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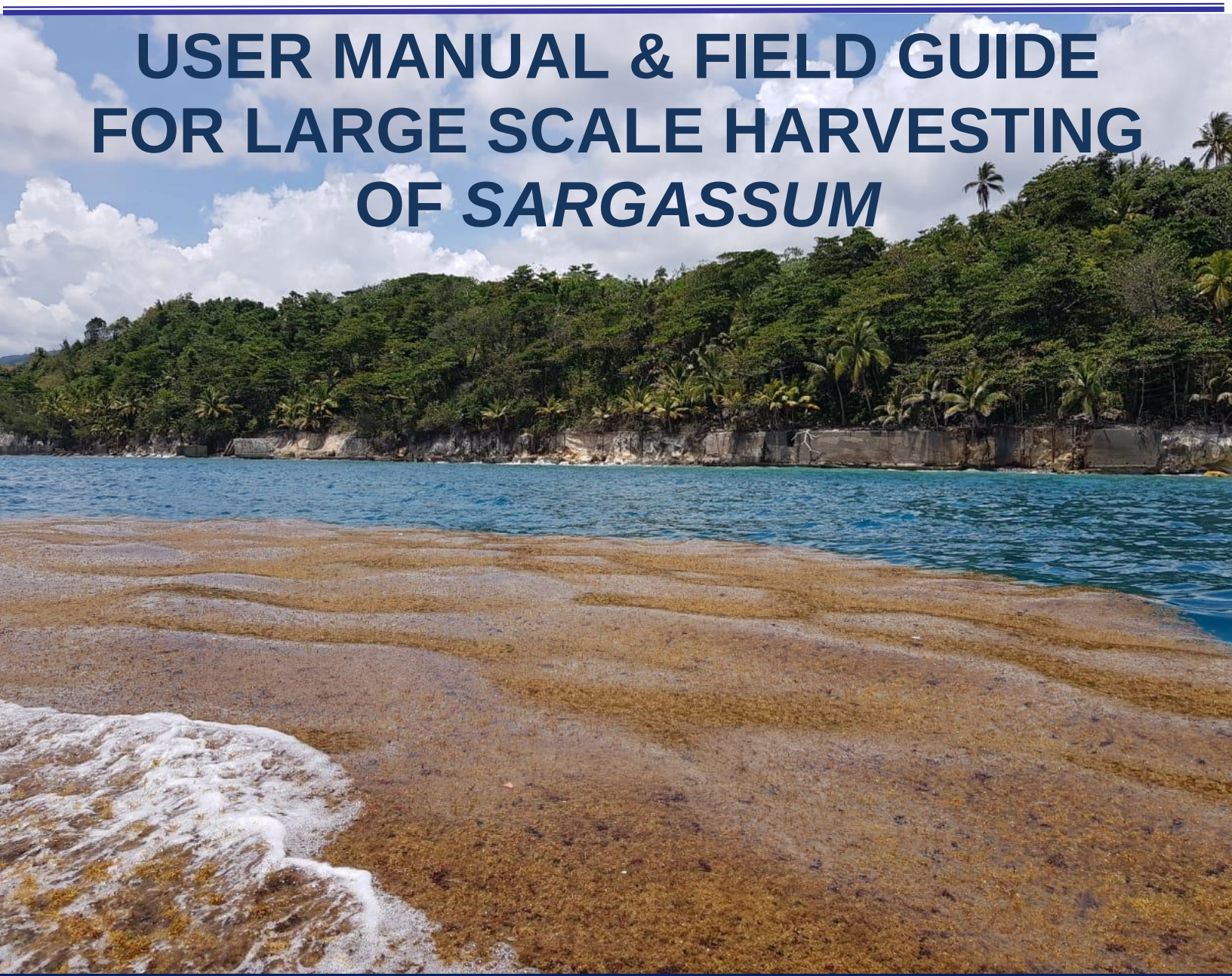
USER MANUAL & FIELD GUIDE FOR LARGE SCALE HARVESTING OF *SARGASSUM*



Developing *Sargassum* Products for Climate Resilience in the Caribbean

CRFM Secretariat
Belize
2021

CRFM Technical & Advisory Document – Number 2021 / 10

User Manual & Field Guide for Large Scale Harvesting of Sargassum For the project: "*Developing Sargassum Products for Climate Resilience in the Caribbean*"

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User Manual & Field Guide for Large Scale Harvesting of Sargassum.
For the project: "*Developing Sargassum Products for Climate Resilience in the Caribbean"*

Cover Picture: Sargassum approaching the St. Mary coastline, Jamaica. (Credits: Kapleton Hall)

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ACRONYMS AND ABBREVIATIONS

CARDI	-	Caribbean Agricultural Research and Development Institute
CC4FISH	-	Climate Change Adaptation in the Eastern Caribbean Fisheries Sector
CERMES	-	Centre for Resource Management and Environmental Studies
CNFO	-	Caribbean Network of Fisherfolk Organisations
CRFM	-	Caribbean Regional Fisheries Mechanism
FAO	-	Food and Agriculture Organization
GCFI	-	Gulf and Caribbean Fisheries Institute
GPS	-	Global Positioning System
IAEA	-	International Atomic Energy Agency
IOCARIBE	-	IOC of UNESCO Sub-Commission for the Caribbean and Adjacent Regions
MFAT	-	The New Zealand Ministry of Foreign Affairs and Trade
NASA	-	National Aeronautics and Space Administration
ORP	-	Oxidation and Reduction Potential
Plant & Food Research	-	The New Zealand Institute for Plant and Food Research
UWI	-	University of the West Indies

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➢ INTRODUCTION

Sargassum seaweed is a genus of a large family of brown algae called Phaeophyceae which can either float on the sea surface in 'island-like' masses or be attached to the seafloor. Although belonging to the brown algae family, the Sargassum may be golden or dark orange in colour (Figure 1). The floating species (called holopelagic) live entirely in the water column, growing and creating huge mats which have been referred to as the "golden floating rainforests of the sea". The seaweed is comprised of many leafy appendages, branches, and berry-like structures attached to the branches (stems). The berry-like structures are called bladders (Schell et al. 2015) or vesicles (Amaral Zettler et al. 2016) but are actually pneumatocysts, which are filled mostly with oxygen (may also have nitrogen and carbon dioxide) and add buoyancy to the alga allowing it to float on the surface of the sea.

Figure 1: Fresh Sargassum beached in Green Island, Hanover, Jamaica. (Photo credits: Shanna-Lee Thomas)

The Sargasso Sea, in the North Atlantic, is where large masses of *Sargassum* seaweed can normally be found. This floating habitat provides food, refuge, and breeding grounds for an array of animals such as fish (127 species), invertebrates (135 species) like shrimps and crabs (Figure 2), sea turtles, marine birds and in addition, supports many species found nowhere else in the world (10 endemics). Some animals, like the *Sargassum* fish (in the frogfish family), live their entire lives only in this habitat. *Sargassum* serves as a primary nursery area for a variety of commercially important fish such as mahi mahi, jacks and amberjacks, and supports an important part of the life cycle of the glass eel.

