



Sargassum: Brown tide or golden jewel?

Background

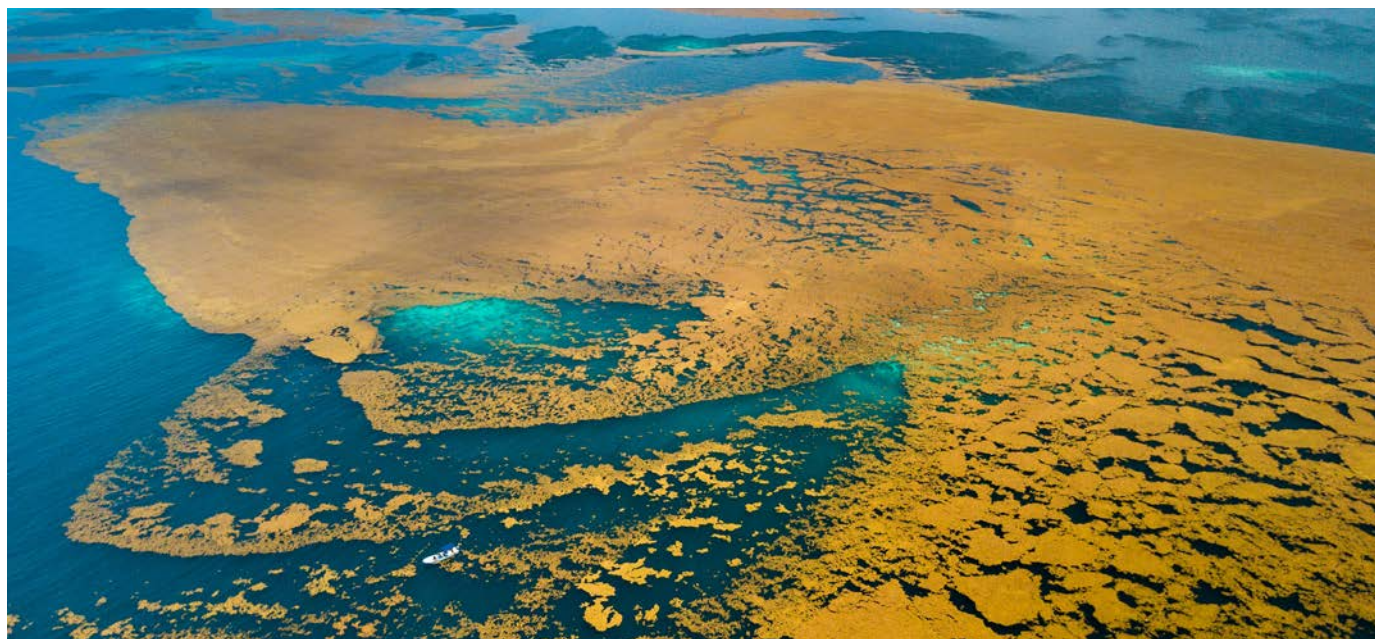
The Foresight Briefs are published by the United Nations Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 24th edition of UNEP’s Foresight Brief focuses on floating sargassum seaweed and aims to support the sargassum paradigm shift from a ‘brown tide’ hazard to a ‘golden jewel’ opportunity.

Abstract

Massive episodic inundations of floating sargassum seaweed have been impacting shorelines on both sides of the tropical Atlantic since 2011. These influxes are now widely considered to be part of the ‘new normal’ facing vulnerable regions in the Wider Caribbean, West Africa and some parts of India. The seaweed itself is not harmful; floating sargassum at sea is beneficial as a unique habitat. It is the large floating mats clogging fishing gear and impeding navigation at sea, and the mass stranding on coastlines and ensuing decomposition that is highly detrimental to people, ecosystems, and economies.



Pelagic brown algae in the genus Sargassum. The berry-like structures are gas-filled bladders (pneumatocysts), which provide buoyancy to the plant
Photo Credit: Shutterstock.com



Drone photograph of a vast mat of sargassum near Silk Cayes, Belize, (4 September 2018)

Photo credit: Tony Rath

A Weighty and Complex Problem

2018 saw record breaking quantities of sargassum reaching the Caribbean, with 20 million metric tonnes reaching the region in June alone. That is equivalent to the weight of 200 large cruise ships.

While 2020 was relatively mild in terms of sargassum volumes, in 2021 an estimated 5.1 and 4.6 million metric tonnes of sargassum have been observed in the tropical Atlantic in January and February respectively, (**Figure 1**) with a stark increase to 10.1 million metric tonnes in March.

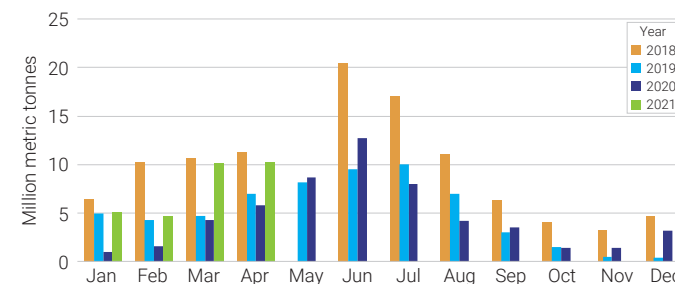


Figure 1: Estimated total amount (million metric tonnes) of sargassum in the tropical Atlantic (2018 – 2021)

Source: USF Outlook Bulletin

The influxes to the Caribbean have been found to consist predominantly of two species of holopelagic sargassum, *Sargassum natans* and *Sargassum fluitans*. There are various morphotypes (*S. fluitans III*, *S. natans I*, *S. natans VIII*) of these species and some debate as to whether there may be third additional distinct species. (Desrochers *et al.* 2020). Sargassum beached or stranded in the nearshore decomposes and/or breaks down in the water column, with significant negative impacts for humans and ecosystems. Decomposition products negatively affect air and water quality and large volumes of sargassum smother wildlife. This creates concerns for human health and well-being, as well as significant knock-on effects to key economic sectors like tourism, fisheries, and maritime transport (**Figure 2**). Responding to this relatively new issue has proven challenging for many impacted territories. The cost of clean-up operations in the Caribbean was estimated at over USD\$120 million in 2018¹. Given existing strain on resources due to the economic downturn and most recently the ongoing COVID-19 pandemic, clean-up operations have been suboptimal.

