM PODCAST

Description: A podcast hosted by marine educators and scientists with a range of expertise in Sargassum and Coastal Communities. The podcasts interviews a variety of stakeholders about how they experience Sargassum, a floating algae that has caused severe problems when beaching in the wider Caribbean and West Africa.

Organisation/Agency: Marine conservation without borders

Year Established: 2021

For more info: www.marinefrontiers.org/sargassum

To listen and subscribe to the podcast go to <https://anchor.fm/sargassum-podcast> (audio only) or [https://youtube.com/playlist?list=PLJmthP9YWdLQbvb7dJz271d1RUvUam3Z5\(video\)](https://youtube.com/playlist?list=PLJmthP9YWdLQbvb7dJz271d1RUvUam3Z5(video)).

You can also listen to it on:

Spotify: <https://open.spotify.com/show/3Y4oa8F6DtpyC4I-7w09NSr>

Breaker: <https://www.breaker.audio/the-sargassum-podcast>

Google podcast: <https://podcasts.google.com/feed/aHR-0cHM6Ly9hbmNob3luZm0vcy80NmE1ZjU3OC9wb2RjYXN0L3Jzcw==>

Pocket cast: <https://pca.st/kv0u4fda>

Radio Public: <https://radiopublic.com/the-sargassum-podcast-Gmb7qN>

13.4 Appendix IV: Sargassum management plans and strategies in the Caribbean

| Country/ Territory | Document type | Plan/Strategy title | Publication year |
|-----------------------|---|--|---------------------|
| Antigua and Barbuda | Request for Expression of Interest | Request for Expression of Interest for the Supply of Equipment and Machinery for Aquatic Sargassum seaweed removal in Antigua and Barbuda | 2018 |
| Bahamas | None found | N/A | N/A |
| Barbados | Management plan Management strategy | Barbados Sargassum Management Plan Barbados Sargassum Adaptive Management Strategy | 2019 2021 |
| Belize | None found | N/A | N/A |
| Dominica | Strategic preparedness plan | Strategic Sargassum Preparedness Plan | 2019 |
| Dominican Republic | None found | N/A | N/A |
| Grenada | Model protocol Management strategy | Protocol for the management of the extreme accumulations of sargassum on the coast of Grenada Grenada Sargassum Adaptive Management Strategy | 2017 2021 |
| Guyana | None found | N/A (supposed to be modifying CRFM protocol) | N/A |
| Haiti | None found | N/A | N/A |
| Jamaica | Strategic preparedness plan | National Response Strategy: The Sargassum Threat | 2015 |
| Puerto Rico | None found | N/A (Protocol for the management of extreme accumulation of Sargassum on the coasts of Puerto Rico) | N/A |
| St Kitts and Nevis | Management brief Management strategy | Plan for the Management of the Accumulations of Sargassum on the Coastal and Marine Ecosystem St. Kitts and Nevis Sargassum Adaptive Management Strategy | 2017 2021 |
| St. Lucia | Management brief Management strategy | Saint Lucia National Strategy for the Management of Sargassum Influxes on Beaches, Bays and Small Harbours St. Lucia Sargassum Adaptive Management Strategy | 2017 2021 |

| Country/ Territory | Document type | Plan/Strategy title | Publication year |
|----------------------------------|--|--|---------------------|
| St Vincent and the Grenadines | Management brief | The Management of Extreme Accumulations of Sargassum on the Coasts of St. Vincent and the Grenadines St. Vincent and the Grenadines Sargassum Adaptive Management Strategy | 2017 2021 |
| | Management strategy | | |
| Suriname | None found | N/A | N/A |
| Trinidad and Tobago | Management brief | National sargassum response plan Draft Tobago Emergency Response Plan | 2016 2016 |
| Turks and Caicos | None found | N/A | N/A |
| US Virgin Islands | None found | N/A | N/A |
| Anguilla (UK) | Management plan | Draft Sargassum management plan | 2015 |
| British Virgin Islands (UK) | Statements to parliament | Statement by Deputy Premier and Minister for Natural Resources and Labour Dr. The Honourable Kedrick D Pickering “Sargassum Seaweed Phenomenon” | 2015 |
| Bermuda (UK) | None found | N/A | N/A |
| Cayman Islands (UK) | None found | N/A | N/A |
| Montserrat (UK) | None found | N/A | N/A |
| Aruba (NL) | Management brief (NL) | Prevention and clean-up of Sargassum in the Dutch Caribbean | 2019 |
| Bonaire (NL) | | | |
| Curaçao (NL) | | | |
| Saba (NL) | | | |
| St Eustatius (NL) | | | |
| St Maarten (NL) | | | |
| Guadeloupe (Fr) | Report and recommendations (FRA) | Le phénomène d'échouage des sargasses dans les Antilles et en Guyane | 2016 |
| Guyane (French Guiana) (Fr) | | | |
| Martinique (Fr) | | | |
| St Martin (Fr) | | | |

