



Sargassum Management Brief

Golden Tides: Management Best Practices for Influxes of Sargassum in the Caribbean with a focus on clean-up

Catrina Hinds¹, Hazel Oxenford¹, Janice Cumberbatch¹,
Frédérique Fardin², Emma Doyle³, Adrian Cashman¹

2016

¹ Centre for Resource Management and Environmental Management (CERMES),
University of the West Indies, Cave Hill Campus, Barbados

² Regional Activity Centre for Specially Protected Area and Wildlife (SPAW-RAC),
Parc National de la Guadeloupe, 97120 Saint Claude, Guadeloupe

³ Gulf and Caribbean Fisheries Institute, PO Box 21655 Charleston SC 29413, USA

The purpose of this management brief is to enable government officials, coastal managers, beach caretakers and coastal residents to get ahead of the “*golden tides*” by providing up-to-date information on the recent ‘sargassum influxes’ (arrival of unprecedented mass quantities of sargassum seaweed) in the Caribbean region; and, importantly, by offering guidance on how best to *sustainably* manage the seaweed, based on lessons learnt to date. This first brief focuses on the immediate problem of clean-up, after mass strandings of the weed. Others will be developed that focus on potential commercial uses of the weed and on adaptation measures suitable for fishers and other vessel operators. This is all part of the on-going efforts by The University of the West Indies and a number of other institutions in the Wider Caribbean to actively research and understand this new phenomenon and develop solutions.



Mass stranding of sargassum on beach at Bathsheba, Barbados.

Source: H. Oxenford, 2015

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 2015. These influxes have given rise to a number of serious socio-ecological and economic concerns, particularly in the hospitality and fisheries sectors.

Sustainably Managing Sargassum Influxes

The sustainable management of sargassum influxes will require both local action and regional co-ordination and collaboration, beyond areas under national jurisdiction. So far the management responses of Caribbean islands to sargassum influxes have been largely reactive rather than proactive, and somewhat haphazard. 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. Here, we attempt to provide a succinct summary of the information shared and key lessons learnt regarding the best management practices for tackling sargassum influxes, in particular, the inundation of shorelines. In the section “*Informing the Public*” we will also provide 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.

Management Best Practices

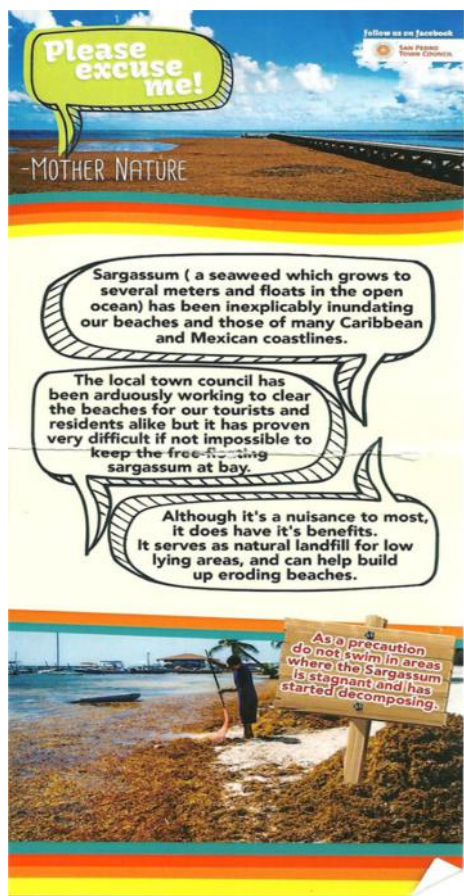
It is important to understand that there is no ‘one size fits all’ solution to managing sargassum influxes. Different management approaches will work best in different situations and locations, depending on factors such as the biomass of sargassum, accessibility of the affected shoreline, whether the 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.

What we present in the next sections are guidelines that can be adapted to the local situation as well as some local examples and some *dos and don'ts* based on experiences around the Wider Caribbean region to date. We also recognise 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.