Beyond the sheer masses of sargassum, there is considerable spatial and temporal complexity to the problem. Spatially the challenges are compounded by the general complexity of transboundary ocean governance within and between the impacted regions.

The Wider Caribbean Region (WCR) is geopolitically diverse and complex (Mahon *et al.* 2013, Debels *et al.* 2017), the most diverse and complex among the Regional Seas Programmes. There are over 35 states and territories, that range from among the smallest to among the largest, as well as from the least developed to the most developed in the world (Debels *et al.* 2017). The WCR contains the largest number of Small Island Development States (SIDS) of any region globally (16). While there are many commonalities and valid generalisations, the WCR is far less homogenous and more variable than many realise.

Temporally-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 in dealing with the issue.

An External Shock to Vulnerable Regions

Sargassum influxes are an external shock to the impacted areas, adding to the already complex development and climate change adaption challenges of the Small Island Developing States (SIDS) and developing countries in the Wider Caribbean Region and West Africa.

Sargassum influxes are likely in part to be manifestations of ocean eutrophication and climate change, which are global issues beyond the direct control of the impacted territories. At the same time, the challenges of sargassum management are extensions of the challenges already faced by many of these countries in responding to natural hazards.

The impacts of sargassum influxes dating back to 2011 are well-known and effectively documented in various places including the [2021 UNEP Sargassum White Paper](#). Key economic sectors like tourism and fisheries are severely impacted and are often the focus of discussion, sometimes overshadowing impacts on public health and quality of life for residents and local beach users,

maritime transport, as well as the quality of nearshore ecosystems.

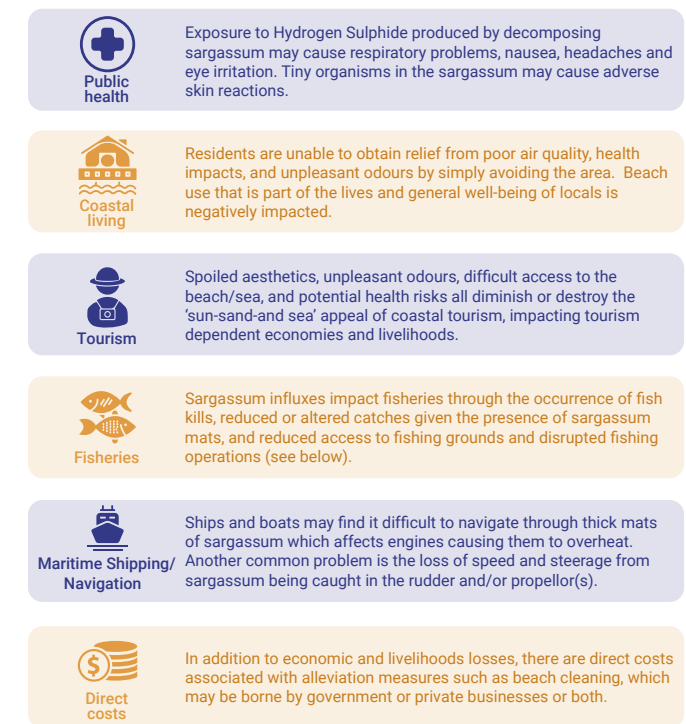


Figure 2: Biophysical and socioeconomic impacts of sargassum influxes

Source: UNEP CEP (2021) *Sargassum White Paper*

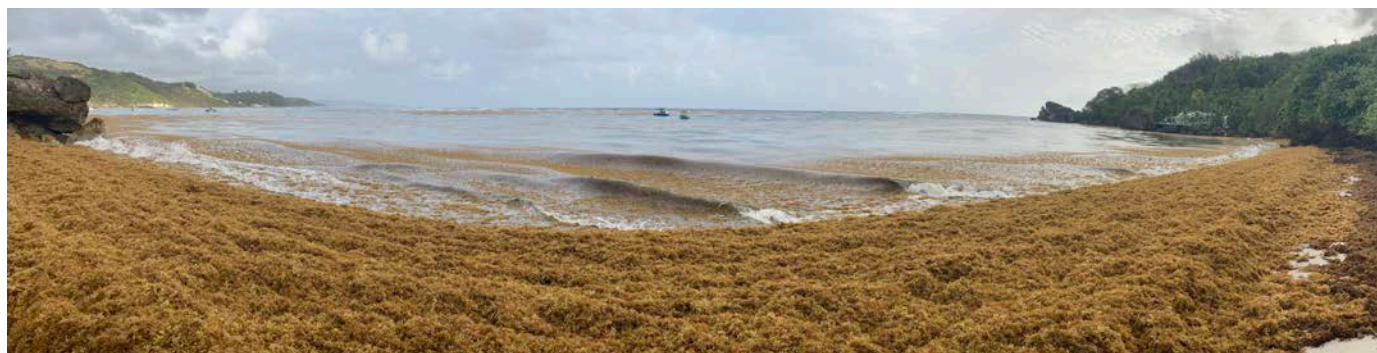


Photo Credit: Hazel A. Oxenford, Conset Bay, Barbados (14 March 2021)

¹ <https://www.frontlinewaste.com/sargassum-seaweed-a-source-of-economic-opportunity>

Main Findings: State of knowledge on Sargassum

Causes and Drivers

Currently causes are less well understood than effects. Understanding causes is critical to efforts in mitigating sargassum impacts as well as to forecasting influxes that would support planning adaptive response. Here we take a systems thinking approach to unpacking the causal pathway leading to sargassum influxes in the Caribbean and West Africa.

Sargassum influxes do not stem from a single or simple cause, but rather from a complex combination of causal factors. A key step in understanding the causes was the identification of the new consolidation region that is the source of these influxes (**Figure 3**), which was confirmed in 2013 through remote sensing.

With this knowledge, we can visualise a causal pathway. At the source, likely the Sargasso Sea, sargassum is transferred to the new consolidation region, where the sargassum persists and proliferates. Sargassum then detaches from the new source region and is subsequently transported to and stranded on coastlines in the Wider Caribbean and West Africa (**Figure 4**, central pathway coloured in grey).