Figure 2: *Sargassum* Swimming Crab which lives amongst the *Sargassum* mats. (Photo credits: JReiderer Photography)

Due to its ecological importance, in 2003, the Sargasso Sea located within the U.S. Exclusive Economic Zone off the southern Atlantic states was designated as Essential Fish Habitat, which afforded the area special protection. The Sargasso Sea is a huge 'coastal' environment about the size of Australia (>3.5 million km^2). It is unique in having no land margins and is contained or kept in place by the currents of the North Atlantic gyre. *Sargassum* mats may 'escape' from this area and can be found seasonally floating for miles across the Caribbean Sea and within the Gulf of Mexico.

➢ OVERVIEW OF THE *SARGASSUM* 'PROBLEM' IN THE CARIBBEAN

Since 2011, the Caribbean has been inundated by Sargassum-seaweed as large quantities of holopelagic *Sargassum* (*Sargassum natans* and *S. fluitans*) have washed up on the shores, clogged bays and harbours and blanketed large areas of near-shore waters. The *Sargassum* influx was unprecedented for coastal communities (Figure 3) in the Wider Caribbean and West Africa and has impacted the region in subsequent years, with inundations documented for 2012, 2014, 2015, 2018, 2019, and 2020. These blooms of *Sargassum* in the Atlantic (in areas other than the Sargasso Sea) have been recorded to occur between April and November with peaks in the summer months. In 2018 huge mats of *Sargassum* stretched from West Africa to the Gulf of Mexico for the entire year. The mass, referred to as the Great Atlantic Sargassum Belt, was 8,850 km long, over 6,000 km^2 in area and estimated to contain over 20 million metric tons of *Sargassum* seaweed biomass! Each year the extent and duration of the *Sargassum* inundation of the Caribbean and West Africa has varied making it difficult to predict.

Figure 3: Brighton Beach, Jamaica inundated with Sargassum in 2020. (Photo credit: NEPA)

Sargassum inundations have adversely impacted national and regional economies, resulting in a range of adverse consequences, such as loss of livelihoods and economic opportunities to fishers, hoteliers and related businesses. Once the seaweed washes ashore it quickly breaks down and eventually rots on the beach substrate or near-shore waters. The combination of hydrogen sulphide gas production and oxygen depletion in the area of the rotting seaweed makes the areas inhospitable to man and marine-life. The fishing industry in particular, has been adversely affected due to the associated disruption of coastal fishing operations through gear entanglement, engine damage, as well as general impediments to fishing and other vessels at sea. This combined with the damage to the habitat and species has led some countries to report a reduction in catches of key commercial fisheries species, such as flyingfish and adult dolphinfish.

In addition to these adverse economic impacts, coastal and marine ecosystems have also suffered degradation. The decomposition of *Sargassum* mats on land and especially in shallow water produces toxic hydrogen sulphide gas and have causes oxygen depletion with subsequent creation of 'dead-zones' in coastal waters. The health of critical marine ecosystems and coastal communities have been threatened due to these adverse effects. Furthermore, the mats can blanket areas with seagrasses and corals, making them unable to receive adequate light, causing irreversible damage and biodiversity loss.

CHALLENGES

Onshore removal of large quantities of *Sargassum* can be costly due to the use of heavy machinery; which has resulted in compaction and structural damage to beaches. Shorelines can further become unstable and beach erosion has been reported. In-water *Sargassum* removal, which utilises booms and barges, has been promoted, however these methods are only suitable in calm areas and, like onshore removal methods, can be very expensive.

PROGRESS AND PROJECTS

The responses within the region to the problem of excess *Sargassum* have included:

(i) *Monitoring and awareness campaigns*
(ii) *Sharing information on best practices*
(iii) *Development of management approaches/responses*
(iv) *Studies that explore the causes and that build understanding of the phenomenon*
(v) *Studies that explore valorization and possibilities for innovation, entrepreneurship and revenue generation/benefits.*

Over the years, a body of relevant resources has also been developed. These include:

(i) *CRFM's Model Protocol for the Management of Extreme Accumulations of Sargassum on the coasts of CRFM Member States*
(ii) *GCFI's Best Practices for Sargassum clean-up*
(iii) *Sargassum Uses Guide: A resource for Caribbean researchers, entrepreneurs and policy makers, published by CERMES*
(iv) *IOCARIBE's Sargassum Hub-Geo Blue Planet*
(v) *Sargassum Regional Outlook Bulletin, produced by the University of South Florida with support from NASA*
(vi) *Sargassum sub-regional outlook bulletin produced by CERMES, University of the West Indies (Cave Hill) with support from FAO, GEF, CBF and IKI (through KfW).*

Nevertheless, some critical knowledge gaps still exist, for example, there has been no Caribbean-wide quantitative analyses done to determine the extent of the impacts on the:

- Marine and coastal ecosystems
- Livelihoods associated with the fisheries and tourism sectors
- Human health

There is currently no information about the tangible benefits to be derived from innovation and entrepreneurship using *Sargassum* as the raw material. Furthermore, there is a need for greater insights into the existing capacities of the various regional and national institutions to inform "realistic options for management responses".

Although the *Sargassum* influxes have had substantial adverse impacts on national and regional economies, its potential uses that have been explored can help mitigate some of these losses. They range from animal feed supplement, bioplastics, bioenergy, construction, cosmetics to paper products. The *Sargassum uses guide: a resource for Caribbean researchers, entrepreneurs and policy makers*, a report by CERMES - UWI (Desrochers et al. 2020) that was funded by the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) Project of the Food and Agriculture Organization (FAO), documents the challenges for *Sargassum* product innovation. These include the unpredictability of supply; major uncertainty regarding *Sargassum* influx timing, quantity and location; insufficient monitoring of volume and location of *Sargassum* strandings; as well as variability in relative abundance of different *Sargassum* species and morphological forms (morphotypes). Other challenges identified are the large variation and uncertainty in the reported concentrations or relative proportions of chemical components of *Sargassum*; its biosorption of heavy metals and other pollutants; limited research on chemical composition, and difficulty accessing the existing knowledge and results.

Additional challenges confronting the region with respect to management and regulation, are the absence of guiding policies or governance frameworks specific to managing *Sargassum* influxes and the lack of protocols and standards to support safe harvesting, transport, storage, and production (in terms of both process and end products). This is primarily the result of limited focus on *Sargassum* as an opportunity, as

opposed to a hazard, as the region has faced challenges with obtaining the requisite funding and support. There is also a low level of support for new ventures and the lack of industrial infrastructure.

➢ OVERVIEW OF THE PROJECT: 'SARGASSUM PRODUCTS FOR CLIMATE RESILIENCE IN THE CARIBBEAN'

The concept of the *Sargassum Products for Climate Resilience in the Caribbean* project had been developed after the New Zealand Institute for Plant and Food Research (Plant & Food Research) project staff visited the Caribbean to explore possibilities for *Sargassum* use. The project was developed in the context of a 3-year partnership with the CRFM after work had been done to explore potential uses of the *Sargassum* seaweed in New Zealand.