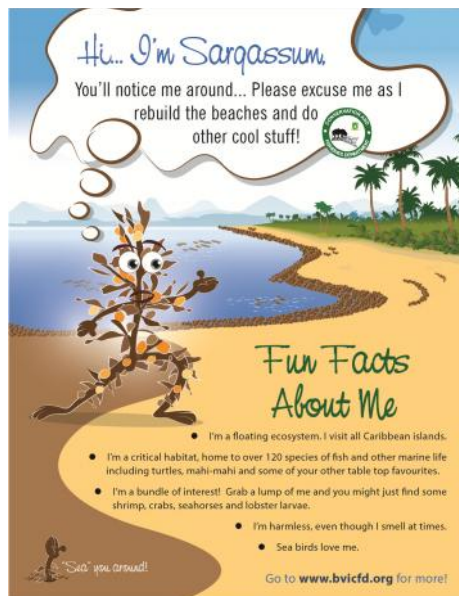
Develop a Communication Plan

An important first step is to ensure coastal users and other stakeholders, including the general public, receive relevant and reliable information about sargassum and the periodic influxes in the region, as well as the on-going management efforts. Various communication methods can be employed such as public announcements, signs on beaches, distribution of fact sheets, brochures, infographics, a telephone hotline, documentary films and traditional (e.g. radio) as well as popular social media platforms. A good place to share information and learn from experiences across the region is the online forum set up for this purpose



Sargassum flyer produced in Belize.
Source: San Pedro Town Council
<https://www.facebook.com/SPtowncouncil>

by the UNEP-CEP Regional Activity Centre for SPAW



Example of poster in the British Virgin Islands. **Source:** www.bvicfd.org

(email sargassum.forum@gmail.com to join). There are also a number of facebook groups dedicated to sargassum and hosted by national organisations or individuals.

Information to help answer some of the most frequently asked questions about sargassum can be found in the “*Informing the Public*” section, and useful links are listed in the bibliography.

Dos and Don'ts

Do:

- Communicate accurate, easy to understand, and interesting 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

Don't:

- Leave the public in the dark or put out misinformation.

Let Nature Run its Course

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 stabilising 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.



Small amounts of sargassum along the tideline are better left alone.

Source: H. Oxenford 2014

Removal of Sargassum

When removal of mass sargassum inundations is deemed absolutely necessary, it may be collected either onshore or in the water along the shoreline. Note that in some countries or specific locations however, a special permit may be required to do this. Based on the scale of mass inundations witnessed in the Caribbean over the last few years, it is essential to prioritise which beaches will be cleaned and which will be left in a natural state. Note also that it is often not necessary or 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.

Onshore collection

Removal can either be manual (preferable) or mechanised, depending on 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.

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



Beach clean-up with volunteers, Bathsheba, Barbados. **Source:** <http://tinyurl.com/zcr2sp3>

contributing to beach erosion. Furthermore, manual removal can take place in a variety of locations such as sandy beaches, pebble beaches, rocky coasts, and beaches with limited vehicular access, and in the presence of other beach goers. The collected sargassum can then be transported using wheel barrows or bags. Piling the seaweed onto tarpaulins and dragging it to the back beach also works. Organised beach clean-ups are a good way to get communities involved in tackling the problem, and can help reduce labour costs.

Where manual pick up is not practical, mechanical equipment will have to be used and adequate storage and/or disposal of the collected seaweed must be organised. Mechanical beach rakes with a perforated conveyor belt and soft tyres have been found to be effective and work best with moderate quantities of weed and on beaches with low relief and easy access. Note however that



Mechanised beach rakes in action in Guadeloupe (left) and picking up sargassum, in Mexico (right).

Sources: F. Fardin, 2015 (left) and modified from <http://tinyurl.com/hovxoag> (right)

this equipment alone will not be adequate for very large accumulations of seaweed. With mass inundations when sargassum piles up along the shorelines forming barriers several metres high, a combination of removal methods is likely to be required. In cases like this, the 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. In such cases a multi-level approach will be needed, where different equipment is used to remove the



Barrier of sargassum along the shore of Skeetes Bay, Barbados. **Source:** H. Oxenford, 2015

top and bottom layers of seaweed. In some countries a front-end loader with large load-bearing tyres has been used to remove the huge quantities. This has been effective when used to remove only the top layer without touching the sand and then a mechanised rake or manual removal is used to collect the rest. In the French Antilles they have experimented successfully with using cane loaders to pick up large quantities of sargassum, prior to clearing with a mechanised beach rake.



