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Sargassum Invasions in Mexican Caribbean Coast (MCC): Public Perspective on Health, Tourism, and Environmental Challenges

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ABSTRACT: Mass blooms and beaching of *Sargassum* spp. Since 2011 has deteriorated the Mexican Caribbean Coast quality beyond the limit. Despite several studies addressed the direct impact of *Sargassum*, the potential health risk from *Sargassum* in Mexican Caribbean Coast (MCC) remains scanty. To address the knowledge gap, the findings of this study highlight the significant socio-environmental impacts of *Sargassum* influxes on the Mexican Caribbean Coast based on the public perspectives using questionnaire survey. The results indicated that female respondents report higher sensitivity to *Sargassum*- related impact markedly health effects such as respiratory discomforts and skin disorders. Additionally, a significant proportion of respondents observed changes in tourism and their significant economic losses. This study further explores the relationship between *Sargassum* beaching and its socio-environmental consequences, highlighting the gendered variation in perception. While economic impacts were highly recognized by male respondents, the environmental and health related concerns were more prevalent among female respondents. These findings emphasize the need for targeted mitigation strategies that include air quality monitoring, public health interventions and sustainable *Sargassum* management programs. Henceforth, addressing these challenges requires integrated approaches that consider both ecological and social interventions for implementing adaptive management policies to foster long term resilience on *Sargassum* impacts.

KEYWORDS: Mexican Caribbean Coast (MCC); *Sargassum*; Survey; Health impact; Socio-environment.

1. INTRODUCTION

Beaches are more than merely sand and water, they are a dynamic interface between land and sea, constantly sculpted by both human and natural influences. Amongst the global beaches, Mexican Caribbean Coast (MCC) is known for its pristine beaches with turquoise waters and white sands. However, natural, and anthropogenic factors are reshaping the coastline and impacting the coastal ecosystem (Macías Pérez, 2009; Fraga & Robledo, 2022).

Since, the MCC is economically enriched regime for the development of Mexico's Gross Domestic Product (GDP), which is resulted from several different marine and coastal ecosystem. Among this a unique onset of calamity, has devasted the coastal and urban community, which is the massive arrival of *Sargassum* since 2011 (Smetacek and Zingone, 2013). Holo-pelagic *Sargassum* is a brown macroalgae which floats on the ocean surface which has two species: *Sargassum natans* and *Sargassum fluitans* (hereafter *Sargassum*) (Martin et al., 2021). These two species of *Sargassum* naturally occur in the Sargasso Sea located in the Atlantic Ocean (Fine, 1970), being habitat for fish, invertebrates, sea turtles and sea birds and it also serves as spawning and nursery areas for many organisms (Pendleton et al., 2014; Sissini et al., 2017). The global term "brown tides" has been coined for the massive beaching of *Sargassum* spp., owing to their brown-yellow color that resembles gold (Smetacek & Zingone, 2013) and their abrupt blooming was explained through several theories includes marine pollution, hydrocarbon spills, spiked concentration of nutrients resulted due to discharges from Amazon, Orinoco and Congo (Wang et al., 2019); sand dust from Sahara Desert (Chavez et al., 2020) and rising ocean temperatures resulted from climate changes alters the currents and wind patterns (U.C. Marx et al., 2021).

Since 2011, some prior changes were noticed in the MCC, with an extensive beaching of *Sargassum* from the Caribbean Sea from the Great Atlantic *Sargassum* Belt (Wang and Hu, 2018; Wang et al., 2019). Since then, throughout the Caribbean, the *Sargassum* has been classified as invasive and destructive marine algae given the ongoing challenges for the coastal communities and tourism (UNEP United Nations Environment Programme, 2018). During the beaching of *Sargassum* in 2015, this MCC coast was estimated with 10,000 wet tonnes, covering an average 9726 m^3 of seaweed accumulated per month per km of coastline (Rodriguez- Martinez et al., 2016), whilst this coast faced inadequate resources for mitigation and elimination. The mass pile up of *Sargassum* on beaches is not a welcome sight or smell, which has been gradually increasing every year, just surpassing 24 million tonnes in June 2022 (USF, 2022). The lack of public awareness, scientific information and institutional guidance during the onset of *Sargassum* and limited resources for mitigation, cost of elimination also has significant impact on environment and economics (Barlett and Elmer, 2021; Milledge and Harvey, 2016). Despite the recent anthropogenic pressures enthralled in MCC, several extensive research have addressed the impact of *Sargassum* on the coastal ecosystems such as addition of organic matter, light diminution, anoxia and leaching (van Tussenbroek et al., 2017; Chavez et al., 2020); beach erosion (Silva et al., 2020); sediment texture alteration (Maurer, 2019); trophic status changes (Cabanillas – Teran et al., 2019). Although the latter has been fully assessed, Langin (2018) estimated that the beaches lost their unique exquisiteness due to this accumulation. However, along with the impact detailed to costal ecosystems, considering human health for the affected communities from the *Sargassum* have remained enigmatic in recent years. Albeit the onset of few studies conducted by Resiere et al (2018) and Devault et al (2021) describes the respiratory and skin health issues in human, however the impact of *Sargassum* on human health remains scarcely explored. Therefore, this study seeks to examine the direct effects as experienced by coastal residents and the costal ecosystems.

To address this knowledge gap, this study investigates the impact of beaching of *Sargassum* in the Mexican Caribbean Coast (MCC) using social analyses via questionnaires. The objectives of this study were to i) assess the perceptions of people regarding the impact of *Sargassum* on MCC; ii) to identify the common health issues encountered by impacted community who is exposed to *Sargassum*; iii) to assess the level of awareness about the potential health risks associates with *Sargassum* exposure and iv) to examine the relationship *Sargassum* exposure and the health problems, in order to improvise the adaptation strategies to mitigate these impacts on human and costal health.

2. MATERIALS AND METHODS

2.1. Study area

In Quintana Roo state, the Mexican Caribbean Coast (MCC) which is about ~ 1176 kilometers long is located adjacent to Yucatan basin in the Caribbean Sea, was formed from an oceanic origin with a uniform depth of ~ 4500 m. This Mexican Caribbean Coast (MCC) contains three main islands located in the continental shelf of Yucatan basin namely Cozumel, Mujeres and Contoy. This coast contains a wide variety of coastal landforms including open sea beach- dune systems, mangrove forests, barrier islands, coastal lagoons namely, Nichupté and Chacmuchuc (which terminates in Boca Paila systems) and three major bays associated with Chetumal, Espiritu Santo and Ascención, where are influenced by the habitats of this tropical region (Rioja-Nieto et al., 2018). Early in the 1970s, the government and local stake holders encouraged the construction of Cancun as well as tourism and urban development which enhanced the country´s economic growth. The extensive urban spread resulted in population growth with an independent trend, shifting in focus from the tourism activities, with moderate industrial activities (Rioja-Nieto et al., 2018).

