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Seaweed Farming in Tanzania: A Study of Working Practices and Geospatial Analysis of Occupational Hazards and Adverse Health Outcomes

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ABSTRACT

Objective: Work in seafood harvesting and processing has been associated with a range of occupational hazards and associated health problems. However, limited information exists regarding the occupational health risks among workers engaged in seaweed handling.
Methods: A cross-sectional study was conducted to map seaweed co-operatives ($n = 45$), assess working practices, and identify common work-related symptoms, occupational hazards, and interventions in seaweed farming sites ($n = 24$), across three regions of Zanzibar, Tanzania.
Results: Seaweed farming in Zanzibar primarily involves the cultivation of Eucheuma Spinosum, with the majority of workers being women. Common work-related symptoms identified include musculoskeletal symptoms, mainly affecting the wrist (87%), back (84%) and lower limbs (73%). Furthermore, a significant proportion of workers were reported to have skin problems (80%) as well as heat and asthma-related symptoms (51%). Walk-through hazard evaluations of work sites identified a range of occupational hazards, with ergonomic (58–68%), biological (50–63%) and chemical (55–65%) hazards obtaining higher scores across the three regions. Geospatial analysis revealed regional variations in occupational hazards and work-related symptom prevalence, with Unguja South having a statistically significant ($p < .05$) higher mean prevalence of skin symptoms (95%) and Mjini Magharibi region reporting a higher prevalence of lower limb pain (100%), back pain (100%), and heat-related symptoms (90%). Despite the high hazard scores, interventions were generally lacking across all regions.
Conclusion: Occupational health hazards and adverse health outcomes vary across seaweed farming and processing regions. Tailored interventions will be key to improving workplace health and safety of workers engaged in this sector.

KEYWORDS
Aquaculture; geospatial analysis; occupational hazards; occupational health and safety; seaweed farming

Introduction

The aquaculture sector is an important component of the global food industry. In recent years, aquaculture has seen significant growth and diversification globally, with various aquatic species being cultivated to supply the increasing market demand for seafood and aquatic plants.[1] This expansion of aquaculture has contributed to the livelihood of millions of workers globally and has become a major driver in alleviating pressures on the overexploited wild fisheries.[2]

In Africa, the importance of aquaculture has been steadily increasing, similar to the global context. Since 2000, aquaculture production in sub-Saharan Africa has experienced remarkable growth, averaging an annual increase of 11%, which is nearly double that of the global average.[3,4] Within the African aquaculture landscape, Tanzania has great potential given its temperate climate, vast water resources, and potential for supplying local, regional, and international markets.[5–7] The country is involved in both inland and marine aquaculture production, with seaweed farming being the most prominent activity for marine aquaculture.[8]

Seaweed farming in Tanzania involves the cultivation of two main species, *Kappaphycus cottonii* and *Eucheuma spinosum*.[9] Despite the benefits of seaweed production in improving the livelihood of coastal communities in Tanzania, the health, safety, and well-being of seaweed workers remain a concern. A previous study of Tanzanian seaweed workers ($n =$ 140) reported a high prevalence of fatigue (74%), low back pain (67%), respiratory problems (65%), ocular symptoms (54%), injuries from hazardous aquatic

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animals and sharp shells (54%), allergies (43%), and asthma (16%).[10] Subsequent research on the same population 5 years later revealed a high prevalence of skin irritation (50%), eye irritation (30%), facial and ocular swelling (25%), and headache (18%).[11] Similar findings have been reported among Indonesian seaweed workers, which included work-related injuries (77%), low back pain (55%), and fatigue (33%).[12] In this study, female gender, employment duration greater than 1 year, and working more than 8 h per day were associated with a high risk of work-related injuries. A follow-up study in this population highlighted various ergonomic hazards, such as frequent bending (56%), twisting (42%), repetitive movements (86%), and use of force (56%), that was associated with a high prevalence of low back pain (67%), strains (60%), and sprains (9%).[13] In this population, low back pain was significantly associated with seaweed processing and maintenance work. In Sri Lanka, labor-intensive seaweed farming work and prolonged exposure to solar radiation and saline water were linked to general fatigue, sore eyes, skin problems, and allergies among seaweed workers.[14] In particular, work activities, such as the establishment of cultivating areas and hauling harvest, were reported to be more physically demanding, thereby causing musculoskeletal disorders.

In addition to the specific occupational hazards, work organizational factors such as enterprise size, economic and business relations, and employment arrangements have also impacted on the health and safety of seaweed workers in Northwestern Europe.[15] The predominance of micro-small enterprises in seaweed production, the limited capacity of owners and/or managers to address health and safety risks, the structural and economic factors in the sector that promote precarious work, and the low visibility and inaccessibility of micro and small enterprises to both public and private regulations contribute to the challenges faced by seaweed workers in maintaining their health and safety in this region. A comparable situation was also observed among Tanzanian seaweed workers, in which the informal to semi-formal nature of seaweed farming work has resulted in many workers having no protection under the current Tanzanian occupational health and safety legislation.[8] The lack of access to basic preventive and protective occupational health services, poor occupational health and safety (OHS), technical support, and inadequate information, education, and training further exacerbate the OHS risks. Similar challenges have been reported among migrant seaweed workers in Malaysia, where health and safety issues receive little or no attention, despite the migrant working population being the dominant seaweed producers in the region.[16]

While previous studies have reported the health risks associated with seaweed farming, few have conducted a systematic assessment of the occupational hazards within seaweed farming environments. Therefore, the aim of the current study was to identify occupational hazards and their associated health risks among seaweed workers in Zanzibar, Tanzania. This included an assessment of the geographical distribution of seaweed farming activities, working practices, and whether the geographical distribution of occupational hazards and adverse health impacts varied across regions in Zanzibar. Understanding the specific occupational hazards and health risks encountered by seaweed workers, as well as their spatial distribution, is crucial in developing targeted interventions to address the specific health and safety needs of seaweed workers.

