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Misperception of drivers of risk alters willingness to adapt in the case of sargassum influxes in West Africa

D. Yaw Atiglo [a], Philip- Neri Jayson-Quashigah [b], Winnie Sowah [c], Emma L. Tompkins [d,*], Kwasi Appeaning Addo [b,c]

[a] Regional Institute for Population Studies, University of Ghana, Ghana
[b] Institute of Environment and Sanitation Studies, University of Ghana, Ghana
[c] Department of Marine and Fishery Sciences, University of Ghana, Ghana
[d] School of Geography and Environmental Sciences, University of Southampton, Southampton SO17 1BJ, UK

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ABSTRACT

Since 2011, large influxes of a brown macroalgae (pelagic sargassum seaweed) have proliferated across the Tropical Atlantic basin, its dispersal and seasonality theorized to be driven by localized and large scale winds and currents, in combination with changes in the Atlantic Meridional Mode and ocean upwelling. These influxes seasonally affect coastal populations across the breadth of the Tropical Atlantic (from central America to West Africa), causing damage to: economies, marine-based and non-marine coastal livelihoods, social functioning, health, ecology, and the aesthetics of the local environment. We use the ongoing sargassum influx in West Africa as a case study of adaptation to an emergent (and compound) risk in progress that also contributes to the empirical gap in sargassum adaptation research in West Africa. The research, in four sites in the Western Region of Ghana employs data from 16 focus group discussions, six key informant interviews, and participant observation. We finds that due to a series of coincidences, participant communities perceive that sargassum influxes were seeded by and then annually driven by oil and gas exploration in Western Ghana. This is in contrast to scientific research that indicates that pelagic sargassum was initially seeded in the tropical Atlantic basin (from the Sargasso Sea) in 2010 following an anomalous weather event in winter 2009–2010. Following Rogers' Protection Motivation Theory, we explore the sources of information and the processing of that information to understand the divergence between scientific and community perceptions of the physical drivers. We find that community perceptions of oil and gas company responsibility for causing the sargassum problem leads the communities to perceive that the oil and gas companies should be responsible for the clean-up activities. Communities are further constrained by a perceived lack of capacity to act. Solutions to address this adaptation impasse could involve the government working with communities and the oil and gas industry to clarify the actual drivers of sargassum. Such guidance may open opportunities for the government and industry to work with communities to address misperceptions of the scientific nature of the influxes. Collaborative approaches, while addressing extant tensions, may also change the narrative about the problem, support affected communities to engage with adaptive measures, including re-use opportunities, and enhance community capacity to act. As a present-day emergent risk, pelagic sargassum provides an unusual yet contemporary empirical study of real-time adaptation and the central role of perceptions in shaping proactive adaptation and seeking exploitable opportunities from new environmental risks.

1. Introduction

Since 2011, the coastlines of West Africa, North, South and Central America, as well as the Caribbean islands have witnessed an unprecedented invasion of a floating brown macroalgae (pelagic sargassum[1]) along their beaches and in their territorial waters (Fidai et al., 2020;

* Corresponding author.
E-mail address: E.l.tompkins@soton.ac.uk (E.L. Tompkins).

[1] Pelagic sargassum, the brown marine seaweed, affecting West Africa since 2011 largely comprises *S. natans* and *S. fluitans*. In this paper pelagic sargassum is interchangeably referred to as 'sargassum' or 'sargassum seaweed'.

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UNEP, 2016; Oyesiku and Egunyomi, 2014; Széchy et al., 2012). A growing consensus attributes the southward shift in the range of pelagic sargassum – from the Sargasso Sea into the tropical Atlantic – to an anomalous North Atlantic Oscillation event in winter 2009–2010 (Johns et al., 2020). This event produced unusually strong south-westerly winds, and drove two species of sargassum (*S. fluitans* and *S. natans*) southward, seeding it within the tropical Atlantic where it has thrived (Johns et al., 2020; Putnam et al., 2018). Patches of sargassum now aggregate along an area of maximum wind convergence – the Inter Tropical Convergence Zone (ITCZ) – and migrate around the tropical Atlantic (Putnam et al., 2018). In 2019, an estimated 8850 km of sargassum stretched across the tropical Atlantic from Central America to West Africa. This new phenomenon is referred to as the great Atlantic Sargassum Belt – GASB (Wang et al., 2019). Annual sargassum influxes are now considered the 'new normal', and quantities of sargassum appear to be increasing annually across the entire tropical Atlantic (Putman et al., 2020).

After the sargassum seeding event in 2009/10, research identifying possible causes of the post-2011 proliferation across the tropical Atlantic suggested: increasing ocean temperature, influx of nutrients from land-use, and Saharan dust carrying nitrogen, phosphorus and iron (Ackah-Baidoo, 2013; Marsh et al., 2021; Ofori and Rouleau, 2020, 2021). Larger ocean–atmosphere theories are developing to connect the various parts of the puzzle to explain what is causing sargassum to bloom seasonally and move in specific ways around the tropical Atlantic. Exceptional sargassum bloom years tend to coincide with a southward shift in the ITCZ, towards the nutrient-rich waters from the Amazon River (Skliris et al., 2022). Other key factors appear to be: ocean upwelling off West Africa in boreal winter (Wang et al., 2019); excessive wind-driven equatorial upwelling and anomalously strong north westward nutrient transport (Skliris et al., 2022). Another newly identified factor that appears to affect reproduction, mortality and movement, is tropical storms (Putman and Hu, 2022) It is worth noting that there is no mention in the scientific literature of oil or gas exploration as a factor in seeding sargassum in the tropical Atlantic, nor as a driver of pelagic sargassum movement and prevalence.

Floating and beached sargassum can have severe impacts on affected societies, economies and environmental resources (Bartlett and Elmer, 2021; Fidai et al., 2020). Massive sargassum influxes have the potential to disrupt coastal livelihoods especially in low- and middle-income contexts (Oxenford et al., 2021). Initial evidence from central America and the Caribbean, suggests that there might be re-use options for sargassum, for example as a compost for mangrove restoration (Trench et al., 2022), as animal feed (Carillo-Dominguez et al., 2023), as bio-crude oil (Marx et al., 2021), as well as a variety of possible uses in food and beverages, bioplastics, paper, and construction materials, among others (Oxenford et al., 2022). Research on adaptation to, and re-use of, sargassum has increased annually (Liranzo-Gómez et al., 2020).

The magnitude of the sargassum problem affecting both sides of the tropical Atlantic has been similar, yet adaptation progress appears to have moved ahead faster in the Caribbean and Americas (Robledo et al., 2021). A key gap in the West African context appears to be available information about the frequency, magnitude and seasonality of the sargassum, its impacts and how to manage it. In the Caribbean and Central America, publications revealing large scale sargassum monitoring started in 2013 (Webster and Linton, 2013), ecological impacts were being documented from 2015 (Maurer et al., 2015), and socio-economic impacts for the Caribbean reported from 2018 (UNEP, 2018). Research into pathways to valorise sargassum in the Caribbean and the Americas started in 2016 (e.g. Milledge and Harvey, 2016), and grew exponentially in 2021, see for example, Amador-Castro et al., 2021; Davis et al., 2021. Yet there is no parallel body of work for West Africa. This fact is exemplified by the contents of a Zotero database on pelagic sargassum in the tropical Atlantic,[2] compiled by the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies. On the database a total of 635 publications and reports exist on pelagic sargassum (dated between 2010 and the 25th September 2023), of those only 22 (3 %) relate specifically to West Africa. This research has documented the arrival of sargassum in West Africa and noted its potential to negatively affect coastal livelihoods (Ackah-Baidoo, 2013; Addico and deGraft-Johnson, 2016; Marsh et al., 2021; Ofori and Rouleau, 2020, 2021). Recent research on sargassum adaptation progress in the Caribbean and the Americas highlights the benefits gained from rapid development of freely accessible sargassum early warnings (e.g. SaWS led by University of South Florida, and SEAS led by Texas A&M University) drawing on open access remotely sensed data (Dominguez-Almela et al., 2023). Sargassum forecasts for the Caribbean have improved over time and since 2018 have provided relatively accurate seasonal forecasts of the spatial and temporal distribution of the seaweed approaching the Americas (Wang and Hu, 2017).