With extensive population growth and urban sprawl, the intensity of tourism activities has accelerated the onset of anthropogenic impacts on MCC ecosystems that includes waste generation, mangrove deforestation, fishing exploitation and groundwater contamination (Rioja-Nieto et al., 2018). This regime's karstic landscape made the coastal aquifer highly vulnerable to these emerging contaminants, later discharging into the sea (Hernández-Terrones et al., 2015). This was well established due to the high connectivity and mixing with the aquifer; thus, the freshwater resources have become contaminated with hydrocarbons (León-Borges & Lizardi-Jiménez, 2017) and sewage along with fecal bacteria resulted from untreated wastewater (Hernandez-Terrones et al., 2015; Secaira & Acevedo, 2017). Furthermore, this region is also vulnerable to hurricanes and climate changes associated with sea level rise and coral bleaching events (López-Pérez et al., 2024).

The Mexican Caribbean Coast has a karst relief regionally known as "Cenotes" which is the main source of freshwater on the Yucatan Peninsula. This regime consists of highly permeable karstic terrain, where the surface water enters the aquifers through fractures and sinkholes, locally known as Cenotes. The preferential pathways for the water to percolate this karstic terrain resulted from two fault/lineaments systems for med 54 – 33 million years ago namely the Holbox Lineament Zone and the Rio Hondo Fault zone (Bauer-Gottwein et al., 2011). The groundwater is connected to the coast through carbonate dissolution by rock/water interaction between meteoric and saline groundwater (Wigley & Plummer, 1976). The freshwater aquifer in the Mexican Caribbean can be found between 5 and 20 m deep from the surface, where Submarine groundwater discharges (SGDs) are common along the coast and water is released into the coastal ocean through seepage or springs which accounts > 77% that is related to springs (Smart et al., 2006; Null et al., 2014).

This zone experiences wave propagation in a south- southeast direction from the Caribbean Sea associated with storms and hurricanes with a significant wave height of more than 10 m (Silva, Mnedoza, Escalante, Ruiz & Mariño, 2009). Due to this dynamic coastal morpho dynamics, frequent tropical cyclones cause widespread destruction in Mexican Caribbean coastal ecosystems and human infrastructure caused from inadequate coastal construction practices and rapid urbanization found close to the coastal zone. In this coast, the prevailing Caribbean current resulted from the Atlantic Ocean which was driven by the westward component of the tropical Atlantic circulation where the South Equatorial Currents merges with North Brazil Current, later bifurcates into two branches, one flowing towards North Equatorial Current and other pursue to flow toward the Caribbean. Also, the three water masses exist in the Caribbean such as the Warm Caribbean Surface Water (CSW), the Subtropical Underwater (SUW) and the Tropical Atlantic Central Water (TACW), whereas the characteristics of these water were modified by the coastal freshwater interactions and the circulation in the Mexican Caribbean. This large-scale circulation plays a crucial role for the connectivity of the ecosystems and the transport of heat, the nearshore dynamics which was responsible for transportation and dispersion of nutrients, pollutants, and sediments from the coastal areas. Further, this circulation results in the flushing of lagoons, where the shallow flows are dependent on bathymetric variability including reef colonies (Mariño- Tapia et al., 2010).

This region is home to 16 natural protected areas (NPAs) including four flora and fauna protection areas, six national parks, five biological reserves and one sanctuary. The ecosystems in this regime include tropical deciduous forests, mangrove forests and other wetlands, seagrass and macroalgae beds and coral reefs (Meso American coral reef). The management and conservation of these ecosystems facing challenges such as illegal fishing, high tourism, unregulated and intensive urban and tourism construction, groundwater contamination. Nevertheless, the existing problems, the beaching of *Sargassum* has evolved with several direct and indirect which demands an intense investigation (Rodríguez-Muñoz et al., 2021).

2.2 Data collection

This investigation aids to capture the insights on the socio- environmental impacts markedly on human health perspective resulted from *Sargassum* using survey to perceive people´s opinion (Jeyakumar et al., 2022). Hence, we made an effort to understand the sensitivity of this brown tide disaster following the highest amount of accumulation encountered on 2021 (~ 10.1 million tonnes). The data were collected during August 2022, when the peak season of *Sargassum* accumulation was noticed from the Rivera Maya corridor that includes four major sites based on the simultaneous accumulation and elimination of *Sargassum* was conducted (Hamel et al., 2024). The study area was presented in Figure 1 initiates from Cancun (a), Playa del Carmen (b), Punta Allen (c) Mahahual (d) to highlight the geographical representation. The survey was conducted for period of 10 days and surveyed among the coastal workers (locally called as sargacero) recruited for the manual elimination of *Sargassum*, stakeholders, exposed individual exposed to *Sargassum* on regular basis and coastal residents based on tourism related activities (maids, vendors, fisherman, boat operators, hoteliers, fishery cooperatives) and geographical representation. On total of 71 individuals from aforementioned background were surveyed with no age limits, to well grasp the perspective of socio- environmental impact from *Sargassum*. Among 71, 36 informants were male and 35 were female. Also, we classified the informants based on their age from 20-30; 30-40; 40-50; 50-60 and above 60. The interviews were voice recorded and used only to verify quotes to avoid any misinterpretation of the informant perspective. The interview varied from 30 minutes to 1 hour depend on willingness of each informant. The responses were recodified, and the data entered spreadsheets for descriptive analysis. In this analysis, only the information delivered by the people were considered for understanding the perception and only gender of the informants were used.

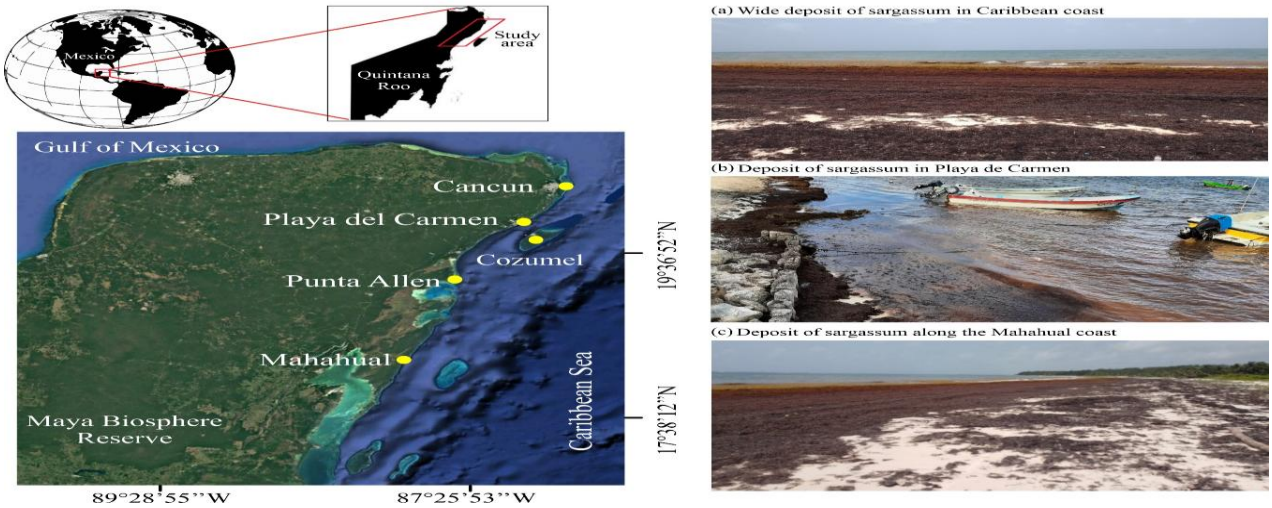

Figure 1: Study area map showing surveyed zones from Mexican Caribbean Coast, Quintana Roo.