The project aims to mitigate the environmental and economic impacts of *Sargassum* seaweed influx in affected Caribbean countries (e.g. Figure 4) through the creation of technologies and value chains for marine biomass.

Figure 4: *Sargassum* inundation of Caribbean coastline (Photo credits: CRFM)

The project is divided into three phases (see Table 1), each containing components corresponding with an output, which will extend over the three-year period (2021 - 2024).

Table 1: *Showing the Projects Components and corresponding Outputs.*

Phase	Component	Output
Phase 1	*Raw material safety testing & harvest operations review*	*Sargassum*-derived production and harvesting method options
Phase 2	*Product and Process Development*	Product specifications and process design for *Sargassum*-derived product
Phase 2	*Product Commercialisation Strategy Development*	Commercialisation strategy for *Sargassum*-derived product
Phase 3	*Outreach and Supply Chain Development*	Dissemination of model to industry stakeholders and wider Caribbean region

The main baseline sampling is to provide a good indication of the oils, heavy metals or other chemicals (nitrates or phosphates) present in the *Sargassum*. This will determine the types of products which could be manufactured from the seaweed. As with any product which it is hoped will provide economic gain, the project is to determine whether the production could be commercialized.

The project aims to eventually harvest large (industrial scale) quantities of floating *Sargassum* using consistent methods across the Caribbean over the period of inundations each year. There is need therefore to define, disseminate, use and refine these methods. The development of a user manual following the *Sargassum Harvesting and Processing for Export Workshop* (Appendix I) is critical to this process.

➢ COLLECTION BASICS 1: HARVESTING METHODS:

Collecting industrial quantities of *Sargassum* across the Caribbean where there is uncertainty about the quantities and periodicity of the influx requires each country to conduct preparatory steps to be ready for harvesting as soon as the seaweed begins to wash up on shorelines. These steps include, knowledge of where the mats most likely to be found (historical data), where will facilitate harvesting or easy removal from the sea and the associated resources for mobilising to harvest and handling post-harvest.

1. SITE SELECTION

Prior to the harvesting of *Sargassum*, it may be important to document the spatial distribution of *Sargassum* inundations associated with different areas of each country so as to produce maps that guide identification of ideal harvesting areas. Information on previous strandings should be collated and *Sargassum* strandings for several previous years may be observed using Google images as well as other open-source satellite imagery. This will allow project participants to know where the Sargassum has been consistently seen in appropriate quantities. This knowledge will also facilitate selecting harvesting locations which have industrial-scale processing facilities that can be used for Sargassum.

Due the quantity and quality of *Sargassum* required, there are specific 'location *criteria'* associated with this project. Sargassum should therefore be harvested from areas where mats are:

a) concentrated by floating barriers (booms) OR
b) naturally concentrated and floating in mats of 'slicks' between 20 and 200 m from shore
c) are accessible by boat / barge (areas which permit shore launch or contain a dock)
d) close to base where sorting (and processing) can be done (within 30 minutes)

Participants are encouraged to harvest the seaweed in a coordinated, timely and efficient manner and should avoid collecting in fish sanctuaries or protected areas.

2. HARVESTING METHOD

Harvesting *Sargassum* for whatever purpose must be well coordinated and managed with a clear set of protocols and as such it is important to select and become familiar with the most appropriate harvesting method. While bulk quantities are required by the current project, it is important to know that *Sargassum* sampling protocols may vary according to a range of factors.

Choosing a method depends on the following:

a) Purpose for collecting
b) Scale or quantities needed
c) Human Resources (available team members)
d) Available Equipment

Collection of between 1 and 5 kg of *Sargassum*

Surf Net / Hand Net

Where small quantities of *Sargassum* are required, individuals may be able to wade into shallow water (<1m) carrying a surf or hand net (Figure 5). Using a sweeping motion, the *Sargassum* should be collected from the water and placed into bags/containers that facilitate drainage. A minimum of two individuals are needed to remove the *Sargassum* from the water and safely transport it to the shore.

Figure 5: Hand Net used in fishing and can be used to collect *Sargassum*. (Photo credits: Fieldandstream.com

Beach Seine with Surf Net / Hand Net

The Seine net (Figure 6) creates a barrier to stop fresh *Sargassum* in the swash from being washed back out to sea or beached. Collection is then done with the use of a surf net while the *Sargassum* is still in water (<1 m depth). A minimum of three individuals are needed to walk the seine net out and around the *Sargassum* in the shallow water and to collect the *Sargassum* from the sea surface.

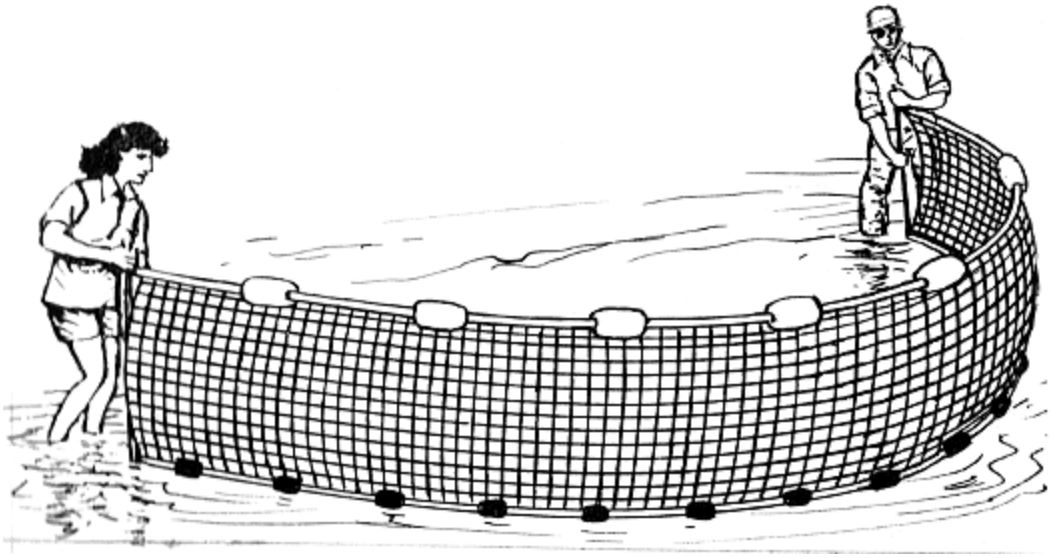


Figure 6: Beach Seine which can be used as a barrier to prevent the Sargassum from washing back out to sea. (Photo credits: FAO- http://www.fao.org/fishery/geartype/102/en)

Collections of ≥ 50 kg of *Sargassum* (project target)

Boat with Seine Net

If the *Sargassum* is in a large mat, it may be possible to simply 'follow the mat' and collect the algae from the water using a surf-net or by hand. Otherwise, collectors may have to concentrate the *Sargassum* with the use of a boat(s) equipped with a seine net (Figure 7).

