POLICY BRIEF
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Managing Ice-Ice Disease in Zanzibar's Seaweed Aquaculture Sector:

Evidence-Based Strategies for Sustainable Production and Coastal Livelihoods

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AT A GLANCE

307
bacterial species detected across healthy and IID-affected samples

36
thalli sampled from 6 farms in Muungoni Village

8
species consistently more abundant in IID-affected tissues

3
species identified for the first time in association with IID

3.30→4.22
Shannon diversity, healthy to IID-affected, K. alvarezii

1.46→2.79
Shannon diversity, healthy to IID-affected, E. denticulatum

4
policy actions recommended

0–5 yrs
implementation timeline and indicators

Executive summary

Ice-Ice Disease (IID) is a major threat to Zanzibar's seaweed sector and coastal livelihoods. Seaweed farming provides important livelihood and income opportunities for coastal communities in Zanzibar, particularly women involved in farming, processing and marketing (Msuya, 2011; Valderrama *et al*., 2013). However, IID causes whitening, tissue degradation, fragmentation and biomass loss, reducing seaweed growth, lower farm productivity and diminished carrageenan quality (Largo *et a*l., 1995; Vairappan et al., 2008; Ndawala et al., 2022).

IID is associated with shifts in the seaweed-associated bacterial community. The study identified 307 bacterial species associated with healthy and IID-affected *Kappaphycus alvarezii* and *Eucheuma denticulatum*. IID-affected plants showed changes in bacterial community structure and higher bacterial diversity than healthy plants (Ndawala et al., unpublished). Eight bacterial species were consistently more abundant in IID-affected tissues, although pathogenicity experiments are still required to determine whether they directly cause disease or proliferate following tissue damage (Ndawala et al., unpublished).

Strengthening prevention, early detection and research is essential for protecting the sector. Evidence indicates that IID arises from interactions among environmental stress, seaweed physiological condition and associated microbial communities (Largo et al., 1995; Vairappan et al., 2008; Egan et al., 2013; Ndawala et al., 2022). Zanzibar should therefore enhance disease surveillance and farm biosecurity, invest in disease-tolerant varieties, expand farmer training, and support research on seaweed–microbe–environment interactions to build long-term resilience in the seaweed value chain.

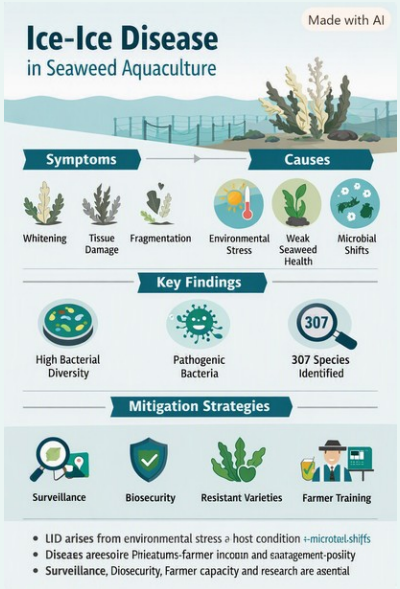


Fig 1: Highlights infographic of the brief generated by AI (Copilot)

Issue overview

Seaweed farming is an important coastal livelihood activity in Zanzibar, providing income opportunities for thousands of coastal households (Msuya, 2011; Valderrama et al., 2013). The main cultivated tropical red seaweeds are *K. alvarezii* (cottonii) and *E. denticulatum* (spinosum), are globally important sources of carrageenan used in food, pharmaceutical and industrial applications (Neish, 2008).

Despite its socioeconomic importance, the sector faces persistent production challenges. Ice-Ice Disease (IID) is one of the major biological constraints affecting commercial seaweed farming and can cause whitening, tissue degradation, fragmentation and loss of biomass (Largo et al., 1995; Vairappan et al., 2008). These effects can reduce growth, farm productivity and carrageenan quality, with direct consequences for farmer income and value chain stability (Ndawala et al., 2022).

Previous studies suggest that IID is not necessarily caused by a single microorganism but may result from interactions among environmental stress, weakened host condition and changes in associated microbial communities (Egan et al., 2013; Ndawala et al., 2022). Elevated temperature, salinity fluctuations, nutrient limitation and epiphyte pressure may compromise seaweed health and facilitate opportunistic microbial colonization (Vairappan et al., 2008; Egan et al., 2013).