2.3 Research design

The survey consists of 23 questions which was classified into two categories focused on perception on coastal and human health respectively due to the beaching of *Sargassum*. The survey on coastal health consists of 10 questions, while the human health consists of 13 questions. The questions were designed based on the pre- existing works on *Sargassum* impacts in the MCC (Rosellón Druker et al., 2023). All the predictive research questions were provided dichotomously with "yes" or "no" to precisely estimate the realistic future intuitions on MCC scenario due to the *Sargassum* beaching.

3. RESULTS AND DISCUSSION

The precured results were divided into two folds for flawless interpretations for the prevailing coastal and health impacts due to *Sargassum*. Among the informants, gender and age analyzed and the demographics were found similar accounting for 35 females and 36 males. For better understanding, the dataset was discussed based on gender as male and female facilitating the gender-based perceptions. For the female informants, about 10% were from the age range of 20 - 30; 30 % were from 30 - 40; 20% were from 40 – 50; 25% were from 50 – 60 and 15% were above 60. Meanwhile in male informants, the 43% were belongs to age range of 20- 30; 10% were from 30 – 40; 14% were 40 – 50; 24% were from 50 – 60 and 10% were above 60. The proportionality in the age groups were found higher for young and middle-aged people for both the gender, which is indicative for the susceptibility for onset of any health issues in the upcoming years based on their time exposed to *Sargassum* (EPA, 2023). The following two sets of discussions handles the perception on the coastal and human health impacted by the *Sargassum* in MCC.

3.1 Coastal health

The survey was initiated with questions to know the opinions from informants to verify the coastal health perceived from *Sargassum* as presented in Figure 2. The initial questions were about the loss of elegance due to *Sargassum*, while majority of informants responded with "Yes" (90%) and 10% with "No" (Figure 2 (1)). This clearly indicates that how the presence of *Sargassum* has ruined the grace of MCC on larger scale. A similar study conducted by Rosellón-Druker et al (2023) reports the similar deterioration of beach landscape components markedly loss of turquoise blue seawater color. However, the 10% of "No", indicate the respondents were less interest towards the landscape importance. This question clearly reveals this perception on *Sargassum* affecting the aesthetics of MCC influence the tourism and other activities. Followed by the next question on feeling any discomfort from the presence of *Sargassum* on the beach (Figure 2 (2)), where 83% of both genders were experiencing discomfort, which shows the sensory factors such as odor and irritation due to the presence of *Sargassum*. This is clearly in accordance with Hamel et al (2024), where the beach users were strongly affected with "overwhelming smell". The combined questions on the presence of any invasive species and mortality nearby on the coast (Figure2 (3,8)), astonishingly, 74% were replied with "yes" and 26% with negative response. This response encounters a disparity with the information, indicating that ecological impact perceived from *Sargassum* has not been recognized well due to lack of awareness. However, a recent study has manifested the arrival and mortality of seagrass and fishes with demersal neritic habitats and crustaceans, and the mortality was due to combined effect of high ammonium and H_2S concentrations together with hypoxic conditions (van Tussenbroak et al., 2017; Rodríguez-Martínez et al., 2019). In addition, a study on ghost crab density manifests the beaching cleaning activities for the removal of *Sargassum* have similar impact for beach quality monitoring (Ocaña et al., 2020). Also, there is discreet impact observed from the *Sargassum*, which was an assemblage of epiphytic carbonates dominated by bryozoan skeletons, serpulid worms tubes and smaller quantities of crustose red algae as identified as Salter et al (2020). This study also estimated the average carbonate import of 7000 $kg.m^{-1}$ of shoreline along a 60 km stretch of coast between Cancun and Playa de Carmen suggesting total carbonate import for that year averaged 179 $kgCaCO_3.m^{-1}$ of shoreline. Following the opinion on noticing changes on nesting behavior of sea turtles after *Sargassum* blooms (Figure 2(4)). Most of the informants (66%) stated for no changes and 34% stated for changes in nesting behavior. The contrary response involves the lack of adequate information on this perspective. Albeit this opinion, a report indicates that in Mahahual, the number of sea turtles has decreased by 70%, with the average number of eggs per nest dropping from around 100 to 30. This decline has attributed to increased amount of *Sargassum*s and trash on the beaches, hindering the female turtles from accessing the suitable nesting sites and pose obstacles for hatchlings trying to reach the sea (Galera, 2023). A scientific study by Maurer et al (2021) identified the changes in sea turtles nesting in the North Atlantic owing to invasion of *Sargassum*.