Using a cane-loader to collect large quantities of sargassum in Guadeloupe.

Source: F. Fardin, 2015

Experience has shown that significant beach erosion can be caused by heavy construction equipment brought in to clear the seaweed, especially bulldozers with caterpillar tracks and buckets that gouge the beach and remove large quantities of sand with the sargassum.

Machines with large soft tyres are preferable over tracked vehicles on sand beaches to prevent compaction of the sand, destruction of vegetation, formation of deep ruts and ultimately, beach erosion. Those with a claw or rake are also less damaging than those with buckets or scoops that gouge the sand. Access to the beach for heavy equipment and routes to the shoreline should be kept to a minimum and follow agreed pathways. Furthermore, such equipment should only be used in the presence of monitors who check for wildlife prior to any cleaning and should never be used in the presence of beach goers. Operators must respect no-go areas such as sea turtle or bird nests, and avoid removing sand and beach vegetation.

In-water collection

Where possible, it is generally agreed that in-water collection very close to shore is often preferable to beach collection, where permitted. This approach avoids removal of sand and damage to coastal vegetation. Concern for the conservation of species associated with the sargassum is warranted if the sargassum were to be collected in open water. However, by the time the sargassum rafts are very close to stranding, the majority of associated organisms will have already abandoned the raft, or will wash ashore



Sea turtle hatchling among sargassum

Source: A. Cox, 2014

and be lost anyway. With that said, special care should always be taken with the removal of sargassum close inshore along sea turtle nesting beaches, as hatchlings leaving the beach will hide and remain in the weed.



Specialised barge for picking up sargassum.

Source: <http://www.guadeloupe.franceantilles.fr>

In-water collection is ideal for small semi-enclosed bays, 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. Throughout the Wider Caribbean a number of methods and specialised equipment have been developed and tested for in water removal. For example, a specialised barge outfitted with a treadmill, has been successfully developed and used in Guadeloupe in relatively calm water to collect and hold up to 10 tons of sargassum at a time. Other countries have tested locally developed prototype vessels. The Mexican

Navy has utilised powerful hydraulic suction pumps to extract the sargassum directly from the water nearshore and pump it straight into waiting trucks. This technology has also utilised floating booms to help funnel the sargassum towards the pumps. In Barbados a local company demonstrated that ponies or horses can be used to pull seaweed traps in the surf to gather up the sargassum (an attractive option for hotels).

Dos and Don'ts

Do:

- Let nature run its course in inaccessible areas or when 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.
- Monitor removal to ensure no loss of endangered sea turtles.
- Where feasible, opt for manual removal.
- Get communities involved with organised beach clean-ups.
- If using machinery, consider the most appropriate types with least impact on beach and wildlife.
- Only operate machinery on wet sand in the inter-tidal zone of the beach
- Minimise the manoeuvring of machinery on beaches and removal of beach sand.

Don't:

- Collect sargassum out in the open sea where it serves as a valuable ecosystem.
- Use heavy tracked machinery, especially on sea turtle nesting beaches.
- Use mechanical equipment without giving consideration to wildlife, beach vegetation and other beach users.
- Use any equipment that causes significant removal of sand as this results in beach erosion.

Booms can be utilised to deflect sargassum away from sensitive areas or to funnel the weed into a nearshore collection area. It is recommended that a set of small booms be linked together to maximise flexibility, allow for ease of deployment and maintenance, as well as the transport to new locations as required. Apart from booms, experiments have shown that it is possible to capture and remove the seaweed with reinforced fishing nets towed by light boats or by hand when located in very shallow waters. Again visual monitoring of the collected sargassum must be maintained in order to free any live trapped creatures (e.g. sea turtles, hatchlings, eels and other fishes and invertebrates).