Methods

This was a cross-sectional study of seaweed workers in Zanzibar, Tanzania, conducted during the period 2021 to 2023. The study involved a survey to enumerate and map seaweed farms to develop a comprehensive database of seaweed farming sites having details of location, size, and type of seaweed species farmed. This was accompanied by walk-through hazard evaluations conducted on a selected group of aquaculture sites to obtain more detailed insights into potential occupational hazards and health risks.

Ethical approval for this study was provided by the Human Research Ethics Committees of the University of Cape Town (Ref: 693/2019) and the Zanzibar Health Research Institute (Ref: ZAHREC/04/ST/JUNE/2021/57). Participants gave informed consent to participate in the study before taking part.

Enumeration and geospatial mapping of seaweed farming sites

Data collection in this phase involved gathering geospatial and farming site-specific data from seaweed farming cooperatives ($n = 45$) located in six villages known for their extensive seaweed cultivation. These cooperatives comprise organized groups of seaweed workers, typically comprising 10–15 workers, formed to provide social support, foster collaboration, and facilitate accessing external support.[17] The recruitment and data collection processes were conducted in collaboration with the Zanzibar Seaweed Cluster Initiative (ZaSCI), a local non-governmental organization with extensive experience in working with seaweed workers over many years. Geographical data collected included Global Positioning System (GPS) coordinates of the seaweed farming sites belonging to seaweed cooperatives obtained from Google Maps.[18] In addition, key information was collected from representatives of seaweed farming cooperatives ($n = 45$) using a short structured questionnaire modified and adapted from a previous study of seafood processing workplaces in South Africa.[19] The information included the type of seaweed harvested, the nature of production process involved, and the presence of work-related health problems among workers.

Walk-through hazard evaluation of selected work sites

A walkthrough hazard evaluation of selected seaweed work sites was conducted in 24 (4 from each of 6-participating villages) of the 45 sites enumerated. These sites were distributed across Unguja South ($n = 12$), Unguja North ($n = 8$), and Mjini Magharibi ($n = 4$) regions. Seaweed farming sites included in this component of the study were selected based on accessibility considerations. This number also provided an optimal opportunity for obtaining data saturation in identifying most hazards encountered by the workers. Interviews were also conducted with cooperative leaders to obtain additional information on the level, frequency, and duration of exposure for each hazard identified. This process further assisted in identifying and confirming the extent of high-risk exposures.

Information obtained from the work sites included specific tasks, hazards, and control measures practiced at each site. A proforma checklist was developed and modified from other tools such as the Online Interactive Risk Assessment (OIRA) tool designed by the European Agency for Safety and Health at Work,[20] the ILO code of practice for safety and health in agriculture,[21] the EurepGAP Checklist for Aquaculture Assurance,[22] and the Best Aquaculture Management Practices (BAMP) Finfish/Crustacean Farm Standards.[23] The checklist was refined further after taking into consideration common occupational hazards in aquaculture settings that have been reported in the literature.[24]

Statistical analysis

Statistical analysis was conducted using the STATA version 14 (StataCorp, College Station, Texas, USA). Univariate analysis was used to summarize data on production, location, and workforce characteristics, as well as the prevalence of work-related symptoms. GPS coordinates of farm sites were mapped using Google Maps, followed by a stratified analysis of work-related symptoms across the three Zanzibar regions: Unguja North, Unguja South, and Mjini Magharibi.[25] The chi-squared test was used to assess the statistical difference in the prevalence of work-related symptoms between these three regions.

A scoring system was devised to analyze data on occupational hazards and associated intervention measures, by assigning a score of 1 to each item contained in the walkthrough checklist. This facilitated the calculation of aggregate scores for each hazard and intervention category (Table 1). The results of the aggregated scores per hazard and intervention category for each cooperative were expressed as percentages. Mean hazard and intervention scores were calculated for each region, which were visually presented using spider web plots to allow for graphical comparison between the regions. The one-way ANOVA and the Kruskal-Wallis tests, for normally and non-normally distributed data, respectively, were used to determine whether there was a statistically significant difference in hazard and intervention scores across regions.

Table 1. Scoring System for Evaluating Occupational Hazards and their Interventions.