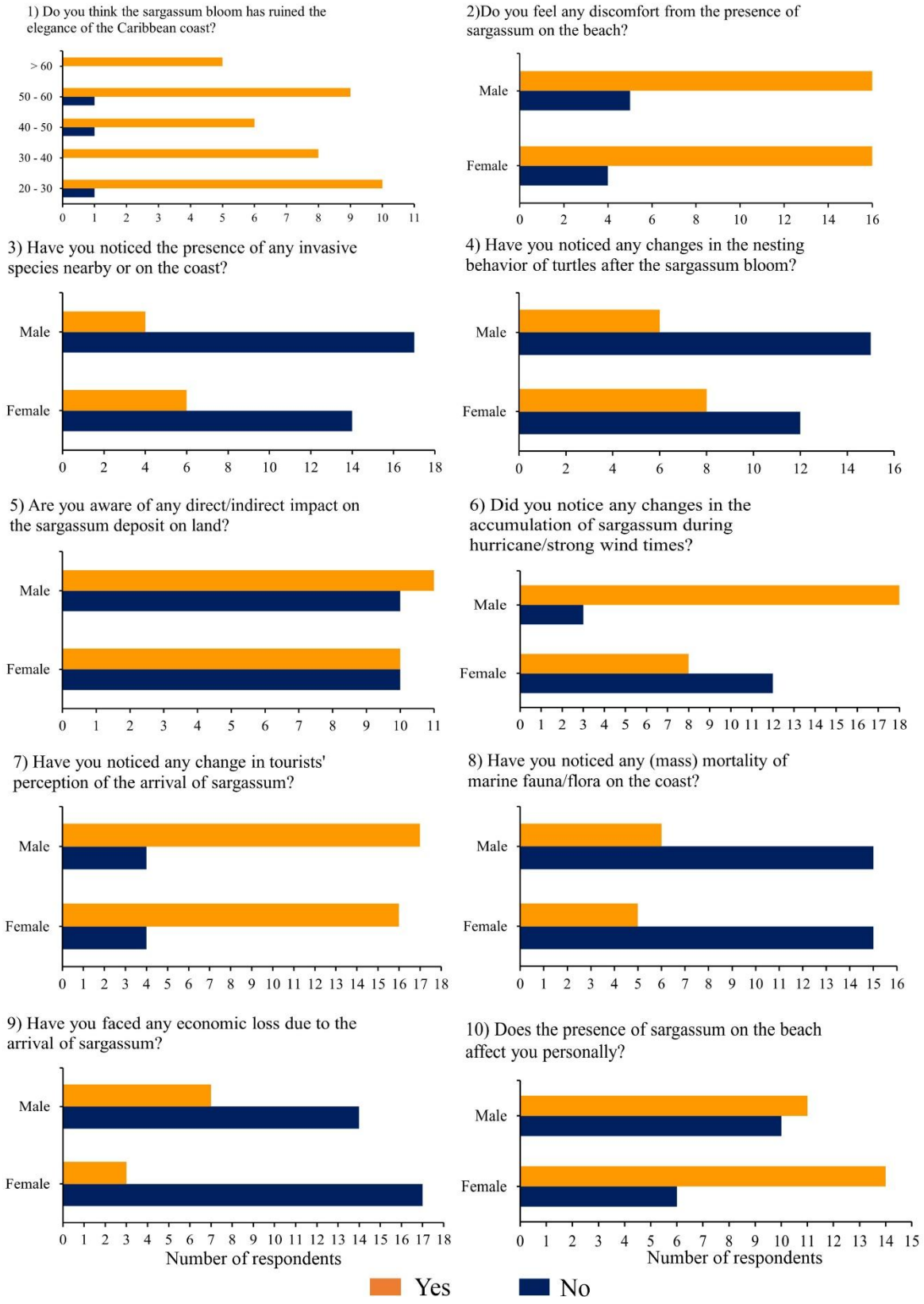

Figure 2: Graphical representation of opinions on environmental impacts perceived from *Sargassum* influxes in Mexican Caribbean Coast

For perceiving the opinion on direct or indirect impact on the *Sargassum* deposit on land (Figure 2 (5)), nearly partial respondents of 61% accepted the impact of burial of *Sargassum* during cleaning activities, while other 39% denied. There is extensive research which initially declared the nutrient input (NH_4^+) by the decomposition of *Sargassum* along with the low availability of dissolved oxygen (Camacho-Cruz et al., 2022). Also, the burial of *Sargassum* along with decomposition releases toxic

metals considerably Arsenic in their leachates (Olguín – Maciel et al., 2022; Rodríguez-Martínez et al., 2020). Also, a study by Soto-Morales et al (2022) and Ortega-Flores et al (2022) presented the accumulation of Mg, Li, Mo, U, Sb, Cs, Cu, Fe, As in the *Sargassum* species, latter having the higher chances of release of leachates and its bioaccumulation. Abdool-Ghany et al (2023) clearly described the limitation of using *Sargassum* compost owing to higher concentrations of Arsenic and its bioaccumulation factors when used in farming. Apart from the metal prefoliation, the *Sargassum* cleanup activities using machinery results in a substantial loss of sediment accounting between 30 and 90% of the material removed from beaches was sand (Oxenford et al., 2021; Roig-Munar et al., 2022). Chavez et al (2020) endorsed on *Sargassum* cleanup activities has reduced the beach length by almost half.

The questions about noticing changes in accumulation of *Sargassum* during hurricane time were found with 30% of respondents denying with "no", while 70% accepted with "yes" (Figure 2 (6)). The drastic change in the response clearly indicates lack of observation among the beach users, however, strong evidence manifests the arrival of *Sargassum* was totally dominated by strong wind and currents prevailing in the North Atlantic Ocean, which is responsible for transportation of *Sargassum* towards MCC (Johns et al., 2020; Zhang et al., 2024). The question about changes in tourist´s perception was accepted by 77% respondents with "yes" and 23% with "no" (Figure 2 (7)). This highlights the baseline impacts of *Sargassum* affecting the tourism in MCC, which was identified through a study by Hamel et al (2024) that endorsed the declining tourists arrival demanding refund for their reservations after having a look at the beach. The main decline of tourism resulted from restrictions of recreational activities offshore and onshore such as water activities like boating, surfing, paragliding (Hamel et al., 2024). The next question directed on economic loss due to the beaching of *Sargassum*, where only 30% for "yes" and 70% for "no" (Figure 2 (9)). This astonishing result for "no "indicate a clear notation that since this survey were done mostly among the sargacero, their principal income resulted from the sargasso elimination on regular basis. Simultaneously, 30% of "yes" were resulted from the other tourists operators such as boat operators, local vendors, and hoteliers who has lost their income due to declined tourism activities from the *Sargassum* arrival (Rodríguez-Martínez et al., 2023). It is noteworthy to mention, the *Sargassum* disposal procedures includes huge cleanup cost up to US$5 million that will share for heavy machinery coasts, labors (sargaceros) transportation and disposal techniques (Milledge and Harvey, 2016). On the other side, nearly over 90 patents were received refers to *Sargassum* that has been used for both fertilizer and animal feed (Laffoley et al., 2011; Joniver et al., 2021). Therefore, most of the negative response indicated the economic benefits received from *Sargassum*, since the people lacking the clear impact perceived from the *Sargassum* and its exposure. Finally, the question about the presence of *Sargassum* affected personally indicated 69% for "yes" and 31% for "no" (Figure 2 (10)). These results clearly represent the presence of *Sargassum* on multitude manner affecting the physical and mental health of the people who is exposed on regular basis. Since, the initial disturbance initiates from the foul smelling of *Sargassum* upon arrival on the coast, latter inviting several tiny bugs and insects affecting the elegance and beach quality (Hamel et al., 2024).

3.2. Human health

The second set of questions involves the human health impacts perceived from *Sargassum* arrival presented in Figure 3 (1-13). The initial question was aimed to check the exposure time of the person to the *Sargassum* (Fig 3 (1)). Nearly, 55% were found with no exposure followed with 15% found for 8 hours of exposure, and 1% for 7 and 4 hours; 4% for 5 – 6 hours of exposure and 11% for 3 hours; 7% for 1 hour of exposure. The highest responses with no exposure resulted from the respondents who is other than sargacero with other economic activities related to tourism, whilst the other responses resulted directly from the sargacero who were supposed to have the exposure to *Sargassum* on timely basis averaging 8 hours/day (Agencias, 2019). The next questions were about the use of protection kits such as gloves, glass, masks, and apron during the exposure of *Sargassum* (Fig 3 (2)). The respondents were replied with 65% for "yes" and 35% for "no" which was found nearly partial. Since the onset of *Sargassum* on MCC was imposing a greater impact within short span of time, only few governments and private entities were able to handle the *Sargassum* deposit by hiring people for manual removing on contract basis. Due to lack of knowledge on the *Sargassum* impact during earlier time, the sargacero handled the *Sargassum* without any protection. However, based on increasing works on *Sargassum* impact on human health, some of the entities implemented the obligatory use of glass, gloves, apron, and mask for the safety of sargacero as represented in Figure 4 (a-e). Then question on sensation of any irritation on eyes and throat resulted with 44% for "yes", while 56% for "no", here most of the negative responses might result owing to the use of mask, glass, and gloves during their exposure to *Sargassum* (Figure 3 (3)). However, the respondents feeling the irritation resulted due to lack of protective measures and longer exposure during removal process. It is also important to mention that, during the decomposition of *Sargassum* based on several environmental factors such as temperature and moisture, hydrogen sulfide gas will be released from few days to weeks, which will cause irritation in sensory organs (Banydeen et al., 2024). This is very evident that patients reported with similar sensory irritability after beaching of *Sargassum* in Atlantic islands were reported by Resiere et al (2020), however, this study regimes still lacks medical history of the patients reported after this *Sargassum* arrival at MCC. Also, the question about skin infection due to *Sargassum* were resulted with 32% for "yes" and 68% for "no" (Figure 3 (4)). This result remains similar with the previous results, endorsing that the time and longevity of the individual exposure to the *Sargassum* describes their personal health impact and also the exposure to freshly beached *Sargassum*, and decaying *Sargassum* have separated effects on individuals (Banydeen et al., 2024).