Burying Sargassum

What to do with the collected sargassum can also be a significant challenge. For wide beaches that experience low volumes of sargassum, especially those with dunes, burying the seaweed further up the beach or in the dunes may be a good option. Sargassum can act as a fertilizer for shore plants and is an excellent medium for beach nourishment, helping to combat beach erosion and increase coastal resiliency to storm surges and rising sea levels. However, this practise is not suitable for narrow beaches where there is insufficient space for burial, or for turtle nesting beaches since burying sargassum can change the organic composition of the sand which may negatively affect hatching success. In these cases sargassum will have to be transported away from the site. Research and development of viable commercial uses for this collected sargassum is still needed. Potential uses are listed here in the “*Value-added Uses of Sargassum*” section.

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. They recommend other tourism groups work with partners in the same way. Collective action allows

Dos and Don'ts

Do:

- Establish a national coordinating body with key stakeholders and with the necessary resources.
- Use existing communication channels to learn from and share information and experiences both locally and regionally.
- Collaborate with regional institutions to consolidate regional efforts and garner external funds.

Don't:

- Try to tackle the sargassum issue alone

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. In the French Antilles, the French Government has funded the recruitment and training of unemployed persons to form *Green Brigades* for the manual removal of sargassum.

Informing the Public

The following sections provide up-to-date information to help answer the most frequently asked questions by the public. It covers aspects of the biology and ecology of sargassum, the need for its sustainable management, the probable causes of the recent influx events in the region and why stranded sargassum is a cause for concern. Lastly, some of the potential value-added uses of sargassum are presented.

What is Sargassum?

Sargassum is a brown marine alga (seaweed) which is generally associated with the Sargasso Sea of the North Atlantic Ocean. It is made up of leafy appendages, branches and round, berry-like structures. These “berries” are actually gas-filled structures (mostly oxygen) which aid in buoyancy, allowing the sargassum to float on the



Floating sargassum with associated pelagic fishes.

Source: R. Goodridge 2014



Sargassum natans & *S. fluitans*. **Source:** H. Oxenford, 2014 ocean surface.

The sargassum species typically associated with the Sargasso Sea are the same species that have made up the recent mass intrusions in the Wider Caribbean and West Africa. These are *Sargassum natans* (common gulfweed) and *Sargassum fluitans* (broad-toothed gulfweed); both of which are native to the North Atlantic

and Caribbean region. These species are unique among the many sargassum species found throughout the world because they are free-floating for their entire life cycle (i.e. never attaching to the ocean floor) and they move with the ocean currents and winds, often forming large rafts and accumulating in the open ocean where currents rotate, such as the Sargasso Sea gyre. As ocean current strengths and winds change with seasons or between years, the sargassum may be 'released' from these accumulation areas and travel more broadly on currents and with winds, eventually sinking in the ocean depths or getting washed ashore.

Ecological Value of Sargassum

While a potential nuisance on land when it occurs as an influx of massive quantities, floating rafts of sargassum in the open ocean form rich pelagic ecosystems which provide critical habitats for a diversity of marine species. These sargassum rafts provide refuge and food for over 250 species of fish and marine invertebrates, some of which are not found anywhere else (e.g. the iconic sargassum anglerfish). The rafts serve as important feeding grounds for migratory and commercially important species such as dolphinfish and tuna; act as spawning areas for flyingfish and eels; and as nursery grounds for endangered sea turtles. In addition, various species of seabirds (e.g. terns and boobies) forage among the seaweed. As sargassum ages and loses its buoyancy, it sinks to the ocean floor, contributing to nutrient cycling. Beached sargassum can also be beneficial by providing rich shorebird foraging areas and helping to reduce beach erosion by binding sand and providing extra nutrients for the growth of shoreline plants. It is therefore not surprising that pelagic sargassum has been designated in the United States as an 'Essential Fish Habitat' because of its ecological value and is managed by the US South Atlantic Fishery Management Council according to a 2002 Fishery Management Plan for Pelagic Sargassum Habitat. Within the Sargasso Sea it also receives special conservation attention by members of the newly formed international Sargasso Sea Commission.