Sargassum early warning systems and seasonal forecasts do not exist for West Africa. Remote sensing of sargassum blooms in West Africa is more challenging due to the high levels of year round cloud cover (Marsh et al., 2021). Cloud cover limits reliability of remotely sensed images and West African countries have had to adopt alternative methods to monitor sargassum bloom events. Alternative methods include use of field measurement and drone imagery, but these are more expensive and time consuming than use of remote sensing technologies. Hence progress in developing West African estimates of impacts of sargassum, and seasonal forecasts lag significantly behind the advances in the western tropical Atlantic. In the Caribbean and Americas, the relative economic importance of the coastal tourism industry may also have an amplifying effect on public and political awareness of the issue. Tourists have easy access to social media outlets (such as twitter and Tripadvisor) to communicate displeasure about sargassum arrivals, thereby influencing tourist arrivals in specific locations, affecting local economies, and being noticed by politicians (Fraga and Robledo, 2022). In West Africa, with fewer tourists, and less economic dependence on tourism, this effect has not been as apparent. Further in West Africa, other attenuating factors could be the perceived lower importance of sargassum in relation to other policy issues, such as hunger, crime and violence – the latter are seen as more important than environmental concerns (White and Hunter, 2010). Pelagic sargassum influxes are therefore a relatively poorly understood problem in West Africa, with less known about the challenges of sargassum in comparison to other more well-known risks such as floods, erosion or oil spills. Irrespective of the cause of the slow progress on sargassum research in West Africa, a significant gulf has opened in understanding community adaptation to sargassum between the eastern and western tropical Atlantic. Filling this gap with a scientific evidence base is an important step to support governments, communities, scientists and entrepreneurs find ways to better cope with the new normal of annual sargassum events.

Decades of research on understanding societal impacts of environmental and climatic change points to the importance of engagement with different knowledges, and active participation of affected people (Thomas et al., 2019). Ignoring the role of communities in management of natural hazards can worsen associated problems (Camargo et al., 2009), particularly where there are low levels of trust in management agencies (Wynveen and Sutton, 2015). Affected peoples' perceptions of risk and their lived experiences, shape their understanding of environmental problems, possible solutions, and their potential role (Adger

[2] The Zotero 'Sargassum Reference Repository' database is online at: Centre for Resource Management & Environmental Studies (CERMES) | The University of the West Indies at Cave Hill, Barbados – Reference-Repository (uwi.edu).

et al., 2013). For example, empirical evidence of household level responses to flood risks reveals a relationship between how people appraise their ability to cope with their actual risk mitigation actions (Bubeck et al., 2012). Yet people's perception of environmental risks and their ability to cope are often ignored in risk management (Aerts et al., 2018), potentially amplifying negative impacts of hazardous natural events (Fan et al., 2022). Despite relatively large amounts of literature on drivers of risk behaviours in relation to floods and hurricanes, there is little research that explores drivers of adaptation and risk perceptions in relation to other hazards (van Valkengoed and Steg, 2019), including community adaptation to mass algal bloom events, such as the sargassum influxes along the West African coast. This study addresses this gap by exploring community perspectives on the nature of sargassum, the physical drivers of the sargassum influxes, and people's perceptions of their capacity to adapt to this risk through application of the Protection Motivation Theory (PMT), developed by Rogers (1975). PMT has been used extensively in developed and developing economies to identify how people cope with environmental risks (Bubeck et al., 2013; Bubeck et al., 2018; Shafiei and Maleksaeidi, 2020); it focusses on the link between sources of information and three cognitive processes that determine people's engagement with protective (adaptive) behaviour: responsibility, threat and coping appraisals, see Fig. 2.

PMT is useful to understand the drivers of household level adaptation as it allows analysis of the sources of information used, the impact of these sources of knowledge on the nature of the risk, and capacity to adapt (Bubeck et al., 2017; van der Plank et al., 2022). This research uses PMT to better understand how households are experiencing sargassum and adapting to sargassum in the Western Region of Ghana.

The following section explains the methods and material used, describes the data collected the participants and study sites. Section 3 presents analysis of the empirical data, drawing out themes of: the nature of sargassum, the drivers of sargassum, the lived experience of sargassum influxes on communities, perceptions of responsibility for action, and how these factors collectively affect adaptive capacity, and adaptation choices. The discussion in section 4, explores Ghanaian community perspectives on sargassum, the coincidence of oil and gas development in Ghana in 2010, extant tensions between the communities and the oil and gas companies, and how this informs adaptive actions. We compare levels of action in Ghana with other countries across the Tropical Atlantic and explore the implications of the findings. Our conclusions draw out lessons learned on adapting emergent and compound risks – whereby a risk is amplified due to extant conditions or unrelated parallel events. We also reflect on the role of PMT in uncovering hidden dimensions of adaptation and the potential for transformational adaptation to occur from emergent risks.

2. Materials and methods

Following Wolf and Moser (2011), to understand the lived experiences and perspectives of communities adapting to a new environmental risk, a qualitative research design is used combining focus group discussions, key informant interviews, and participant observation. These methods are applied in our case study in Ghana, with analysis shaped by the Protection Motivation Theory.

2.1. Study area: Western region of Ghana

Low lying sandy beaches appear to experience the worst effects of sargassum influxes, as seen in Mexico (Chávez et al., 2020). The Western Region beaches are predominantly sandy and low lying, and interspersed with some lagoons and estuaries, putting them at risk of sargassum influxes. Two low lying coastal districts (also vulnerable to the impacts of sea level rise) in the Western Region were chosen for this study: Ellembelle District and Jomoro District (Boateng et al., 2017; Wiafe et al., 2013). Ellembelle has a population of 120,893 with a population density of 124.3 while Jomoro has a population of about 126,576 with a density of 87.7 persons per square kilometre. Within the two districts, four communities were selected due to their reported history of sargassum stranding and beaching (Ackah-Baidoo, 2013; Marsh et al., 2021), see Fig. 1.

The four communities were chosen to include: a geographic spread across the coast of the Western Region and diverse livelihoods including fishing and non-fishing livelihoods (the latter includes: tourism, cassava and other crop farming, as well as coconut plantations and processing). To maintain the anonymity of participants, we refer to the four communities as: Large Community (most urbanized with population of approximately 8,000), Small Community 1 and Small Community 2 (fishing communities with populations between 1,000 and 1,300), and Medium Community (more westerly community with a population of around 2,000 people).

The main economic livelihoods in the Western Region are artisanal fishing, fish processing and fish trading (GSS, 2013). These activities are gendered where women dominate in fish processing and trade while men dominate the fishing processes. Crop farming and keeping of livestock, exist on subsistence levels inland together with other trading activities. In addition, the region is dotted with several tourist resorts which receive local tourists. Tourism relies on the presence of colonial forts, beaches and ecotourism sites, though it employs not as many people as fishing and other agricultural activities (GSS, 2013).

