

# Prevention and clean-up of Sargassum *in the Dutch Caribbean*



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# Executive Summary

*“In 2011, the shores of several Caribbean islands and West African countries were inundated by unprecedented quantities of pelagic sargassum. Since then, influxes of this golden-brown seaweed have become a recurrent event in both the Caribbean Sea and West Africa, with observers in these regions reporting levels reaching a critical high in 2018” (Hinds et al., 2016).* Some piles of stranded sargassum towered several meters high on beaches, and affected bays were covered with dense floating clusters of the seaweed. Finding ways to clean-up sargassum from coastal ecosystems has become a priority for the region. The recent and likely recurring seaweed influxes have given rise to a number of socio-ecological and economic concerns, particularly in the hospitality and fisheries sectors, as well as threatening already fragile and often endangered coastal ecosystems such as mangroves and seagrass beds. The good news is that these negative effects do not seem to persist when the sargassum is removed, with the physicochemical quality of the water returning to its prior state (Anses, 2017). Cleaning-up large quantities of sargassum is however no easy or cheap feat. Strandings have so far proven to be highly variable in terms of quantity and sites affected, making these irregular events hard to predict and therefore mitigate. A recent estimate suggests that it will take at least \$120 million to clean up the sargassum inundations across the Caribbean (Milledge and Harvey, 2016). “The sustainable management of sargassum influxes will require both local action and regional co-ordination and collaboration, beyond areas under national jurisdiction. A better understanding of the geographic origin, causes, spatial and temporal patterns, management options, as well as the economic potential of sargassum is necessary if adaptive strategies are to be implemented” (Hinds et al., 2016). This management brief, adapted from Hinds et al. (CERMES/GCFI/SPAW Management Brief, 2016), focuses on the immediate problem of clean-up after mass strandings of the weed, helping coastal communities find effective solutions for the collection and use of sargassum.



# Management Brief Purpose

- Highlight the urgency of the sargassum problem.
- Assist government officials, coastal managers, beach caretakers and coastal residents by offering guidance on how best to sustainably manage the sargassum, based on up-to-date information on the recent 'sargassum influxes' and lessons learnt to date.
- Present feasible, cost-effective and environmentally sound solutions for removing sargassum close to shore and on beaches in the least damaging way.
- Present a range of solutions adapted to local conditions and the varying volume of sargassum influxes. The variety of coastal ecosystems throughout the Caribbean requires a range of solutions adapted to each location.
- *"Propose short and long-term mitigation strategies to reduce the impacts of sargassum events"* (Hinds et al, 2016).
- Present current solutions for the use and valorization of collected sargassum.
- Help local stakeholders gain a better understanding of the phenomenon, by *"providing information on aspects of the biology and ecology of sargassum, what the most recent science is saying about the source and cause of this new phenomenon in the Caribbean region, as well as potential value-added uses. This contextual information is necessary to alleviate fears and misconceptions about sargassum and to encourage persons to adopt the most sustainable management practices"* (Hinds et al., 2016).
- Promote stakeholder engagement.

# Context and Scope of the Sargassum Invasion

## Regional Extent of the Issue

Massive strandings of pelagic sargassum have intermittently washed ashore the coastlines of the Caribbean, northern and central America, West Africa (Sierra Leone to the Gulf of Guinea) and the West Indies since 2011. Sargassum had not been reported in the majority of affected locations prior to that, and in fact 2011 was the first time drifting sargassum reached the African coast. In places, seaweed has piled up meters thick on shore. The 2011 peak sargassum biomass in the Caribbean was reported to be 200-fold higher than the previous eight years' average (Gavio et al, 2015). Similar events took place in 2012. The next wave of sargassum invasion took place in 2014/2015, with large amount of seaweed dumped on coastlines throughout the Caribbean. In late 2014, accounts were made of 3 to 4 feet high piles of beached seaweed, and the blooms continued throughout 2015. One estimate reported an average of 10,000 wet tons of seaweed dumped on beaches of the Caribbean islands daily (Milledge and Harvey, 2016). The year 2018 saw record-high sargassum blooms throughout the affected region, with accumulations estimated to be 33% higher than previous years (Mexican News Daily, 2018). Major infestations of sargassum were reported in Barbados, the Grenadines and Bonaire as early as February (Conover, 2018).

## Current Situation in the Dutch Caribbean

### Aruba:

the few bays located on Aruba have so far escaped the Sargassum influx as the currents and winds are offshore there. Deposited sargassum on the island's beaches is generally removed immediately with heavy machinery, regardless of the amount, notably in tourist areas. Little concern has so far been given to compacting and eroding impacts of this heavy machinery or the damage inflicted to sea turtle nesting beaches.

### Bonaire:

the island has been hit hard by sargassum strandings, especially the east coast where seaweed mats washed in and coated the coastline, including sand/rubble beaches (Lagun, Washikemba and Lac Sorobon area) and mangrove lagoons (Lagun and Lac) (STINAPA Bonaire). During the March 2018 sargassum invasion, the worst to date, the gases emitted by rotting sargassum reached concentrations known to cause health problems for people. After several episodes of sargassum influx this year (Lac Bay, Lagun – March and July 2018) and for the past several years (Lagun - June 2015, December 2017), these areas have experienced direct die-offs (fish, seagrass) and damage (mangroves). In Lac Bay, the March 2018 sargassum incident resulted in the death of thousands of fish, dead patches of seagrass, brown tide and large tracts of mangroves had their leaves turn yellow and fall off (STINAPA Bonaire). STINAPA Bonaire has organized massive clean-ups of Lac Bay with the help of volunteers, and is currently experimenting with booms. In 2018 a draft for a Civil Service Checklist (Ambtelijk Bestuurlijke Checklist (ABC Card)) has been made for emergency services (fire department, police, Area Health Authority and Public Entity): a detailed work plan on how to assist STINAPA Bonaire during a sargassum disaster including responsibilities and contact details. However, criteria on when a massive sargassum influx is qualified as a disaster and becomes the responsibility of the Public entity are not clear and urgently needed. Other missing information is an inventory of heavy equipment on island (type, name contractor) and identifying whether suitable or not and identifying sargassum disposal sites.

### Curaçao:

large quantities of sargassum have washed ashore on the island and impacted many of Curaçao's bays, including Shete Boka, Boka Ascensionm, Boka Mansalina, Boka Dejgu, Un Boka, and Dos Boka. In 2015, three neighborhoods had to close their windows due to the smell of the rotting sargassum. In 2018, the quantities of sargassum at Boka Ascension were so significant that the water in the bay was barely visible. Sea Turtle Conservation Curacao is currently experimenting with booms.

### Saba:

the impact has been limited as the coastline has few bays and is mostly made up of rocky shores.

### St. Eustatius:

a large influx of sargassum in 2015 resulted in some of the island's beaches being covered with a thick layer of sargassum, including sea turtle nesting beaches.

### St. Maarten:

sargassum first plagued St. Maarten in 2011 and 2012, with the Nature Foundation St. Maarten (NFSM) having to warn swimmers to avoid swimming in Guana Bay in August and September due to the large amount of sargassum weed, and many beachfront residences and hotels having to continuously clean washed up sargassum. In July 2018, the sargassum invasion resulted in a significant fish-die off event in the Oysterpond wetland. Residents of coastal communities started to experience adverse health effects due to gasses released by decomposing sargassum seaweed. Residents of Guana Bay and Pointe Blanche have requested that NFSM look into the matter.