Ergonomic hazards	**Score**	**Biological hazards**	**Score**	**Psychosocial hazards**	**Score**	**Chemical hazards**	**Score**	**Physical hazards**	**Score**	**Safety hazards**	**Score**
• Working with the neck or back bent	1	• Lyngbyatoxin	1	• High demand low control work situation	1	• Hydrogen peroxide	1	• Extreme temperature	1	• Sharp shells	1
• Squatting	1	• Carrageenan	1	• Remote locations away from family	1	• Hydrogen sulphide	1	• Solar radiation	1	• Sea urchin/Jelly fish stings	1
• Kneeling	1	• Endotoxin	1	• Harassment or intimidation	1	• Sodium hydroxide (caustic soda/lye)	1	• Wet work	1	• Fire and electrocution	1
• Gripping an unsupported object	1	• Fungal spores	1	• Working having negative effects on private life	1	• Oils	1	• Poor ventilation	1	• Unprotected machinery	1
• Pinching an unsupported object	1	• Mold	1	• Seaweed die-offs	1	**Total score**	**4**	• Poor lighting	1	• Slips, trips, falls	1
• Repeated movements	1	**Total score**	**5**	**Total score**	**5**			• Glare	1	• Drowning	1
• Using the hand or knee as a hammer	1							**Total score**	**6**	**Total score**	**6**
• Heavy lifting	1										
• Awkward postures	1										
• Prolonged sitting	1										
Total score	**10**										

Interventions for ergonomic hazards	**Score**
• Presence of breaks during the day	1
• Pace of work adapted to workload	1
• Work characterized by moderate and adequate amount of workload, time pressure and/pace	1
Total score	**3**
Interventions for biological hazards	**Score**
• Assessment of hazardous biological exposure conducted	1
• Workers handling biological agents familiar with the safety procedures	1
• Seaweed storage in dry, well-ventilated area to prevent mould growth	1
• Use of suitable personal protective equipment when working with chemicals	1
Total score	**4**
Interventions for psychosocial hazards	**Score**
• Work characterized by moderate and adequate amount of workload, time pressure and/pace	1
• Appropriate amount of variety in the work routine	1
• Measures taken to reduce time pressure	1
Total score	**3**
Interventions for safety hazards	**Score**
• Measures to minimize risk of stings and cuts from sea organisms	1
• Measures to minimize the risk of injury from sharp shells	1
• Machines used for seaweed processing protected to reduce risk of injury	1
• Availability of emergency response plan	1
• Availability first aid kits	1
Total score	**5**

Interventions for chemical hazards	**Score**
• Availability of the inventory of hazardous chemicals	1
• Assessment of hazardous chemical exposure conducted	1
• Availability of safety data sheets for chemicals used	1
• Chemicals storage in accordance with the label instructions and legislation	1
• Chemicals stored in original packaging and kept in a suitable condition to allow label instructions to be read easily	1
• Storage containers bear labels/pictograms to indicate that they contain hazardous chemical substances	1
• Workers handling chemical substances familiar with the safety procedures	1
• Use of suitable personal protective equipment when working with chemicals	1
Total score	**8**
Interventions for physical hazards	**Score**
• Presence of preventative measures against extreme temperatures exposure	1
• Workers able to recognize symptoms of heat stress	1
• Pace of work adapted to thermal environment and workload	1
• Task rotation to prevent few workers being constantly exposed to extreme temperature	1
• Portable water available near the worksite	1
• Workers using light coloured, loose-fitting, breathable clothing while working	1
• Presence of preventive measures to avoid exposure to solar radiation	1
• Workers able to recognize ultraviolet radiation injury and take necessary steps	1
• Exposure to noise exceeding exposure limits	1
• Measures taken to minimize noise exposure	1
• Noise exposed employees briefed on the risk of noise and use of personal protective equipment	1
• Indoor workspaces well ventilated	1
• Indoor workspaces well illuminated	1
Total score	**13**

Each total score for a specific component is expressed as a percentage in the results table.

Results

Production, location and workforce characteristics of seaweed farming co-operatives

The study included 45 seaweed co-operatives, all of which cultivated *Eucheuma Spinosum* seaweed species, with an average monthly production of 100 kg (Table 2). The majority of workers worked in Unguja South (44%) and Unguja North (33%) regions, located in specific farming villages of Kidoti (33%), Muungoni (20%), Buyu (16%), Paje (13%), Chwaka (11%), and Bweleo (7%) (Figure 1). All 45 cooperatives were engaged in seaweed drying, while 9% also conducted seaweed processing activities. The latter involved soap-making (16%), food item preparation (13%), body lotion production (7%), and cooking (2%). On average, each cooperative comprised 15 workers that were predominantly women.

Common work-related symptoms reported among seaweed workers

Musculoskeletal symptoms were more common and mainly affected the wrist (87%), back (84%), and lower limbs (73%) (Table 3). Furthermore, a significant proportion of workers reported skin problems (80%) and less so for heat and asthma-related symptoms, having similar prevalences (51%).

More than 50% of cooperatives reported an annual prevalence of at least one work-related symptom exceeding 5%. Furthermore, back, wrist, and lower limb pain symptoms exceeding 10% prevalence per cooperative were reported by 82%, 76%, and 69% cooperatives, respectively, while the annual prevalence of work-related skin symptoms reported per cooperative was substantially higher for skin (67%) than for asthmatic (29%) symptoms.