Offshore in the Western region of Ghana, there have been oil and gas discoveries in commercial quantities with production starting in December 2010 (Ackah-Baidoo, 2012). Exploration and extraction of this abundant oil and gas supply have contributed to Ghana's steady national economic growth since 2010 (Obeng-Odoom, 2015). Despite the economic benefits generated by oil and gas extraction in many resource-extracting economies community-industry, conflicts between nearby communities and the oil and gas companies related to perceived links between declining environmental quality and mineral extraction are common (Omeje, 2017). These conflicts often arise due to inadequate engagement with local communities creating mistrust, and conflicts simmer due to unaddressed grievances (Siakwah, 2018). In the Western region of Ghana, tensions emerged relatively quickly after 2010 between the resource exploration and extraction companies, and the local communities (Agyei et al., 2012). Initial problems related to fishing communities' complaints about the lights used on the offshore rigs, which attract the fish away from traditional fishing grounds towards the exclusion zone around the rigs. This reduces the catch of local artisanal fishers (Adjei and Overå, 2019). Coincidental to the start of oil and gas drilling in 2010, the mass proliferation of floating and beaching sargassum started across the tropical Atlantic in 2011. Fishers rapidly associated the arrival of sargassum and the related impacts on the local fishing industry, with the extraction of oil and gas (Ackah-Baidoo, 2013). By the time of data collection for this study in 2021, significant discord existed between the oil and gas companies and local communities in the Western region of Ghana (Mohammed et al., 2022a).

2.2. Data collection methods and ethics

Data collection occurred between March 2021 and December 2021. Four focus group discussions were held in each community, stratified by age group and gender (16 in total). The four groups were: young males, young females (aged 18–34 years), adult males and adult females (aged 35 years and above).[3] Key informant interviews were held during the same period with opinion leaders across the four communities as well as

[3] In Large Community, a young male aged 31 years joined the adult group because of his role as a leader in the community and his association with other persons who were in the older adult group. In this same community, there was a 40-year old who participated in the youth group because he associated and identified with these younger adults. Similarly, the young female group in Small Community 1 included 37-year old females.

Fig. 1. Map of the study area in the Western Region of Ghana showing the two districts of Ellembelle and Jomoro, from which four coastal communities were selected.

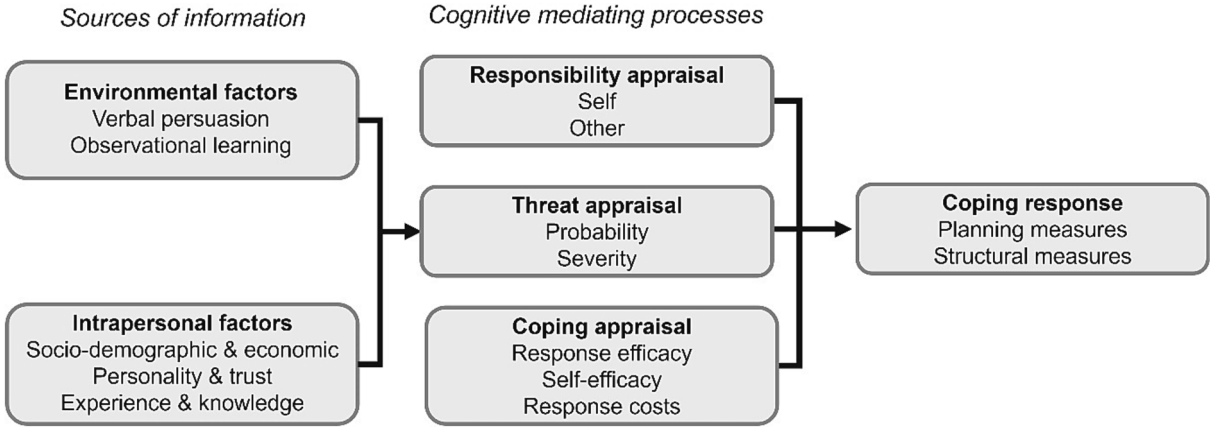

Fig. 2. Modified Protection Motivation Theory (van der Plank et al., 2022).

actors in the tourism sector. All interviews were transcribed verbatim. Respondents' statements were coded and developed into themes based on the PMT framework, and then analysed using thematic content analysis to make sense of the shared normative values and experiences (Braun and Clarke, 2006). Participant observation occurred in all four communities over 10 visits. This involved field observation of life and livelihood activities along the coast, and taking pictures of sargassum beaching impacts on community activities. During such visits over 50 pictures were taken with both drones and phones to record the beaching of sargassum and the impacts on residents and fisherfolk. Ethical approval was granted for this work from the University of Ghana Ethics Committee in April 2021. Standard ethical procedures were followed to ensure confidentiality of information provided by participants. Participants were required to declare their consent to participate, be recorded and provide their personal background information (Table 1), however all transcripts were anonymized.

2.3. Data collected and study participants

Focus group participants were selected based on two criteria (i) living in close proximity to the beach and (ii) identified as lifetime or regular residents. Following best practice in focus group sampling, priority was given to participants who lived closest to the beach and had livelihoods related to the beach (Nyumba et al., 2018). The research team used existing gatekeepers to recruit participants who, in some sites, were encouraged to suggest other potential respondents.

Across all four sites, recruited through a combination of purposive and snowball sampling, the final set of participants comprised 119

Table 1
Adaptation methods tried in all four communities.

Event type	Adaptation type	Actors	Reason for adaptation
Floating	Not going to seaAltering fishing techniques	Fishers	Entangled nets Low fish catch
Beaching	Not going to seaSeeking alternative livelihood options	Fishers	Entangled nets
	Cleaning (gathering, collection and burying)	Tourism actorsCommunity	AestheticsStench
	Do nothing (leave to rot)	Community	n.a.
	Wearing nose/face masks	Community	Stench
	Taking out loansMigration (short-term and long term)	FishersCommunity	Livelihood disruption
Both floating and beaching	Food/fish rationing (reduce amount of fish/food consumed)	Community (women)	Livelihood disruption

participants: 50 % male, 50 % female; 47 % younger adults, 53 % older adults; 82 % with no or basic education and 18 % with secondary education or above; and 71 % of total were fishers. Unemployed persons accounted for 24 % of the total, and students 6 %. The distribution of educational attainment and occupations is differentiated by gender. Among males, 72 % had no or basic education and 28 % had secondary education or above whereas among females 91 % had no or basic education and 8 % had secondary education or above. Also, there were higher proportions of males (78 %) involved in fishery-related occupations than females (63 %) with a higher proportion of women in other occupations. Detailed characteristics shown in Supplementary material, Table 1.

In addition to the focus groups, six key informant interviews were undertaken with traditional leaders, local assemblymen and opinion leaders. These interviews were held in community leisure centres, chief's palace, private homes among others and lasted approximately 40 min and 50 min for females and males, respectively. Older male interviews were the longest while younger female adult interviews were the shortest. The interviews asked questions around the nature of sargassum, community sargassum experience, coping strategies and perceptions of causes of sargassum and roles of community (and their leaders) in dealing with sargassum. Responses were recorded and later transcribed. When interviewees from focus groups are quoted within the text the acronym FGD is appended to their code e.g. 'Small Community 2 male FGD' and 'Large Community female' represents respectively a male focus group participant from Small Community 1, and a female interviewee from Large Community. If multiple types of participants from the same group are quoted, these are differentiated by number e.g. Large Community older male 1, Large Community older male 2.