## Future Prospects

According to Hinds et al. (2016), *"influxes of sargassum in the Caribbean since 2011 have so far shown considerable variation from year to year in the amount of seaweed and when and where it has been stranding throughout the region".* Sargassum is carried throughout the Caribbean region by a complex array of circulation ocean currents, notably the North Brazil Current System. Massive landings have affected different locations at different times of the year, making it difficult to predict which locations will be hit next. *"If there is any pattern to be detected to date (...continued from Hinds et al, 2016), it seems that the greatest influxes of sargassum have occurred from spring, through summer and into the fall months. Furthermore, the prevailing surface currents and winds have meant that some windward coastlines have experienced much higher volumes of stranded sargassum than the more protected leeward shores of Caribbean islands; and the windward coasts of Central America (Honduras, Belize, Mexico's Yucatan Peninsula) have been severely impacted by mass strandings of the seaweed. It is not certain whether the sargassum influx will occur every year. However, the fact that these events have recurred over the past four years have demonstrated to scientists and affected communities the need to understand the causes of these influxes, and to develop prediction, alert and management systems and local adaptation measures"* (Hinds et al., 2016).

The development of a regional early detection and monitoring system for sargassum strandings is of great importance. While it may not be possible to prevent the invasions from happening, prior knowledge of sargassum occurrence, magnitude and movement will help to-be impacted locations prepare for and respond appropriately to sargassum events. Several regional sargassum warning systems have been developed in the past few years based on satellite imagery. However, satellite images alone are not sufficient to determine the actual risk. On Bonaire, for example, Lagoon and Lac are hardly visible on satellite images due to their size, which makes predicting the large sargassum beds tricky. Extra information and help from e.g. coastguard, fishermen and aircraft could be helpful to determine if action has been taken or not.





### Regional sargassum warning systems:

- Sargassum Early Advisory System (SEAS): in the northwestern Gulf of Mexico, Texas A&M University at Galveston created the SEAS using LANDSAT satellites to track blooms nearing shore in an attempt to forewarn and prepare beach management efforts.
- Sargassum Watch System (SaWS): warning system, allowing to visually estimate sargassum aggregation and movement direction. This prediction gives at least two months of lead time to respond to beaching events.
- I-Sea and HydroCote forecasting device: allows monitoring of Sargassum at sea in the Caribbean. weekly watch of Sargassum beds at sea. They predict the 4-day trajectory of the banks approaching the islands and publish predicted groundwater stranding bulletins.
- CERMES sargassum outlook bulletin: the University of South Florida in collaboration with NASA disseminates a monthly bulletin entitled Outlook of 2018 Sargassum blooms in the Caribbean Sea. This bulletin provides a general outlook of current bloom condition and future bloom probability for the Caribbean Sea.
- The consortium Collecte Localisation Satellites- Nova Blue Environment (CLS-NBE) has been awarded a project with the ESA (European Space Agency) to implement an innovative service to monitor floating Sargassum algae in the Caribbean area. This project will allow using of synergy of Earth Observation imagery to detect drifting Sargassum rafts in the open sea: Sentinel-1, Sentinel-2, Sentinel-3 MODIS-Aqua. Sargassum index (FAI) is computed on all these sensor data and released every day.

# Partnerships

## Local Partnerships





*“Given the socio-ecological and economic implications of sargassum influxes, public and private sector partnerships can be very advantageous when seeking to manage and mitigate the unwelcome impacts. A good example is the Galveston Island Park Board of Trustees (a government entity overseeing tourism in Galveston) that teamed up with the Texas A&M University and beachside homeowner associations to agree on which beaches to clean, where access would be permitted and the best times and conditions for any beach cleaning. Collective action allows governments, businesses and communities to leverage their resources much more effectively. Teaming up with non-governmental organisations, charities, and local recycling centres is also great for disseminating information, assisting with environmentally safe clean-ups, and the responsible disposal of sargassum. Setting up a “Sargassum Task Force” is another strategy that has been used by several countries and has been effective in national level coordination efforts and in getting local communities involved” (Hinds et al., 2016).*

-  Establish a national coordinating body with key stakeholders and with the necessary resources.
-  Community engagement (business and tourism sector, non-governmental organizations, government agencies...)
-  Use existing communication channels to learn from and share information and experiences both locally and regionally.
-  Try to tackle the sargassum issue alone.



## National and Regional Partnerships

Inter-island and regional cooperation is key when dealing with the sargassum issue. A coordinated national response is especially needed, and lessons can be shared regionally e.g. by regional organizations such as GCFI, FAO and CRFM. Most responses within the region have so far been reactive and uncoordinated. There is an urgent need for better coordination of efforts and sharing of information. Since 2015 SPAW-RAC and SPAW UNEP Caribbean Environment Programme have worked to enhance cooperation around the region through: 1) the launch of an on-line forum/information platform to share regional information, experiences, management and research about the sargassum influx (email [sargassum.forum@gmail.com](mailto:sargassum.forum@gmail.com) to join); 2) networking, and 3) support of sargassum research. The collaboration of SPAW-RAC and SPAW Secretariat with other organizations of the region also recently led the preparation and circulation of a Sargassum management brief (Hinds et al, 2016) with the aim to assist stakeholders on how best to sustainably manage sargassum influxes (CAR-SPAW, 2018). The Gulf and Caribbean Fisheries Institute (GCFI) has also been at the forefront of sharing information about the pelagic sargassum influx within the Gulf of Mexico and Caribbean region. At the 71st GCFI Conference in Colombia in November 2018, new developments in research, monitoring and adaptation to the sargassum influx were presented.

-  Share best practices and lessons learned in removal efforts (equipment, methods) to build regional capacity and develop region-wide best management practices.
-  Share ideas on how collected sargassum is being stored and used locally.
-  Collaborate with regional institutions to consolidate regional efforts and garner external funds (Hinds et al., 2016).
-  Try to tackle the sargassum issue alone (Hinds et al., 2016).

# Clean-up and Disposal of Sargassum from Bay Ecosystems

## When To Take Action

According to Hinds et al. (2016), *“the most sustainable practice is almost always to let nature be. If sargassum washes ashore in small quantities or inaccessible, non-tourist or non-critical locations, it is generally preferable to leave the seaweed where it is. This has proven to be the simplest and least costly approach, and has the added benefits of potentially nourishing beaches and stabilizing the shoreline. During decomposition of large amounts of weed there will inevitably be a smell and insects around; but, experience in locations that have left the sargassum on the beach is that it will eventually get washed away, buried by the next high waves, or sun dried, eliminating the smell”*. There are however a number of scenarios which require immediate action in removing sargassum, which are listed below. Individual locations must clearly define which areas are most at risk from the long-term accumulation of the seaweed, and prioritize these areas for cleanup efforts. For example, seafloor covered in rubble should be given a lower priority than a coral reef with high coral cover.

- Sargassum influx into areas that have high ecological value and where large amounts of sargassum can have a negative impact. This is especially the case for sea turtle nesting beaches, or fragile ecosystems like seagrass beds and mangroves.
- Areas where hydrogen sulfide released by decomposing sargassum can put at risk the health of the community.
- When floating sargassum blocks important access to and from harbors, preventing the deployment of fishing vessels.
- When large amounts of sargassum (mass strandings) wash onto coastlines, removal must take place as soon as possible to limit the accumulation of seaweed.

## Best Practices

*“It is important to understand that there is no ‘one size fits all’ solution to managing sargassum influxes. Different management approaches will work best in different situations and locations, depending on factors such as the biomass of sargassum, accessibility of the affected shoreline, whether the area is ecologically sensitive, important for tourism or fishing, or whether it is adjacent to a coastal community or coastal industry. Other factors such as the legislation and institutional arrangements, stakeholder capacity for self-help, and available funds will also influence the approach taken. In fact, management strategies may have to be modified or combined in order to achieve an optimal outcome. When removal of mass sargassum inundations is deemed absolutely necessary, it may be collected either onshore or in the water along the shoreline”* (Hinds et al., 2016). There are no permit requirements regarding the harvesting of sargassum for the BES islands, so there is a special need for adherence to best practices in order to avoid possible negative impacts of insensitive beach cleaning or in-water removal practices. *“Note that it is not necessary nor desirable to clean-up all of the sargassum or to clean the entire beach. Only clean up the worst of the seaweed, leaving small amounts behind, and only clean some sections of larger beaches as needed to support essential local activity”* (Hinds et al., 2016).