Geo-spatial distribution of common work-related symptoms among seaweed workers

Figure 2 illustrates the geo-spatial distribution of common work-related symptoms among seaweed worker cooperatives across the three regions in Zanzibar. Overall, cooperatives in Mjini Magharibi and Unguja South regions consistently reported a higher mean prevalence across multiple symptoms compared to Unguja North. Specifically, cooperatives in Unguja South had a statistically significant ($p < .05$) higher mean prevalence of skin symptoms (95%), while the cooperatives in Mjini Magharibi reported a higher prevalence of lower limb pain (100%), back pain (100%), and heat-related symptoms (90%). An elevated mean prevalence of asthma-related symptoms was also reported by cooperatives in all three regions: Unguja South (70%), Mjini Magharibi (40%), and

Table 2. Production, location and workforce characteristics of seaweed farming cooperatives enumerated in Zanzibar, Tanzania.

Characteristic (n = 45)	n (%), Median (IQR)
Gender of key informants (%Female:Male)	91:9
Seaweed species farmed	
– *Eucheuma Spinosum*	45 (100%)
– *Eucheuma Cottonii*	4 (9%)
Production per month (kg)	100 (75-150)
Location of the farming regions	
– Unguja South	20 (44%)
– Unguja North	15 (33%)
– Mjini Magharibi	10 (22%)
Location of the farming villages	
– Kidoti	15 (33%)
– Muungoni	9 (20%)
– Buyu	7 (16%)
– Paje	6 (13%)
– Chwaka	5 (11%)
– Bweleo	3 (7%)
Farming cooperatives engaged in drying of seaweed	45 (100%)
Farming cooperatives engaged in other forms seaweed processing methods (cooking, making soap, body lotions, food items)	4 (9%)
Number of workers per cooperative in a village	15 (12-25)
– Number of men per cooperative	1 (0-2)
– Number of women per cooperative	15 (12-21)

Continuous variables, median (IQR); categorical variables, number (%).

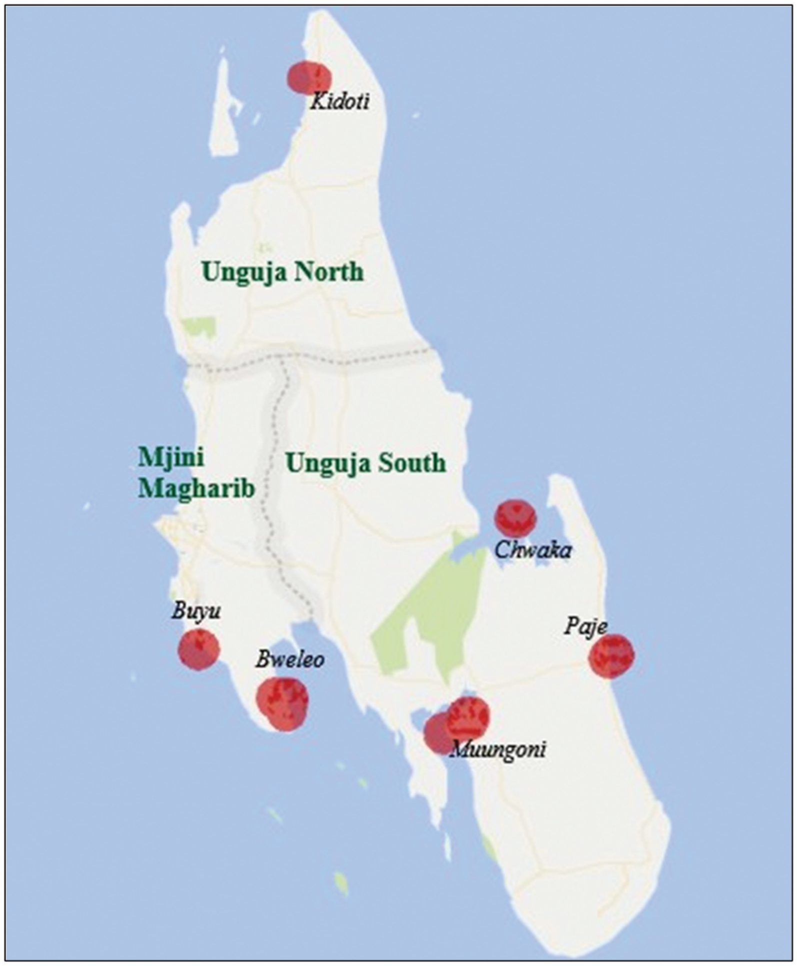

Figure 1. Geospatial locations of enumerated seaweed farming cooperatives in Zanzibar, Tanzania ($n = 45$).

Table 3. Distribution of annual prevalence of common work-related symptoms reported by seaweed workers per cooperative in Zanzibar, Tanzania ($n = 45$).

Prevalence (%)	Asthma-related symptoms	Heat-related symptoms	Skin-related symptoms	Lower limb-related pain	Back-related pain	Wrist-related pain
0	22 (49%)	22 (49%)	9 (20%)	12 (27%)	7 (16%)	6 (13%)
1-5	2 (4%)	0	0	0	0	0
6-10	8 (18%)	0	6 (13%)	2 (4%)	1 (2%)	5 (11%)
≥11	13 (29%)	23 (51%)	30 (67%)	31 (69%)	37 (82%)	34 (76%)
Overall	**23 (51%)**	**23 (51%)**	**36 (80%)**	**33 (73%)**	**38 (84%)**	**39 (87%)**

Unguja North (33%), but there were no statistically significant differences in the mean prevalence between the seaweed worker cooperatives in these regions overall.

