# Biosecurity policy and legislation of the seaweed aquaculture industry in Tanzania



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#### **Abstract**

Pest and disease outbreaks have significant impacts on the livelihoods of seaweed farmers each year, particularly in low- to middle-income countries around the world. Commercial seaweed farming of the red carrageenophytes, *Eucheuma denticulatum*, *Kappaphycus alvarezii* and *Kappaphycus striatus*, in Tanzania was established in 1989. The impacts of pests and diseases on the local seaweed industry had serious implications for the environment, society, local culture and human health. The industry was initially characterised by growth, but since 2002 has been severely limited due to pest and disease outbreaks, exacerbated by the effects of climate change. This paper identifies existing biosecurity frameworks in Tanzanian legislation and policies in order to assess their content regarding the management of pests and diseases in the seaweed industry. A total of thirteen frameworks were identified and analysed for their general biosecurity scope and inclusion of specific risks. Of the thirteen, only four were legally binding, and only four were identified to be applicable to the seaweed industry. National frameworks were predominantly designed to support finfish aquaculture; therefore, national authorities lack the expertise, experience and scientific basis on biosecurity issues in seaweed industry compared with other aquatic commercial commodities to identify and mitigate the risks from pest and disease outbreaks in the seaweed farming industry. Recommendations are provided to assist regulators in establishing biosecurity policies, which either explicitly include or are specifically designed, to support the Tanzanian seaweed industry. This analysis reveals where biosecurity capacity can be developed to support a sustainable and economically productive national seaweed farming industry.

Keywords Biosecurity · Diseases · Pests · Legislation · Policy · Tanzania

#### Introduction

The cultivation of red, carrageenophyte seaweeds *Eucheuma denticulatum*, *Kappaphycus alvarezii* and *Kappaphycus striatus* was established in Tanzania in 1989 (Lirasan and Twide 1993; Mshigeni 1998; Lyimo et al. 2006; Msuya 2010, 2017) using imported strains from the Philippines (Msuya 2005). It has been actively supported by the government and academia since 1996, through improvements in farming techniques and the provision of advice to help

empower the farmers (Msuya 2010). Seaweed farming is also not only a direct source of income to the farmers, but it indirectly supports approximately 31,000 farmers living on the coast of Tanzania (Msuya et al. 2014), although information on farmers at the family unit is lacking. The industry has become particularly important for women in the community, who typically manage the farms (Eklöf et al. 2012; Msuya 2012; Cai et al. 2013; Valderrama et al. 2013; Msuya and Hurtado 2017). Their personal income from seaweed farming contributes to an increase in the living standards of their households, enabling them to buy clothes and food for dependents, pay for their children's schooling and generally improve the quality of their living standards (Msuya 2011b; Msuya and Hurtado 2017). Most males are not engaged in seaweed farming due to low prices of the seaweed, although men would produce more seaweed because they have more energy and time to conduct the activity. In addition, seaweed farmers have been able to use their income to process the seaweed crop themselves and sell it as a value-added product. For example, since 2006, the Zanzibar Seaweed Cluster



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initiative (ZaSCI) trains farmers on how to make various seaweed value-added products, mainly food and cosmetics. ZaSCI has links with other stakeholders including the government, NGOs, UN bodies, academia and other seaweed exporters to advance these value addition activities (Msuya 2011a, 2013; Degenhardt 2015; Msuya and Hurtado 2017; Hassan and Othman 2019). Members of ZaSCI are now producing seaweed value-added products from over 20 villages including Paje, Bweleo, Bwejuu, Kidoti, Makangale and Mkoani in Zanzibar and Bagamoyo in the mainland Tanzania.