What we present in the next sections are guidelines for the removal and disposal of sargassum that can be adapted to local circumstances based on experiences around the Wider Caribbean region to date. Removing sargassum will help minimize the seaweed's negative impacts on coastal ecosystems but can bring its own set of issues such as erosion. We recognize like Hinds et al. (2016) that further research still needs to be carried out on some management methods to determine the best approach for specific local conditions. This is an emerging issue in the Caribbean that requires further research and development.

## In-Water Collection Close to Shore

According to Hinds et al. (2016), *“where possible and permitted, it is generally agreed that in-water collection very close to shore is often preferable to beach collection. This approach avoids removal of sand and damage to coastal vegetation, and may also prevent sargassum from rotting in the water. In-water collection is ideal for small semi- enclosed bays, lagoons, marinas and ports where the water is calm. It can be a lot more difficult or impossible where there is significant surf, swell or currents”* (CERMES/GCFI/ SPAW Management Brief, 2016). The storage and disposal of sargassum must take place on shore, as shallow currents and sargassum weight prevents storage on floating performs.

- ✓ Let nature run its course in inaccessible areas or when the volume of weed is small.
- ✓ If removal is necessary, collect sargassum directly from the water along the shoreline to prevent it sinking and/or stranding, and to avoid removal of sand.
- ✓ In-water collection must be done with a clear set of guidelines so that marine life is not disturbed.
- ✓ Always check for marine species, especially trapped turtles.
- ✓ Special care should be taken when removing sargassum from sea turtle nesting beaches as hatchlings leaving the beach “will hide and remain in the weed” (Hinds et al, 2016).
- ✓ Vessel used for removal efforts must have a collection mat or pump and storage capacity.
- ✓ Sargassum in shallow waters can be removed *“using reinforced fishing nets – either toed by light boats or by hand in very shallow waters. On Isla Bonita, Belize, volunteers devised a unique method of using a seine net to harvest the floating sargassum out of the water”* (Hinds et al, 2016).
- ✓ Make sure all users of the waters being cleaned are alerted/and or involved with cleanup efforts.

The ideal machine to remove sargassum does not yet exist. Some current options include dredge or pumping on barges with a flat bottom and low draft collection conveyor. Dirty water suction pumps operated from a boat can help remove sargassum from the water. A boat with a conveyor belt can be useful in difficult to reach mangrove areas. If conveyor belts and suction pumps don't work, loaders with sieves and large tires may be used to remove seaweed from shallow water (STINAPA, unpublished to date). A number of methods and specialized equipment have been developed and tested for in water removal throughout the Wider Caribbean, but these methods are typically being operated in a way that is insensitive to the occurrence of juvenile fish and protected species such as sea turtles in the sargassum. Wildlife observers are needed in conjunction with in-water collection in order to find and return such wildlife to the sea with some sargassum for habitat.

- A company in Guadeloupe created the “Sargator”, a specialized barge outfitted with a treadmill capable of harvesting 6 tons of algae per hour. This interesting initiative however has its limitations as it can only be used in calm waters.
- In Mexico, the Sarganeitor machine has been used to clean up sargassum at sea but it is very expensive. The machine was originally designed to clean up vegetation in inland waterways.
- In Ambergris Caye (Belize), the team at Captain Shark’s Boatyard has built a prototype of a Sargasso skimmer to remove the seaweed from the water more easily and efficiently. The machine includes a set of rubber floating booms which guide the sargassum to the skimmer’s tooth conveyor belt. The seaweed is picked up by the belt, dropped into bins and removed by trucks. The machine was tested in August and performed well but improvements are needed.
- *“The Mexican Navy has used powerful hydraulic suction pumps to extract sargassum directly from the water nearshore and pump it straight into waiting trucks. This technology has also utilized floating booms to help funnel the sargassum towards the pumps”* (Hinds et al, 2016).
- *“A local company in Barbados demonstrated that ponies or horses can be used to pull seaweed traps in the surf to gather up the sargassum”* (Hinds et al, 2016).

## Collection At Sea

Collection of sargassum in the open ocean is not recommended. Not only is the open sea not conducive to collection due to swells and currents, but there is concern that this would remove the ecological value of sargassum at sea and endanger the species associated with the seaweed rafts. According to Hinds et al. (2016), *“by the time the sargassum rafts are very close to stranding, the majority of associated organisms have already abandoned the raft, or wash ashore”* (Hinds et al., 2016). Care can be taken to ensure that protected species such as sea turtles that strand with sargassum are collected and released at sea into sargassum that is drifting offshore.

## Deflecting Sargassum: Containment Booms





Removing sargassum from fragile coastal ecosystems such as mangroves and seagrass beds is not only tricky but also expensive as it requires the use of specialized equipment. According to Hinds et al. (2016), one strategy to minimize the amount of seaweed reaching shore and accumulating in the shallows is *“to divert sargassum away from sensitive areas or to funnel the weed into a nearshore collection area through the use of containment booms”*. The containment booms used to help deviate seaweed are temporary floating barriers such as the ones used to contain oil spills. They are lightweight, typically foam-filled and quick to install. Hinds et al. (2016), recommend that a set of small booms *“be linked together to maximize flexibility, allow for ease of deployment and maintenance, as well as the transport to new locations as required”*. The booms must be placed in such a way that boats can access the open sea. They also must be anchored, either temporarily with small anchors or permanently with small helix moorings, and must be marked with buoys for safety. It is important that a clear plan of where the sargassum will be directed to and how it will be collected is set up before the deployment of booms. Visual monitoring of the collected sargassum must be maintained in order to free any live trapped creatures (e.g. sea turtle hatchlings, eels and other fishes and invertebrates) (Hinds et al, 2016). Because containment booms can be very expensive, and because they can break under the weight of sargassum and have negative impacts on marine wildlife, some communities have used fishing nets instead to deflect sargassum. Other issues with the use of booms include maintenance cost, stability during storms and habitat damage if they break free. The results of using booms to prevent sargassum reaching shores have been mixed. It is vital that communities who decide to install booms consider coastal dynamics. As sargassum moves in longshore drift, the use of booms can result in the full load of sargassum deflected onto communities further along the coast who cannot afford to install a boom.