Within this broadly outlined causal pathway, there is much complexity in the underlying causes or drivers of each stage:

- *Transport to new consolidation region:* one recent study theorises that a 2009-2010 wind anomaly or temporary shift in wind direction is responsible for sargassum being transported from the Sargasso Sea to the tropics, where conditions are favourable for it to persist (Johns *et al.* 2020). Additional research is needed in this area.
- *Persistence and proliferation of sargassum in the new source region:* there are numerous interrelated

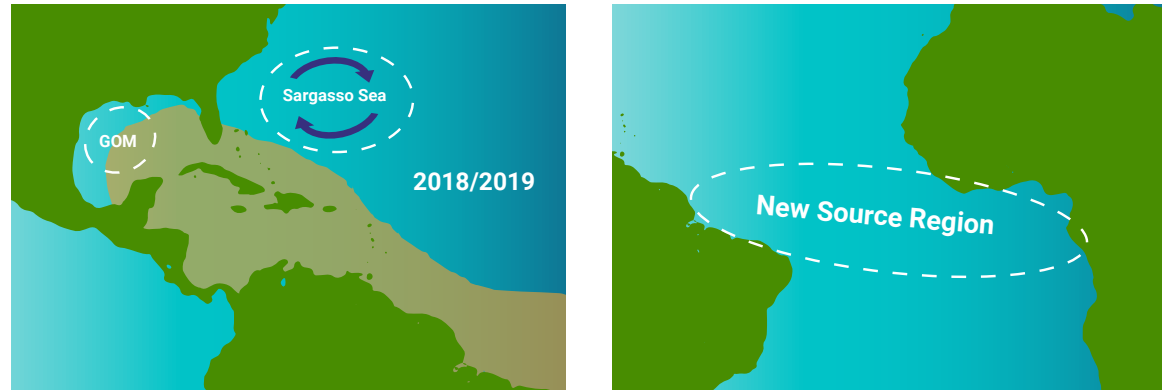


Figure 3: Schematic map showing - Left: impact zone of sargassum influxes in the Western Atlantic in relation to the Sargasso Sea in the Northern Atlantic and Right: New Tropical Atlantic Source Region
Source : CERMES 2020. Sargassum Project