The economic benefits of seaweed production saw the Tanzanian industry grow steadily from 808 tonnes in dry weight (dw) in 1990 to 15,000 t dw in 2012. Since 2012, however, the annual production declined to 10,000 t dw in 2018 (Department of Marine Resources Zanzibar 2019). This decline was attributed to a multitude of factors, including climate change-induced stress, which increased water temperatures in the hot season from below 30 °C in the 1990s to 38 °C in 2009 (Hayashi et al. 2010; Msuya 2011b; Msuya and Porter 2014) and was associated with disease outbreaks, such as "ice-ice" (Msuya 2011b; Cottier-Cook et al. 2016). Coupled with the pressure of disease outbreaks, farmers have also faced the additional challenge of epiphytic filamentous algae (EFA) (Msuya and Porter 2014). Globally, the most commonly observed EFAs are Polysiphonia/Neosiphonia consortium (Hayashi et al. 2010; Eklöf et al. 2012; Msuya and Porter 2014; Valderrama et al. 2015; Msuya 2017; Ward et al. 2019; Largo et al. 2020). The EFA can either grow on top of or penetrate the surface of the seaweed thallus (Ingle et al. 2018; Largo et al. 2020), causing the disintegration of the crop tissue and degradation of crop quality. Such epiphytes can wipe out the whole seaweed industry. In some parts of Tanzania, the decrease of production due to EFAs has been observed, e.g. in Songo Island from 423.9 t in 2003 to 26 t in 2008 (Msuya and Porter 2014). This massive decline is thought to have been exacerbated by the outbreaks of EFAs which reduced expected harvest and caused some farmers (especially men) to stop seaweed farming.

In Zanzibar, Tanzania, seaweed production of *Kappaphycus* was severely affected by EFA and disease outbreaks, such that the production decreased from 1048 t in 2008 to 16.5 t dw in 2010 (Msuya 2011b). Production of *E. denticulatum* has also been observed to decrease, from 9500 dw in 2003 to 7000 t dw in 2005 (Msuya 2013; Msuya et al. 2014). Most farmers opt to grow *Eucheuma denticulatum* which is resistance to diseases (ice-ice) and epiphyte attack (Msuya 2005). Another example is Madagascar where an epiphyte outbreak led to the decrease in production of *K. alvarezii* from 1860 t dw in 2010 to only 110 dw in 2012 (Msuya et al. 2014).

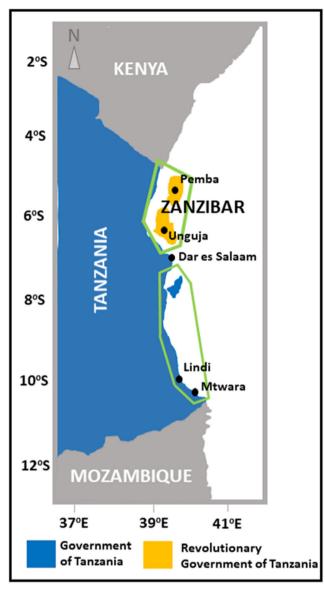
The increasing frequency of disease and pest outbreaks has led to a decline in seaweed farming productivity (Msuya 2011b; Msuya and Porter 2014; Cottier-Cook et al. 2016; Largo et al. 2020), which has been negatively impacting farmers' personal income and family livelihood (Msuya

2011a), and has threatened the empowerment of the female farmers in society (Msuya 2013). In addition, recent low and unpredictable prices for seaweed have forced farmers to seek employment in other sectors (Hassan and Othman 2019). The increasing trend in outbreaks of pests and disease in Tanzania is synonymous with the growing global concern for their collective impacts on the industry over the last decade (Cottier-Cook et al. 2016; Hurtado et al. 2017; Ward et al. 2019).

In order to limit the impacts of pests and disease in an industry, the biosecurity approach to managing risks has been widely adopted across agriculture and aquaculture. It is broadly defined as: "a strategic and integrated approach that encompasses the policy and regulatory frameworks (including instruments and activities) for analysing and managing relevant risks to human, animal and plant life and health, and associated risks to the environment" (FAO 2007). Biosecurity legislation and policies have been introduced and their measures incorporated into the management of farms across many aquaculture sectors (Rodgers et al. 2015; Stentiford et al. 2017). However, the seaweed aquaculture industry has been slow to adopt this approach (Cottier-Cook et al. 2016) and it is poorly integrated into policy and legislation at both the international and national scales (Campbell et al. 2019a; Kambey et al. 2020).