It is assumed that collections by boat will be done between 20 and 200 m from shore in water depths ≥ 10 m. An individual in the boat will need to deploy one end of the seine net while the boat maneuvers around the *Sargassum* creating a closed circle. Individuals will then pull the seine towards the boat while another collects the seaweed. This method is used when the *Sargassum* has not beached but may be moving shoreward in patches or 'slicks' and need to be intercepted and cordoned before it reaches the shore. A *minimum of three individuals* are needed to maneuver the boat, pull the seine and collect the *Sargassum*.

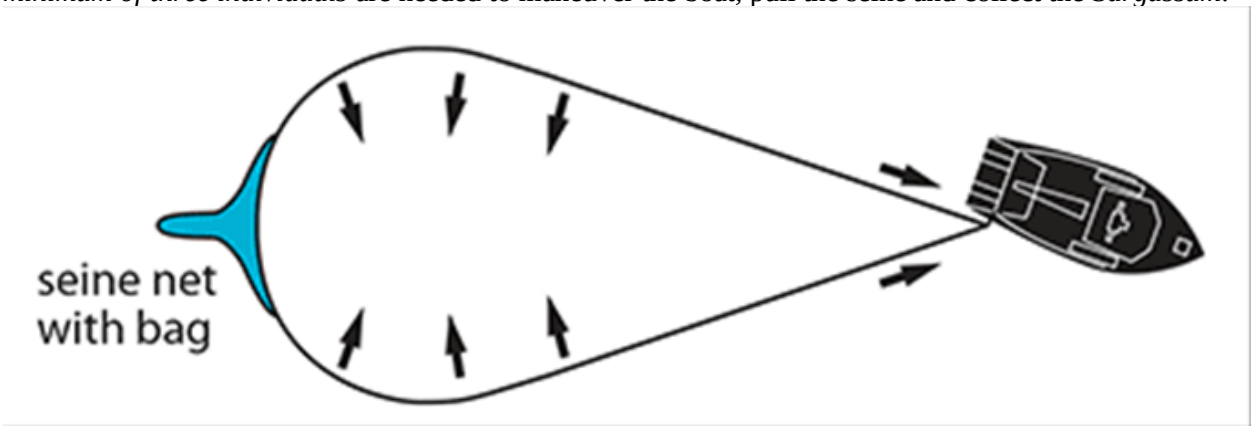


Figure 7: Boat with seine net and bag deployed which can be used to collect the seaweed. (Photo credits: https://www.fish.gov.au/fishing-methods/nets)

Barge Harvester with Boom

In many areas booms (Figure 8a) are deployed permanently or seasonally prior to the arrival of *Sargassum* especially where sensitive shore habitats or infrastructure need to be protected. The boom simply prevents the seaweed from washing up onto the shore and effectively concentrates in deeper waters on the seaward side of the boom. Barges (Figure 8b) have been redesigned to collect *Sargassum* from the water by having a powered trolley or treadmill attached or a suction pump which can then move along the seaward edge of the boom and remove the *Sargassum* from the water; depositing it on the boat.

Barges may vary in size and the storage capacity for *Sargassum* and also may have mechanically powered harvesters with a few being manually operated. A *minimum of two persons are needed*; one to captain the barge and the other oversee the collection process. Barges are the most expensive of the harvesting methods but yield large quantities. There are however important recommendations to guide the process.

Recommendations:

1. Operators must monitor to ensure marine animals like turtles are not brought in and if they are, these must be returned to the sea.
2. Collectors / sorters must take care when handling *Sargassum* to avoid stings from marine organisms trapped within the mats.
3. Persons handling *Sargassum* in mass are advised to use thick / cut-proof gloves.

Figure 8a. The different types of Booms used in the region to handle the *Sargassum* influx. (Photo credits: algeanova.com and sargassumsolutionsltd.com)

Figure 8b: The different types of Booms and Barges used in the region to handle the *Sargassum* influx. (Photo credits: algeanova.com and sargassumsolutionsltd.com)

➢ COLLECTION BASICS 2: ACCESSORY (FIELD) DATA: PHYSICOCHEMICAL PARAMETERS; INSTRUMENTS

During the harvesting of *Sargassum*, it is important to collect accessory data, which could be essential for management, as the region is still learning about the *Sargassum* phenomenon. When the sites have been identified or *Sargassum* observed, a checklist of items must be prepared and used prior to departure to ensure the following are packed:

- Protective gear (you and your electronics),
- First Aid Kits,
- Harvesting Equipment,
- Equipment for accessory data collection / recording (e.g. phone / GPS)
- Datasheets printed on waterproof paper / book.

Several factors can affect or inhibit field collection such as the availability of transportation to take the harvested material from the site, equipment and tools necessary to harvest seaweed, team support, time of day that the *Sargassum* is sighted and weather conditions.

Site Information

After arriving at the site it is necessary to record the date, time, GPS readings (using a mobile phone or GPS device), name of the area or port, from which the site was accessed. Individuals are encouraged to take pictures of the site. Note any important 'general observations' other than what is required on the data sheet. E.g. weather / sea state.

Equipment: Camera, GPS, (or mobile phone), datasheet on waterproof paper, writing instrument

Physicochemical Parameters

Physical and chemical properties of seawater near, around and under the *Sargassum* will indicate how the *Sargassum* may be affecting the water and the associated flora and fauna.

- *Temperature* is an important physical parameter as water masses blanketed by *Sargassum* have been known to be hot. Tropical sea surface temperatures are normally 28 – 30^{o}C and values in excess are cause for concern.

- *Dissolved Oxygen* (DO) is the amount of oxygen that is present in water. Water bodies receive oxygen from the atmosphere and from photosynthetic activity of aquatic plants. Actively growing *Sargassum* produces oxygen while water blanketed by old or decaying *Sargassum* could show low oxygen levels. Sites with low DO levels should be avoided. A healthy oxygen level in the sea ranges 6.5 – 8 mg/L.

- *pH*: Seawater is slightly alkaline and has a very stable in pH. The mean or average pH for seawater is expected to be 8.2 (now more often 8.1).

- *Salinity* is the amount of salts dissolved in a body of water. This parameter is not usually affected by *Sargassum* but can indicate presence of freshwater and thus nutrient inputs. Seawater can range from 33-37 ppt (parts per thousand) with a mean of 34.73ppt.

Equipment:

Multi-parameter sampler (e.g. YSI Probe- Figure 9); used to measure more than one physicochemical parameter at a time. Many devices can indicate up to six different parameter readings such as Oxidation and Reduction Potential, which is indicative of health or the ratio of oxidising to reducing conditions, can also indicate oxygen depletion. The probe is placed in the water so that reading may be recorded at that depth and will not work properly if it is not submerged. Many Multi-Parameter Samplers can store the collected data, however, it is recommended that readings be recorded in a *waterproof notebooks or paper* (on which forms or required tables can be printed or photocopied).

Figure 9: The YSI Multi-parameter probe which can collect the physio-chemical analysis for data collection. (Photo credits: Mona Webber)

A minimum of three (3) readings should be taken i.e. at the Surface free of *Sargassum* (10 – 15 cm depth), within the *Sargassum* mat (same 10 – 15cm) and 0.5 / 1 / 1.5 m below the mat depending on the depth of water (Figure 10). The thickness of the *Sargassum* mat at the specified site should also be determined (using a metre rule) and recorded before the *Sargassum* is encircled and cordoned off, as the thickness would increase during the process.