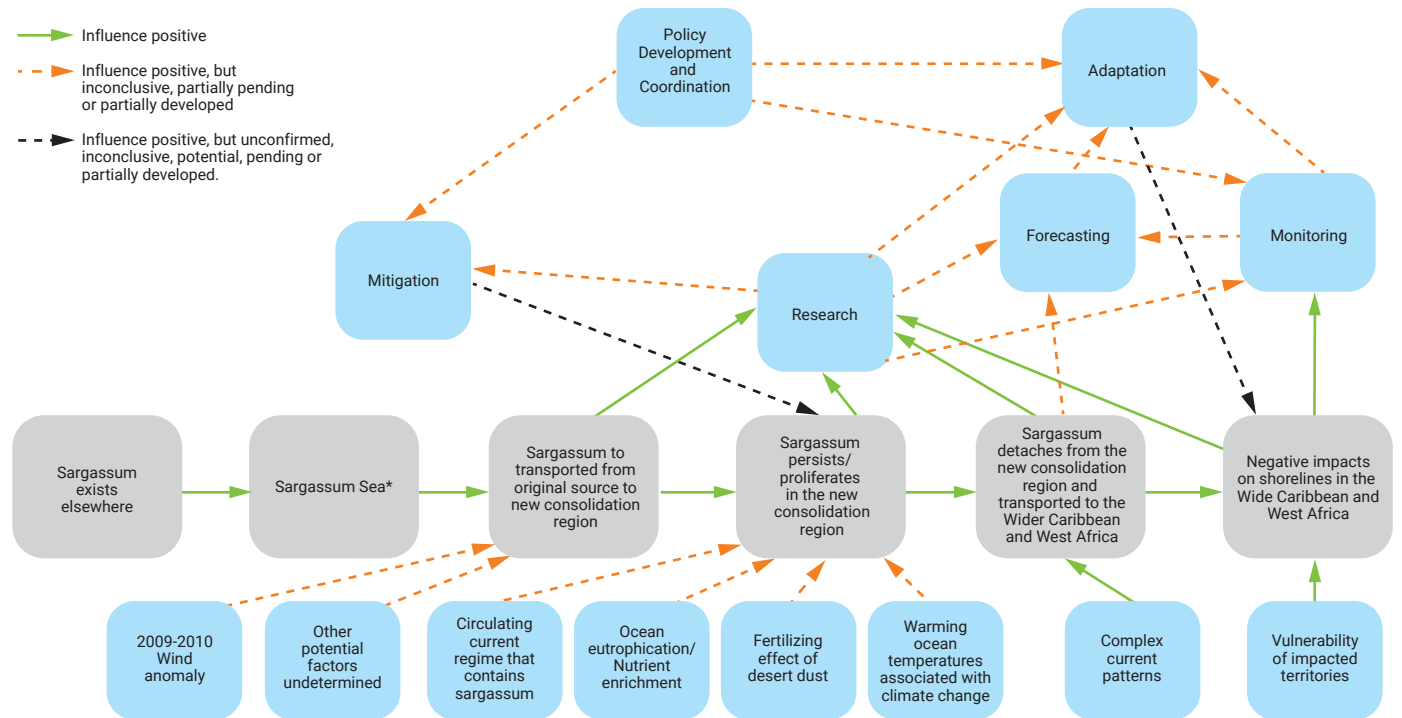


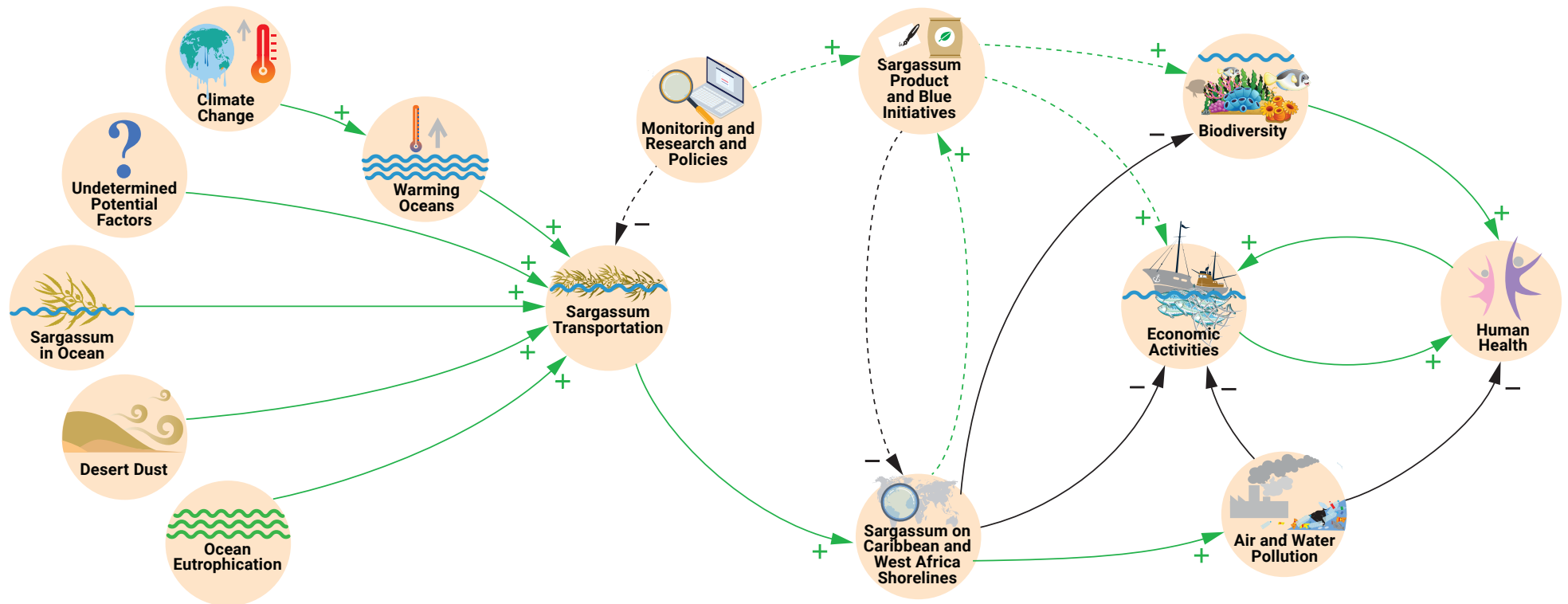
Figure 4: Systems thinking approach for Sargassum Influxes to Coastlines on both sides of the Tropical Atlantic (main causal pathway for influxes indicated in grey)
Source: UNEP- Caribbean Environment Programme

factors involved that may be linked to the broader underlying issues of land-based nutrient pollution and climate change. There are multiple pathways of nutrient enrichment including conventional land based sources of pollution and the possible fertilizing effect of desert dust (LaPointe 1995, Fulton *et al.* 2014, LaPointe *et al.* 2014, LaPointe 2019, Barkley *et al.* 2019, UNEP 2020, Lapointe *et al.* 2021).

- *Detachment from the consolidation region and transport to impacted regions:* the dynamics of this are complex; influxes do not follow a regular pattern and there are significant interannual variations. Complex ocean currents/circulation and growth/mortality dynamics of pelagic sargassum are involved (Wang *et al.* 2019, Putman *et al.* 2020, Johnson *et al.* 2020).

- *Sargassum stranded on coastlines causes numerous negative impacts:* the scale, severity, and spatial distribution of the impacts is not uniform. Not every coastline is exposed to the same extent, and the vulnerability of the exposed locations is a key determinant of the severity of impacts.

A Systems Thinking Perspective



Warming oceans due to climate change and other environmental conditions including undetermined potential factor leads to massive quantities of sargassum being transported to coastlines in the Caribbean and West Africa. This in turn reduces economic activities in climate sensitive sectors such as tourism, maritime transport and fisheries, and adversely affects ocean biodiversity and human well-being. Sargassum decomposition on shorelines also increases air and water pollution. Increasing pollution, decreasing biodiversity and declining economic activity causes human health directly or indirectly to decline. The decline in human health in turn reinforces a further decline in economic activity. These trends can be reversed through appropriate measures including monitoring and research into the causes of sargassum transportation and policies leading to the development of sargassum product and blue initiatives. These initiatives would result in sargassum being used on shorelines to increase economic activities and in turn improving biodiversity and reducing pollution. Policy interventions that result in reduced sargassum on shorelines can therefore improve overall human health through reinforcing beneficial causal loops. (+) Influence is in the Same direction, (-) influence is in the Opposite direction.

Sargassum Response is now a Dynamic Arena



Sargassum on the beach at Bottom Bay, St. Philip Parish, Barbados
Photo Credit: Shutterstock.com

There are a range of possible interventions to sargassum influxes, some more developed or in common use than others. Unfortunately, responses to addressing the issue have generally been reactive rather than proactive resulting in environmental degradation and inefficient use of resources. 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 very similar in nature, yet attempts to explore opportunities for promoting synergies to avoid unnecessary duplication have not yet yielded successful outcomes. The Caribbean Cooperation Programme Against Sargassum (SARG'COOP), signed in 2019 at the International Sargassum Conference in Guadeloupe, was an attempt to promote synergies by bringing together regional partners to share knowledge and expertise and foster collaboration across language barriers. However, this initiative is still in its early stages and does not currently rise to the level of a governance mechanism.