Table 1: Main advantages and disadvantages of sargassum prevention in the seagrass beds and mangroves of Lac Bay, Bonaire (e.g. with use of booms) and clean-up without use of booms (STINAPA, 2018)

Item	Prevention	Cleanup w/o use of booms, special equipment
Costs	Cost of deployment of booms, specialized machinery, supervision	Heavy machinery, 1000's of staff and volunteer hours – labor intensive
Beach	No erosion	Erosion
Mangroves	No impact	Potential severe impact
Mangroves: indirect	No impact	Loss of filtering capacity, shore-line protection, nursery function, carbon sequestration
Seagrass beds	No impact	Severe impact versus loss
Seagrass beds: indirect	No impact	Loss of sand stabilization, filtering capacity (clear water, pathogens), carbon sequestration
Human health	None	H2S gas hazard
Beach tourism Sorobon	Minimal impact	High impact
Windsurfing at Lac	May be inconvenienced	Impact
Fauna (interstitial, seagrass beds, mangroves)	May be saved – only affected at extraction points	High mortality
Removal of Sargassum	Controlled in one area	Only a few accessible areas, many inaccessible areas
Compost	Sargassum without sand may be used for compost	High sand content bad for decomposition
Risk	Unsupervised booms may end up on down-wind side of area or be damaged	Loss of mangroves, seagrass beds, sea life in general

## Collection from Beaches

According to Hinds et al. (2016), *“removal can either be manual or mechanized, depending on the frequency and amplitude of strandings, the volume and depth of seaweed, availability of manpower and equipment, beach access and sensitivity of the beach to erosion and presence of wildlife like seabirds and nesting turtles or hatchlings”* (CERMES/GCFI/SPAW Management Brief, 2016). Due to the potential for damage of the beach’s natural environment, especially fragile beach vegetation and sea turtle nests, the least intrusive method should always be favored. Harvesting must be well coordinated and managed with a clear set of rules to follow so as to minimize erosion and disturbance to marine life. In case of mass strandings, *“sargassum should be removed as soon as possible after arrival to avoid vast accumulations of the seaweed along the tideline which decomposes and serves to trap more weed in the water and form dark brown plumes nearshore. Based on the scale of mass inundations witnessed in the Caribbean over the last few years, it is essential to prioritize which beaches will be cleaned and which will be left in a natural state”*. GCFI has developed of a poster on best practices for cleaning sargassum from beaches. The poster is geared towards a range of stakeholders including the tourism industry and coastal zone managers, and can be downloaded online from <https://www.gcfi.org/sargassum-influx/>

-  *“If sargassum washes ashore in small quantities or in inaccessible, non-tourist or non-critical locations, it is generally preferable to leave the seaweed where it is.”*
-  In case of mass strandings, sargassum should be removed as soon as possible after arrival to avoid vast accumulations of the seaweed along the tideline which decomposes and serves to trap more weed in the water and form dark brown plumes nearshore.
-  *“Prioritize which beaches will be cleaned and which will be left in a natural state (Hinds et al., 2016)”*.
-  Harvesting must be well coordinated and managed with a clear set of rules to follow so as to minimize erosion and disturbance to marine life.

## Manual Cleanup

According to Hinds et al. (2016), “where the volume of sargassum is relatively small, manual removal (e.g. hand raking) is preferable because it is less intrusive and reduces the likelihood of disturbing sea turtle nests and contributing to beach erosion. Furthermore, manual removal can take place in a variety of locations such as sandy beaches, pebble beaches, and beaches with limited vehicular access, and in the presence of other beach goers. Organized beach clean-ups are a good way to get communities involved in tackling the problem, and can help reduce labor costs” (CERMES/GCFI/SPAW Management Brief, 2016).

- ✓ The use of forks or rakes can help reduce the amount of sand removed while cleaning up sargassum. Staff at Algas Organics in St. Lucia use specially designed forks with the teeth facing upwards to clean beaches and minimize damage.
- ✓ Always check for wildlife and avoid sea turtle and bird nests.
- ✓ Seaweed must be removed quickly before it decomposes and poses a health risk to workers.
- ✓ Adequate storage and/or disposal of the collected seaweed must be organized.
- ✓ Wheelbarrows and bags can be used to transport collected sargassum. Another option is to pile it onto tarpaulins and drag it (Hinds et al, 2016).
- ✓ Extra care must be taken to avoid trampling beach vegetation.
- ✗ Manual cleaning requires a large number of staff/volunteers and is strenuous work and is therefore not an option for mass strandings.
- ✗ Chemicals that can kill wildlife should never be used to dispose of sargassum.

Green brigades have been created in Martinique and Guadeloupe to collect sargassum manually on beaches that have a high ecological value. The workers are paid at 90% by the state. Workers are equipped with gloves, masks and boots. They use spades and rakes to collect seaweed, and take it away in wheelbarrows. However, the use of heavy machinery is required when the sargassum layer is too thick (Guadeloupe Dpt of Env't, Land Planning and Housing, 2015).



## Mechanized Cleanup

While manual cleanup is a preferable option, some situations such as mass strandings will require the use of mechanical equipment. When using machinery, the most suitable type with the least impact on the beach and wildlife should be chosen. Using mechanical vehicles on a regular basis can wreak havoc on sandy beaches.

- ✓ Reduce environmental impact: staff must be trained in wildlife monitoring and check for live creatures before commencing removal activities.
- ✓ Reduce environmental impact: avoid sea turtle and bird nests.
- ✗ Chemicals that can kill wildlife should never be used to dispose of sargassum.
- ✓ Reduce environmental impact: do not use equipment that can cause significant removal of sand as this results in beach erosion. This includes heavy tracked equipment like road grader, tractors or backhoes with caterpillar tracks and buckets that gouge the beach and remove large quantities of sand with the sargassum. If only this equipment is available, use claw buckets to reduce the impact on the beach.
- ✓ Favor machines with low bearing capacity, soft low pressure tires and a claw or a harrow to pick up the less possible sand. According to Hinds et al. (2016), "this will help prevent compaction of the sand, destruction of vegetation, formation of deep ruts and ultimately, beach erosion. Mechanical beach rakes with a perforated conveyor belt and soft tires have been found to be effective and work best with moderate quantities of weed and on beaches with low relief and easy access". In Bermuda, beach tractors that drag large rakes behind them are used. In Galveston Island State Park (USA), a "surf rake" machine collects seaweed on a conveyor belt that allows excess grains of sand to fall back down to the beach.
- ✓ Front loaders must utilize a bucket-level control indicator to prevent gouging of the beach.
- ✓ Avoid mechanical beach cleaning in the presence of fishers or beach-goers to ensure public safety.
- ✓ Only operate machinery on wet sand in the inter-tidal zone of the beach.
- ✓ To reduce damage to the beach, heavy equipment should be maneuvered only on agreed pathways.
- ✓ Reduce the maneuvering of machinery to limit eroding and compacting impacts on the beach.
- ✓ "Adequate storage and/or disposal of the collected seaweed must be organized" (Hinds et al., 2016).



Large accumulations of seaweed along the shoreline requires a combination of removal methods where different equipment is used to remove the top and bottom layers of seaweed. After using machinery to remove large amounts from the top layer, a mechanized rake or manual removal can be used to collect the rest so as to minimize the amount of sand removed. *“In the French Antilles they have experimented successfully with using cane loaders to pick up large quantities of sargassum prior to clearing with a mechanized beach rake”* (Hinds et al., 2016).

**Table 2: Main advantages and disadvantages of different mechanized beach collection techniques (adapted from SIPS, ADEME and DEAL 972, 2018)**

	Main Advantages	Main Disadvantages
<b>Public Works Machinery (e.g. tractor, digger, excavator)</b>	<ul style="list-style-type: none"> <li>• Available</li> <li>• High efficiency</li> <li>• Effective for massive strandings</li> </ul>	<ul style="list-style-type: none"> <li>• Sand catch and packing.</li> <li>• Damage to the coastline. Can cause much erosion, destroy dunes and destroy turtle and bird nests.</li> <li>• Must plan rigorous maintenance.</li> </ul>
<b>Beach Grooming Equipment</b>	<ul style="list-style-type: none"> <li>• Low sand intake</li> </ul>	<ul style="list-style-type: none"> <li>• Low capacity</li> <li>• In case of mass strandings, the experience from several places, notably Galveston (US), has been to use the equipment in a phased manner: large machinery with scoops/claws is first used to pickup sargassum without touching sand; when there is a manageable amount of sargassum left on the beach, the beach grooming equipment is then used.</li> <li>• Several passages necessary</li> </ul>
<b>Self-propelled collection machine (Sargassum cleanup harvester vehicle prototype AXINOR)</b> Rehabilitated agricultural vehicle with combs mounted on a treadmill and located at the front of the vehicle. Harvested algae then transported via conveyors to the storage bin equipped the vehicle.	<ul style="list-style-type: none"> <li>• Low environmental impact as selective collection tool, low sand intake.</li> <li>• Able to unload alone in the bucket</li> <li>• Able to work in shallow water</li> <li>• Easy movement on the beach via the use of low pressure tires and high volume</li> </ul>	<ul style="list-style-type: none"> <li>• Size of gear restricts its use to accessible and stable beaches</li> <li>• Must adapt driving according to each stranding, otherwise jamming risk</li> <li>• Undifferentiated collection of algae and waste (plastics ...)</li> <li>• Risk of crushing turtle nests in traffic case on the beach top</li> </ul>

## Safety of Workers

The release of hydrogen sulfide (H<sub>2</sub>S) by decomposing sargassum and its potential health impacts on workers and/or volunteers that clean up the impacted zones must absolutely be monitored and managed. Not only should collection take place as quickly as possible after each stranding (preferably within 48 hours), but workers should be equipped with hydrogen sulfide portable meters to ensure that H<sub>2</sub>S levels stay within healthy limits.