3. Knowledge of sargassum, perceptions of drivers, impacts and capacity to adapt

To fully understand how people are adapting to sargassum, we first explore participants' perceptions of the nature and drivers of pelagic sargassum, their lived experience and then perceptions of responsibility, coping appraisals and adaptive behaviours.

3.1. Appraisal of pelagic sargassum threat (influx and its drivers)

Participants presented a wide array of opinions about the origins and drivers of sargassum influxes. A few believed sargassum influxes were due to natural causes, some perceived the drivers to be a variety of anthropogenic causes, but the majority (of all ages and both sexes) believed that (in contrast to the prevailing scientific understanding – see section 1) the sargassum influxes were directly related to oil and gas exploration in the Gulf of Guinea.

3.1.1. Misperception of the nature of sargassum (biology of the seaweed)

Pelagic sargassum is a floating seaweed, it lives and dies on the ocean surface and at no point attaches to the seabed (Oyesiku and Egunyomi, 2014). Yet some respondents incorrectly believed that the sargassum washing ashore was previously attached to the seabed:

> *I believe they are weeds that grow on the seabed. So when it comes to a time for these weeds to leave the seabed, that is when they are washed to our shores. That's what I think… I think it has to do with seasons. The weeds I think appear here because it is time for them to appear. (Small Community 1, Younger Male)*

This misunderstanding of the nature of sargassum was particularly common among Small Community 1 males, and was repeated by many:

> *I am of the opinion that everything has its season. The weeds are no different so when it reaches its season, it leaves the seabed and comes to the surface. They are seasonal plants just like other plants. It is similar to how plants shed their leaves at a certain point in time. (Small Community 1, adult male)*

There were other beliefs about sargassum that were not biologically accurate, for example, that sargassum is an animal and not a seaweed:

> *I think the weeds are animals because when they get stuck in the net and you handpick them out of the net, it feels like they are moving in your palms… I believe the weeds are actually animals. Because when you touch them, it feels like they are moving. (Small Community 1, younger male)*

The lack of credible and accessible information available to the communities about the biological nature of sargassum appears to be a cause of later misunderstandings about the drivers of sargassum influxes.

3.1.2. Misperceptions of the drivers of sargassum influxes

For some, the misconception that the seaweed is benthic (i.e. fixed to the ocean floor), leads to mistaken assumptions about the importance of these seaweeds in coastal ecosystems, and how it is disturbed from the ocean floor. For some respondents, the (erroneous) understanding is that benthic weeds are disturbed by oil drilling activities:

> *The weeds are light and they come from the seabed. It is in these weeds that the fish birth fingerlings and nurture them till they grow. When the oil explorers started drilling for oil, they cut these weeds which are later pushed by the winds to the shore…When the oil explorers start drilling and laying their pipes, they cut the weeds to make way. So when the wind blows, it pushes them ashore… These weeds are in the sea and they are very fragile so the least disturbance suspends them and when the wind blows, they are washed ashore. (Small Community 1, Older Male FGD).*

Despite oil industry denial of a link between oil and gas and sargassum (Ackah-Baidoo, 2013), the coincidences in the timing of the start of drilling activities and the first arrival of sargassum reinforce this thinking in affected communities. In the absence of accessible trusted information that shows the cause of the initial seeding of sargassum in the tropical Atlantic by the NAO anomaly in 2009/10, community residents appear to have logically perceived a link between the timing of the sargassum influxes and the start of oil and gas exploration activity. An incorrect pathway of causality is therefore developed – oil drilling causes benthic sargassum to become detached which leads to influxes:

When they[4] *start drilling the gas, that is when the seaweeds appear… Four or six years ago there were no seaweeds here. When xxx*[5] *and xxx companies came here and started drilling oil, that is when the weeds started coming. Sometimes the weeds stop appearing for say a week but sometimes it doesn't even take two months for the weeds to reappear (Small Community 2, Younger Male FGD).*

Further, participants perceived a coincidence between the timing of offshore flaring of gas (visible from the beaches at night) and sargassum influxes. While no scientific empirical research has been undertaken to explore this issue, in the absence of other information, a respondent alluded to gas flaring as a driver of sargassum beaching events:

*What causes it [*sargassum influx*] is the gas exploration. When they start operations, then it shows up. When they halt their operations, the weeds do not show up. Anytime they light up their fire* [referring to gas flaring] *and it reflects on the waters, then we know that the weeds will show up soon (Small Community 1 Younger Female FGD).*

Building on the perceived evidence (coincidental timing of start of influxes and oil and gas exploration, and the flaring of gas and arrival of sargassum), participants provided a third piece of evidence to verify their perception of a link between sargassum arrivals and the oil and gas company activity. Fishers, more familiar with ocean tides and currents, had noticed that sargassum only arrives when winds come from the west (where the oil and gas companies are located). Scientific evidence confirms that sargassum appears to be brought into the Ghanaian coast from the west, but explains that this is due to the nature of oceanic and prevailing Ghanaian coastal currents and winds (Skliris et al., 2022). Without access to this scientific evidence about sargassum, it appeared to participants that the coincidence of all three preceding factors pointed clearly to a link between sargassum influxes and the activities of oil and gas companies:

I fish at deep seas, when the tides are high, you will see the weeds coming from the direction of Half Assin, Atoabu [west]*, where [*oil and gas company*] is located. When the wind blows from this side* [the east] *the weeds don't come, but when it blows from this side* [the west] *the weeds come. That's where xxx Gas is located (Large Community, younger male).*

Despite these strongly-held perceptions and certainty among some, that sargassum influxes were related to oil and gas exploration, there were divergent opinions in some groups on what drives sargassum strandings. For some, sargassum influxes were naturally occurring, reflecting openness to scientific input on the source of sargassum:

We do not know what causes it, all we know is, it comes from the sea (New Town, Adult Female).
We actually can't tell where the weeds are coming from. We the fisherfolks sometimes accuse the oil drillers of being the cause of the weeds, the oil drillers can equally accuse the fisherfolks of being the cause of the weed. We can't really tell where the weeds are coming from, only God knows where it is coming from (Medium Community, Young Adult Male).

3.2. Appraisal of lived experience of sargassum impacts

Sargassum stranding has multifaceted impacts on communities, directly through impacts on health and environmental quality, beach aesthetics and tourism, marine livelihoods, but also indirectly on non-marine livelihoods, and social order.

3.2.1. Health and environmental quality impacts

Sargassum can reduce the environmental quality of coastal communities. During peak sargassum influx events, the sargassum can cover an entire beach, piling up to one metre high and preventing any beach-based livelihood activity (Fig. 3).

Beached sargassum decomposes and emits hydrogen sulfide causing respiratory problems and other direct and indirect impacts on the health of coastal residents (Resiere et al., 2018). In all the study sites participants reported a foul stench emanating from decomposing seaweeds, and explained how the seaweed caused difficulties in beach access and use, breathing problems, skin irritation and coughing:

The stench from the weed makes it difficult for us to stay at the shore or even at home (Medium Community, young male).
We are always told to keep garbage out of our environment, because the stench from garbage is not good for our health so if the weeds are here and it smells when it rots, how then can we be healthy when we smell that bad stench… It smells so bad that even human excreta cannot be compared to it (Small Community 1, adult female).
When you touch it, it itches. (Medium Community, Adult Female).
Those of us situated at the coastal areas tend to be coughing a lot and there is a high rate of malaria too. This is because when the weeds get rotten, the stench which it produces when inhaled causes us to cough a lot but because our leaders haven't done further research to know the cause of it, we are very much exposed (Large Community, adult male).