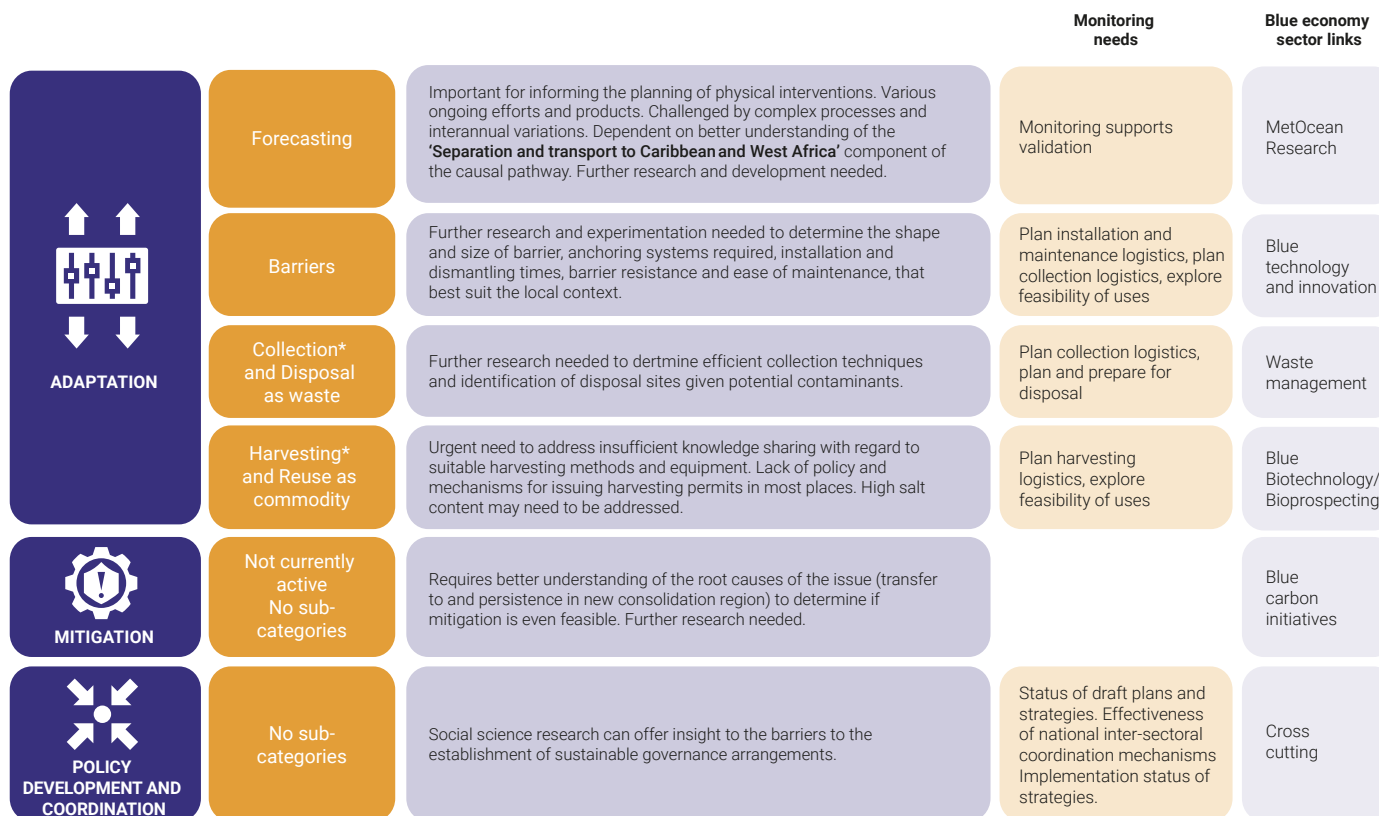
Systematic Framework for Possible Interventions

Figure 5 provides a systematic strategy framework for categorising the range of possible interventions to support critical assessment of the needs of each type of intervention, identification of gaps, and linkages to other policy areas.

Interventions may be broadly categorised as either adaptation or mitigation (referring here to mitigation of the sargassum issue as distinct from climate change mitigation). Adaptation responses may be further categorised as efforts related to forecasting, barriers, collection and disposal, or harvesting and reuse. Mitigation options are not well developed because the root causes are not well enough understood or are too complex to effectively target them. Policy development and coordination is also critical to enabling both adaptive and mitigative interventions.

Monitoring and quantifying sargassum influxes is key to supporting all categories of interventions. Monitoring is needed to help validate forecasts, plan collection/harvesting logistics, plan and prepare for disposal, and explore use/commoditisation opportunities. The strategy framework (Figure 5) indicates the monitoring needs of each category of intervention.

Blue economy sector links are also indicated in the framework to explore synergies with the emerging concept that promotes the sustainable use of ocean resources.

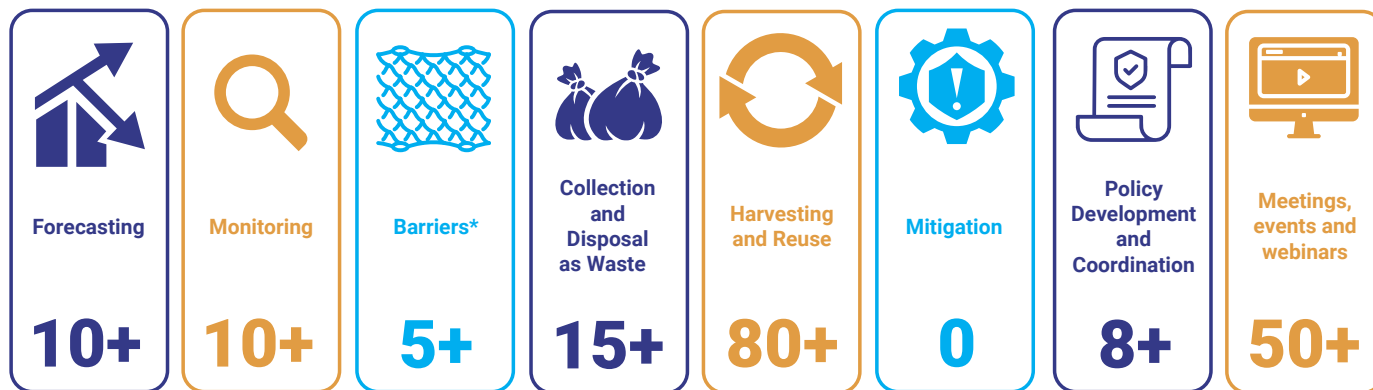


* Note that 'collection' and 'harvesting' here overlap significantly, the difference is in the next step, whether disposal or putting the material to use.

Figure 5: Systematic framework for categorising interventions to sargassum influxes

Source: UNEP-CEP (2021) Sargassum White Paper

Sargassum Projects/Initiatives in the Wider Caribbean Region in Numbers



* Well established initiatives producing or supplying barriers specific for sargassum management
Also note that some Projects work across categories/thematic areas and may therefore be counted multiple times.
The numbers presented are based on the best available information at time of reporting

Figure 6: Dashboard showing numbers of projects/initiatives in the Caribbean according to type. Source: UNEP-Caribbean Environment Programme

To illustrate the sheer number of projects and initiatives in these areas, a tally of existing initiatives according to the framework categories is outlined in **Figure 6**.