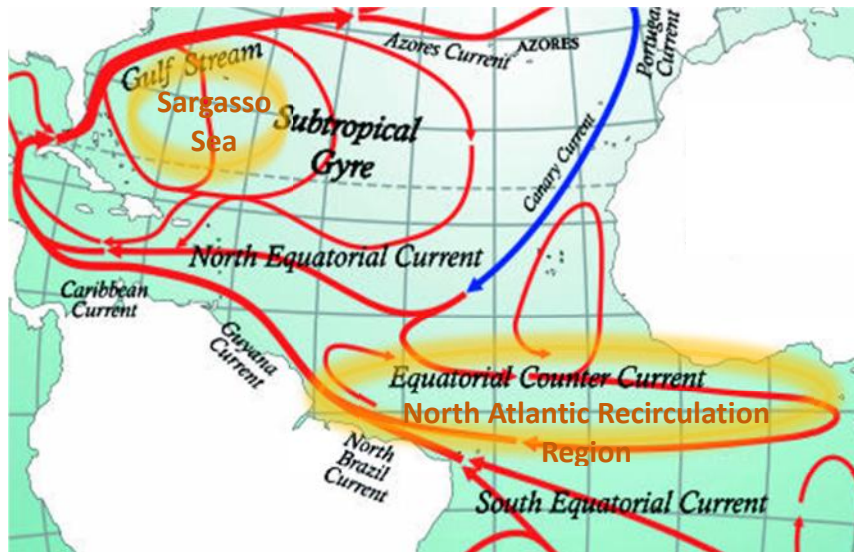
Flyingfish eggs on sargassum.

Source: H. Oxenford, 2013

Given the high socio-ecological value of sargassum it must be managed sustainably!

What Causes the Influx of Sargassum in the Caribbean?

The verdict is still out on the exact cause of the recent unprecedented influxes of sargassum to the Caribbean, but the source location has now been established. Initially, the source was thought to be the Sargasso Sea, dubbed “*The Golden Floating Rainforest*”, which is estimated to hold up to 10 million metric tons of sargassum. It was assumed that sargassum was transported



Simplified map showing the locations of the North Equatorial Recirculation Region, the Sargasso Sea and major surface currents in the central Atlantic.

Modified from: <http://www.bigmarinefish.com/currents.html>

West Africa are related to massive sargassum blooms occurring in the equatorial area of the Atlantic where the ocean currents rotate in what oceanographers call the North Equatorial Recirculation Region (NERR), an area which is not directly associated with the Sargasso Sea and is essentially a new ‘source’ region for sargassum.

Factors believed to be contributing to the anomalous quantities of sargassum in this region include warming ocean temperatures due to global climate change and increasing discharge of nutrients (nitrogen and phosphorus) into the marine environment from land-based sources, which are allowing rapid growth of the seaweed. In addition, fluctuations in the strength of the recirculating currents in the NERR driven by increasing fluctuations in major climate indices are allowing a cycle of build-up and subsequent release of large quantities of the seaweed which then travel north westwards up into the Caribbean Sea with the complex and seasonally variable surface water currents (North Brazil and Guiana Currents).

from the Sargasso Sea directly into the Caribbean on ocean currents moving in a south westward trajectory. However, by back-tracking the movement of sargassum from its first mass stranding locations in 2011 with the use of ocean models, satellite trackers, and examining high resolution satellite images, scientists are now convinced that the recent influxes to the Caribbean Sea and along the coast of

Will the Sargassum Influx Occur Every Year?

Observations from the Sargasso Sea indicate that free-floating sargassum circulates seasonally between the Gulf of Mexico and North Atlantic, and exhibits considerable inter-annual variation in biomass of the seaweed and in frequency and volume of shoreline strandings. This year to



Inundation of Skeetes Bay, Barbados with sargassum.