The minimal detectable concentration of H<sub>2</sub>S is 0.05ppm and this level can be used as a warning signal. Workers collecting rotting algae should always be equipped with masks. These masks must be worn when H<sub>2</sub>S levels reach 5 ppm. When levels reach 10 ppm, the impacted area must be evacuated. Workers who operate heavy machinery must also have hydrogen sulfide detectors within the vehicle's cabin. Other recommendations to ensure the safety of workers include personal protective equipment and training in safe practices. If communities cannot afford or obtain hydrogen sulfide portable meters, the smell released by decomposing sargassum can be used as an indicator of harmful effects. According to the US Occupational Safety and Health Administration, the rotten egg smell becomes first noticeable at a concentration of 1.5ppm. The odor becomes much more noticeable at a concentration of 3-5ppm, and above 30ppm, "*the odor is described as sweet or sickeningly sweet*" (OSHA, retrieved from <https://www.osha.gov/SLTC/hydrogensulfide/hazards.html>).

## Disposal of Collected Sargassum

What to do with the collected sargassum is a significant challenge, especially as decomposing sargassum releases toxic hydrogen sulfide which is harmful to humans as well as marine and coastal ecosystems. Currently, most of the sargassum collected throughout the Caribbean is stored, with a significant amount then spread on dedicated land. Because transport is an important cost of sargassum collection, it is important that storage sites are erected close to collection sites. These storage sites must be carefully monitored to ensure that their environmental impact on surrounding areas, such as soil contamination, is well understood. Dehydration/compaction can help reduce seaweed volume and make storage easier.

### Burying and Spreading Sargassum

The overall consensus to date is that burying the collected sargassum is not a good idea as this will turn sand beaches into slime-like dirt. It can also negatively impact sea-turtle nesting by changing the organic composition of the sand. However, if the beach is large and the amount collected small, the seaweed can be buried further up the beach or in the dunes. In low enough volumes sargassum will fertilize beach vegetation and help combat beach erosion. If spread, it is vital that the sargassum be spread in a thin layer – approximately 10 cm thick – to allow the seaweed to oxidize and therefore prevent the release of hydrogen sulfur. Sargassum should never be piled up, and the spreading zone must be far from ecologically valuable areas.

## Sargassum Uses

Given the myriad problems associated with stranded sargassum, Hinds et al. (2016) note that *“there is a need to sustainably manage the seaweed and reduce management costs. Research and experimentation to date have revealed a number of potential value-added uses of sargassum”*, although further research is needed to identify and develop viable commercial uses of the algae that will offset the economic impact of the strandings. Some of the current developments in the use of sargassum are listed below:

- **Biostimulant:** sargassum contains important plant nutrients such as potassium and phosphates, making it a promising biostimulant. The seaweed has also been found to optimize the nutrient uptake of plants by promoting strong root development. The high salt content of the seaweed is however an issue as it can result in soil salinity if not washed out. Removing this excess salt is not only expensive and time consuming but it may wash out key nutrients. In St. Lucia, Algas Organics has successfully created the Algae Total Plant Tonic, a natural bio-stimulant made from collected sargassum. In partnership with the Saint Lucia Fisher Folk Cooperative Society Ltd, the company has to date removed over 300 tons of seaweed from the beaches in eastern St. Lucia. Six local community members have been trained in harvesting and drying techniques, as well as processing, packaging, and quality control. The product was recently introduced to Barbados.
- **Biosorbent for removal of heavy metals in polluted water.**
- **Take-away containers for food and drinks** possibly in combination with cassava starch and banana fiber (Dominican Republic)
- **Charcoal briquettes:** sargassum can be ground into a powder and mixed with other carbon sources to produce charcoal briquettes.
- **Adobe bricks for construction of houses:** in Quitana Roo, Mexico, a house was recently constructed entirely from sargassum. Sargassum bricks are a brown-reddish color, do not smell and cost 50% less than usual adobe bricks.
- **Charcoal briquettes:** sargassum soap is now produced by Oasis Laboratory in Barbados.
- **Other uses currently being studied:** chemical compounds for pharmaceuticals/food supplements, biofuel and bioplastics.









According to Hinds et al. (2016), "*considerable research and development is still needed to commercialize the products and to ensure economic viability under an uncertain supply of the raw material*". Some of the issues with the use of sargassum include:

- *"Use of sargassum for consumptive purposes will require careful biochemical analysis to determine the local levels of possible contaminants. Given the strong biosorbent properties of the seaweed, it can absorb heavy metals and other pollutants depending on where it has travelled"* (Hinds et al., 2016).
- The transportation and pre-treatment of sargassum can be very expensive.
- The high concentration of arsenic in sargassum excludes use for animal or human nutrition and necessitates meticulous control of emitted gases.
- Seasonality of strandings means that methods to preserve sargassum must be developed to ensure reliable and continuous supply.
- The strong salt content of sargassum means that there is risk of soil salinization if not well cleaned.

# Outreach and Education

## Stakeholder Participation

Stakeholder engagement and continued collaboration with affected stakeholders is absolutely vital to ensure the continued success and support of clean-up initiatives. Meeting the wide range of needs and interests of different coastal users, from tourists to fishermen, must be central to management decisions and will foster engagement. Each stakeholder group affected by the sargassum invasion will have distinct issues, concerns and questions. Communication methods and materials used must therefore be targeted to these specific needs. When possible, stakeholders should be consulted directly so that concerns may be addressed while taking into account local expertise and opinions. This will also help gather feedback on key decisions that will impact them, past clean-up activities and gauge the level of involvement desired. Consultations can take the form of meetings and presentations or through individual communication. Community outreach and education should take place prior, during and after sargassum cleanup activities to ensure awareness, understanding and support of actions.

-  Reduce environmental impact: staff must be trained in wildlife monitoring and check for live creatures before commencing removal activities.
-  Reduce environmental impact: avoid sea turtle and bird nests.
-  Communicate accurate, easy to understand information on sargassum.
-  Suggest tangible voluntary activities to usefully engage public participation.
-  Inform stakeholders about relevant regulations.
-  Share examples of adaptation measures
-  Involve the youth in environmental education about sargassum
-  Leave the public in the dark or put out misinformation.

While communication methods will vary depending on a wide range of factors such as location, infrastructure, available media outlets, some suggested targeted communication methods include:

- Distribute “Frequently Asked Questions” factsheet about sargassum and its various impacts, as well as other informational material, in key tourist locations as well as popular local spots such as the local post office and supermarket.
- Make public announcements on current sargassum volume and which beaches are open for recreation on the local radio and TV as well as popular social media platforms.
- Keep up to date website with updates on seagrass volume and hydrogen sulfide level.
- For beaches that are closed due to large sargassum volume, a sign should be placed which concisely explains why the beach is closed.
- In case of mass strandings, set up a telephone hotline with information on current sargassum volume and hydrogen sulfide level.