The systems thinking approach (**Figure 4**) incorporates this strategy framework to show how each category of intervention targets particular stages of the causal pathway. Since mitigation efforts by definition target the underlying causes of the issue (mainly proliferation in the new consolidation region), a better understanding of those processes is required to advance mitigation. Key questions in exploring mitigation may 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).

Forecasting, which informs adaptation, is more concerned with the process by which sargassum

detaches from the main consolidation region and is transported to the Caribbean. Forecasting efforts to date have been relatively low in precision, which is the result of a number of constraints related to the input and validation data required for numerical models that researchers are working to resolve.

Shifting the Paradigm from Hazard to Opportunity

Sargassum influxes have been a catalyst for innovation and have the potential to form part of a sustainable and equitable blue recovery to the COVID-19 crisis. Shifting the sargassum paradigm from hazard to opportunity is the best case scenario for reducing vulnerability and increasing resilience to this new phenomenon. Merging opportunity and adaptation may offer SIDS and developing countries potential solutions that are both directly beneficial to their vulnerable economies, and independent of global efforts on climate change mitigation that are behind target. This paradigm shift requires not just shifting mindsets but also developing technologies, capacities, and safeguards and creating the appropriate enabling environment.

Hazard exposure and vulnerability mapping

Hazard exposure and vulnerability mapping are recommended as a means of systematically addressing the spatial complexity and variation of hazard impacts toward optimising response planning. **Figure 7** shows the exposed areas of coastline in Barbados. This is a starting point, to which additional spatial information - tourism, fisheries, communities and more - can be included to assess what types of impacts occur where. Vulnerability assessments of the exposed areas and assets can also be added, and the combined output used to target the response towards areas or sectors that are the most exposed and vulnerable.

ICZM Sub Areas & Sargassum Affected Locations

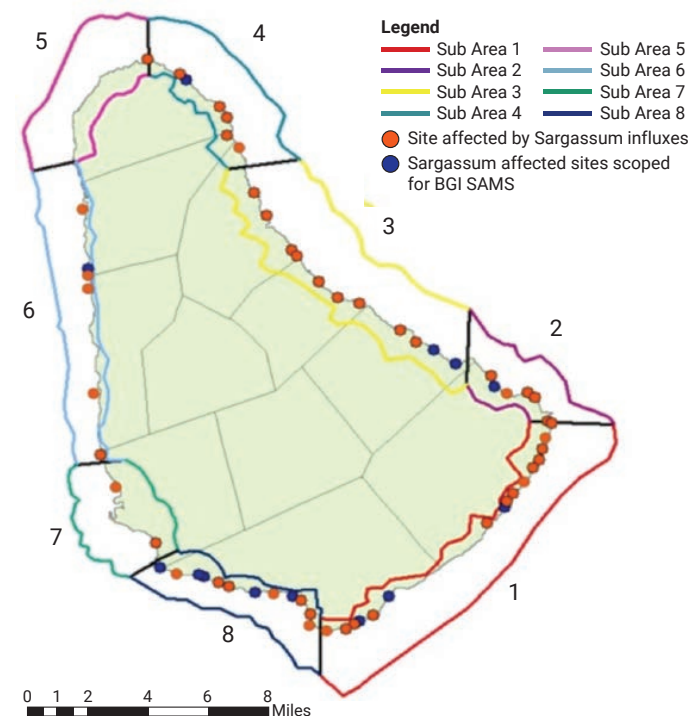


Figure 7: Preliminary country-level exposure mapping of sargassum influxes in Barbados within the framework of existing Coastal Zone Management Sub-Areas
Source: CERMES and MMABE 2021

Vulnerability assessments of the exposed areas and assets can also be added, and the combined output used to target the response towards areas or sectors that are the most exposed and vulnerable.

Sargassum product development

There is potential for commoditisation of sargassum through a variety of uses including agriculture e.g. as a soil amendment, biochar, bioenergy, bioplastics, bioremediation and purification, construction e.g. as building blocks and cosmetics among others (Figure 8; see also [FAO-CERMES Sargassum Uses Guide](#)).

Efforts are underway to assess feasibility and marketability of sargassum uses and products, extending even to nascent product development. While promising, there are a few factors that should be taken into consideration on both the supply and demand sides:

- When extracting sargassum as a raw material, its availability is highly variable and difficult to predict.
- Not all applications are the same, e.g. some processes require fresh sargassum, others dry; some uses achieve a better yield (Figure 8) with certain types of sargassum (Davis *et al.* 2021).
- Sargassum may be unsafe for some applications because of toxins/contaminants such as heavy metals and microplastics – more research is needed (Devault *et al.* 2021, Davis *et al.* 2021, Rodríguez-Martínez *et al.* 2020, Milledge *et al.* 2020).
- Small scale operations requiring low volumes of sargassum are unlikely to make a significant dent in the massive volumes of influxes. Large-scale operations, if feasible, offer better chances of using up the sargassum as a co-benefit, but may themselves result in negative impacts such as displacement of residents or small businesses.



A man cleaning up a pile of tangled turquoise and white rope ghost fishing nets, abandoned gear washed up among a carpet of sargassum seaweed in Bathsheba, Barbados.
Photo Credit: Shutterstock.com