Hazard evaluation of seaweed cooperatives

Occupational hazards identified during walkthrough hazard evaluations in seaweed working environments are presented in Table 4. These included various ergonomic, chemical, biological, physical, safety, and psychosocial hazards. Figure 3 illustrates the comparative analysis of mean occupational hazard and occupational health intervention scores for seaweed cooperatives across the three regions. Although no statistically significant differences in hazard and intervention scores were demonstrated, there were notable variations in specific hazards and intervention strategies across regions.

Ergonomic hazards, characterized by repetitive tasks, awkward posture, use of excessive force, and

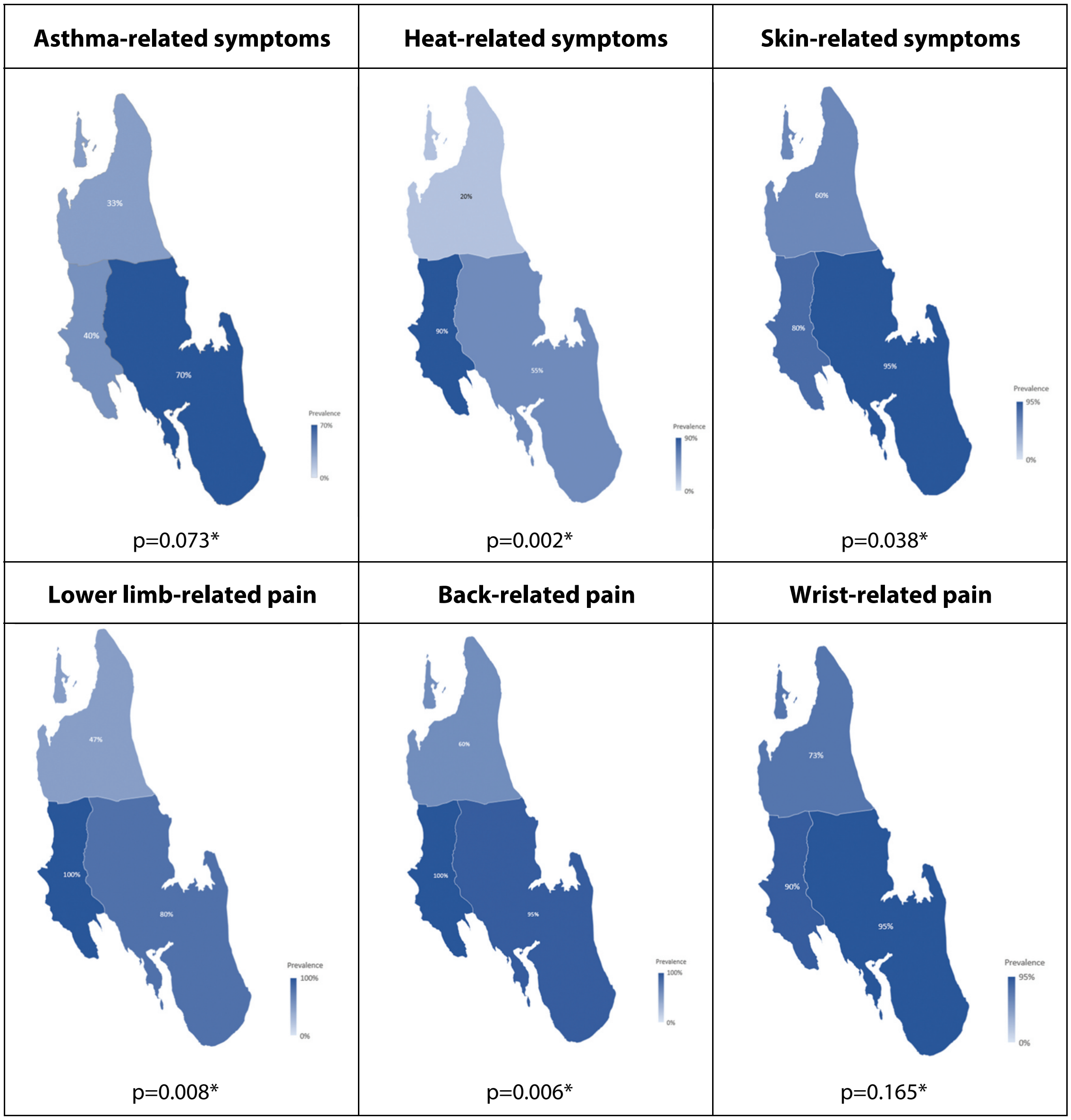

Figure 2. Geo-spatial patterns (mean prevalence) of common work-related symptoms reported among seaweed worker cooperatives across the three regions of Zanzibar, Tanzania (results are presented as a percentage of responding farming cooperatives, $n = 45$).
** Chi-square test*

heavy lifting were prevalent across regions, with Unguja South having the highest score (68%) compared to Mjini Magharibi (65%) and Unguja North (58%). However, intervention scores for ergonomic hazards were substantially lower compared to the hazard scores in all regions, with Unguja South (11%) being the lowest.