Source: H. Oxenford, 2015

year variation is caused by differences in sea water temperatures and nutrient availability (e.g. from agricultural runoff, wastewater and oil spills) affecting the growth rate of the seaweed, and differences in the strength and direction of surface currents and winds which affect the exact trajectory of the floating sargassum and frequency and location of strandings.

So far in the Caribbean the influxes of sargassum since 2011 have also shown considerable variation from year to year in the amount of seaweed and when and where it has been stranding throughout the region. If there is any pattern to be detected to date, 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 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.

When is Sargassum a Problem?

While it is recognised that sargassum rafts form a very important ecosystem in the open ocean and can even be beneficial when washed ashore in small quantities, the recent influxes of sargassum in the Caribbean are impeding the operation of fishing and other vessels at sea; impacting the catches of key fish species; and disrupting coastal fishing communities, tourism activities and sea turtle nesting.



Decomposing sargassum along the shore. **Source:** H. Oxenford, 2015

Stranded sargassum can lead to beach fouling and reduce their attraction significantly, even more so when associated with entrapped anthropogenic litter such as plastics and hazardous medical wastes. As sargassum builds up along the shoreline, often becoming several metres thick, it can limit swimming and access to nearshore boat moorings and harbours, and prevent watersports activities.

Although sargassum is generally harmless (the alga itself is non-toxic), the seaweed collects epiphytes (small plants and animals that attach and grow on the blades of algae) as it floats in the ocean and many of these can sting on contact with the floating seaweed. A major complaint is the very unpleasant smell of decaying sargassum and the large number of flies it attracts when it is trapped in heaps along

the shoreline and unable to dry out. The smell and flies may in part be attributed to the presence of dead and dying organisms caught within the rafts, but the decay of tons of seaweed alone can lead to anoxia (oxygen-deprived conditions in the water) and the build-up of poisonous hydrogen sulphide gas, which smells awful and is harmful to most marine animals. Prolonged exposure to high concentrations of hydrogen sulphide gas can also cause human health problems (including nausea, headaches, skin rash and even breathing difficulties) and can tarnish metals (coins, bathroom fittings, door knobs, even jewellery etc.) as well as damage sensitive electronic appliances (TVs, computers, air-conditioning units). As a result, insurance companies in the French Antilles are now covering losses caused by the hydrogen sulphide emitted by sargassum. Furthermore, decaying sargassum trapped along the waterline results in aesthetically unpleasant brown plumes in the water, which are also a threat to the health of critical ecosystems such as coral reefs due to the low oxygen content and high levels of nutrients.



Mass influx of sargassum decomposing near shore and producing a dark brown plume. **Source:** www.neogaf.com.

Under these conditions of mass strandings, many locations have witnessed fish kills, entanglement and drowning of adult turtles, further stress on the fragile nearshore coral reefs and significant disruption of livelihoods, especially those associated with the tourism and fishing sectors.

Value-added Uses of Sargassum

Given the myriad problems associated with stranded sargassum, 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, such as:

- Fertilizer, plant tonic, compost, mulch and pest control.
- Chemical compounds for pharmaceuticals/personal care products/food supplements.
- Biofuel/biogas.
- Chipboard.
- Biosorbent for removal of heavy metals in polluted water.
- Livestock and fish food.

A caveat is that considerable research and development is still needed to commercialise the products and to ensure economic viability under an uncertain supply of the raw material. In particular, the 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 which means that it could ‘collect’ heavy metals and other pollutants depending on where it has travelled.

Please cite as: Hinds, C., Oxenford, H., Cumberbatch, J., Fardin, F., Doyle, E. & Cashman, A. (2016). *Golden Tides: Management Best Practices for Influxes of Sargassum in the Caribbean with a Focus on Clean-up*. Centre for Resource Management and Environmental Studies (CERMES), The University of the West Indies, Cave Hill Campus, Barbados. 17 pp.

Acknowledgement: We gratefully acknowledge the thorough review, comments and edits from Jim Franks, University of Southern Mississippi.

Bibliography and Useful Links

ADEME & SAFEGE. (2015). *Avis technique et recommandations préliminaires d'utilisation du ratisseur de plage BARBER 600HD, pour la collecte des algues sargasses*.

