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This article is a commentary on Sosa-Gutierrez et al. [2022] https://doi.org/10.1029/2021GL097484.

Key Points:

- The distribution and abundance of a species is the result of the reproduction, mortality, and movement of organisms
- For marine organisms, like pelagic *Sargassum*, these three processes can each be strongly impacted by tropical storms
- Understanding the mechanisms that drive storm impacts will be valuable for predicting *Sargassum* dynamics and problems like beaching events

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Sinking *Sargassum*

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Abstract Blooms and coastal inundations of pelagic *Sargassum* have caused major problems to coastal communities and ecosystems throughout the tropical Atlantic over the past decade. Understanding *Sargassum* growth, movement, and mortality is essential to being able to predict and mitigate these events. In principle, tropical cyclones that occur in this area could have an impact on all three processes. In a recent article, Sosa-Gutierrez et al. (2022, https://doi.org/10.1029/2021GL097484) investigated the potential impacts of tropical cyclones (TCs) on pelagic *Sargassum* using satellite-based *Sargassum* maps and 86 hurricane tracks during 2011–2020. Their statistical analysis showed an average drop of 40% in *Sargassum* coverage under TC trajectories, which was attributed to possible sinking of *Sargassum*. Here, we discuss implications of these findings, and advocate continued research on how storms and other physical factors influence the dynamics of growth, movement, and mortality in this ecologically and economically important macroalgae.

Plain Language Summary Pelagic *Sargassum* in the Atlantic Ocean plays an important role in ocean ecology, yet excessive *Sargassum* on beaches can have dramatic negative consequences to human communities and coastal ecosystems. Predicting beaching events requires knowledge on how *Sargassum* grows, moves, and dies. In principle, major storms like tropical cyclones could impact each of these processes. A recent *GRL* article by Sosa-Gutierrez et al. (2022, https://doi.org/10.1029/2021GL097484) investigated some of these questions by comparing satellite-based *Sargassum* estimates before and after the passage of hurricanes and found substantially decreased *Sargassum* amounts. Regardless of how much this pattern results from *Sargassum* sinking, rafts fragmenting, or uncertainties in the satellite-derived *Sargassum* maps, storms may have a major impact on *Sargassum*'s distribution and abundance—with important implications for its function in the ecosystem.

Currents, waves, winds, and tides keep many of the ocean's inhabitants in constant motion. The need to understand these physical forces introduces significant complications to our ability to study and understand marine ecosystems. These complexities are epitomized in pelagic *Sargassum*, a genus of brown macroalgae that forms floating rafts or mats at the ocean surface. These *Sargassum* rafts or mats are seasonally abundant in the North Atlantic where they serve as important habitat for ecologically and economically important marine animals (including sea turtles, fishes, and sea birds), and have shaped the evolution and biogeographic patterns of numerous and diverse marine species (Bertola et al., 2020; Witherington et al., 2012). Moreover, recent studies indicate that *Sargassum* can be an important carbon sink at local scales (Hu et al., 2021; Paraguay-Delgado et al., 2020). When washed ashore, *Sargassum* can enhance dune plant growth by its contribution of marine-derived nutrients to littoral habitats and thus improve shoreline stability (Williams & Feagin, 2010). *Sargassum* has also been considered a marine resource with potential applications as biochemicals, feed, food, fertilizer, and fuel (Milledge & Harvey, 2016). When impinging on shorelines, "golden tides" of *Sargassum* can also cause major problems (Smetacek & Zingone, 2013). The release of hydrogen sulfide and ammonia when *Sargassum* decomposes on beaches can result in health problems for humans (Resiere et al., 2021) and produces unpleasant smells that attract insects and diminish tourism. Other environmental problems include negative impacts on seagrass communities, corals, and water quality that can increase sea turtle mortality, fish kills, and further economic disruption (Duffy et al., 2019). Being able to predict *Sargassum* distribution, abundance, and movement would be highly desirable as this could lead to forecasts of *Sargassum* beaching events so that coastal zone managers can be prepared for mitigation responses (Trinanes et al., 2021).