Chemical hazard scores associated with soap-making and exposure to toxic gases produced by marine algae were higher in Mjini Magharibi (63%) compared to the other two regions (50%). Despite these high hazard scores, interventions for chemical hazards were absent in seaweed cooperatives in all three regions.

Mean hazard scores for biological hazards such as exposure to marine micro-organisms and their toxins, seaweed, and its contaminants such as endotoxin and mold also demonstrated regional variations between 55% and 65%, with Mjini Magharibi reporting the highest score. However, intervention scores for biological hazards were very low across all regions (0–10%).

The mean scores for physical hazards, encompassing solar radiation, glare, high ambient

Table 4. Common hazards and causative agents or work processes observed during site hazard evaluation in seaweed farming cooperatives in Zanzibar, Tanzania.

Hazard category	Causative agent/processes
Ergonomics	• Repetitive movements (while tying seaweed onto ropes), awkward postures (twisting and bending of the back, squatting, kneeling), heavy lifting (carrying seaweed load), use of force (anchoring seaweed stakes to the seabed), walking long distances (from farms to drying areas) while carrying heavy loads
Chemical	• Sodium hydroxide (used in soap making) • Irritants (fragrances, colourants, oils) used in soap making • Toxic gases (hydrogen sulphide, hydrogen peroxide) derived from marine algae or decomposing seaweed
Biological	• Marine micro-organisms and their toxins • Seaweed dust • Endotoxins present in seaweed dust • Mold in damp seaweed storage areas
Physical	• Solar radiation • High ambient temperature • Noise (operating seaweed milling machine) • Glare • Wet work
Safety	• Sharp shells • Marine organisms • Working in deep waters • Poor electrical installation, exposed electrical cables • Slips, trips, and falls (walking on uneven and slippery surfaces or traversing through ropes used for cultivating seaweed)
Psychosocial	• High demand and low control work situations, poor work-life balance, seaweed die-offs

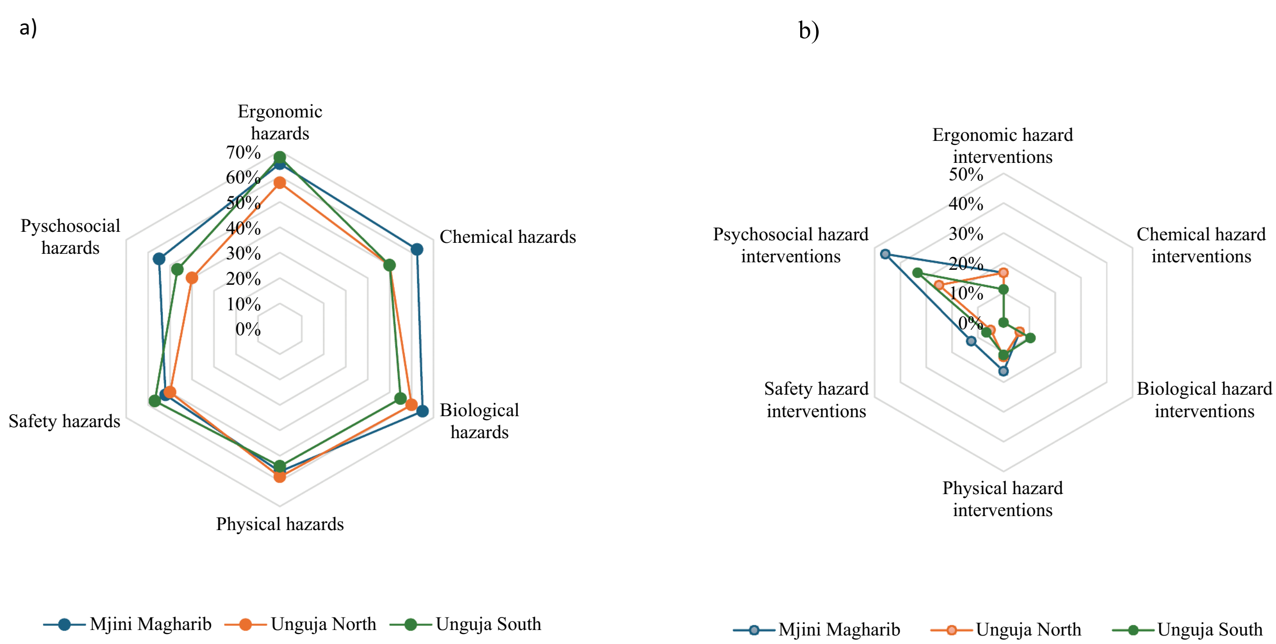

Figure 3. Comparative presentation of mean occupational hazard (a) and occupational health intervention (b) scores in seaweed farming cooperatives across the three regions in Zanzibar, Tanzania ($n = 24$).

temperatures, noise, and wet work were comparable across all regions (45–58%). A similar pattern was also observed for safety hazards (50–57%). For both hazard groups, very low intervention scores were found across the regions, with Mjini Magharibi faring slightly better, with mean scores of 13% and 16% for safety and physical hazards, respectively.

Psychosocial hazards, such as high demand, low control work situations, and poor work–life balance affected workers in seaweed cooperatives across all three regions, with Mjini Magharibi reporting the highest mean score (55%). Interventions for psychosocial hazards also varied, with Mjini Magharibi having higher intervention scores (46%) as well.