Consequently, IID management requires an integrated approach combining disease surveillance, farm biosecurity, farmer capacity, climate adaptation measures and targeted research to safeguard production and sustain coastal livelihoods.



Fig 2: Seaweed farm at low tide in Muongoni, Unguja, Zanzibar

Context

Overview: A short molecular study conducted in Muungoni Village on the southwest coast of Zanzibar provides new insights into the microbial changes associated with Ice-Ice Disease (IID). Seaweed samples were collected in July 2023 from six farms, comprising 36 thalli (18 *Kappaphycus alvarezii* and 18 *Eucheuma denticulatum*), with equal representation of IID-affected and healthy plants. Triplicate sampling within each farm ensured adequate coverage of within-farm variability (Ndawala et al., unpublished).

Molecular analysis: Bacterial communities were characterized using high-throughput Next-Generation Sequencing targeting the V3–V4 regions of the 16S rRNA gene using Illumina sequencing technology. These regions are widely used for comparative bacterial-community analysis because they provide a useful balance between taxonomic resolution and reference-database coverage (Klindworth et al., 2013; Kozich et al., 2013). The bacterial sequence data will be deposited in a public repository following publication of the associated manuscript[1].

Interpretation: The study provides molecular evidence of differences in bacterial communities associated with IID but does not confirm any of the identified bacteria as causal pathogens (Ndawala et al., unpublished). In total, 307 bacterial species were detected across healthy and IID-affected samples, indicating that IID is associated with broader microbial shifts rather than a single causal organism. IID-affected seaweeds exhibited higher bacterial diversity than healthy plants, with Shannon diversity increasing from approximately 3.30 to 4.22 in *K. alvarezii* and from 1.46 to 2.79 in *E. denticulatum*. This increase in diversity may reflect dysbiosis of normal seaweed–microbe interactions, creating conditions favourable for opportunistic colonization (Egan et al., 2013; Zhang et al., 2024).

Eight bacterial species—*Desulfovibrio subterraneus*, *Vibrio stylophorae*, *Oceanispirochaeta sediminicola*, *Sediminispirochaeta sinaica*, *Vallitalea okinawensis*, *Alteromonas mediterranea*, *Pseudoalteromonas piratica* and *Marinomonas agarivorans*—were consistently more abundant in IID-affected tissues. Three of these (*D. subterraneus*, *O. sediminicola* and *S. sinaica*) were identified for the first time in association with IID (Ndawala et al., unpublished). Their enrichment in diseased tissues demonstrates association rather than causation; pathogenicity experiments are required to determine whether these bacteria directly contribute to IID or increase following tissue damage.



Fig 3:Sun-dried seaweed sample

[1]At the time of preparation of this policy brief, the manuscript is still under preparation.

Policy recommendations

Action 1. Establish a Zanzibar Seaweed Health Surveillance and Early-Warning Programme

The responsible fisheries authority should establish routine monitoring of IID occurrence and severity, particularly in high-production areas, using standardized disease assessment, environmental measurements and farmer-based reporting. A coordinated surveillance system will enable early detection of disease hotspots and support timely management responses. Field monitoring should be complemented by molecular diagnostic capacity at ZAFIRI and partner TAFIRI laboratories to characterize disease-associated microbial changes and strengthen understanding of IID dynamics (Ward et al., 2025; Ndawala et al., unpublished).

Responsible institutions: Zanzibar fisheries authority/Ministry responsible for Fisheries, ZAFIRI, TAFIRI, local government authorities, seaweed farmer associations/cooperatives and research partners.

Action 2. Strengthen Biosecurity practices across seaweed farms

Biosecurity should be integrated into all seaweed extension and farm-management programmes. Recommended measures include the use of healthy planting materials, quarantine of newly introduced stocks, regular farm inspection, removal and safe disposal of infected seaweed, cleaning and disinfection of equipment, and improved farm hygiene (Bondad-Reantaso et al., 2005; Ndawala et al., 2022). Farmers should also be trained to recognize early IID symptoms and report outbreaks promptly.

Responsible institutions: ZAFIRI, Ministry responsible for Fisheries, local government authorities, farmer associations/cooperatives, seaweed buyers and exporters, universities and research partners.