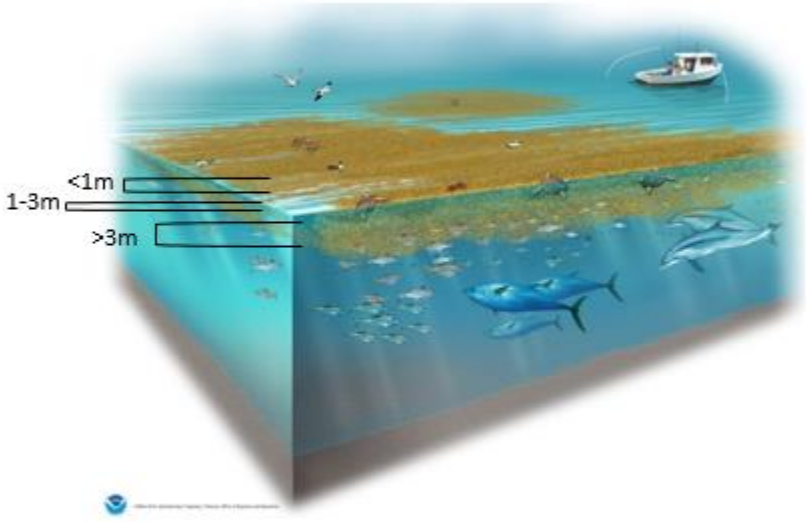


Figure 10: Picture displaying the different depths at which the physicochemical parameters will be recorded. (Photo credits: NOAA &CMS)

Sample Requirements:

The project requires five replicate samples collected at least 10 meters apart, and the replicate samples should be labelled (sample or number code) and stored separately. Each replicate should weigh 10 kg, (as it will be subdivided into similar quantities of each species and morphotype), with five replicates having a combined total weight of 50 kg. There should be 1 kilogram (minimum) of each of the three species and types of *Sargassum* seaweed most commonly found. Since there should be 5 replicates of each, the total would amount of 15 kg of wet material must be available for drying (1 kg of each type- 3 x 5 replicates = 15 kg).

The types of *Sargassum* in the Caribbean are not evenly represented in the mats and may vary on any given day during the season. In the 2020 season, in some cases, *S. fluitans III* (Figure 11) was found to have a dominance as high as 91%. At best, the dominance of one type was found to be 64%. With such a high degree of dominance of that species, harvesters are asked to collect 50 kilograms, as this will likely yield the desired amount of the less common types.

Figure 11: Proportions of Sargassum species and types collected in Jamaica. (Photo credit: Mona Webber)

Containment of Samples:

Gloves should be worn at all times to prevent being stung by hydroids or being cut by unseen items. After removal from the water *Sargassum* should be placed in cloth (burlap) or mesh bags to allow for draining and more accurate determination of wet biomass. The filled bags (5 replicates) should each weigh 10 kg prior to leaving the site. If doing multiple sites, it is advised that a code or a number-sequence is used to differentiate. It is recommended that the bags be pre-labelled and it is best to have an idea of the weight that the respective bag sizes are able to accommodate. The bag number on the label can also be recorded on the datasheet for the associated sample.

Processing should be done as soon as possible after collection (4 - 6 hrs after collecting), as fresh *Sargassum* is required. If severely encrusted and weathered seaweed are present in the sample this should be discarded. After the *Sargassum* has been collected, it should be spread out on a non-metallic surface for cleaning (removal of all non-*Sargassum* material as well as old encrusted pieces) and washed with seawater. *Sargassum* is then sorted into the different species, weighed (1 kg of each species needed), dried, re-weighed and packaged (*See Collection Basics 3*).

Other associated data to be recorded on the *Sargassum* datasheet could include the type of debris, including any other seaweed varieties, plastics, macrofauna (fish, crabs, turtles), or unidentified organic matter.

The following is a summary list of data required:

Table 3: Summary- Data required by this project (Appendix II)

Data Sheet	Sample Quantity
• Information to record while sampling should include: o Total sample weight o Weight of sorted samples (Sflu III, Snat I, Snat VIII, other) o Location of sampling (GPS coordinates) o Water depth o Water quality o Mat thickness o Weather conditions o Site photography o Time sample removed from water o Date o Debris types	5 replicate samples taken 10 m apart Total weight of each sample Weight of sorted samples (by species and types) aiming for 1 kg each

➢ COLLECTION BASICS 3: MATERIAL HANDLING: CLEANING, SORTING, PACKAGING

After the *Sargassum* has been washed with seawater, it should be cleaned to remove solid waste and non-*Sargassum* specimens. *Sargassum* may be fouled (Figure 12) with epibiota (other plant and animal life) which can either be attached or encrusting. These sections which are fouled should be removed / discarded as excessive amounts of foreign plant and animal life may affect experimental results and the epibiota are difficult to remove. Clean, fresh, golden brown seaweed is the desired quality for the samples.

Figure 12: Contrasting appearance of old and fouled *Sargassum* (left side) and fresh *Sargassum.* (Photo credits: Mona Webber)

IDENTIFICATION:

The genus *Sargassum* has 351 species identified to date, with most being described as benthic (associated with the sea floor and shallow water). These are distinguished from the holopelagic by being dark in colour, having a holdfast and short crinkled leaves. Holopelagic *Sargassum* species are described as 'planktonic' as they reproduce (by fragmentation) and grow within the water column without being rooted. Benthic seaweed can break free during rough weather and so may be found amongst holopelagic seaweed; however, this is less of a problem in locations further away from the shore. *Sargassum* species and types are distinguished based on major morphological features (Figure 12) with the most obvious being associated with the air bladders or bulbs and the blades (= leaves).

Holopelagic *Sargassum* Species in the Caribbean

Sargassum mats found throughout the Caribbean are dominated by three main species and types of *Sargassum*. Each can be distinguished from the other on the basis of the relative size of blades, presence of absence of thorns on the stem and the nature of the bulbs / bladders (Table 4 and Figure 13).

While there are only two holopelagic *Sargassum* species in the Atlantic, there are several morphotypes; *S. fluitans* has two (III; X) and *S. natans* has four (I, II, VIII, IX). However, only two species and two types of one are currently dominating the blooms in the Atlantic (outside of the Sargasso sea) and in the Caribbean (Schell et al. 2015). These are distinguished in table 4 below and Figure 13.

Table 4: Distinguishing features of species and types of *Sargassum* found in the Caribbean.