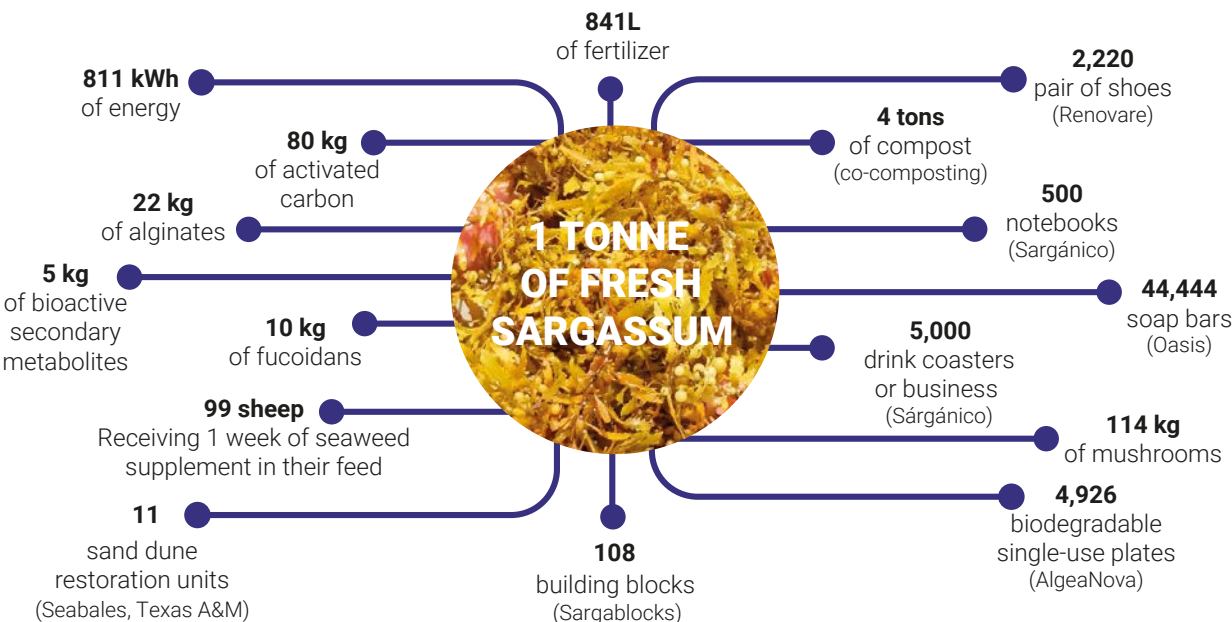


Figure 8: Relative product yields that could potentially be produced from one metric tonne (1000 kg) of fresh sargassum
Adapted from Desrochers *et al.* 2020.

- There is a need to map out the full process for sargassum uses as shown in Figure 9. Costs for each stage must be factored in. Logistics are likely to vary significantly across territories, and may be especially complex/costly in small islands.
- Potential environmental and social impacts for each stage must also be considered, e.g. harvesting from beaches may damage the beach ecosystem, or there may be environmental impacts of the storage or the production process such as strong odours or potential pollution.

In addition, the potential commoditisation of sargassum raises issues around ownership and extraction rights to the 'resource.' Policymakers are encouraged to consider how sargassum fits into existing natural resource ownership and rights legislation and policy in their countries/territories, and pursue updates as needed.

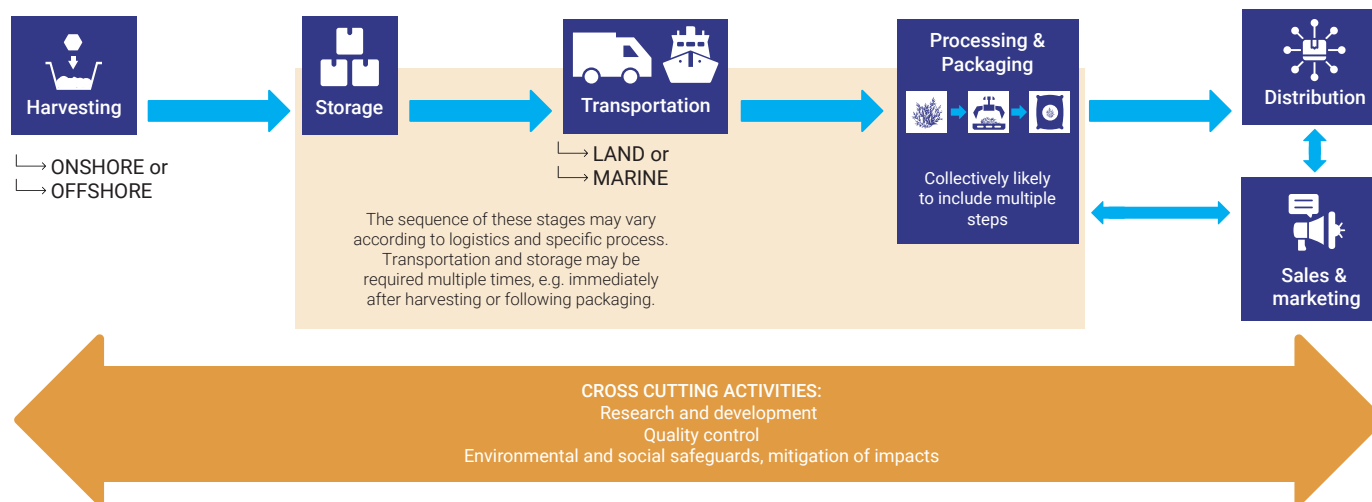


Figure 9: Sargassum value chain schematic

Source: UNEP-CEP (2021) *Sargassum White Paper*

Blue carbon

Another emerging application that has potential in the future is the leveraging of sargassum in sequestering 'blue carbon' (Orr 2014, Krause-Jensen and Duarte 2016, Paraguay-Delgado *et al.* 2020, Gouvêa *et al.* 2020). According to Desrochers *et al.* 2020, commercialising blue carbon credits of sargassum currently faces a number of significant challenges including: relatively low values; ownership of pelagic sargassum; development of appropriate technology to effectively sink sargassum; loss of biodiversity; and potential creation of deep-sea dead zones due to excessive accumulation of biomass in oxygen minimum zones of the ocean.

These challenges are already being addressed through research and development with some solutions advancing to the pilot testing phase. Examples of blue carbon projects with funding from 'voluntary carbon markets' in Kenya, India, Vietnam and Madagascar reveal the strengths and challenges of implementation as well as policy implications (Wylie *et al.* 2016). However, the absence of an accepted methodology for quantifying carbon sequestration by marine ecosystems including

pelagic sargassum as well as seagrass beds, coral reefs, and the open ocean itself, is the primary barrier to trading in carbon credits on any significant scale to benefit SIDS' limited terrestrial space and forest resources. Sargassum blue carbon may add impetus to advance the science to support such methodologies.