Action 3. Develop and Promote Disease-Tolerant Seaweed Varieties

Research programmes should prioritize identification of IID-tolerant strains, selective breeding and evaluation of locally adapted varieties. Developing resilient planting materials will reduce reliance on susceptible stocks and improve production stability. Observed differences in microbial communities between healthy and IID-affected seaweeds provide a basis for further investigation of species- and strain-specific disease tolerance (Ndawala et al., unpublished).

Responsible institutions: ZAFIRI, TAFIRI, SUZA, University of Dar es Salaam, Ministry responsible for Fisheries and national and international research partners.

Action 4. Strengthen Farmer Capacity and Advance Research on IID Mechanisms

Farmer training should focus on early recognition of IID, environmental risk factors, improved farming practices, biosecurity and disease reporting. Community-based disease-monitoring networks can further support rapid detection and response. Research should integrate microbial genomics, environmental monitoring, climate-stress assessment and pathogenicity testing. Such research is necessary because changes in seaweed-associated microbial communities may reflect both disease processes and responses to environmental or host stress (Egan et al., 2013; Ndawala et al., unpublished).

Responsible institutions: ZAFIRI, TAFIRI, SUZA, University of Dar es Salaam Institute of Marine Sciences, Ministry responsible for Fisheries, farmer associations and national and international research partners.

Implementation Timeline and Indicators

Period	Priority activities	Key indicators
0–12 months	Establish IID surveillance pilot; develop disease scoring; develop biosecurity SOPs; train farmers and extension officers	Number of farms monitored; number of farmers trained; SOPs developed; disease reports received
1–2 years	Expand surveillance; strengthen molecular diagnostic capacity; implement farm biosecurity; establish community monitoring	Percentage of target farms covered; reporting completeness; response time; farms implementing biosecurity
2–3 years	Screen and evaluate IID-tolerant strains; conduct comparative microbiome and environmental studies	Number of strains evaluated; varieties assessed; research outputs produced
3–5 years	Integrate surveillance, biosecurity, farmer monitoring and research into routine sector management	Reduced IID prevalence; improved productivity and carrageenan quality; improved farmer income security

Expected outcomes/Impact

Implementing these actions is expected to reduce the frequency and severity of Ice-Ice Disease (IID), stabilize seaweed production and improve carrageenan quality, thereby strengthening the reliability of Zanzibar's seaweed value chain (Ndawala et al., 2022; Ndawala et al., unpublished). Routine surveillance and early-warning systems will enable faster detection and response, reducing losses at farm level. Improved biosecurity and farmer capacity will lower reinfection rates and enhance day-to-day farm management, while development of disease-tolerant varieties will provide longer-term resilience against environmental and biological stressors.

These measures will contribute to higher and more predictable farmer incomes, improved livelihood security for coastal households, particularly women, and greater resilience of community-based production systems. Strengthened diagnostic and research capacity will also enhance national ability to monitor emerging threats, support evidence-based decision-making and foster innovation within the seaweed sector.

*At the macro level, the combined actions will reinforce Zanzibar's contribution to the blue economy by safeguarding a strategic export commodity, supporting value-addition opportunities and maintaining the competitiveness of Zanzibar's seaweed industry in global carrageenan markets***.** Over time, reduced disease burden and improved production stability will enable expansion of processing, trade and investment opportunities, contributing to broader economic growth and coastal development.

Conclusion

Ice-Ice Disease (IID) remains a major threat to Zanzibar's seaweed aquaculture and the coastal livelihoods that depend on the sector. Previous research has demonstrated the central role of disease pressure, biosecurity gaps and environmental stressors in shaping seaweed production outcomes (Vairappan et al., 2008; Ndawala et al., 2022). The present molecular study adds new evidence by showing that IID is associated with substantial shifts in bacterial community structure, reinforcing the need to consider both biological and environmental drivers of disease (Ndawala et al., unpublished).

A coordinated policy response is therefore essential. Strengthening surveillance, farm biosecurity, farmer empowerment, development of disease-tolerant varieties, climate-adaptation measures and microbiome-focused research will collectively reduce disease burden and enhance production stability. These actions will improve the resilience and sustainability of Zanzibar's seaweed industry, safeguard the livelihoods of coastal communities, particularly for women, and reinforce the sector's contribution to the national blue economy.

By acting now, Zanzibar can protect a strategic export commodity, secure rural incomes and position its seaweed sector for long-term growth, innovation and competitiveness.

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