Species	**Thorns**	**Bladders**	**Blades**
Sargassum natans I	spine on each bladder	spherical bladder	narrow and long narrow blades with serrated edges
Sargassum fluitans III	thorns on the stipe (=stem)	oval bladders	broad and medium length blades with serrated edges
Sargassum natans VIII	no thorns/rare	spherical bladder	long blades with serrated edges

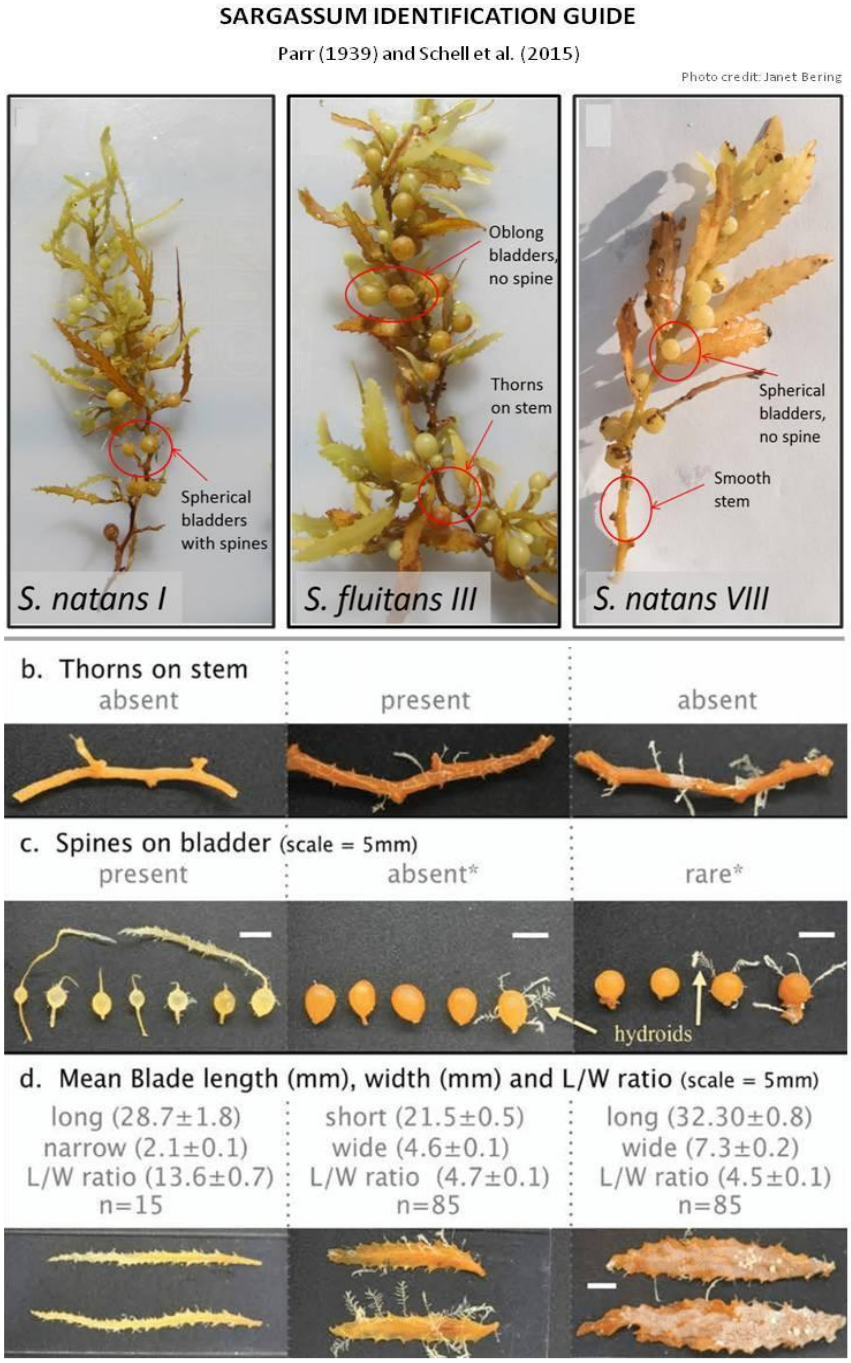


Figure 13: Three holopelagic *Sargassum* frequently found in the Caribbean region (Photo Credits: Jeff Schnell et al. 2015; picture modified by Mona Webber)

Species and types are more easily distinguished by their relative sizes (they look different in the mass) and are easily identified using the more obvious features (size of blades and bladders), rather than the less obvious feature of presence of thorns on stems.

Persons sorting large masses of *Sargassum* should therefore focus on the two easily distinguished features (leaves and bulbs) that help with rapid identification. The shape, size and length of leaves and the shape of, and presence or absence of a spine on each bulb are the most obvious distinguishing features. Sorting large masses can also be aided by the overall appearance of each and as such it should be noted that *S. natans I* is not as thick (stems or leaves) as *S. natans VIII*. The former is characterized by long slender leaves and a spherical bulb with spines growing from the bulbs, while the latter has long but broader leaves without spines growing from the spherical bulbs. *S. fluitans III* has shorter broad leaves and oblong bulbs without spines. Some degree of morphological variability has been observed within some specimens collected from different locations, however they are still easily distinguished from other specimens (Davis et al. 2019).

SORTING:

The following is a step by step process in sorting the *Sargassum* after it has been collected:

(a) Wash seaweed with salt water collected from the respective collection site (never with freshwater)
(b) Remove visible non-*Sargassum* content, heavily fouled sections (encrustation due to epibiota) and foreign matter.
(c) Sort into the 3 types as it is important to know which is dominant spatially and temporally. The chemical composition of each species and type was also found to be very different.
(d) Keep the 5 replicates separate
(e) Sort material on clean (non-metallic) surfaces e.g. plastic. (Figure 14).

Figure 14: Sargassum which has been identified and sorted, left to dry on tarpaulin. (Photo credits: Mona Webber)

(f) Use 5 to 6 (plastic) trays:
  (i) 1 for each species / type (3 in total)
  (ii) 1 for unidentified seaweed that do not match the characteristics of the common forms (to be recorded as OTHER)
  (iii) 1 for live animals and / or debris;

(g) Weighing should be done after foreign matter is removed and a 'fisherman's scale' is recommended.

(h) Minimum of 1 kg of fresh seaweed of each type needs to be sorted;

(i) Handling 50 kg of seaweed means working at an industrial scale so the Fisheries authorities and/or agencies doing the work should seek to get access to a fish or food processing facility with long tables at the correct height for standing.
  (i) Persons handling the seaweed should maintain a comfortable standing position;
  (ii) They should work on raised surfaces, which should be covered with plastic. Metallic surfaces should be avoided, since heavy metal analysis will be performed on the samples, plastic or other non-metallic surfaces should be used for sorting
  (iii) Protective gear (gloves and apron at the minimum) must be used;

(j) Seaweed may be oven-dried in plastic or other non-metallic pans at a temperature not exceeding 50^{o} C, for a period of 24 hours at a time. Large drying ovens are preferred if they are available at the fish processing facility and if small ovens are used, the material may need to be turned periodically. Temperatures should not exceed 50^{o}C so as not to remove volatile organic compounds.

(k) The seaweed should be cooled then weighed and returned to the oven for at least another 24 hours, until constant or < 5% difference is obtained between successive dry weights.

(l) There should be at least two successive weights (after the first and second oven drying periods), before the seaweed is packaged.

(m) After drying, the seaweed's weight may be reduced substantially to 10% of the wet mass; (1 kg wet weight should yield ~ 100g of dried mass). Each type and replicate (n = 5) MUST be dried separately.