## Overview of Frequently Asked Questions

The following section provides up-to-date information to help answer the most frequently asked questions by the public and help ensure that they receive relevant and reliable information about the periodic influxes of sargassum.

### What is Sargassum?

Sargassum is a brown marine algae (seaweed) that typically floats on the ocean surface. It is made up of leafy appendages, branches and round, berry-like structures filled with gas (mostly oxygen) that aid in buoyancy. There are many Sargassum species in tropical and subtropical waters, but only two species that are holopelagic: *Sargassum fluitans* and *Sargassum natans*. These species are subdivided into several morphological forms (Winge 1923, Parr 1939). Forms most recently observed in Caribbean, Sargasso Sea, and West African waters are *Sargassum natans* (Common Gulfweed; delicate fine leaf structure, smooth stem, (*S. natans* I and *S. natans* VIII)) and *Sargassum fluitans* (Broad-toothed Gulfweed - large lance like leaves, “thorns”, (*S. fluitans* III)) (Schell et al. 2015; Whittaker et al., 2018). While most sargassum species are benthic - anchored to the ocean floor by a root-like structure - *S.natans* and *S.fluitans* - are pelagic throughout their entire life cycle. This means that they never attach to the ocean floor but typically grow into large, dense mats - some as large as football fields - in the open ocean. Small sections of these mats are carried away by winds and ocean currents and are washed onshore coastlines throughout the Atlantic. Sargassum species blossom naturally in the Sargasso Sea, a large subtropical circular stream (gyre) off the eastern coast of the United States, which is estimated to hold up to 10 million metric tons of sargassum.

### Why does Sargassum receive protection in parts of the Atlantic?

The United States has designated floating mats of sargassum as 'Essential Fish Habitats' which are managed by a Fishery Management Plan. The mats also receive special conservation attention within the Sargasso Sea by members of the newly formed international Sargasso Sea Commission. A number of countries in the Caribbean, such as Bermuda and the Cayman Islands, also offer legal protection of sargassum for its importance as a habitat.

- Value at sea: mats of sargassum in the open ocean form rich pelagic ecosystems which provide critical habitats for a diverse assemblage of marine species including commercially important fish species, marine invertebrates, sea turtles and migratory mammal species such as whales. The mats offer rich foraging grounds. Smaller, non-benthic fauna live permanently on the rafts, while benthic mobile species like crabs, shrimp, snails live there temporarily. Certain species, notably newly fledged sea turtles, use the rafts as a temporary shelter from predators. Passing seabirds such as terns and boobies also use sargassum mats to rest and forage. Ten fish and invertebrate taxa are currently considered endemic to Sargassum, including the sargassum anglerfish (*Histrio histrio*), Sargassum frogfish and Sargassum pipefish.
- Value on shore: naturally beached Sargassum offers shorebirds and beach fauna a rich source of food. It also helps reduce coastal erosion by helping bind sand, and provides nutrients for beach and dune plants.

### Why is so much Sargassum washing onto Caribbean shores?

Prior to 2011, small quantities of free-floating Sargassum drifted at irregular intervals from the Sargasso Sea into the Caribbean Sea. Recent studies have found that the unprecedented influx of Sargassum onto Caribbean shores does not originate from the Sargasso Sea but rather from a region located off the northeast of Brazil, in the North Equatorial Recirculation Region (NERR) of the Atlantic Ocean. The complex array of circulating currents in the area then carries mats of floating seaweed to Central America, the Caribbean and the northwest African coastline. The verdict is still out as to what exactly triggered the creation of this new "small Sargasso Sea" in the NERR, however scientists have put forward a number of probable factors to explain anomalous quantities of sargassum in the region, all of which are anthropogenic:

- Global climate change and associated warming ocean surface temperatures, changes in ocean currents and winds: research suggests that warmer waters stimulate the growth of Sargassum considerably and unusual patterns of winds and ocean-surface circulation are related to the mass beachings.
- Increase nutrient load: the waters of the three large equatorial rivers that drain into the tropical Atlantic (Orinoco, Amazon, Congo) now have very high levels of nutrients as a result of an increase in industrial/urban pollution as well as agricultural run-off caused by widespread deforestation. These nutrient-rich waters then enter the Atlantic and stimulate the overproduction of seagrass.



### Why is the influx of stranded sargassum cause for concern?

Sargassum rafts form a very important ecosystem in the open ocean and can even be beneficial when washed ashore in small quantities. However, the recent influxes of sargassum in the Caribbean are threatening fragile and endangered coastal ecosystems such as mangroves and seagrass beds as well as significantly disrupting the livelihoods of communities, especially those associated with the tourism and fishing sectors. Decaying sargassum trapped along the waterline are a threat to the health of critical and already threatened ecosystems such as coral reefs due to the low oxygen content and high levels of nutrients, light interception and release of hydrogen sulfide. If the influxes become a recurrent occurrence, near-shore ecosystems will be put under much stress with detrimental consequences for coastal stability and other ecosystem services. The 2017 sargassum influx in Mexico caused a massive die-off of seagrass beds, with increase in epiphytes and calcareous algae, and near-shore hard corals growing in these seagrass meadows suffered total or partial mortality. The main threats are listed below.

#### Biodiversity

**Formation of anoxic zones** (low oxygen conditions) when sargassum is trapped in bays and decomposes in large quantities, leading to massive fish die-off. Resulting anoxic sediments threaten survival of trees, function and structure of mangrove forests.

**Eutrophication:** high levels of nutrients (nitrogen, and phosphorus) are brought into coastal ecosystems by drifting sargassum. The accumulation of sargassum near the shoreline leads to so-called brown tides, murky, turbid brown waters with high loads of organic material. Release of hydrogen sulfide: Poisonous hydrogen sulphide gas is released by decomposing sargassum, which is hazardous to most marine animals. Other compounds such as heavy metals may also be released.

**Reduced light penetration:** large quantities of stagnant sargassum restricts the light that reaches corals and seagrasses. This can lead to the mortality of these benthic organisms as they require light for photosynthesis.

**Indirect competition with native biota:** floating sargassum can monopolize space where native species typically grow, as well as harbor invasive species.

**Entangled marine life:** if sargassum is too dense, marine life such as dolphins and turtles can become entangled and trapped when trying to reach the ocean surface.

**Hindrance to Sea Turtle Nesting:** when thick layers of sargassum cover turtle nesting beaches, this can prevent females from reaching their nesting grounds. Hatchlings can also have great trouble pass passing over dense tangled seaweed mats.

## Health

**Release of hydrogen sulfide:** decomposing sargassum can be hazardous to human health with the release of the toxic colorless gas hydrogen sulfide. Effects depend on how much is inhaled and for how long. Groups most at risk are persons with respiratory problems, elderly people, babies and pregnant women

- Concentration of 1 to 10 ppm: common effects include eye irritation, headaches, nausea, shortness of breath. Access not recommended for sensitive people.
- Concentration of 50 ppm or less:
- Concentration of 100 ppm or more: effects can be life-threatening and include shock, convulsions, inability to breathe, coma and even death.

*In Guadeloupe, 22 hydrogen sulfide sensors will soon be deployed to issue daily bulletins for local communities. All data will be posted on an open data and participatory website.*

## Fishing

**Impedes the operation of fishing vessels:** large mats of sargassum damage fishing gear as well as boat propellers and engines. They also make boat launching and maneuvering difficult, and prevent the deployment/retrieval of fishing gear.

**Changes in fish community:** there have been reports of changes in catch composition in areas with large influxes of sargassum.