3.2.2. Impacts on beach aesthetics and tourism

Community members expressed concern about the effect of sargassum stranding and beaching on aesthetics. Reduced aesthetic and environmental quality affect both community leisure, cultural activities and tourism (Bartlett and Elmer, 2021). The latter impact affects the nascent tourism industry and potential income for the community, as well as local recreational and cultural use.

When the weeds come, the water changes colour and looks starchy. The sea loses its beauty (Small Community 1, adult female)
When the weeds come, we are affected, especially on 1st January, we have celebrations at the beach. Now we are unable to celebrate because of the weeds (Medium Community, young male).
The weeds have an unpleasant odour when they rot. Tourists from Accra and Kumasi pass by here to go to Nzulezo. Sometimes they would like to come to the beach but the stench repels them (Small Community 1, adult male).

3.2.3. Impacts on marine livelihoods

Both beaching and floating sargassum have impacts on fishery-related livelihoods in all affected parts of the tropical Atlantic (Ramlogan et al., 2017). In the Western region, direct impacts come from loss and damage to fishing gear and the financial and time cost of replacing/mending nets and engines. Fishers also indicated that they catch sargassum instead of fish, causing immediate losses in the affected days, but also longer term damage to nets (Fig. 4):

We fish both on the surface and beneath the sea, when we cast our nets, we end up catching weeds… (Medium Community, adult male).
Our source of income is fishing but when the sea weeds appear we cannot fish. They destroy our nets and other fishing equipment. When this happens for months, we end up eating into our savings because we are homebound (Small Community 2, adult male).
The weeds really disturb us. As we speak, my brothers just came back from fishing and they couldn't get any good fish. Their nets have been clenched together by the weeds and ruined. There is no cash to even fix the nets or buy a new one (Large Community, adult male).

Participants indicated that sargassum seaweeds can also destroy or impede their fishing vessels (Fig. 5).

[4] Oil and gas companies operating in the Western region of Ghana.
[5] 'xxx' is used in place of the oil and gas company names that were stated by respondents.

Fig. 3. Aerial view of beached Sargassum at Large Community (30th September 2021), photograph taken with drone as part of field measurements.

Fig. 4. Fishing nets filled with sargassum.

The weeds can even trap the boat. We have to use our hands to clear the weeds before we can come ashore (Small Community 2, adult male).

Indirect costs negatively affect the fishers due to the man-hours spent removing tangled weeds from the nets and repairing damaged nets. This involves spending longer periods mending and cleaning the fishing nets.

When we go fishing and we catch weeds, we now have to sit and remove the weeds (Medium Community, younger male)

Other indirect costs come from wasted fuel for fishing vessels which go out to fish, but whose nets catch sargassum instead of fish. The wasted trips reduce the potential profit from the sale of the fish, and

Fig. 5. (left) nets tangled with sargassum; (right) fishers untangling nets and removing sargassum strands from fishing gear.

reduce the ability of fishers to make other trips (as they have less cash for fuel).

> *Sometimes you can buy two gallons of petrol and go to sea to catch fish. Because of the weeds, you might catch little or no fish at all. Then you have to waste petrol to get back to the shore (Small Community 1, young male).*
> *We end up wasting our fuel and not making any income. We the fisherfolks don't get fuel to work, the fuel that is sold at 5.5 cedis, when they distribute it amongst themselves, we end up buying it at 150 or 200 cedis. If you don't have such an amount, you can't buy fuel and go to work (Medium Community, adult Male).*

3.2.4. Indirect economic and social disruption

Respondents noted that sargassum influxes appear to have wider indirect social impacts. The negative effects appear to ripple through the entire local economy due to the linked nature of marine-based and non-marine livelihoods.

Most respondents recognized the relationship between marine and non-marine livelihoods within their communities. Comments made reflected participants' insights that the money from fisheries passes through many different hands within the community (such as: drivers, transport operators, other local businesses, traders, fishmongers, local restaurants), and correctly identified that the sargassum influxes were hence affecting everyone:

> *It* [sargassum] *brings a lot of problems. There is an exchange cycle. We get money when we get fish, without that we cannot go out and buy stuff from traders which is very worrying…. The presence of the weeds poses a lot of threats that worries traders. Fish becomes expensive. Drivers (transport operators) also suffer because without any catch, they cannot transport anything (Small Community 2 adult male)*
> *If we don't get fish, the business of drivers and other traders does not progress. Because when we fish and make some money, that's when we are able to patronize other businesses and the drivers also get to load the fish. When we don't make money, all other businesses are affected. (Medium Community, adult male)*
> *It affects everyone because when they go fishing and do not bring fish, the fishmongers will not get fish to sell as well as inhabitants to also buy to cook with. It affects everyone. (Small Community 1, adult female)*
> *The weeds disturb those who engage in trading on the beaches. Why I am saying this is because I am a businessman, I sell and so if the fishermen go fishing and return empty handed, how can I also grow in business? (Large Community, adult male)*
> *It affects drivers, the fishmongers and all those who sell in this town because when we stop going fishing, they don't make much sales. Most chop bars* [local eateries] *are not opened now because if people don't have money to purchase the food, the caterer will run at a loss. So we are all affected. It affects the drivers too a lot (Small Community 1, adult male)*

Some noted the gendered impacts on livelihoods. While men are generally those catching the fish, women have the role of cleaning and selling the fish (i.e. the fishmongers). These two businesses are interdependent, which means that both men and women are negatively affected:

> *Okay, I am a photographer and a businessman. I work with the fisher folks, especially the women who sell, but due to the occurrence of the weeds, it has caused low patronage in my business which also causes hardship for me (Large Community, adult male)*
> *When the weeds show up, it is us (the fishmongers) and fishermen who are affected the most. Because if they (fishermen) do not go fishing we do not get fish to buy and sell. (Small Community 1, adult female)*
> *Another problem is the fact that the women do not get fish to smoke and sell. Ideally they would have supported the family but since they also depend on the fish to survive, both men and women are at a loss. (Small Community 1, adult male)*

Economic disruption from sargassum influxes appear to be generating social consequences. Male respondents recounted the impacts of failed fishing trips on their personal relationships, and others mentioned that there may be a link between sargassum influxes and petty crime:

> *Your wife knows you've gone to work, thinking you will bring money home, only for you to return with debt. You didn't return home with money neither with fish, when that happens, it brings misunderstanding (Large Community, young male)*
> *The weeds affect me personally. My wife wants to leave me, because of the weeds, I'm unable to work and my wife always complains (Large Community, young male).*

Participants also cite a possible link between sargassum events and petty crime:

> *It* [sargassum] *has brought hunger because when we work we are able to buy food to eat but if we do not work, how can we fend for ourselves? Young boys are stealing to feed because they cannot go fishing (Small Community 1, young females)*

Participants clearly perceive a link between sargassum and health problems, livelihood losses, economic disruption, and knock-on consequences across society.

3.3. Appraisal of responsibility to adapt to sargassum influxes

All groups discussed who they perceived to be responsible for addressing the sargassum problem. This section is grouped into 'others' and 'self'.