The question on any stings or bites from any insects found among the *Sargassum* resulted with 73% for "no" and 27% for "yes" (Figure 3 (5)). This was disparate and indicated that use of protection kits and exposure to fresh *Sargassum* aids in escaping from sting bites, whilst the decaying *Sargassum* attracts several insects over fouling smell, that indeed affects the person exposed to the insects (EPA, 2023). Also, the information about feeling difficulty in breathing resulted in 89% for "no" and 11% for "yes" (Figure 3 (6)). These results were found astonishingly disparate, because the preliminary impact from the *Sargassum* beaching was foul smelling along with gas emissions, but these negative responses indicate the higher exposure to fresh *Sargassum* and 5% responses clearly delt with the respondents who were exposed to decayed *Sargassum* and the simultaneous fouling smell causes difficulty in breathing even respiratory problems (Resiere et al., 2021; Banydeen et al., 2024). The question on specification on any health problems manifested the onset of following problems such as blurry vision (11%), headache (28%), mood swing (13%) others (10%) and none (38%) as shown in figure 3 (7). The incongruous responses clearly indicated that most of the respondents doesn't indicate any signs of health problems, however 28% of the people had headache and 13% for mood swing and 11% for blurry vision (Schmidt, 2023). The onset of the problem resulted from the *Sargassum*, because the studies conducted by Resiere et al (2021) reported few neurological disorders such as headache, dizziness and sleep disorders for the patients who exposed to the *Sargassum* in North Atlantic Islands. But 38% of the respondents indicated none of the disorders, owing to the respondent recent exposure to *Sargassum* and their age factors, that's play a dominant role for the intensity of health disorders (Banydeen et al., 2024). The following question about showing symptoms of slurred speeches with changes in facial expressions showed 89% for "no" and 11% for "yes" as shown in figure 3 (8). Even though, only 11% of the responded, this indicates the mild onset of neurological disorders among the people who has exposed to the *Sargassum* (Resiere et al., 2021). Also, responded were agreed for temporary memory loss by 14% and denied that response by 86% (Figure 3 (9)), which is also resultant of neurological disorders. In order to avoid the misinterpretation of these health impacts, the respondents were checked for COVID-19 infection during the pandemic resulted with 75% for "no" and 25% for "yes" (Figure 3 (10)), since the outcomes of COVID-19 were also related to some neurological disorders including disturbances in sleep cycle (Xu et al., 2022).

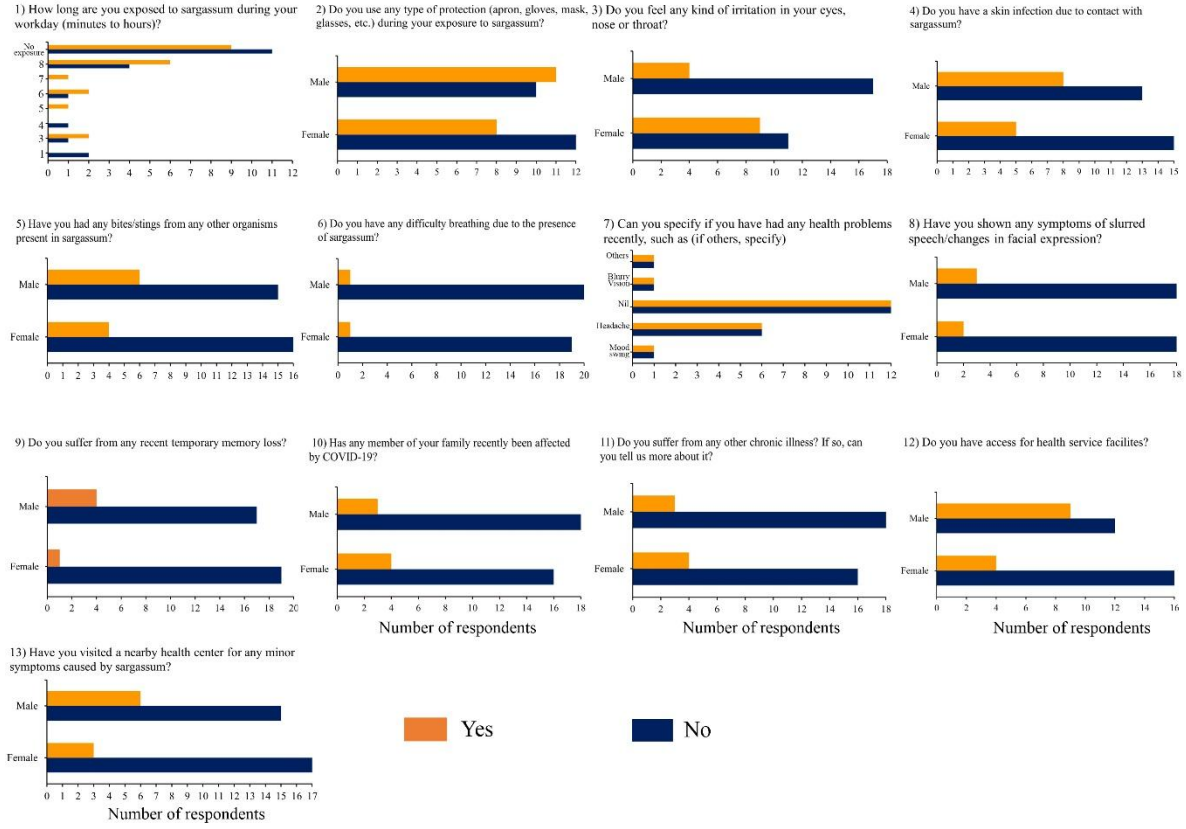

Figure 3: Graphical representation of opinions on human health impacts perceived from *Sargassum* influxes in Mexican Caribbean Coast

The question about presence of any chronic illness were identified with 87% with no chronic illness, while 13% with "yes" (Figure 3 (11)). Also, this question aids understand well that most of the recent health discomforts indicated after the exposure to *Sargassum*, moreover, this response confirms that most of the respondents do not have any chronic illness, but other skin and respiratory problems that eventually resulted from the *Sargassum*. Finally, the question about visiting the health care facilities after showing any symptoms due to *Sargassum* resulted in 78% for "yes" and 22% for "no" (Figure 3 (13)). These two responses highly

demonstrates that the people are affected by *Sargassum* presence that required a large-scale health monitor study in the MCC. The higher percentage of people using the health center facilities due to symptoms experienced after *Sargassum* exposures, indicates the reality of health impacts perceived from the *Sargassum*, thus requiring an immediate investigation on human health in the MCC.