Discussion

Seaweed farming is an important economic activity in Zanzibar but poses significant health and safety risks to workers. This study revealed a wide range of occupational hazards and a high prevalence of work-related symptoms in seaweed farming environments, as has been reported for other aquaculture environments.[24,26] While these hazards and occupational health risks demonstrate geographical variations across Zanzibar's regions, the implementation of intervention measures is suboptimal.

Since the introduction of commercial seaweed farming in Tanzania, two species have dominated the industry: *Kappaphycus cottonii* and *Eucheuma spinosum*. Despite *K. cottonii* being the preferred species due to its broader industrial applications and higher market price,[27] the findings of this study reveal a notable shift, with *E. Spinosum* emerging as the primary seaweed species cultivated, consistent with other country reports.[28,29] This shift is attributed to the vulnerability of *K. cottonii* to climate change, currently struggling to survive in shallow water growth conditions.[27] As a result, farmers have shifted away from cultivating this species, leading to economic instability among seaweed workers, since the more prevalent *E. Spinosum* is less profitable.

This study involved 45 seaweed cooperatives, predominantly women, with an average of 15 members each. While previous studies have documented numerous seaweed cooperatives in Zanzibar, each village with an active Seaweed Farmers' Association, the declining profitability of seaweed farming has resulted in the dissolution of many cooperatives in recent years.[30,31] Initiatives such as the Marine and Coastal Environment Management Project (MACEMP) and ZaSCI have provided training, support, and opportunities for value addition to seaweed products.[17] A similar pattern of work organization among seaweed workers has been reported in Indonesia, the Philippines, and India, where workers also tend to cluster together in villages and organize themselves into work groups.[32] India, like Tanzania, has a higher proportion of female seaweed workers organized into Self Help Groups (SHGs), which serve as major sources of financing and training.[32,33]

Being a traditionally female-dominated industry, seaweed farming has, over time, experienced a noticeable decline in participation of the small number of men that were previously involved.[20] This decline has been attributed to the labor-intensive nature of seaweed farming with low profitability, as opposed to alternative income sources such as fishing activities available to men.[29] The government's current initiative to revitalize the seaweed sector has the potential to attract a more diverse workforce, potentially encouraging increased participation of both men and women in this sector.[9]

This study identified a concentration of seaweed farming activities primarily along the coastal areas of Unguja North and Unguja South regions, with relatively lower activity in Mjini Magharibi. This could be due to limited alternative sources of economic activity in the two rural regions compared to the relatively urbanized Mjini Magharibi region, with alternative economic activities that are more lucrative and less labor-intensive and time-consuming than seaweed farming.[17]

Despite the potential for seaweed applications in cosmetics, food, and pharmaceuticals, the findings of the current study indicate farmers primarily rely on seaweed drying as their main post-harvest processing method. While renewed focus on value-added products has been a recent focus of the government,[9] there is the added concern about the increasing potential of occupational health and safety risks associated with heightened economic activity, as has been previously reported in fish processors.[34,35] This suggests that plans for expanded processing activities should include occupational health risk assessment and developing mitigation measures at an earlier stage to ensure the health, safety, and well-being of seaweed workers.

This study identified the entire spectrum of occupational hazards and a high prevalence of work-related symptoms in seaweed farming environments, which showed variability across regions. However, the implementation of intervention measures was consistently low or lacking across all regions for most occupational hazards. In general, the Mjini Magharibi region demonstrated higher hazard scores, as well as higher prevalence of work-related symptoms for lower limb pain, back pain, and heat-related symptoms. Interestingly, while this region demonstrated high psychosocial hazard scores (55%), it also had higher intervention scores (46%) corresponding to this hazard. Given its higher level of urbanization and the availability of additional job opportunities, workers in Mjini Magharibi are more likely to engage in multiple jobs beyond seaweed farming, potentially increasing physical exertion and the likelihood of musculoskeletal symptoms. Conversely, the increased variety of work routine and economic stability introduced by additional work opportunities may explain the better psychosocial intervention scores in this region. However, the lower prevalence of work-related symptoms in Unguja North may be attributed to better seaweed processing infrastructure and a relatively higher proportion (18%) of workers having received OHS training in this region. This suggests that investments in improved processing facilities and OHS training could contribute to reducing work-related health risks among seaweed workers.[36] The overall lack of OHS intervention measures reported across regions in this study is consistent with studies pointing to inadequate intervention measures in seaweed farming environments in other countries.[15,16,37] For example, in Malaysia, despite seaweed workers being covered by the national occupational health and safety legislation, little to no action has been taken to protect them.[16] Similarly, in Europe, despite existing regulatory frameworks, fragmented efforts in safety assessment and implementation continue to leave seaweed workers inadequately protected.[37]

In the context of this study, musculoskeletal symptoms were the most commonly reported, mainly affecting the wrist (87%), back (84%), and lower limbs (73%). These results are comparable to the findings of a previous Tanzanian epidemiological study ($n = 140$), which reported a higher prevalence of musculoskeletal pain among seaweed workers (67–74%) compared to non-seaweed workers (34–50%).[10] Similar results have also been reported among seaweed workers in Indonesia, in which low back pain (55%) and work fatigue (67%) were the most common health problems reported in an epidemiological study of workers.[12] Long working hours, labor-intensive tasks, poor work posture, and heavy lifting have been identified as some of the reasons for the high prevalence of musculoskeletal disorders in seaweed workers.[10,12]