3.3.1. Responsibility for adaptation by 'others'

Across all groups, due to the belief that benthic weeds are disturbed by oil extraction, many participants perceived the oil and gas companies to be responsible for both causing the sargassum influxes, and for dealing with the consequent problems affecting the community. Participants laid responsibility for adaptation – notably sharing information about the seaweed and drivers of the influxes, as well as the distribution of financial support to help those affected – at the door of the oil and gas companies.

> *We the fisherfolks complain the oil drillers are the cause of the weed, so, we suggest they stop the oil production and observe whether the weeds will come or not. If they stop the oil production and the weeds still come, then we know it's not due to the oil production. When we stop them and the weeds stop coming, then we know the weeds come as a result of the oil production. (Medium Community, young male)*
>
> *Maybe the people from xxx will know what it can be used for since they are the cause of the weed. (Large Community, young male)*
>
> *Both xxx and xxx have done nothing to help us. They do not even have the courtesy to come and explain to us why the weeds keep coming. Since the weeds don't affect them, they do not come here to tell us anything (Large Community, adult male).*

Others pointed to the government as the key agency responsible, while recognizing the central role of the oil and gas companies in causing the problem:

> *Government initiative is the solution. As we have already established, xxx is the main culprit so halting their exploration will help (Small Community 1, adult female).*

For most respondents, individual community members saw responsibility for adapting to the large recurrent problem of sargassum, as outside of their domain.

3.3.2. Responsibility for adaptation by self

Almost all respondents felt that they had no responsibility to address the sargassum problem – as they had not caused the problem. It was repeatedly noted there was nothing that communities or fishers could do to prevent the seaweed from arriving and damaging their livelihoods. Many felt that the only action that would generate a reduction in sargassum inflows was stopping drilling by the oil and gas companies. Statements were repeatedly made indicating that 'there is nothing we can do':

> *The oil drilling should be stopped because apart from that, nothing can be done. Unless they decide to give us huge sums of money to establish new business so that we wouldn't have to depend on fishing to make ends meet. (Small Community 1, adult male).*
>
> *There is nothing we can do about the weeds. We can only be relieved if the oil and gas company halts its operations. (Medium Community, older male 1)*
>
> *We can't do anything about the weeds, we are under the control of the government, the oil and gas company is also under the control of the government. If they don't halt their operations, we can't say anything. As you have come, please inform the government that though the income from the oil exploration is to develop the country, the activities of fisherfolks are being affected, that's the little we have to say. (Medium Community, older male 2)*

This self-appraisal of own responsibility is likely linked to the ongoing tensions between local communities and the oil and gas companies in the Western region of Ghana. In the absence of these community-industry tensions, there is evidence from Central America and the Caribbean, that the community could become more actively involved in better understanding the nature of the phenomenon, long term risk mitigation, preparedness for events, responding to events, recovering after events, and in finding opportunities from the sargassum. For example, in Mexico evidence shows that multiple groups have taken responsibility for different parts of the sargassum problem: communities to raise the alarm, the media to raise awareness of the issue, academia to monitor the blooms using remote sensing, governments to provide management guidance, individual villages and business affected to clear the sargassum, and entrepreneurs to find uses for the sargassum (Rosellón-Druker et al., 2022). This collaborative approach and a sense of shared responsibility across society was not evident in Ghana and could be considered part of the 'resource curse' often associated with extraction of minerals and oil (Owusu, 2018).

3.4. Appraisal of coping ability and adaptation actions

Perceptions of ability to cope with the sargassum proved to be intricately linked to perceptions of responsibility for action, and in turn actual adaptations undertaken.

3.4.1. Coping appraisal

Respondents focused their discussion of how they coped in two main areas: (i) their affected livelihoods and (ii) how they managed the sargassum on the beach. Other aspects of coping / adaptation were not considered, for example, trialling sargassum for use in local subsistence agriculture, preventing sargassum from beaching, or accessing tropical Atlantic-wide early warnings of sargassum blooms. Overall, participants perceived themselves to have limited ability to cope with the sargassum influxes; this appears to be a result of their focus on impacts on their livelihoods. Participants perceived that they had narrow skillsets, and could not undertake alternative livelihoods (when there is disruption due to sargassum) and they pointed to the limited effectiveness of the local adaptations already attempted (Table 1).

Communities indicated that they have limited livelihood options, and are unable to diversify into alternative livelihood strategies due to a lack of basic and specialist skills. These sentiments were expressed typically in the male groups:

> *We the fishermen don't have any other occupation; we are Fanti and this town is an Nzema town. We are migrants, who have come here to fish. So, if we are unable to fish, we can't go and steal coconut. We don't have farms to depend on, we only depend on fishing, so, if we are unable to fish, that's all (Medium Community, adult male).*
>
> *I am illiterate. Fishing is my only source of income. When the weeds arrive, it is difficult to fish so I cannot make ends meet when they (the weeds) start coming (Small Community 1, young male).*
>
> *If I had learnt any other trade, I would have stopped fishing. We are not able to make a living; we don't enjoy fishing any longer. When I was young, I didn't attend school because of fishing. I thought I could fish and make a living but since the weeds started coming, we no longer enjoy the work (Medium Community, adult male).*
>
> *Because we live on the coast and are a fishing community, we do not have anywhere to relocate to or work. We aren't good with farming but just the fishing. So when the weeds come like that, it brings a halt to our fishing activities, which disturbs us greatly (Large Community, adult male).*

In addition, to perceiving that they lacked skills, since 2011, all communities indicated that they have tried a variety of adaptations to live with both floating and beaching sargassum (Table 1).

In many cases adaptations involved taking action to cope with the negative impacts of the sargassum e.g. losing income, increasing work effort to generate the same income, or engaging in adaptations that reduce capacity such as food rationing or taking out loans to cover expenses. The only preventative action trialed was beach clearance, although this was stopped once it was realized that the sargassum

problem was continuous and that the weeds returned regularly.

> *We used to gather them and burn them… Even after burning them, more are washed ashore so we have stopped doing that (Small Community 2, adult male).*

Many of the adaptations tried by the communities could be considered maladaptive as they make the affected population even more vulnerable to recurrent impacts (Schipper, 2020). Most of the adaptations in Table 1 were perceived to be ineffective by the communities themselves. When discussing their choices, the groups expressed a sense of helplessness and frustration in their inability to respond to the massive sargassum influxes. People returned to their feelings of lack of responsibility to do anything themselves due to the cause of the problem being beyond their control:

> *We have told the people from the oil company, but they are not helping us, during the periods that we are unable to fish, they should help us with at least 100 cedis each. The drilling of oil has destroyed the livelihoods of fisherfolks, we are suffering, they should help us. (Medium Community, older male 3).*
> *Let's halt the oil production for sometime and see whether the weeds will come or not. If the weeds don't come, then we know they are not the cause. Then we can think of other solutions. (Medium Community, younger male 2).*

Respondents felt that they needed to confirm the causes of the sargassum before they could identify who should be acting to address the problem. Overall, the language in the groups pointed to both hopelessness, and a lack of perceived options available.

Unlike affected communities in the Caribbean and Central America, in Ghana, preventative methods have not been considered to stop the beaching events, e.g. through the use of offshore collection and disposal (Chávez et al., 2021) or inflatable booms to protect important parts of the coast (Liranzo-Gómez et al., 2021). There is also no evidence of other beach management options such as mechanical removal (Oxenford et al., 2021), or leaving sargassum *in situ* to decompose and then support dune stabilization (Williams and Feagin, 2010).