CRFM. (2014). *Sargassum Seaweed Invasion - What, Why & What We Can Do?* Caribbean Regional Fisheries Mechanism Secretariat:
http://crfm.int/~uwohxjxf/images/Sargassum_Communication_Brief-_Final.pdf

- DEAL Guadeloupe. (2015). *Creation of Green Brigades for Collecting Sargassum in Guadeloupe*. Department of Environment, Land Planning and Housing: http://www.guadeloupe.developpement-durable.gouv.fr/IMG/pdf/anglais_sargasse.pdf
- Department of Environment. (2015). *Guidelines on Removing Sargassum from Beaches*. Cayman Islands Government: <http://www.doe.ky/wp-content/uploads/2015/10/Guidelines-on-Removing-Sargassum-from-Beaches.pdf>
- Doyle, E., & Franks, J. (2015). *Sargassum Fact Sheet*. Gulf and Caribbean Fisheries Institute: <https://www.gcfi.org/Publications/GCFISargassumFactSheet.pdf>
- Feagin, R. A., Williams, A. M., Martínez, M. L., & Pérez-Maqueo, O. (2014). How does the social benefit and economic expenditures generated by a rural beach compare with its sediment replacement cost? *Ocean & Coastal Management*, 89: 79-87.
- Franks, J. S., Johnson, D. R., Ko, D. S., Sanchez-Rubio, G., Hendon, J. R., & Lay, M. (2012). Unprecedented Influx Of Pelagic Sargassum Along Caribbean Island Coastlines During Summer 2011. *Proceedings of Gulf and Caribbean Fisheries Institute*, 64: 6-8 http://www.gcfi.org/proceedings/sites/default/files/procs/GCFI_64-3.pdf
- Franks, J. S., Johnson, D. R., Ko, D. S. (2015). Retention and Growth of Pelagic Sargassum in the North Equatorial Convergence Region of the Atlantic Ocean: A Hypothesis for Examining Recent Mass Strandings of Pelagic Sargassum Along Caribbean and West Africa Shorelines. *Proceedings of Gulf and Caribbean Fisheries Institute*, 67:... http://flseagrant.ifas.ufl.edu/GCFI/67_proceedings/data/papers/GCFI_67_26.pdf
- Frazier, J. (2014). *Advanced Prediction of the Intra-Americas Sargassum Season through Analysis of the Sargassum Loop System Using Remote Sensing Technology*. Master's thesis, Texas A & M University: <http://oaktrust.library.tamu.edu/handle/1969.1/153840>
- Gavio, B., Rincón-Díaz, M. N., & Santos-Martínez, A. (2015). Massive quantities of pelagic Sargassum on the shores of San Andres island, Southwestern Caribbean. *Acta biol. Colomb*, 20: 239-241.
- Gower, J., Young, E., & King, S. (2013). Satellite images suggest a new sargassum source region in 2011. *Remote Sensing Letters* 4: 764- 773.
- Hill, B. N., Rydzak, A., Webster, R., & Linton, T. (2015). *A comparison of Sargassum landing amounts vs cold fronts on the Gulf Coast. A Whitepaper from the SEAS Team*. Sargassum Early Advisory System (SEAS): <http://seas-forecast.com/Papers/coldfrontsvsSarglandings.pdf>