The current study also found a high prevalence of work-related asthma and skin symptoms among the seaweed workers, with skin symptoms reported by cooperatives having a higher annual prevalence (80%) compared to asthma symptoms (51%). The observed high prevalence of skin symptoms is consistent with a previous study of Tanzanian seaweed workers, in which a high prevalence (up to 80%) of skin irritation was reported.[11] However, the mean prevalence of asthma-related symptoms reported by seaweed cooperative workers in this study (51%) is higher than that documented in a similar study conducted in South African fish processing workplaces (18%).[19] This disparity may be explained by the differences in occupational exposures and occupational health and safety practices between these two sectors. While the South African study reported 45% of workplaces provided onsite occupational health services, and 58% conducted some form of medical surveillance of their workers, none of the seaweed farming environments in Tanzania reported such measures. The higher prevalence of work-related skin symptoms compared to asthma symptoms reported in the current study may be attributed to the easily visible skin conditions that are readily reportable to cooperative leaders, who served as the main informants in this study. In contrast, work-related asthma-related symptoms could be overlooked or attributed to other respiratory conditions, especially in the early stages. Workers may also be less inclined to report respiratory symptoms, since they may not make the link with work, especially if asthma is poorly controlled. Although the specific causes of skin and respiratory symptoms remain unclear, exposure to seaweed allergens and irritants, such as algal toxins, sodium hydroxide, and fragrances used in seaweed processing, may be responsible.[8,38] Wet work in particular may contribute to irritant contact dermatitis by disrupting the barrier function of the skin, given the long hours that women spend in the sea.[39]

A high prevalence of heat-related symptoms was also reported in this study, with half the seaweed workers from cooperatives reporting work-related symptoms of excessive sweating, thirst, heat rash, headache, dizziness, fainting, nausea, and vomiting. Seaweed farming is mainly conducted outdoors, exposing workers to high ambient temperatures in their work. This, together with the physically demanding nature of this work, increases the risk of heat-related health effects such as muscle cramps and more severe conditions such as heatstroke, chronic kidney disease, and even death.[40] While the effects of heat exposure are widely reported among agricultural workers,[41,42] few studies have been conducted among aquaculture workers, mainly focusing on fish farmers.[43–45] A Norwegian study of fish farmers demonstrated workers experiencing high levels of work strain exhibited elevated core temperature and heart rates during their tasks, potentially increasing their risk of heat-related symptoms, particularly in areas with high ambient temperature.[43] The International Labour Organization (ILO) estimates temperatures in Africa are projected to rise faster than the global average during the twenty-first century, leading to an anticipated productivity loss of over 1.6 million full-time jobs by 2030.[46] Specifically, in the United Republic of Tanzania alone, the projected loss of 0.76% in 2030 is expected, equivalent to approximately 303,000 jobs. This trend underscores the urgent need for effective mitigation and adaptation measures for climate change impacts to safeguard employment opportunities in the region. Recommendations suggest that while workers should be empowered to self-pace as a basis for heat mitigation, implementing preventive strategies that focus on hydration, work-rest cycles, wearing ventilated garments, and work mechanization can further reduce the physiological heat strain experienced by workers.[47]

Strengths and limitations

While this study provides valuable insights into the occupational health and safety challenges faced by seaweed workers in Zanzibar, the reliance on cooperative leaders as the primary informants to provide important information could have introduced reporting biases. Leaders of seaweed cooperatives may have different perspectives and levels of awareness compared to individual workers with varying degrees of experience, possibly leading to under or over reporting of certain health symptoms. However, given the concordance between the symptoms reported and the prevalence of hazard scores determined objectively by the researchers, this is unlikely to have played a major role. It should be highlighted that while the convenience sampling method used for cooperatives was necessary due to constraints in accessing these semi-formal groups, the findings of the study may not fully represent the diversity of experiences across all seaweed farming operations in Tanzania. Despite these limitations, this study laid the groundwork for future detailed investigation to explore the occupational hazards and associated adverse health outcomes reported by seaweed workers.

Conclusion

This study confirmed that seaweed workers are exposed to a range of occupational hazards, resulting in a high prevalence of work-related symptoms referable to various organ systems. These hazards and adverse health outcomes show variability across regions in Zanzibar, with poor control measures prevailing across all three regions. To our knowledge, this is the first study of seaweed workers that assessed the geospatial distribution of occupational hazards, adverse outcomes, and associated intervention measures. Recognizing these regional variations may contribute to the development of effective and targeted preventive measures relevant to the regions to safeguard the health, safety, and well-being of seaweed workers. Future epidemiological studies should aim to investigate in more detail the specific occupational exposures and adverse health outcomes of individual workers, using objective measures and clinical assessments alongside self-reported data to enhance the accuracy of health-related findings. Furthermore, the relative contribution of seaweed farming versus processing methods in contributing to the adverse health risks identified needs to be explored further. Given the predominantly female workforce in seaweed farming, future research should investigate potential gender-based differences in occupational exposures and vulnerability to health risks. This gender-sensitive approach will be essential in developing equitable and effective interventions that promote the occupational health and well-being of all seaweed workers.

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