Despite considerable research in recent years, a mechanistic understanding of the drivers of *Sargassum* dynamics is presently elusive. For example, it is unclear how *Sargassum* growth in the natural environment depends on temperature, nutrient availability, light, etc. Likewise, it is unclear what drives the seasonality in observed

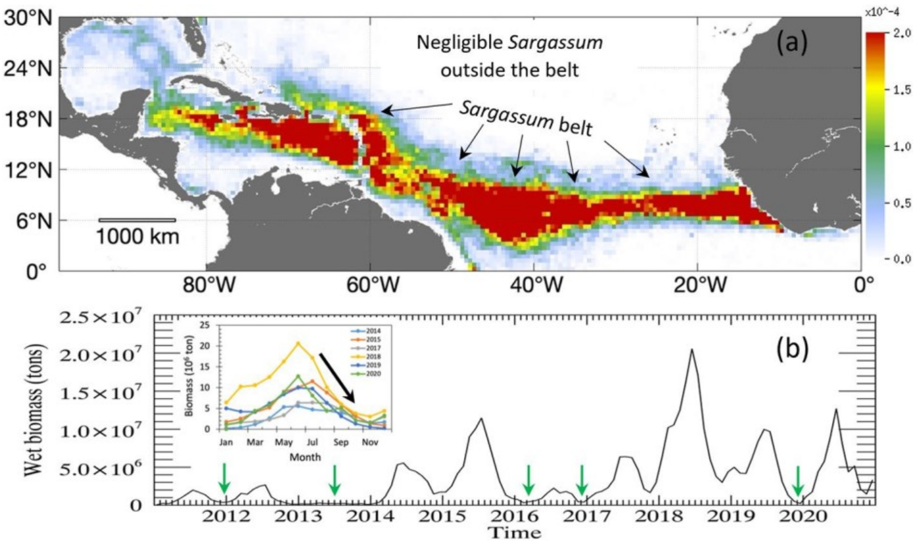

Figure 1. (a) The Great Atlantic *Sargassum* Belt (GASB) from west Africa to the Gulf of Mexico, derived from Moderate Resolution Imaging Spectroradiometer satellite observations between 2011 and 2020 during the months of June–November. Color legend indicates fractional cover or areal density (e.g., $1.0 \times 10^{-4} = 0.01\%$); (b) Monthly mean *Sargassum* biomass integrated over the study region of (a), where ~20 million tons of biomass were observed during the peak month in 2018 (Wang et al., 2019). Unlike maps presented in Sosa-Gutierrez et al. (2022), there is negligible *Sargassum* outside the belt, and there is minimal amount during most winter months and during 2013 (green arrows). The inset figure shows seasonal patterns in several major *Sargassum* years, where monotonic decreases start from June or July (black arrow).

Sargassum biomass. These knowledge gaps became apparent to the wider scientific community in 2011, when an unprecedented bloom of *Sargassum* occurred in the tropical Atlantic and the algae inundated coastlines in Africa, South America, and the Caribbean Sea (Gower et al., 2013). Such knowledge gaps also make it a pressing need to understand *Sargassum* origin, growth, and fate, especially after the discovery of a recurrent *Sargassum* "belt" stretching over a distance of >8,000 km from coast of west Africa to the Gulf of Mexico nearly every year since 2011 (Gower & King, 2019; Wang et al., 2019; Figure 1).