Figure 4: a-e. Photographs on *Sargassum* deposit, transportation and disposal by sargacero.

4. CONCLUSION

The findings from this study highlighted the socio- environmental impacts of *Sargassum* influxes on the Mexican Caribbean Coast. By conducting a survey over 71 informants who were dedicated to manual removal of *Sargassum* and other tourism related workers upon exposing themselves to *Sargassum* on regular basis. The survey was conducted in point of view focused on coastal and human health impact perceived to *Sargassum* and its exposure. The results on coastal health clearly denoted that the MCC is negatively impacted by *Sargassum* affected tourism, marine ecosystems, thus deteriorating overall coastal aesthetics. The focus on human health results indicate that women tend to report greater concerns focused on health effects of *Sargassum*, markedly in respiratory discomforts. The gendered variation in the perception affirms the *Sargassum´*s consequences extend beyond ecological degradation thus affecting social and economic dimensions. Whilst some individuals experience direct effects such as health symptoms and economic losses. Henceforth, understanding these differences in people´s perspectives is crucial for designing inclusive and effective management strategies. To mitigate the adverse effects of *Sargassum*, this study underlines the importance to implement targeted interventions through improved monitoring of air quality, enhanced cleanup operations and sustainable adaption measures for the consideration of ecological and human health concerns. Thus, this study is considered as a baseline study which enforces the need for longer term multidisciplinary research for addressing the multifaceted challenges posed by *Sargassum* influxes and encouraging coastal communities can work towards sustainable solutions that protects both environmental and human wellbeing, therefore ensuring long term resilience for facing the recurring *Sargassum* tides in MCC.

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AUTHOR'S CONTRIBUTIONS

Conceptualization: NPMS, SSLJ, DCEU; Data curation: NPMS, SSLJ, NPA; Formal analysis: NPMS, SSLJ, TZJV; Funding acquisition: NPMS, DCEU; Investigation: NPMS, SSLJ, MNC, TZJV, NPA, DCEU; Methodology: NPMS, SSLJ, DCEU; Project administration: NPMS, DCEU; Resources: NPMS, DCEU; Software: NPMS, SSLJ, MNC, TZJV, DCEU; Supervision: NPMS,

SSLJ, DCEU; Validation: NPMS, SSLJ, MNC,TZJV, DCEU; Visualization: NPMS, SSLJ, MNC,TZJV; Roles/Writing - original draft: NPMS, SSLJ, MNC, TZJV, NPA, DCEU; Writing: - review & editing: NPMS, SSLJ, MNC, TZJV, NPA, DCEU. All authors reviewed the manuscript.

REFERENCES

1) Abdool-Ghany, A. A., Pollier, C. G. L., Oehlert, A. M., Swart, P. K., Blare, T., Moore, K., & Solo-Gabriele, H. M., 2023. Assessing quality and beneficial uses of *Sargassum* compost. *Waste Management*, *171*, 545–556. https://doi.org/10.1016/j.wasman.2023.09.030
2) Agencias., 2019 (May 10). *Sargacero, el nuevo empleo de moda en Cancún, ¿cuánto pagan? - El Imparcial de Oaxaca*. El Imparcial de Oaxaca. https://imparcialoaxaca.mx/economia/sargacero-el-nuevo-empleo-de-moda-en-cancun-cuanto-pagan/
3) Banydeen, R., Lacavalerie, M. R., Florentin, J., Boullanger, C., Medhaoui, H., Resiere, D., & Neviere, R., 2024. Central sleep apnea and exposure to ambient hydrogen sulfide emissions from massive strandings of decomposing *Sargassum* in the Caribbean. *Science of the Total Environment*, *912*, 168886. https://doi.org/10.1016/j.scitotenv.2023.168886
4) Bartlett, D., & Elmer, F., 2021. The Impact of *Sargassum* Inundations on the Turks and Caicos Islands. *Phycology*, *1*(2), 83–104. https://doi.org/10.3390/phycology1020007
5) Bauer-Gottwein, P., Gondwe, B. R. N., Charvet, G., Marín, L. E., Rebolledo-Vieyra, M., & Merediz-Alonso, G., 2011. Review: The Yucatán Peninsula karst aquifer, Mexico. *Hydrogeology Journal*, *19*(3), 507–524. https://doi.org/10.1007/s10040-010-0699-5
6) Cabanillas-Terán, N., Hernández-Arana, H. A., Miguel-Ángel Ruiz-Zárate, Vega-Zepeda, A., & Sanchez-Gonzalez, A.,2019. *Sargassum*blooms in the Caribbean alter the trophic structure of the sea urchin*Diadema antillarum*. *PeerJ*, *7*, e7589–e7589. https://doi.org/10.7717/peerj.7589
7) Camacho-Cruz, K., Rey-Villiers, N., Ortiz-Hernández, M. C., González-Jones, P., de, R., Matus-Hernández, M., & Sánchez, A., 2022. Changes in the enrichment of dissolved inorganic nutrients in the coastal waters of the Mexican Caribbean, influenced by submarine groundwater discharges 2016–2019. *Marine Pollution Bulletin*, *185*, 114308–114308. https://doi.org/10.1016/j.marpolbul.2022.114308
8) Chávez, V., Uribe-Martínez, A., Cuevas, E., Rodríguez-Martínez, R. E., Tussenbroek, van, Francisco, V., Estévez, M., Celis, L. B., L. Verónica Monroy-Velázquez, Leal-Bautista, R., Álvarez-Filip, L., García-Sánchez, M., Masia, L., & Silva, R., 2020. Massive Influx of Pelagic *Sargassum* spp. on the Coasts of the Mexican Caribbean 2014–2020: Challenges and Opportunities. *Water*, *12*(10), 2908–2908. https://doi.org/10.3390/w12102908
9) Devault, D. A., Modestin, E., Victoire Cottereau, Fabien Vedie, Valérie Stiger-Pouvreau, Pierre, R., Coynel, A., & Franck Dolique., 2021. The silent spring of *Sargassum*. *Environmental Science and Pollution Research*, *28*(13), 15580–15583. https://doi.org/10.1007/s11356-020-12216-7
10) EPA- Environmental Protection Agency., 2023 (July 5). *Sargassum Inundation Events (SIEs): Impacts on Human Health | US EPA*. US EPA. https://www.epa.gov/habs/*Sargassum*-inundation-events-sies-impacts-human-health?utm_source=chatgpt.com
11) Fine, M. L., 1970. Faunal variation on pelagic *Sargassum*. *Marine Biology*, *7*(2), 112–122. https://doi.org/10.1007/bf00354914
12) Fraga, J., & Robledo, D., 2022. Covid-19 and *Sargassum* blooms: impacts and social issues in a mass tourism destination (Mexican Caribbean). *MAST. Maritime Studies/Maritime Studies*, *21*(2), 159–171. https://doi.org/10.1007/s40152-022-00267-0
13) Galera, A., 2023 (March 5). *Basura y sargazo reducen población de tortugas en Mahahual*. Sipse.com. https://sipse.com/novedades/basura-y-sargazo-reducen-poblacion-de-tortugas-en-mahahual-442805.html
14) Hamel, K., Garcia-Quijano, C., Jin, D., & Dalton, T., 2024. Perceived *Sargassum* event incidence, impacts, and management response in the Caribbean Basin. *Marine Policy*, *165*, 106214. https://doi.org/10.1016/j.marpol.2024.106214
15) HernándezTerrones, L. M., Null, K. A., OrtegaCamacho, D., & Paytan, A., 2015. Water quality assessment in the Mexican Caribbean: Impacts on the coastal ecosystem. *Continental Shelf Research*, *102*, 62–72. https://doi.org/10.1016/j.csr.2015.04.015
16) Jeyakumar, S. S., Ponniah, J. M., Vasudevan, J., Muñoz-Sevilla, N. P., Urrutia-Goyes, R., Escobedo-Urias, D. C., & Rodriguez-Espinosa, P. F., 2023. Public views on tourist beach environment from multinational countries and ensuing changes during global epidemic. *Environmental Science and Pollution Research*, *31*(29), 41329–41341. https://doi.org/10.1007/s11356-023-26277-x
17) Johns, E. M., Lumpkin, R., Putman, N. F., Smith, R. H., Muller-Karger, F. E., Rueda-Roa, D. T., Hu, C., Wang, M., Brooks, M. T., Gramer, L. J., & Werner, F. E., 2020. The establishment of a pelagic *Sargassum* population in the tropical Atlantic:

Biological consequences of a basin-scale long distance dispersal event. *Progress in Oceanography*, *182*, 102269–102269. https://doi.org/10.1016/j.pocean.2020.102269

18) Joniver, C. F. H., Photiades, A., Moore, P. J., Winters, A. L., Woolmer, A., & Adams, J. M. M., 2021. The global problem of nuisance macroalgal blooms and pathways to its use in the circular economy. *Algal Research*, *58*, 102407. https://doi.org/10.1016/j.algal.2021.102407
19) Laffoley, D.d'A.; Roe, H.S.J.; Angel, M.V.; Ardron, J.; Bates, N.R.; Boyd, L.L.; Brooke, S.; Buck, K.N.; Carlson, C.A.; Causey, B.; 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: St. George's, Bermuda.
20) Langin, K., 2018. Seaweed masses assault Caribbean islands. *Science*, *360*(6394), 1157–1158. https://doi.org/10.1126/science.360.6394.1157
21) León-Borges, José-A., & Lizardi-Jiménez, M. A., 2017. Hydrocarbon pollution in underwater sinkholes of the Mexican Caribbean caused by tourism and asphalt: Historical data series and cluster analysis. *Tourism Management*, *63*, 179–186. https://doi.org/10.1016/j.tourman.2017.06.018
22) López-Pérez, A., Granja-Fernández, R., Ramírez-Chávez, E., Valencia-Méndez, O., Rodríguez-Zaragoza, F. A., González-Mendoza, T., & Martínez-Castro, A., 2024. Widespread Coral Bleaching and Mass Mortality of Reef-Building Corals in Southern Mexican Pacific Reefs Due to 2023 El Niño Warming. *Oceans*, *5*(2), 196–209. https://doi.org/10.3390/oceans5020012
23) Macías Pérez, R. A., 2009, Cancún: Los avatares de una marca turística global. Mexico: Universidad de Quintana Roo.
24) Martin, L. M., Taylor, M., Huston, G., Goodwin, D. S., Schell, J. M., & Siuda, A. N. S., 2021. Pelagic *Sargassum* morphotypes support different rafting motile epifauna communities. *Marine Biology*, *168*(7). https://doi.org/10.1007/s00227-021-03910-2
25) Marx, U. C., Roles, J., & Hankamer, B., 2021. *Sargassum* blooms in the Atlantic Ocean – From a burden to an asset. *Algal Research*, *54*, 102188–102188. https://doi.org/10.1016/j.algal.2021.102188
26) Maurer, A. S., Stapleton, S. P., Layman, C. A., & Burford Reiskind, M. O., 2021. The Atlantic *Sargassum* invasion impedes beach access for nesting sea turtles. *Climate Change Ecology*, *2*, 100034. https://doi.org/10.1016/j.ecochg.2021.100034
27) Milledge, J., & Harvey, P., 2016. Golden Tides: Problem or Golden Opportunity? The Valorisation of *Sargassum* from Beach Inundations. *Journal of Marine Science and Engineering*, *4*(3), 60–60. https://doi.org/10.3390/jmse4030060
28) Ocaña, F. A., de Jesús-Navarrete, A., & Hernández-Arana, H. A., 2020. Co-occurring factors affecting ghost crab density at four sandy beaches in the Mexican Caribbean. *Regional Studies in Marine Science*, *36*, 101310. https://doi.org/10.1016/j.rsma.2020.101310
29) Olguin-Maciel, E., Leal-Bautista, R. M., Alzate-Gaviria, L., Domínguez-Maldonado, J., & Tapia-Tussell, R., 2022. Environmental impact of *Sargassum* spp. landings: an evaluation of leachate released from natural decomposition at Mexican Caribbean coast. *Environmental Science and Pollution Research*, *29*(60), 91071–91080. https://doi.org/10.1007/s11356-022-22123-8
30) Ortega-Flores, P. A., Serviere-Zaragoza, E., De Anda-Montañez, J. A., Freile-Pelegrín, Y., Robledo, D., & Méndez-Rodríguez, L. C., 2022. Trace elements in pelagic *Sargassum* species in the Mexican Caribbean: Identification of key variables affecting arsenic accumulation in S. fluitans. *Science of the Total Environment*, *806*, 150657. https://doi.org/10.1016/j.scitotenv.2021.150657
31) Oxenford, H. A., Cox, S.-A., Tussenbroek, van, & Desrochers, A., 2021. Challenges of Turning the *Sargassum* Crisis into Gold: Current Constraints and Implications for the Caribbean. *Phycology*, *1*(1), 27–48. https://doi.org/10.3390/phycology1010003
32) Pendleton, L., Krowicki, F., Strosser, P., Hallett-Murdoch, J., Acteon, & Marine, M., 2014. *Assessing the Economic Contribution of Marine and Coastal Ecosystem Services in the Sargasso Sea*. https://www.sargassoseacommission.org/storage/documents/ni_r_14-05_final.pdf
33) Resiere, D., Mehdaoui, H., Florentin, J., Gueye, P., Lebrun, T., Blateau, A., Viguier, J., Valentino, R., Brouste, Y., Kallel, H., Megarbane, B., Cabie, A., Banydeen, R., & Neviere, R., 2020. *Sargassum* seaweed health menace in the Caribbean: clinical characteristics of a population exposed to hydrogen sulfide during the 2018 massive stranding. *Clinical Toxicology*, 1–9. https://doi.org/10.1080/15563650.2020.1789162
34) Resiere, D., Valentino, R., Rémi Nevière, Rishika Banydeen, Gueye, P., Florentin, J., André Cabié, Lebrun, T., Mégarbane, B., Guerrier, G., & Hossein Mehdaoui., 2018. *Sargassum* seaweed on Caribbean islands: an international public health concern. *The Lancet*, *392*(10165), 2691–2691. https://doi.org/10.1016/s0140-6736(18)32777-6
35) Rioja-Nieto, R., Garza-Pérez, R., Álvarez-Filip, L., Ismael, M.-T., & Cecilia, E., 2018. The Mexican Caribbean: From Xcalak to Holbox. *Elsevier EBooks*, 637–653. https://doi.org/10.1016/b978-0-12-805068-2.00033-4
36) Rodríguez-Martínez, R. E., van Tussenbroek, B., and Jordán-Dahlgren, E., 2016. Afluencia masiva de sargazo pelágico a

la costa del caribe mexicano, (2014–2015). Florecimientos Algales Nocivos en México. Ensenada: CICESE 352, 352–36.