While there was an expression of desire to exploit the sargassum for profit, there was little perception of capacity within the community to do this. While one respondent enthusiastically asked for guidance on how to re-use it (Large Community chief fisherman), many were not confident in their ability to transform the seaweed into an opportunity:

> *The weed has no use. It can't be sold; I don't think the weeds can be used for anything useful. If you have any knowledge about it, you can share it with me. If it could be used as manure to fertilize the soil for farming, we would have done that… if it is confirmed that it could be used for fertilizer, both the fisherfolks and farmers would collect the weeds and sell them. We will find ways of conveying the weeds to the farmlands. We will convey it to lands that are not fertile. (Large Community, chief fisherman)*

When asked about re-use opportunities, many respondents looked to outsiders for input:

> *There is no company who comes for the weeds to make anything useful. We even pray that it becomes useful so we can gather them and sell to these companies for some money (Large Community, adult male)*
> *When the weed is fresh, it's yellow, when it dries it turns black. If our brothers who make fertilizers can use their knowledge to help us make fertilizers here, most of us would stop fishing and get employed there. We are pleading with fertilizer makers to come and check whether the weeds could be used to make fertilizers (Large Community, young male)*

In general, the groups perceived that they lacked the knowledge or skills to use the sargassum for profit. They also perceived that they lacked the social networks and contacts to bring in people with the skillsets to re-use the sargassum. This perception of low self-efficacy contributed to their frustration and pessimism about the sargassum situation, but also points to the opportunity to explore the potential for re-use from the sargassum in West Africa.

3.4.2. Coping responses

Directly linked to community perceptions about responsibility ('Others' are to blame for the sargassum influxes) and risk (the threat is high, continuous and damaging), is the lack of perceived adaptation options. Communities perceive that there is little they can do themselves. Many of the coping responses suggested by respondents do not relate to the villagers themselves, but to actions of 'Others', notably the formal and traditional governments, and the oil and gas companies.

Respondents articulated that the oil and gas companies should compensate the fisherfolk during the periods when the sargassum beaching volumes are higher and the fishers are unable to go fishing. This perception appears driven by the communities' mistaken perceptions of links between the timing of the influx of sargassum and oil exploration activities, and their assessment of responsibility for the problem.

> *They cannot prevent the weeds from coming… and we cannot do anything about it. What they* [the oil and gas companies] *can do is to give us some funds to help us survive when the weeds cause us not to go fishing. So, if they are going to explore the oil for three months, they need to give us funds to survive so that when they leave after the three months we can go back to fishing (Large Community, adult male).*
> *We have told the people from the oil company, but they are not helping us, during the periods that we are unable to fish, they should help us with at least 100 cedis each. The drilling of oil has destroyed the livelihoods of fisherfolks, we are suffering, they should help us. (Medium Community, older male 3)*

In Ghana there is both a formal Government and a traditional/ system of governance (customary governance system led by traditional chiefs and elders). Respondents note that neither the formal government, nor the chiefly system were yet providing support, advice or leadership for the problem. Various groups of respondents, particularly male, report that they receive no assistance from the government or other institutions to deal with the impacts of sargassum influx. They have through their unions or cooperatives and local authorities (district/ municipal assemblies) attempted to reach higher levels of formal government for support but with little success.

> *We have gone to the Ministry of Fisheries and the Presidency. They told us to give them some time. To date, we have not heard from them both. Right now, it is a 'do or die' affair (Small Community 1, adult male)*
> *Those over there, all the drag fishermen have formed an association. So, the moment this began to disturb their work, they informed the municipal assembly about it and also sent letters to the Presidency and the Fisheries Ministry to draw their attention to the challenge they were facing from this issue. But since then, we are still waiting for a response from the government, but nothing has been done (Community Assemblyman).*

Traditional authorities are also not perceived to be supporting communities or leading the response to sargassum. When asked about the role of the chiefs in mobilizing support to deal with sargassum:

> *I have never seen a chief who has put things in place to help us. Whether the weeds come or not, it is no concern of theirs (Small Community 2, adult male).*

The lack of reflection on adaptation could relate to the feelings of helplessness (a result of the failure of previous small-scale attempts at clearing the beaches), combined with a lack of external input or formal guidance on what to do:

> *When the weeds come, we the fishermen only observe and wait till the weeds go back to the sea… It comes when it wants to, when in its peak season, it gathers on the shores and gets rotten naturally when the sun scorches it. So when it rots and vanishes, that is when we resume our*

fishing activities but even that, we do not get any harvest (Large Community, adult male)

Participants did not consider potential adaptations over different timescales which have been seen in other locations affected by sargassum, notably, long term risk mitigation e.g. moving away, getting insurance; cyclical preparedness e.g. awareness of seasonality and seasonal plans, identifying alternative livelihoods during the worst periods of sargassum influx; response during events e.g. beach clearance, removal, collection, composting; and recovery e.g. engaging academia to explore management and re-use options, development of early warning systems, or engaging the private sector to identify alternative uses for the sargassum.

4. Discussion

A clear message that emerges from the data in western Ghana is that sargassum-affected communities (both men and women) do not appear to understand the biological nature of sargassum, its lifecycle and seasonality, the causes of sargassum influxes, and how to manage it. Three factors identified in the study compound this misperception. First, the onset of offshore oil and gas exploration in Ghana was followed in close succession by the first major sargassum influx in 2011. It is important to reinforce that this perception does not align with available scientific evidence which attributes the initial seeding of pelagic sargassum in the tropical Atlantic to an initial anomalous weather event in winter 2009–2010 (Johns et al., 2020) – see introduction. Second, across all communities, respondents incorrectly perceived that sargassum naturally attaches to the seabed (i.e. it is a benthic macroalgae). This misunderstanding reinforces the belief that drilling for oil on the seabed disturbs the sargassum, causing it to float to the surface. This perception is not in line with scientific understanding of the life cycle of the pelagic sargassum affecting West Africa. Evidence clearly shows that sargassum spends its entire life afloat until it dies, when it decomposes and drops to the ocean floor (UNEP, 2021; Corbin and Oxenford, 2023). Given the longevity of the sargassum problem in the tropical Atlantic (now recurring annually for 12 years), and the massive growth in literatures exploring its cause and drivers of movement over that period (e.g. Chávez et al., 2020; Amador-Castro et al., 2021) it is surprising to find across the tropical Atlantic such different levels of community understanding of the nature of the seaweed and its causes, its management, possible adaptations and alternative uses for it.

Perceptions of communities in coastal West Africa presented in this study highlight a divergence in understanding of sargassum among communities across the tropical Atlantic. It is useful here to compare community perceptions and locally relevant sources of information across the tropical Atlantic. Fact sheets and guidance, developed by regional universities and agencies representing the Americas and the Caribbean, on sargassum management were targeted at regionally relevant sectors e.g. fisheries (Doyle and Franks, 2015), local clean-up (Hinds et al., 2016), and tourism (CAST, 2015). Since then, studies on the impacts on communities, and their adaptations have continued in the Western Atlantic e.g. in Mexico (Chavez et al., 2020), the Dutch Caribbean (López-Contreras et al., 2021), and the wider Caribbean (Liranzo Gómez et al., 2021; Oxenford et al., 2021). The lack of comparable locally-relevant sources of information about sargassum, its impacts and adaptation options, appears to be an important knowledge gap creating management challenges in West Africa.