## Tourism

**Popular tourist beaches no longer desirable:** piles of stranded sargassum significantly reduce the attractiveness of popular tourist beaches, especially when associated with entrapped litter such as plastics and hazardous medical wastes.

**Foul smell of decaying sargassum:** often described as “rotten eggs”, the smell along the shoreline along with associated biting sand fleas has led tourists to cancel hotel and restaurant reservations. The smell may in part be attributed to the presence of dead and dying organisms caught within the rafts

**Disturbance of watersport activities:** Piles of beached sargassum restrict access to the beach and water, make swimming difficult and prevents boats from leaving the harbor.

**Damage to hotels and restaurants:** prolonged exposure to hydrogen sulfide causes the oxidation of metals and therefore damages electronics and appliances, including air conditioning units and TVs. It also tarnishes metals and discolors paint in affected areas.

*A recent study by Charles et al. (CERMES, 2018) found that tourists in Barbados are willing to pay an average of \$20 to assist in the management of sargassum, and that they are willing to drive an average of 10-15mins from where they are staying to find a clean beach – indicating that not all beaches need to be cleaned.*

The recent and unprecedented influx of sargassum in the Caribbean is a serious and challenging new environmental crisis for a region that has already suffered from many setbacks over the past decades. Pollution, overfishing and coastal development, to name a few, have led to severe impacts on coastal biomes including fragile ecosystems such as coral reefs, mangroves and seagrass beds. While there is still much to learn about how large amounts of seaweed affects different locations in the Caribbean, what we do know so far is incredibly worrying and highlights the need for immediate and widespread action. Our goal with this management brief was to offer some guidance to local communities on how to best approach the sargassum invasion, keeping in mind that no real solution has yet been found. New removal techniques are currently being tested in several locations in the Caribbean, and new partnerships are emerging between different island nations affected by the seaweed invasion. Continued national and regional partnerships will be central to the success of future initiatives to tackle the issue and find the best solutions available.

## References

Anses (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail). 2017. Expositions aux émanations d'algues sargasses en décomposition aux Antilles et en Guyane. Rapport d'expertise collective, mars 2017.

Caribbean Agricultural Research and Development Institute (CARDI). 2015. Sargassum Seaweed and its use in crop and livestock production: possible agri-business opportunities. Policy Brief Issue 01, September 2015.

Caribbean Hotel and Tourism Association (CAST). 2015. Sargassum: A Resource Guide for the Caribbean. pp. 14.

CAR-SPAW-CAR. 2018. Regional cooperation on the Sargassum issue. Retrieved from: <http://www.car-spaw-rac.org/?Regional-cooperation,654>.

Djakouré, S., Araujo, M., Hounsou-Gbo, A., Noriega, C. & Bourlès, B. 2017. On the potential causes of the recent Pelagic Sargassum blooms events in the tropical North Atlantic Ocean. *Biogeosciences Discussions*, pp. 1-20.

Doyle, E. & Franks, J. 2015. Sargassum Fact Sheet. Gulf and Caribbean Fisheries Institute.

Eggertsen, L., Ferreira, C., Fontoura, L., Kautsky, N., Gullström, M. & Berkström, C. 2017. Seaweed beds support more juvenile reef fish than seagrass beds: Carrying capacity in a south-western Atlantic tropical seascape. *Estuarine, Coastal and Shelf Science*. 196. 10.1016/j.ecss.2017.06.041.

Franks, J.S., Johnson, D. & Ko, D. 2016. Pelagic Sargassum in the Tropical North Atlantic. *Gulf and Caribbean Research*. 27.

Gavio, B., Rincon-Díaz, N. & Santos-Martínez, A. 2015. Massive quantities of pelagic Sargassum on the shores of San Andres Island, Southwestern Caribbean. *Acta Biologica Colombiana*. 20. pp 239-241.

Gavio, B. & Santos-Martínez, A. 2018. Floating Sargassum in Serranilla Bank, Caribbean Colombia, may jeopardize the race to the ocean of baby sea turtles. *Acta Biológica Colombiana*. 23. pp 311-313.

Hinds, C., Oxenford, H., Cumberbatch, J., Fardin, F., Doyle, E. & Cashman, A. 2016. Sargassum Management Brief - Golden Tides: Management Best Practices for Influxes of Sargassum in the Caribbean with a focus on clean-up. CERMES UWI, CAR-SPAW-RAC and GCFI.

Johnson, D., Ko, D.S., Franks, J.S., Moreno, P. & Sanchez-Rubio, G. 2012. The Sargassum Invasion of the Eastern Caribbean and Dynamics of the Equatorial North Atlantic.

Louime, C., Fortune, J. & Gervais, G. 2017. Sargassum Invasion of Coastal Environments: A Growing Concern. *American journal of environmental sciences*. 13. pp 58-64.

Maréchal, JP., Hu, C., Wang, M., Franks, J. & Johnson, D. 2018. Prévission des blooms de sargasses dans la région Caraïbe et les Petites Antilles. Synthèse du projet PSB-CARIB. Juillet 2018. 10 pp.

## References

- Martin, L.M. 2016. Pelagic Sargassum and Its Associated Mobile Fauna in the Caribbean, Gulf Of Mexico, and Sargasso Sea. Master's thesis, Texas A & M University.
- McReynolds, C. 2017. Invasive Marine Macroalgae and their Current and Potential Use in Cosmetics. Project Report for obtaining the Master's Degree in Marine Resources Biotechnology. Escola Superior de Turismo e Tecnologia do Mar, Instituto Politécnico de Leiria. 90pp.
- Milledge, J.J. & Harvey, P.J. 2016. Golden Tides: Problem or Golden Opportunity? The Valorisation of Sargassum from Beach Inundations. *Journal of Marine Science and Engineering*, 4, 60.
- Guadeloupe Dpt of Env't, Land Planning and Housing. 2015. Creation of green brigades for collecting Sargassum in Guadeloupe deal.
- Putman, N.F., Goni, G.J., Gramer, L.J., Hu, C., Johns, E.M., Trinanés, J. & Wang, M. 2018. Simulating transport pathways of pelagic Sargassum from the Equatorial Atlantic into the Caribbean Sea. *Progress in Oceanography*. Volume 165, July–August 2018, pp. 205-214.
- Réserve Naturelle Saint-Martin. 2016. Get rid of sargassum, but respect the turtles. Newsletter 25. Retrieved from: <https://reservenaturelle-saint-martin.com/en/journaledition/newsletter-25>
- SAFEGE. 2016. Fiche de Synthèse – Vehicule Automoteur de Ramassage. Evaluation des Methodes de Ramassage de Sargasse 07/01/2016, funded by ADEME.
- SAFEGE. 2018. Fiche de Synthèse – Barge de Collecte Algeanova 1. Evaluation des Methodes de Ramassage de Sargasse 01/06/2018, funded by ADEME.
- SAFEGE. 2018. Fiche de Synthèse Provisoire – Drague Aspiratrice en Marche. Evaluation des Methodes de Ramassage de Sargasse 01/06/2018, funded by ADEME.
- Schell, J.M., Goodwind, D.S., Siuda, A.N.S. (2015). Recent Sargassum inundation events in the Caribbean: Shipboard observations reveal dominance of a previously rare form. *Oceanography* 28:8–10.
- SIPS, ADEME and DEAL 972, 2018 (To do)
- University of South Florida. 2018. Outlook of Sargassum blooms in the Caribbean Sea for 2018. Published on 04/04/2018. University of South Florida Optical Oceanography Lab.
- Willians, A.M. & Feagin, R.A. (?) Sargassum and Beach Erosion: Potential Costs and Benefits for Coastal Managers. Final Report, Spatial Sciences Laboratory, Department of Ecosystem Science & Management, Texas A&M University. 47pp.
- Wynne, Stuart. 2017. Observational Evidence of Regional Eutrophication in the Caribbean Sea and Potential Impacts on Coral Reef Ecosystems and their Management in Anguilla BWI.