(n) The dried seaweed should be cooled, bagged in transparent plastic (which will arouse less suspicion from authorities), with the label inserted inside the bag (Figure 15).

(o) The total (bag and contents) final weight should be determined for shipping purposes.

Figure 15: Dried *Sargassum* in clear plastic packaging, clearly labelled and ready to be shipped. (Photo credit: Mona Webber)

PACKAGING / LABELLING FOR SHIPPING

A coding system has been devised for labelling of the packaged *Sargassum* to be shipped to New Zealand (for this project). The respective country codes are:

a) The Bahamas – MAS
b) Barbados – DOS
c) Belize – IZE
d) Jamaica – JM

Process codes are *OD for oven dried* or *FD for freeze dried*, and replicates can be numbered 1 through to 5 (R1 to R5).

For example, the code MAS-F3-OD-R1 identifies a sample collected in The Bahamas of *S. fluitans* III, processed by oven drying (replicate 1).

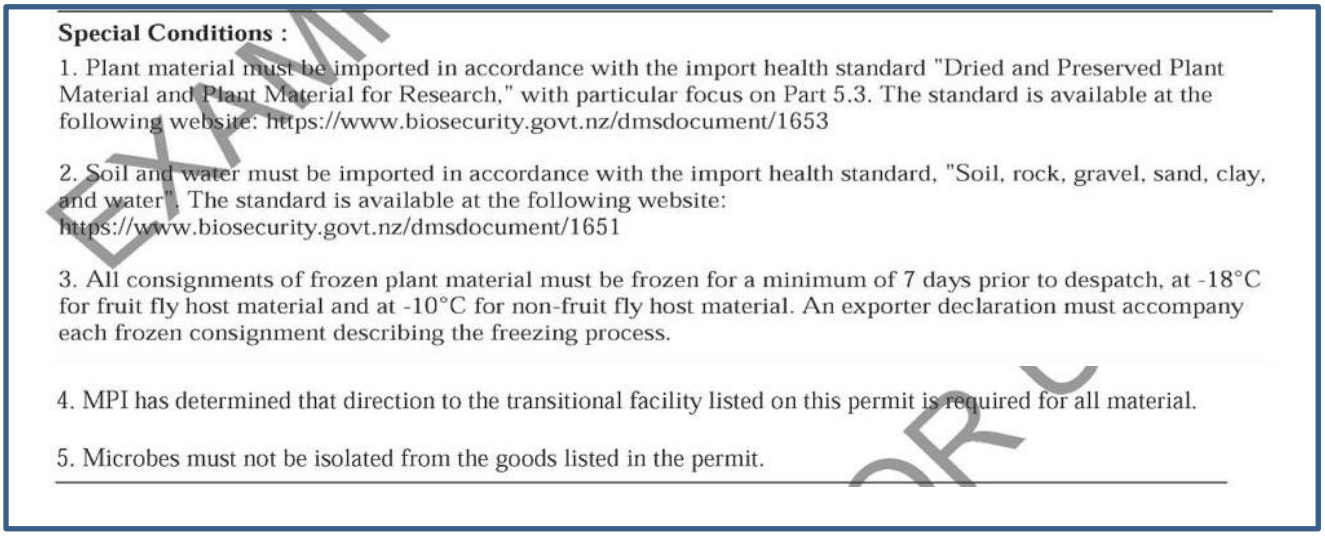
➢ SHIPPING PERMITS (EXPORT & IMPORT) AND ARRANGEMENTS WITH SHIPPERS

The export / import procedures are not complex, however they may be unique for every country. Basic information required for the shipment are the *name of the shipper, the recipient, the destination, the exact weight of the shipment, and the botanical name of the specimen*. The shipment must be in clear bags with labels inside the bags. After the inspection, the package would need to be re-weighed and re-labelled. The required information would also be needed for the other countries through which the *Sargassum* would be shipped.

Exporting *Sargassum* from Jamaica

Proof of phytosanitary inspection is required to confirm that the shipment has been checked before export. Authorities open and inspect the package, primarily to look for insects and potential infectious organisms. Once satisfied, a phytosanitary certificate for export is issued. Generally, there should be no issue with shipping or exporting dried or frozen (- 20 C) *Sargassum* for research purposes.

Import requirements for New Zealand



Special Conditions :

1. Plant material must be imported in accordance with the import health standard "Dried and Preserved Plant Material and Plant Material for Research," with particular focus on Part 5.3. The standard is available at the following website: https://www.biosecurity.govt.nz/dmsdocument/1653

2. Soil and water must be imported in accordance with the import health standard, "Soil, rock, gravel, sand, clay, and water". The standard is available at the following website: https://www.biosecurity.govt.nz/dmsdocument/1651

3. All consignments of frozen plant material must be frozen for a minimum of 7 days prior to despatch, at -18°C for fruit fly host material and at -10°C for non-fruit fly host material. An exporter declaration must accompany each frozen consignment describing the freezing process.

4. MPI has determined that direction to the transitional facility listed on this permit is required for all material.

5. Microbes must not be isolated from the goods listed in the permit.

IMPORTANT INFORMATION FOR PERMIT HOLDERS AND AGENTS

1. This permit, and compliance with the provisions of the specific import health standard(s) and/or entry conditions, does not guarantee that the goods you import will be given biosecurity clearance. There are other restrictions in sections 27 and 28 of the Biosecurity Act 1993 which apply to the giving of biosecurity clearance. The Biosecurity Act may be accessed at www.legislation.govt.nz
2. You will need to ensure that the goods you import comply with the provisions of the specific import health standard(s) and/or entry conditions that are applicable. The import health standard may be amended during the course of your permit. Import Management will notify you of any significant changes to the import health standard and will re-issue the permit to accommodate these changes.
3. There are a number of other provisions in the Biosecurity Act 1993 which may affect you. If you commit an offence against the Biosecurity Act 1993, heavy penalties under section 157 of the Act might apply.
4. Apart from the Biosecurity Act 1993, there are other laws relating to or prohibiting the importation of goods. This permit, and compliance with the provisions of the specific import health standard(s) and/or entry conditions, does not absolve you of the need to comply with these laws.
5. Unless specifically identified in 'Description of Items' or 'Special Conditions' of the permit, NO new organisms, including genetically modified organisms, are permitted entry under this permit.
6. All cultures must be:
   - clearly labelled with the scientific strain and name
   - consigned in leakproof packaging
   - free from contaminants
7. All new organisms must not be opened until received by the nominated containment facility.

➢ HEALTH AND SAFETY PLAN

Under the Health and Safety at Work Act (2015), which was enacted in New Zealand in April 2016, all initiatives that benefit from the New Zealand Aid Programme must have a Health and Safety Plan for all workers. The Ministry of Foreign Affairs and Trade (MFAT) expects that all partners on the Aid Programme will do what is reasonable and practicable to keep workers safe. The Ministry wants to ensure adherence to the health and safety standards, notwithstanding that health and safety standards may vary across countries.