There are many possible reasons for the lack of research on sargassum in West Africa. One significant challenge relates to the gathering evidence of distribution and movement of floating and beached sargassum. In coastal West Africa, unlike the Caribbean and Central America, remote-sensing data quality is poor for most of the year due to high levels of cloud cover (Knauer et al., 2012). That absence of large scale monitoring data leads to a reliance on local level and small scale data collection, which tends to be more costly and can create data gaps. To date, in contrast to the Caribbean and the Americas where sargassum forecast systems now proliferate (e.g. Wang and Hu, 2017; Marsh et al., 2022), there are no comparable studies estimating quantities, volumes or seasonality of pelagic sargassum affecting West Africa. Lack of an understanding of magnitude of events, quantity and seasonality is a significant barrier in itself to advancing other locally relevant work on sargassum. Hence, there are still many unknowns about the sargassum influxes in West Africa.

This research finds that in line with work in the Caribbean and the Americas, sargassum can disrupt the main coastal economic activities (fishing and related activities) by breaking fishing gears and impeding mobility on the beach (Ramlogan et al., 2017; Solarin et al., 2014; Ofori and Rouleau, 2021). We show that there in western Ghana, there are multiple dimensions of economic loss associated with floating and beached sargassum, such as wasted fuel in fishing boats that return with no fish and unproductive time spent repairing fishing gear. Research gaps still remain in West Africa around quantifying the economic losses from lost fishing days, damages to fishing gear, and associated losses in the fisheries-related sector including fish processing, transport and retail.

Our research also finds a gendered dimension to the experienced impacts in line with the traditionally gendered occupational and social roles in West Africa, which appears to diverge from findings in the Caribbean and Americas. Males in Ghana are predominantly affected through direct impacts on fishing activities (replacing and repairing damaged nets, waste of money on fuel, lost income), as well as through their social role as breadwinners. Traditional artisanal fishers also note the limited livelihood options they can resort to when unable to fish due to sargassum. The impacts on women, though differentiated, are interlinked with the direct impacts on fishers. Women's livelihoods are mostly dependent on fishers' ability to fish, so that any impact on fishers affects their ability to work and earn an income, thereby affecting many families which are dependent on marine-related livelihoods. This research highlights that the combination of livelihoods of coastal communities and households shape their vulnerability to sargassum (Atiglo et al., 2022). Further research could explore how impacts on the main economic activities on which communities collectively depend for survival, affects shared senses of security, belongingness and identity (Tschakert et al., 2017).

Finally, the application of PMT in this study has highlighted the main barriers in western Ghana to local scale action on adaptation to sargassum influxes, which are buried in beliefs about responsibility and capacity. Where the volume of beached sargassum is small, participant communities remove the weeds from the beach, but became frustrated when beaching was persistent or severe and when person-hours were perceived to be wasted. Communities affected by sargassum noted an absence of capacity to adapt: a lack of capacity to take specific action (adaptive capacity), a lack of ability to take any action (self-efficacy). These feelings of incapacity appear to come from a combination of sense of failure and learned helplessness from unsuccessful previous experiences of local sargassum management; the magnitude of beaching events; perceptions of the drivers of the sargassum; and an attribution of responsibility to oil and gas companies or the government. Crucially, because of the various misunderstandings, some communities appear to perceive that the oil and gas companies should be taking action to address sargassum influxes, and that external support is needed. Both of these beliefs appear to be fueled by misperceptions of the drivers of sargassum. As Aerts et al (2018) note people's perceptions of risks and their ability to cope is often ignored in environmental risk management. Yet ignoring community risk perceptions in relation to sargassum in West Africa appears to have exacerbated the way in which communities have experienced the impacts.

5. Conclusion

In this study, PMT has proven useful in structuring analysis of

community adaptation to an emergent risk, drawing out the drivers of and barriers to proactive adaptation. Oil and gas exploration and extraction co-occur with sargassum influxes in the Gulf of Mexico and in West Africa, but the belief in a causal relationship between the two only continues to exist within West Africa (within participating communities in this study). This belief appears to have become entrenched over time. The social amplification of the message within the communities – that sargassum is caused by and proliferated by the oil and gas companies – is not being countered by clear and believable messaging from elsewhere. As a result, the belief has become embedded that oil and gas companies are responsible for: all aspects of clear up, alternative livelihood provisioning and management of sargassum. This belief is entwined with a lack of community willingness to engage with sargassum to improve management or to investigate possible business opportunities. Given the urgent need to ratchet up adaptation activity as part of the Paris Agreement (Tompkins et al., 2018), we conclude that the PMT offers a practical and critical research approach to household and community scale adaptation that usefully draws out drivers of adaptation and highlight areas for increased action.

For this case study, obvious policy lessons emerge by comparing findings from West Africa with findings from the Caribbean and the Americas. A first priority for West Africa is the rapid development of large-scale monitoring of the seasonality and magnitude of annual sargassum arrivals. A second priority is the development, with the affected communities, of sectoral guidance (fisheries and fisheries-related) on management and re-use opportunities from both floating and beaching sargassum. In Ghana, due to the (now) longstanding tensions between communities and oil and gas companies as a result of other conflicts e.g. access to fishing grounds, cooperation needs to be developed in finding solutions to the sargassum problem. It is the not aim of this paper to identify how to heal rifts between oil and gas exploration and extraction companies and adjacent communities – there is already a large, accessible and West African facing literature on how to do so (e.g. Mohammed et al., 2022b). Instead, we see opportunities initially for the oil and gas companies in researching how their sector might be affected by sargassum inundations, and then for collaboration between the extraction companies, the government and communities in encouraging and supporting entrepreneurship in monitoring the sargassum, re-using the sargassum locally, and potentially in developing supply chains to support industries using sargassum. There is relevance here for any new or emergent climate or environmental risk that is affecting communities already perceiving stress from another cause. The perceived stress has to be addressed in parallel to the collation of evidence about the new risk. The sharing of knowledge between affected sectors and communities can inform the wider process of sargassum risk management (van der Plank et al., 2022). Without a collaborative community-government-industry approach to knowledge collation, information, data and experience sharing and use of trusted lines of communication, it is unlikely that improvements will be seen in how saragssum is managed in West Africa.

Sargassum influxes are unlikely to be the last emerging risk co-created by human activity and climate change for coastal nations. Developing generic management strategies to respond to novel emergent risks, such as sargassum, could potentially support all countries better prepare for the surprises that are likely to affect us into the future. From this work, and drawing on lessons from the Caribbean and the Americas, we propose the following strategy to other nuisance seaweeds, and environmental emergent risks: start with rapid assessments of the spatial and temporal distribution of the problem; assess and share estimates of potential seasonality, magnitude and frequency; invest in early sectoral and community impact assessments to identify key issues; encourage research and development in local and regional universities; use locally appropriate routes to investigate simple innovation and re-use potential; create a freely accessible information portal and regional network for quickly sharing all evidence, knowledge and guidance. Action is needed by all actors with research capacity (regional bodies, governments, universities, NGOs etc) to prepare to be rapidly responsive to new risks and hazards as we move further into an Anthropocene increasingly dominated by climate change.

CRediT authorship contribution statement

D. Yaw Atiglo: Conceptualization, Methodology, Project administration, Formal analysis, Writing – original draft. **Philip- Neri Jayson-Quashigah:** Writing – original draft, Project administration. **Winnie Sowah:** Visualization, Writing – review & editing. **Emma L. Tompkins:** Conceptualization, Funding acquisition, Writing – review & editing. **Kwasi Appeaning Addo:** Supervision, Funding acquisition, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2023.102779.

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