## Online Media Resources

Berke, J. 2018. A dramatic seaweed invasion has hit coastlines across Florida and the Caribbean, killing wildlife — here's what it looks like on the ground. Business Insider Magazine, published on 04/09/2018. Retrieved from: <https://www.businessinsider.com/sargassum-seaweed-invasion-killing-wildlife-2018-9>

BES Reporter. 2018. STINAPA on Sargassum Crisis: Early Detection and Prevention Imperative. Published on 16/03/2018. Retrieved from: <http://bes-reporter.com/index.php/2018/03/16/stinapa-on-sargassum-crisis-early-detection-and-prevention-imperative/>

Caribbean News Now. 2018. Region faces another sargassum seaweed invasion. Published on 08/06/2018. Retrieved from: <https://www.caribbeannewsnow.com/2018/06/08/region-faces-another-sargassum-seaweed-invasion/>

Conover, J. 2018. Atlantic, Caribbean Sea and the Gulf of Mexico: Major Seaweed Invasion Underway. Caribbean Compass Magazine, 30/4/2018.

Copeland, J. 2018. The Sargassum Invasion: Addressing the issues of a weed-choked Caribbean . Marlin Magazine, published on 5/06/2018. Retrieved from: <https://www.marlinmag.com/sargassum-invasion-in-the-caribbean>

Davis, S. 2018. SOS Save Our Sea Creatures – Call for Volunteers for Sargassum Cleanup. Info Bonaire, published on 07/03/2018. Retrieved from: <https://www.infobonaire.com/sos-save-our-sea-creatures-call-for-volunteers-for-sargassum-cleanup/>

Engel. M.S., 2018. Sargassum: impact on tourism and fisheries and its cascading effects on Bonaire, Dutch Caribbean. Proceedings GCFI71.

Jones Jr., R.C. 2018. Holy Sargassum Seaweed Invasion. Miami News, published on 25/06/2018. Retrieved from: <https://news.miami.edu/stories/2018/06/seaweed-invasion.html>

Langin, K. 2018. Mysterious masses of seaweed assault Caribbean islands. Science Magazine, published on 11/06/2018. Retrieved from: <http://www.sciencemag.org/news/2018/06/mysterious-masses-seaweed-assault-caribbean-islands>

Mexican News Daily. 2018. Quintana Roo set to install containment barriers to halt sargassum invasion. Published on 7/8/2018. Retrieved from: <https://mexiconewsdaily.com/news/containment-barriers-to-halt-sargassum-invasion/>

Riviera Maya News. 2018. First seaweed barrier to be placed in Cancun waters this week. Published on 07/08/2018. Retrieved from: <https://www.riviera-maya-news.com/first-seaweed-barrier-to-be-placed-in-cancun-waters-this-week/2018.html>

Rubetti, M. 2018. Antilles: Hulot annonce un plan antisargasses de 10 millions d'euros. Le Figaro Magazine, published on 12/06/2018. Retrieved from: <http://www.lefigaro.fr/actualite-france/2018/06/12/01016-20180612ARTFIG00119-guadeloupe-hulot-annonce-un-plan-anti-sargasses-de-10-milions-d-euros.php>

## Online Media Resources

San Pedro Sun. 2015. Statement by the Caribbean Tourism Organization on the influx of sargassum seaweed. Published on 17/8/2015. Retrieved from: <https://www.sanpedrosun.com/environment/2015/08/17/statement-by-the-caribbean-tourism-organization-on-the-influx-of-sargassum-seaweed/>

San Pedro Sun. 2018. Island resorts test alternatives to tackling the Sargassum epidemic. Published on 29/08/2018. Retrieved from: <https://www.sanpedrosun.com/environment/2018/08/29/island-resorts-test-alternatives-to-tackling-the-sargassum-epidemic/>

San Pedro Sun. 2018. Residents join in the fight against Sargassum after SPTC declares the situation a natural disaster. Published on 27/09/2018. Retrieved from: <https://www.sanpedrosun.com/community-and-society/2018/09/27/residents-join-in-the-fight-against-sargassum-after-sptc-declares-the-situation-a-natural-disaster/>

San Pedro Sun. 2018. The San Pedro Town Council pleased with Sargassum clean-up campaign. Published on 05/10/2018. Retrieved from: <https://www.sanpedrosun.com/community-and-society/2018/10/05/the-san-pedro-town-council-pleased-with-sargassum-clean-up-campaign/>

San Pedro Sun. 2018. Is Sargassum hazardous to our health? Published on 01/09/2018. Retrieved from: <https://www.sanpedrosun.com/health/2018/09/01/is-sargassum-hazardous-to-our-health/>

San Pedro Sun. 2018. Sargassum blamed for mass fish death on Ambergris Caye; Marine Environmentalists suggest solutions. Published on 9/5/2018. Retrieved from: <https://www.sanpedrosun.com/environment/2018/05/09/sargassum-blamed-mass-fish-death-ambergris-caye-marine-environmentalists-suggest-solutions/>

San Pedro Sun. 2018. Sargassum continues to plague the Caribbean, including Belize; tourism industry affected. Published on 25/8/2018. Retrieved from: <https://www.sanpedrosun.com/environment/2018/08/25/sargassum-continues-to-plague-the-caribbean-including-belize-tourism-industry-affected/>

San Pedro Sun. 2018. Captain Shark's is testing a machine to combat Sargassum on Ambergris Caye. Published on 28/8/2018. Retrieved from: <https://www.sanpedrosun.com/environment/2018/08/28/captain-sharks-is-testing-a-machine-to-combat-sargassum-on-ambergris-caye/>

Schuessler, R. 2018. The Eastern Caribbean Is Swamped by a Surge of Seaweed. Hakai Magazine, published on 11/06/2018. Retrieved from: <https://www.hakaimagazine.com/news/the-eastern-caribbean-is-swamped-by-a-surge-of-seaweed>

Whittaker, K., Schell, J., Goodwin, D., Sioda, A. (2018). Molecular divergence of holopelagic Sargassum species using extensive field samples from the tropical and subtropical Atlantic. Proceedings GCFI71.

## Outreach and Educational Materials Currently Available

- A good place to share information and learn from experiences across the region is the online forum set up for this purpose by the UNEP-CEP Regional Activity Centre for SPAW (email [sargassum.forum@gmail.com](mailto:sargassum.forum@gmail.com) to join).
- GCFI developed a poster which details how to best respond to this massive influx. The poster is intended for use by the tourism industry including hotels and resorts, coastal zone managers, fisheries ministries, and homeowners. GCFI's sargassum factsheet and A2 poster can be downloaded here: <https://www.gcfi.org/sargassum-influx/>
- A sargassum management briefing paper by key regional partners CERMES, SPAW-RAC and GCFI provides further guidance for coastal managers (Hinds et al, 2016) and can be downloaded here: [https://www.cavehill.uwi.edu/cermes/getdoc/123bf91c-1565-414d-8e21-e59fb6f7ca2d/cermes\\_sargassum\\_management\\_brief\\_2016\\_08\\_24.aspx](https://www.cavehill.uwi.edu/cermes/getdoc/123bf91c-1565-414d-8e21-e59fb6f7ca2d/cermes_sargassum_management_brief_2016_08_24.aspx)
- There are a number of facebook groups dedicated to sargassum and hosted by national organisations or individuals.
- Detailed information on the short and long-term effects of exposure to hydrogen sulfide by the United States Department of Labor can be found online at: <https://www.osha.gov/SLTC/hydrogensulfide/hazards.html>