A new paper in *Geophysical Research Letters* by Sosa-Gutierrez and colleagues improves our understanding of the fate of *Sargassum* in the Atlantic by investigating the role of tropical cyclones on the observed *Sargassum* amount. Like other organisms, the distribution and abundance of *Sargassum* are the result of its' reproduction, mortality, and movement (Brooks et al., 2018). In principle, tropical cyclones might have a strong influence on all three of these processes. There is no sexual reproduction in pelagic *Sargassum*, and its' spread is entirely due to fragmentation and vegetative growth. The mechanical energy imparted by tropical cyclones could break apart rafts, possibly improving nutrient uptake by increasing the surface area to volume ratio of mats and further enhancing growth through vertical mixing of the water column. Alternatively, the high winds and strong wave action might result in the submergence of *Sargassum* and the detachment of the air-filled vesicles which maintain its buoyancy. Under such conditions, *Sargassum* might sink and die. Finally, tropical cyclones might not appreciably alter the biomass of *Sargassum* but redistribute it by imparting additional velocity to the ocean surface from windage (the direct force of winds blowing across the *Sargassum*) and Stokes drift (the additional velocity imparted to objects at the ocean surface by waves). Under such circumstances, the redistribution may result in small *Sargassum* mats or clumps that are invisible to satellites.

Sosa-Gutierrez and colleagues investigated some of these possibilities by overlaying 10 years (2011–2020) of tropical cyclone position/intensity data on daily grided maps of the fractional coverage (i.e., areal density) of *Sargassum* at 0.25° (~25 km) resolution, based on satellite observations. For the analysis, 86 tropical cyclones were considered, consisting of 501 total positions along the storm tracks. For each position, the daily averages of *Sargassum* fractional coverage and chlorophyll concentration (a proxy for nutrient availability) were obtained over a radius of 200 km 3–10 days before and 3–20 days after the storm's passage over that point. The before-after comparison showed that, on average, the detectable coverage of *Sargassum* was of 40% lower following the storm's passage. In contrast, chlorophyll concentration increased the day following a storm's passage and then returned to values similar to the 10 days prior to the storm. The dramatic losses in the observed *Sargassum* were speculated to be a result of sinking, and the initial influx of nutrients to surface waters (as indicated by the spike in chlorophyll) appears insufficient to recover those losses.

Assuming sinking is the primary reason leading to the post-storm reduction in *Sargassum* coverage, Sosa-Gutierrez and colleagues suggest that tropical cyclones would contribute to the seasonal decay of *Sargassum* given that in some months, up to 25% of detectable *Sargassum* was under the influence of these storms. Interestingly, the topic of sinking *Sargassum* through ocean engineering is currently being discussed by the community as one of the means to reduce carbon (Gouvea et al., 2020; Lopez-Contreras et al., 2021). In that regard, the findings of Sosa-Gutierrez et al. are indeed significant, as nature appears to work its course on carbon reduction. For the same reason, because many coastal residents suffer from excessive *Sargassum* inundation, the reduction of *Sargassum* following the passages of tropical cyclones may ease some of the coastal stresses.

As such, the study by Sosa-Gutierrez et al. points out the importance of tropical cyclones in modulating *Sargassum* coverage and biomass. Yet much remains to be answered regarding the mechanisms driving the observed *Sargassum* patterns. Some of the annual and monthly statistics as well as the relatively large and overlapping standard deviations in the before-after comparisons may be, in part, due to *Sargassum* maps that appear to contain large uncertainties in both space and time. In contrast to the maps provided in Wang et al. (2019) for the Atlantic Ocean (Figure 1), Sosa-Gutierrez et al. showed large amounts of *Sargassum* outside the main belt, and also large amounts of *Sargassum* during the winter months. Such differences may be due to uncertainties induced by specific approaches to screen clouds, cloud-adjacent straylights, cloud shadows, and to quantify *Sargassum* amount when processing satellite data. Although the same alternative floating algae index (AFAI) method (Wang & Hu, 2016) was used to detect and quantify *Sargassum* from the same satellite data collected by the Moderate Resolution Imaging Spectroradiometer (MODIS), *Sargassum*-containing image pixels in Sosa-Gutierrez et al. were not unmixed to estimate the subpixel coverage, but rather treated in the same way after selecting the pixels with strong signals. For the coarse MODIS pixels (1-km resolution), subpixel coverage can vary over two orders of magnitude from 0.2% to 20% (Wang & Hu, 2016), and simply counting the number of *Sargassum*-containing pixels without proper unmixing will put unrealistically high weights on the low-coverage pixels, contributing to large uncertainties when summarizing all *Sargassum*-containing pixels within a region or period or deriving *Sargassum* distribution maps. For example, there are substantial amounts of *Sargassum* outside the *Sargassum* belt as reported in Sosa-Gutierrez et al. (2022), but Figure 1 shows the opposite. Additionally, because all tropical cyclones occurred in June–November when the total *Sargassum* amount in the belt is already in a declining phase (Wang et al., 2019; Figure 1), and because large *Sargassum* rafts or mats may be dissipated by the strong winds into smaller mats or clumps that are not visible by satellites, more work appears necessary to decipher the observed before-after changes. For example, application of high-resolution satellite data may be able to detect and quantify individual *Sargassum* mats including their numbers and sizes (Wang & Hu, 2021), thus enabling the assessment of possible dissipation effect - provided that cloud free images are available along the hurricane tracks.