Research and innovation opportunities

Given the fact that sargassum is still a relatively new environmental issue, significant gaps remain in information and understanding as well as effectiveness of response strategies. This offers research and development opportunities for scientists and entrepreneurs to inform decision-making. The UN Decade of Ocean Science 2021-2030 may offer an opportunity to advance research related to the areas of interest outlined below:

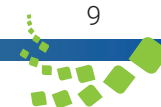
1. Forecasting and monitoring of sargassum influxes;
2. Interannual and seasonal variability in sargassum influxes and strandings;

3. Impact due to land-based pollution sources vis-à-vis fertilization by desert dust;
4. Chemical composition of sargassum (to inform its suitability as a raw material);
5. Biosorption of heavy metals and other pollutants (suitability for consumptive and contact uses);
6. Nutrient dynamics before and after sargassum influxes;
7. Variability in the relative abundance of different sargassum species and morphological forms;
8. Efficient harvesting methods and equipment that minimise environmental damage;
9. State-of-the-art storage and transportation solutions;
10. Protocols and standards to support safe harvesting, transport, storage and production (process and end products);
11. Economic impact of sargassum influxes on climate sensitive sectors;
12. Gender-differentiated data and information on sargassum impacts;
13. Sargassum value chain analysis; and
14. Effectiveness of existing governance arrangements at national and regional levels specific to managing sargassum influxes.

What are the implications/links for policies?

Policy implications/Creating the enabling environment

Given the complexity of this issue and the urgent need to explore opportunities, targeted policy interventions are needed to guide the adaptation of legal and regulatory frameworks to meet the issues and facilitate knowledge sharing at the science-policy interface. Compiling spatially explicit information (mapping) on exposure, vulnerability, and available resources is recommended. This, along with clear policies and regulations, contributes to the enabling environment by reducing uncertainty for investors and facilitates efficient use of resources and effective management interventions.



Global governance mechanism

The Caribbean Large Marine Ecosystem (CLME+) Strategic Action Programme (SAP) Interim Coordination Mechanism (ICM) should be leveraged to promote interactive governance of the sargassum issue in the Wider Caribbean region (UNEP-CEP 2021a). The ICM provides a framework based on extensive study that aims to enhance regional coordination and collaboration and support oversight and integration of actions for the protection and sustainable use of marine resources. The SARG’COOP can support the proposed regional governance mechanism to fulfil its role in strengthening cooperation and building Caribbean States’ and territories’ capacities to respond to massive sargassum influxes.

Beyond the Caribbean, transatlantic collaboration through links with the Abidjan convention and the Guinea Current Large Marine Ecosystem (GCLME), including impacted countries/territories from both the Caribbean and West Africa should be pursued. The shared challenge of sargassum influxes may be an opportunity to foster mutually beneficial transatlantic south-south cooperation. Currently however, while some collaborations have begun, this remains an area in need of strengthening. Scaling up the proposed regional governance mechanisms to the global level can be initiated with a potential United Nations Environment Assembly (UNEA) resolution, which could also be linked to the [UNEA4 resolution on Sustainable Nitrogen Management](#). Although not legally binding, the UNEA resolution would represent the joint aspirations of the international community as it relates to the management of sargassum influxes, frame consensus around actions to be taken, and help to coordinate funding and technical assistance to address the issue.

Blue economy sector linkages

Sargassum adaptation interventions outlined in the strategy framework (**Figure 5**) have clear links with Blue Economy sectors. In that context, they should be explored further in coordination with various regional Blue Economy initiatives, including the development of regional and national strategies. Sargassum opportunities

and responses should be integrated into Blue Economy strategic frameworks as potential blue growth prospects. Exploring the feasibility of commercialising blue carbon credits of sargassum should be seen as part of broader effort in blue carbon development for SIDS and developing countries, potentially adding impetus to advancing development of methodologies, legal frameworks and regional markets. When investigating these opportunities, a regional or transboundary cooperative approach is recommended to promote sustainable exploitation of what may come to be viewed as a common good.

Considerations for sargassum product development

Sargassum-specific policies, protocols and standards are needed to prevent environmental damage and ensure the safety of products for consumptive or contact uses, thereby supporting sustainable sargassum-related businesses and protecting public and environmental health.

Territories are advised to develop policies that encourage investment in sargassum exploitation in such a way as to mitigate the negative effects, while putting safeguards in place against risks such as environmental impacts, conflicts around resource rights, or displacement of people or small businesses.

Governments may wish to consider Public-Private Partnerships (PPPs) and/or Blended Finance models to encourage private sector involvement in sargassum exploitation, with effective safeguards to ensure delivery of the public service (alleviation of impacts) and avoid or minimise potential negative impacts.

Gender considerations

Women and youth are particularly vulnerable to negative impacts of sargassum influxes especially health related impacts (UNEP-CEP 2021b). However, there is a dearth of gender-differentiated data and information on sargassum impacts to support the development of appropriate, evidence-based responses and policies.

The following policy actions are recommended to promote the engagement of women and youth in sargassum management and innovation:

- Promote the equitable participation of women and women’s groups in decision-making processes for sargassum management.
- Appoint women and youth to decision-making organs, such as sargassum task forces/sargassum management committees, and allow leadership in the implementation of activities.
- Develop gender-responsive sargassum adaptive management strategies and plans that address influxes as a hazard and an opportunity.
- Improve the economic empowerment of women and youth in the sargassum value-chain in the Caribbean by supporting entrepreneurship and facilitating access to venture capital.

Conclusion

Significant progress has been made in the last decade since sargassum influxes first emerged as a coastal hazard in the tropical Atlantic. While there is general consensus that we should view influxes as an economic opportunity, the reality is that sargassum inundations remain more of a threat than a benefit until key issues are resolved. A shift in mindset is a critical step, but must be followed through with deliberate action. This foresight brief aims to support the sargassum paradigm shift from a ‘brown tide’ hazard to a ‘golden jewel’ opportunity. It cuts through information overload with a systematic and strategic big picture review of causes and effects and the current state of knowledge and intervention. Moreover, it frames gaps as research and innovation opportunities, and presents practical insights into the actions and considerations that will advance the paradigm shift.

However, efforts to explore the potential opportunities are underway.

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This brief was prepared based on the findings of the updated 2021 Sargassum White Paper entitled 'Turning the crisis into an opportunity'. Link to the paper: <https://www.unep.org/cep/resources/publication/sargassum-white-paper-turning-crisis-opportunity>



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