- Hu, C., Feng, L., Hardy, R.F. & Hochberg, E.J. (2015). Spectral and spatial requirements of remote measurements of pelagic sargassum macroalgae. *Remote Sensing of Environment*, 167: 229-246.
- Huffard, C., Thun, S., Sherman, A., Sealey, K., & Smith, K. (2014). Pelagic Sargassum community change over a 40-year period temporal and spatial variability. *Marine Biology*, 161: 2735-2751.
- Johnson, D.R., Ko, S.D., Franks, J.S., Moreno, P., & Sanchez-Rubio, G. (2012). The Sargassum invasion of the eastern Caribbean and dynamics of the Equatorial North Atlantic. *Proceedings of Gulf and Caribbean Fisheries Institute*, 65: 102-103.
- Lapointe, B., West, L. E., Sutton, T., & Hu, C. (2014). Ryther Revisited: Nutrient Excretions by Fishes Enhance Productivity of Pelagic Sargassum in the Western North Atlantic Ocean. *Journal of Experimental Marine Biology and Ecology*, 458: 46-56.
- Laffoley, D.d'A., Roe, H.S.J., Angel, M.V., Ardron, J., Bates, N.R., Boyd, I.L., Brooke, S. et al. (2011). *The protection and management of the Sargasso Sea: The golden floating rainforest of the Atlantic Ocean. Summary Science and supporting evidence case.* Sargasso Sea Alliance 44 pp.
- Neumann, J., & Elder, L. (2015). *The Sargassum Sum Up*. The Ocean Foundation:
<https://www.oceanfdn.org/blog/sargassum-sum>
- NOAA. (2014). *What is Sargassum?* Ocean Explorer:
<http://oceanexplorer.noaa.gov/facts/sargassum.html>
- Ped, J., Scaduto, E., Accorsi, E., & Torres-Perez, J. (2016). *Caribbean Oceans: Utilizing NASA Earth Observations to Detect, Monitor, and Respond to Unprecedented Levels of Sargassum in the Caribbean Sea*. NASA Ames Research Center:
<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160006408.pdf>
- Schell, J. M., Goodwin, D. S., & Siuda, A. N. (2015). Recent Sargassum Inundation Events in the Caribbean: Shipboard Observations Reveal Dominance of a Previously Rare Form . *Oceanography*, 28: 8-10.
- SAFMC. (2002). *Fishery management plan for pelagic sargassum habitat of the South Atlantic Region*. South Atlantic Fishery Management Council, National Marine Fisheries Service, NOAA. 153 pp.

- UNEA. (2016). *Climate Change and Our Changing Oceans: The case of Sargassum Seaweed Invasion in West Africa and Caribbean Coasts*. United Nations Environment Assembly:
<http://staging.unep.org/docs/sargassum%20web%20story.pdf>
- UWI. (2015a). *Roundtable 6 - Beach Clean-up & Maintenance: Developing Appropriate Mechanisms*. Sargassum Symposium, University of the West Indies, Cave Hill Campus:
http://media.wix.com/ugd/adbc66_1a6170ff3011489bb8d247de8a5cc9c5.pdf
- UWI. (2015b). *Roundtable 7 - Beach Clean-up & Maintenance: National & Regional Responses*. Sargassum Symposium, University of the West Indies, Cave Hill Campus:
http://media.wix.com/ugd/adbc66_bfcoadad6c774426af8bcc2cbded2119.pdf
- Webster, R.K, and T. Linton. 2013. Development and implementation of Sargassum Early Advisory System (SEAS). *Shore & Beach* 81:1-6.
- Williams, A. M., & Feagin, R. A. (2010). *Sargassum and Beach Erosion: Potential Costs and Benefits for Coastal Managers*. Texas A&M University:
https://repositories.tdl.org/tamug-ir/bitstream/handle/1969.3/29002/06_019_final_report%5B1%5D.pdf?sequence=1&isAllowed=y

Useful Links

- CERMES Sargassum And Future Enterprises (SAFE): <http://www.sargassum-at-cermes.com/>
- Galveston sargassum symposium 2015: <http://seas-forecast.com/Symposium.php>
- Sargasso Sea Commission: <http://www.sargassoseacommission.org/about-the-sargasso-sea>
- Sargassum Early Advisory System (SEAS): <http://seas-forecast.com/>
- SEA Semester: http://www.sea.edu/sea_research/sargassum_ecosystem
- SPAW-RAC (UNEP-CEP) Sargassum issue in the Caribbean: <http://www.car-spaw-rac.org/?Sargassum-a-regional-issue-for-the,638>
- SPAW-RAC on-line forum: <https://spawrac.teamwork.com/dashboard>;
sargassum.forum@gmail.com (to join)
- University of Southern Mississippi sargassum reporting site:
<http://www.usm.edu/gcrl/sargassum/index.php>