37) Rodríguez-Martínez, R. E., Roy, P. D., Nuria Torrescano-Valle, Cabanillas-Terán, N., Carrillo-Domínguez, S., Collado-Vides, L., García-Sánchez, M., & Tussenbroek, van., 2020. Element concentrations in pelagic*Sargassum*along the Mexican Caribbean coast in 2018-2019. *PeerJ*, *8*, e8667–e8667. https://doi.org/10.7717/peerj.8667
38) Rodríguez-Martínez, R.E., A.E. Medina-Valmaseda, P. Blanchon, L.V. Monroy-Velázquez, A. Almazán-Becerril, B. Delgado-Pech, L. Vásquez-Yeomans, Francisco, V., & M.C. García-Rivas., 2019. Faunal mortality associated with massive beaching and decomposition of pelagic *Sargassum*. *Marine Pollution Bulletin*, *146*, 201–205. https://doi.org/10.1016/j.marpolbul.2019.06.015
39) Rodríguez-Muñoz, R., Aarón Israel Muñiz-Castillo, Euán-Avila, J. I., Héctor Hernández-Núñez, Valdés-Lozano, D. S., Collí-Dulá, R. C., & Jesús Ernesto Arias-González., 2021. Assessing temporal dynamics on pelagic *Sargassum* influx and its relationship with water quality parameters in the Mexican Caribbean. *Regional Studies in Marine Science*, *48*, 102005–102005. https://doi.org/10.1016/j.rsma.2021.102005
40) Roig-Munar, F. X., 2022. Reseña de Manual dels hàbitats de Menorca. Hàbitats terrestres. *Investigaciones Geográficas*, *77*, 409. https://doi.org/10.14198/ingeo.20919
41) RosellónDruker, J., Laura, M., Suca, Justin J, Rachel, S., GaytánCaballero, Adriana, EscobarBriones ,Elva, Hazen ,Elliott L, & Frank, M., 2023. Local ecological knowledge and perception of the causes, impacts and effects of *Sargassum* massive influxes: a binational approach. *Ecosystems and People*, *19*(1), 2253317. https://doi.org/10.1080/26395916.2023.2253317
42) Schmidt, C., 2023. Escape from Sargasso Sea: Tremendous *Sargassum* Blooms Challenge Caribbean and Atlantic Communities. *Environmental Health Perspectives*, *131*(9). https://doi.org/10.1289/ehp13418
43) Secaira, F., & Acevedo, C., 2017. Importancia de los arrecifes y dunas en la protección de la costa. Serie técnica. El papel de los sistemas naturales en la dinámica costera en el caribe mexicano y el impacto de las actividades humanas en su condición actual. The Nature Conservancy, Mexico.
44) Silva, R., María Luisa Martínez, Tussenbroek, van, Guzmán-Rodríguez, L. O., Mendoza, E., & López-Portillo, J., 2020. A Framework to Manage Coastal Squeeze. *Sustainability*, *12*(24), 10610–10610. https://doi.org/10.3390/su122410610
45) Sissini, M. N., de Barros Barreto, M. B. B., Széchy, M. T. M., de Lucena, M. B., Oliveira, M. C., Gower, J., Horta, P. A., et al., 2017. The floating *Sargassum* (Phaeophyceae) of the South Atlantic Ocean – likely scenarios. Phycologia, 56(3), 321–328. https://doi.org/10.2216/16-92.1.
46) Smart, P. L., Beddows, P. A., Coke, J., Doerr, S., Smith, S., & Whitaker, F. F., 2006. Cave development on the Caribbean coast of the Yucatan Peninsula, Quintana Roo, Mexico. *Perspectives on Karst Geomorphology, Hydrology, and Geochemistry - a Tribute Volume to Derek C. Ford and William B. White*. https://doi.org/10.1130/2006.2404(10)
47) Smetacek, V., & Zingone, A., 2013. Green and golden seaweed tides on the rise. *Nature*, *504*(7478), 84–88. https://doi.org/10.1038/nature12860
48) Soto-Morales, S., L.I. Martínez-Rodríguez, E. Serviere-Zaragoza, A.I. Martínez-Sálcido, & M.F. Soto-Jiménez., 2022. Identification of Li as a reference element in *Sargassum* bioaccumulation of conservative-type elements (Mg, Mo, Sb, Cs and U). *Marine Chemistry*, *242*, 104110–104110. https://doi.org/10.1016/j.marchem.2022.104110
49) UNEP (United Nations Environment Programme), 2018. *Sargassum* white paper- *Sargassum* outbreak in the caribbean: challenges, opportunities and regional situation. Pan 2018 (14).
50) USF (University of South Florida), 2022. Outlook of 2022 *Sargassum* blooms in the Caribbean Sea and Gulf of Mexico. University of South Florida Optical Oceanography Lab. July. https://optics.marine.usf.edu/projects/saws.html.
51) van Tussenbroek, B. I., Arana, H., Rodríguez-Martínez, R. E., Espinoza-Avalos, J., Canizales-Flores, H. M., González-Godoy, C. E., M. Guadalupe Barba-Santos, Vega-Zepeda, A., & Collado-Vides, L., 2017. Severe impacts of brown tides caused by *Sargassum* spp. on near-shore Caribbean seagrass communities. *Marine Pollution Bulletin*, *122*(1-2), 272–281. https://doi.org/10.1016/j.marpolbul.2017.06.057
52) Wang, M., & Hu, C., 2018. On the continuity of quantifying floating algae of the Central West Atlantic between MODIS and VIIRS. *International Journal of Remote Sensing*, *39*(12), 3852–3869. https://doi.org/10.1080/01431161.2018.1447161
53) Wang, M., Hu, C., Barnes, B. B., Mitchum, G., Lapointe, B., & Montoya, J. P., 2019. The great Atlantic *Sargassum* belt. *Science*, *365*(6448), 83–87. https://doi.org/10.1126/science.aaw7912
54) Xu, E., Xie, Y., & Ziyad Al-Aly., 2022. Long-term neurologic outcomes of COVID-19. *Nature Medicine*, *28*(11), 2406–2415. https://doi.org/10.1038/s41591-022-02001-z
55) Zhang, Y., Hu, C., McGillicuddy, D. J., Barnes, B. B., Liu, Y., Kourafalou, V. H., Zhang, S., & Hernandez, F. J., 2024. Pelagic *Sargassum* in the Gulf of Mexico driven by ocean currents and eddies. *Harmful Algae*, *132*, 102566. https://doi.org/10.1016/j.hal.2023.102566.