As a result, the project incorporates inspection and audit processes. The CRFM and Plant & Food Research, which are collaborating to implement the project, will need to ensure that staff and workers comply with health and safety procedures and processes. These processes would encapsulate, *inter alia*, briefings and reminders of health and safety practices for staff preparing to travel for in-country work, as well as daily informal observations to encourage safe work practices (such as the use of sunscreen, hydration, daily vehicle inspection and the use of appropriate clothing). In-country meetings would include reviews of any safety concerns, to be followed by the necessary adjustments.

Additionally, the coordinator(s) will be expected to notify the CRFM and Plant & Food Research of any health and safety incidents, injuries, illness, and even 'near misses', as soon as possible. A range of measures for identified risks are provided as examples.

Table 5: List of approved associated risks by the New Zealand Ministry of Foreign Affairs and Trade

Risks	Potential Harm	Eliminate or minimise	Isolate or engineer	Administration
Working alone	Working alone is not necessarily a risk, however not having a second person could increase risk when working in security risk areas.	Do not work alone if possible. Identify potential high risk situations and plan to have a second person present.	Monitor or track all employees if entering risk areas. Have ICE (In Case of Emergency) details in mobile phone. Inform other staff about whereabouts.	Staff training on safe distances, safe areas and exit plans. Call in procedure. Discuss with CRFM or PFR as to their procedures.
Infectious diseases	There are many infectious diseases that can cause harm: Zika virus, COVID-19, dengue, fever, STDs, cutaneous leismansiasis*, etc. Disease transmission varies, thru food, water, soil, blood, animals, air, or genital contact.	When a serious outbreak occurs, notify staff and delay travel. Follow health and safety protocols.	Monitor or track all workers' health conditions. Have ICE (In Case of Emergency) details in mobile phone. Inform other staff if have become seriously unwell.	Concerns have to be highlighted before any work activity. This includes medical checks, vaccinations, education, and safety equipment (incl. face coverings). Also, be knowledgeable of recommended medical practitioners / clinic options.
Hazardous animals and plants	These animals and plants can cause serious harm or death to workers.	Clearance secured from in-country counterparts on potential work sites. Work sites checked and identified animals and plants removed prior to work commencing.	Avoid high risk areas, where hazardous animals and plants thrive or are found in large quantities.	Briefing or inductions to include overview of these dangerous animals and plants, how to avoid attacks or bites, and how to apply emergency treatment. Threat assessment before entering areas. Wear protective clothing and repellent from insect bites. Proper (swimming) gears for protection if collecting specimens inshore or offshore.

Land / sea transport	Motor vehicle or boating accident could cause serious harm or loss of life to workers. Also, significant damage to property, equipment and resulting loss of productivity.	Cannot eliminate since travel is required.	Ensure seatbelts are fastened in vehicles. Hire or use boats, vehicles that meet the relevant standards.	Plan journeys to minimise safety risks. Engage good suppliers and check competencies of drivers / skippers and certification of plant and equipment. Have first aid kits kept in all vehicles. Lifejackets taken for all workers on any boat travel.
Environment	You will be spending a significant time outdoors and exposed to a range of weather conditions (heat and / or rain). Weather conditions may cause flooding and strong waves. These may cause disruption on project activities.	Monitor weather forecasts prior to travel to project sites.	N/A	Ensure you have adequate protection from the sun (hats, long-sleeved shirts, sunblock, sunglasses), rain (waterproof jackets, umbrella, water-resistant shoes).
Entanglement with moving parts	Operators of machinery can be entangled or trapped.	N/A	Guard – isolate by ensuring fixed guards as per manufacturer's instructions. Isolate and lock out during maintenance	All operators to be trained on safe operating procedures and be directly supervised.

Exposure to *Sargassum* (particularly in its decomposing state) is identified among the risks associated with hazardous animals and plants that require specific measures to eliminate/minimize harm. Similarly, potential contact with stinging jellyfishes hiding in *Sargassum* is also seen as a caution. Measures also covered the need for proactive action to avoid harm and the application of emergency treatment in the event of harm. The need for caution to ensure safety at sea - particularly to avoid strong waves - was also highlighted.

APPENDIX I

AGENDA

Training Workshop Programme
Wednesday, 3 March 2021
3:00 – 5:30 pm Eastern Caribbean Time
***Sargassum* Harvesting and Processing for Export**

	Session title	**Materials / Resources**	**Duration (minutes)**
Item 1	Welcome, Introduction and preliminaries including participant check-in		20
Item 2	Overview of the *Sargassum* 'problem' in the Caribbean	PPT	10
Item 3	Overview of the Project, "*Sargassum* Products for Climate Resilience in the Caribbean"	PPT	10
Item 4	Collection basics 1: Harvesting methods: Modified seine (2 small boats) Barge harvester	PPT	10 10
Item 5	Collection basics 2: Accessory (field) data: physicochemical parameters; instruments Containment (short term storage bags) / weighing	PPT	15
Item 6	Material Handling: Cleaning, Sorting, Packaging Identification and separation of species and types Weighing before and after drying Air drying / Oven drying / Freeze drying and packaging	PPT	40
Item 7	Shipping permits (Export and Import) and arrangements with shippers	PPT	15
Item 8	Health and Safety Plan	PPT	10
Item 9	Question and answer, next steps and closing		15
		TOTAL	155 minutes

APPENDIX II: Sampling protocol development for *Sargassum Products for Climate Resilience in the Caribbean.*

- Sample collection should be carried out from mats concentrated near shore by floating barriers or at a distance of 20m>200m from shore.
- Replicate samples at a single location should be collected at a minimum distance of 10m from each other
- Sample should be washed with salt water and sorted into *Sargassum* and non-*Sargassum* species
- Information to record while sampling should include:
    - Total sample weight
    - Weight of sorted samples (SFlu III, SNat I, SNat VIII, other)
    - Location of sampling (GPS coordinates)
    - Water depth
    - Water quality
    - Mat thickness
    - Weather conditions
    - Site photography
    - Time sample removed from water
    - Date
- Once washed, sorted and weighed, only 1.0kg of material needs to be bagged, labelled and returned for drying
- Standardized sample nomenclature should be used with shorthand as follows: Location_Species_Drying Method_Replicate

Location	Species	Drying Method	Replicate
Bahamas **MAS**	S Fluitans III **F3**	Oven Dried **OD**	**1-5**
Barbados **DOS**	S Natans I **N1**		
Belize **IZE**	S Natans VIII **N8**	Freeze Dried **FD**	
Jamaica **JAM**			

e.g. MAS_F3_OD_1

- Oven drying protocol to consist of heating on trays at 50C and collecting and recording daily sample weights until evaporative weight loss is <5% of the sample weight on 2 consecutive measurements. (Samples (1.0kg) should yield ~100g dry matter so should show 2 measurements with a loss <5g)

APPENDIX III: List of Key Contacts

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CRFM

The CRFM is an inter-governmental organisation whose mission is to "Promote and facilitate the responsible utilisation of the region's fisheries and other aquatic resources for the economic and social benefits of the current and future population of the region". The CRFM consists of three bodies – the Ministerial Council, the Caribbean Fisheries Forum and the CRFM Secretariat.

CRFM members are Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, and The Turks and Caicos Islands.