Harmful Algae News

An IOC Newsletter on Toxic Algae and Algal Blooms

No. 66 - December 2020 · www.ioc-unesco.org/hab

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

The Recurring Great Atlantic Sargassum Belt Impacts the Caribbean and South Florida

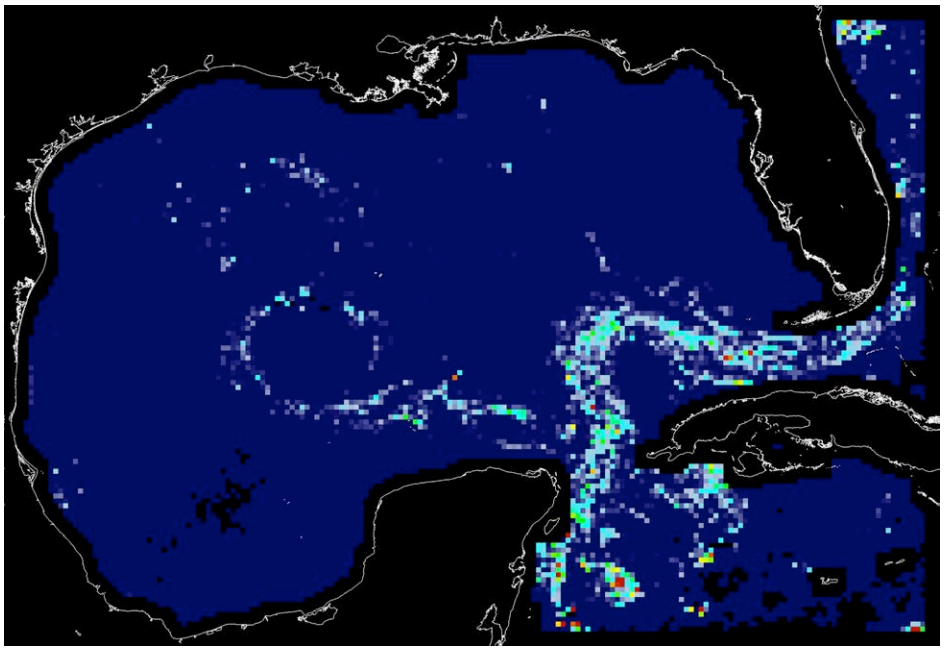

Fig. 1. MODIS satellite image of Sargassum transport from the Caribbean through the Yucatan Channel and into the Loop Current and Florida Current on July 16, 2020

Since 2011, the floating brown seaweeds known as pelagic *Sargassum* have formed a *Great Atlantic Sargassum Belt* (GASB) in the tropical Atlantic Ocean extending between Africa and South America [1]. The GASB represents an expansion in the distribution of this unique floating vegetation, which was historically restricted to the Gulf of Mexico (GOM), Loop Current, Gulf Stream, Sargasso Sea, and Caribbean Sea (Fig. 1). This vegetation was first reported by Christopher Columbus in the Sargasso Sea in 1492 and includes two pelagic species – *Sargassum natans* and *Sargassum fluitans* - that reproduce by vegetative fragmentation (Fig. 2). Early oceanographers were impressed with the vigorous appearance of *Sargassum* in the Sargasso Sea and estimated that ~ 90% of this vegetation was comprised of *S. natans* with the remainder being *S. fluitans* and several benthic species recruited from shallow coastal waters of the West Indies [2].

The precept that pelagic *Sargassum* flourishes in surface waters of the Sargasso Sea became a paradox to modern oceanographers who referred to this oligotrophic gyre as a "biological desert" [3]. Studies of the productivity and nutrition of *Sargassum* showed that photosynthesis and growth of these oceanic populations were nutrient-limited in the Sargasso Sea, compared to more productive nutrient-enriched plants in neritic waters of the GOM, Loop Current, and Gulf Stream [4]. These studies documented the importance of nutrient cycling by associated fish and invertebrates within the pelagic *Sargassum* community that has been designated "Essential Fish Habitat" by the National Oceanic and Atmospheric Administration (NOAA). A variety of nutrient sources in neritic waters of the western North Atlantic Ocean and GOM explained the higher nutrient contents and productivity of *Sargassum*, which included shelf-break upwelling, continental runoff via rivers (Mississippi River, Everglades), submarine groundwater discharge, benthic sediment recycling,

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and atmospheric inputs [5]. Human influences on several of these nutrient sources greatly increased in the 1980s and 1990s as a result of increased application of agricultural fertilizers, urbanization, atmospheric pollution, and extreme rainfall and flooding associated with climate change. These increasing nutrient inputs correlated with increasing accumulations of *Sargassum* on beaches and shorelines around the GOM [5].