The *Sargassum* belt shows a clear seasonal cycle with basin-wide biomass increasing over the spring and early summer, and then decreasing over late summer to winter (Figure 1). Understanding such a seasonal cycle, on the other hand, is anything but easy. While free-running circannual rhythms, which were found in other brown seaweed species (Lüning, 1994), might be one factor to control the timing of *Sargassum* growth or decline, other factors also need to be considered. For the case of *Sargassum*, more detail is needed to understand how growth rates and fragmentation are related as well as the limitations imposed by nutrients, temperature, and light (Lapointe et al., 2021). For movement, the inertial effects of *Sargassum* need to be carefully considered as well as how the physical network of the raft influence its variable response to surface currents, winds, and waves (Beron-Vera & Miron, 2020). Uncertainty around mortality, as mentioned above, remains particularly problematic. Cooler ocean temperatures correspond to reduced growth and apparent degradation (Brooks et al., 2018) but dissociating temperature (or storms) from a seasonal pattern of senescence has yet to be done. Knowing under what conditions *Sargassum* dies is an essential component to any attempt to model its movement and distribution. For instance, if *Sargassum* mortality is assumed to be minimal (or ignored), models can predict connectivity between the North Atlantic/Sargasso Sea and the Tropical Atlantic/Caribbean Sea, whereas if mortality is assumed to be relatively high such connections are unlikely (Johns et al., 2020). This has important implications for understanding a wide range of topics, from beaching dynamics (Trinanes et al., 2021) to biogeographic patterns and the evolutionary diversification of species (Bertola et al., 2020).

These questions are not restricted to *Sargassum* but are important for many taxa that move at the ocean surface (Monzon-Arguello et al., 2012; Smith et al., 2018; Waters & Craw, 2018). For instance, a study modeling colonization potential of Antarctica by rafting species fringing the Southern Ocean showed that accounting for the impact of storms on transport (via Stokes drift) greatly increased the probability of species reaching the Antarctic coast (Fraser et al., 2018). Alternatively, these storms might also result in higher probabilities of macroalgal rafts sinking, thus reducing the potential for species invasion (Putman, 2018). More work is required to assess post-storm changes in macroalgae rafts by using improved macroalgae maps and statistical analyses, and more work is needed to disentangle the influence of storms on mortality versus movement. Nonetheless, the work by Sosa-Gutierez et al. clearly indicates that tropical cyclones can have an important reorganizing impact on the distribution of *Sargassum*. Whether by dispersing/fragmenting large rafts or by inducing mortality by sinking, the impact would likely have important implications for the associated species and the potential for coastal inundation. Continued work on the role of storms on pelagic *Sargassum* will be valuable, as will other research to understand the dynamics of growth, movement, and mortality in this ecologically and economically important macroalgae.

Data Availability Statement

No new data was used in this paper.

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