A variety of nutrient sources appear to also be supporting the development of the GASB in the tropical Atlantic Ocean since 2011. Studies using MERIS (Medium Resolution Imaging Spectrometer) and MODIS (Moderate Resolution Imaging Spectroradiometer) satellite remote sensing described a new *Sargassum* bloom event north of the Amazon River in April 2011, which by July had spread eastward to Africa and westward to the Lesser Antilles and Caribbean Sea [6]. With the exception of 2013, the GASB has since formed annually, developing during spring months and peaking in abundance in summer; in July 2018, the GASB extended for 8,850 km from Africa to the GOM and ranked as the largest algae bloom on earth [1]. Over its broad distribution, the GASB can be supported by nutrients from the Amazon, Orinoco, and Congo rivers, upwelling in the eastern tropical Atlantic off the African coast [1,7,8], and atmospheric deposition of Saharan dust and biomass burning in South Africa [9]. Annual flooding events in the Amazon basin since 2009 combined with increased nutrient supply from deforestation and fertilizer use are factors potentially supporting bloom initiation in the central western Atlantic Ocean in 2011 [1,6,8,10].

Fig. 2. Collection of Sargassum natans (left side of photo) and Sargassum fluitans (right side of photo) off Ft. Pierce, Florida, for nutrient analysis

Fig. 3. Sargassum influx to the south side of Big Pine Key in the lower Florida Keys, June, 2014. Note absence of abundant fishes associated with Sargassum in the bottom photo

The excessive *Sargassum* biomass transported from the GASB to coastal waters in the Caribbean region have been causing a myriad of environmental impacts. Offshore, the extreme abundance of *Sargassum* has fouled fishing gear and caused challenges for safe navigation in and around the extensive mats. Decreased catches of the dolphinfish or mahi mahi (*Coryphaena hippurus*; -37%) and flying fish (family Exocoetidae; -52%) have been reported in Barbados. After stranding on beaches and coastlines, decomposition of *Sargassum* releases large amounts of brown leachate and results in *hypoxia* and *anoxia,* releasing toxic hydrogen sulphide and ammonia. The resulting water quality degradation from *Sargassum* exacerbates coastal eutrophication, resulting in fish kills, sea turtle mortality, and increased die-off of seagrasses and corals [11]. The massive influx of *Sargassum* to the Mesoamerican reef system was identified as a contributing cause of decreasing water quality and the outbreak in stony coral tissue loss disease (SCTLD) in 2018 [12].

As in the Caribbean, *Sargassum* influx to South Florida has increased

Fig 4. Sargassum stranding event on the south side of the Ft. Pierce inlet, Ft. Pierce, Florida, July, 2020

since 2011, especially following the larger size of the GASB after 2014 [1]. Extensive mats of *Sargassum* washed ashore in the Florida Keys between May and August 2014 (Fig. 3), a trend that has continued through summer of 2020 (Fig. 4). The massive strandings and decomposition have impaired water quality in nearshore waters of South Florida, especially in coastal bays and canals where *Sargassum* can become concentrated (Fig 4). Since 2014, SCTLD has spread from Miami through the Florida Keys during the same time frame when *Sargassum* influx has increased. This correlation parallels research in the Caribbean that has linked increasing *Sargassum* influx to worsening water quality and coral reef health [12].

Public health issues related to the increasing *Sargassum* influx have also increased in recent years. During large-scale strandings in the summer of 2018, more than 11,400 residents in Martinique and Guadeloupe were diagnosed with acute exposure to toxic H_2S gas produced by decaying *Sargassum* [13]. Additionally, bacterial (fecal coliform, enterococcus) and heavy metal (arsenic, cadmium) pollution associated with excessive *Sargassum* strandings are causing concern for recreational beach use, as well as attempts to safely dispose of *Sargassum* or recycle its biomass into fertilizers and soil conditioners for use on food crops.

The serious environmental and public health issues resulting from the harmful *Sargassum* influx pose major economic challenges to the Caribbean and South Florida region. *Sargassum* removal from Texas beaches during earlier, less severe inundations was estimated at $2.9 million per year. In 2018, the Caribbean-wide clean-up cost $210 million [8] and Florida's Miami-Dade County alone estimated removal expenses of $45 million in 2019. In addition, the direct economic impacts to tourism and commercial fishing are substantial, underscoring the urgent need for research focused on the various physical, chemical, and biological mechanisms underlying the development of the GASB.

The United Nations Environment Program (UNEP - GPNM) in collaboration with IOC UNESCO and the IOC-SCOR GlobalHAB programme hosted four webinars on *Sargassum* in 2020, and the Secretariat has shared the current realities of the impacts and approaches being taken to address the issue. Various stakeholder groups participating in the webinars have expressed their concern for the recurring *Sargassum* events in West Africa and the Caribbean region, highlighting the necessity for mainstreaming the issue in the policy arena, possibly a resolution at the United Nations Environment Assembly.

The scale of the GASB, which extends from Africa to the GOM and South Florida, is unprecedented for a HAB, as is the complexity of physical, chemical, and biological factors supporting initiation, seasonal development, and transport of the GASB.

Recently, the Scientific Steering Committee of the IOC-SCOR GlobalHAB Programme, through its Science and Implementation Plan, has recognized the *Sargassum* expansion as an emerging HAB issue. A new subcommittee dedicated to this topic has been established (see GlobalHAB this issue)

Acknowledgements

The authors are grateful to Drs. Chuanmin Hu and Mengqiu Wang (University of South Florida) for providing remote sensing imagery of Sargassum, and to Ileana Lopez (UN Environment, Cartagena Convention Secretariat) and Dr. Elisa Berdalet (Institute of Marine Sciences, Barcelona; GlobalHAB SSC Chair) for their review and comments.

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