In Tanzania, biosecurity policy and practice is governed through the United Republic of Tanzania, which is composed of two main governmental bodies: one governing mainland Tanzania and the other governing the semi-autonomous region of the Zanzibar Islands. As a consequence, there are two governments: one catering for the governmental union (Government of Tanzania, GoT) and one for Zanzibar (Revolutionary Government of Zanzibar (RGoZ)) (Fig. 1). For the case of Zanzibar, the GoT controls only matters related to the union (e.g. home affairs and military operations), while RGoZ, as an autonomous government, controls matters that are specifically for Zanzibar, such as education, health and industries such as fisheries and aquaculture. Both governments have their own ministries, and thus have separate policies, although the names of the ministries are similar (e.g. both have a Ministry of Agriculture, Natural Resources, Livestock and Fisheries). The two Ministries of Agriculture, through their respective Departments of Marine Aquaculture, are responsible for developing draft policies that are approved by their respective parliaments, before implementation across the seaweed industry. In both departments, plant quarantine and phytosanitary measures already exist, in order to control plants or plant products introduced to the country or exported (GoT 1998). However, to date, a majority of biosecurity policies have been developed for the capture fisheries and finfish aquaculture sectors (GoT 2015a). Both governments have shown recent interest in developing policies to assist in the development of the seaweed industry in the region. As part of this support for aquaculture sectors, a broader aquaculture





**Fig. 1** Map of seaweed cultivation areas (highlighted in green), with survey sample locations Pemba, Unguja, Lindi and Mtwara, plus the main trading port Dares Salaam

policy strategy is expected to be developed in the coming years, with the seaweed sub-sector a component of this broad-scale strategy (GoT 2018). The objective of this policy strategy is to align the seaweed industry with the Tanzanian poverty alleviation strategy (2010–2020); the Tanzania Development Vision 2020; the Zanzibar Vision 2020; and the United Nations Millennium Sustainable Development Goals. In addition, it aims to provide support for the seaweed farmers to access appropriate farming equipment and propagules, and to promote best practices, such as some aspects of biosecurity (GoT 2010a; 2015b).

The aim of this study was to identify biosecurity capacity in existing legislation, policies and guidelines—herein

collectively known as biosecurity frameworks—which are relevant to the seaweed industry in Tanzania (both mainland and Zanzibar). This analysis identified the biosecurity themes and already included risks in existing frameworks, which are of relevance to the national seaweed industry. These results highlight critical gaps in existing national frameworks, and point out where areas of existing capacity could be built on to address the gaps. Finally, recommendations are provided for both governments to inform the future development of a coherent biosecurity strategy for seaweed cultivation, limit the impact of diseases and pests, and support a sustainable national industry.

# **Materials and methods**

Selected biosecurity legislation, policies and guidelines (collectively known as frameworks) were identified through a thorough review of both published and grey literature. The frameworks were chosen for their relevance to biosecurity and seaweed farming in Tanzania. Texts of frameworks were obtained from either government websites or directly from government offices (both GoT and RGoZ) including the Ministry of Natural Resource and Tourism, Ministry of Livestock and Fisheries (Fisheries division), National Environmental Management Council and Seaweed Cluster Initiative Office. The texts of frameworks were comparatively analysed using methods adapted from Dahlstrom et al. (2011) and using the FAO biosecurity toolkit guidelines (FAO 2007). The biosecurity content of the framework texts was analysed in the context of the national seaweed farming industry in Tanzania.

# Thematic analysis

In order to understand the scope and objectives of selected biosecurity frameworks, five "themes" were analysed based on methods used by Campbell et al. (2019a) and Kambey et al. (2020). The themes included the force of the framework, the terminology used for the inclusion of seaweed aquaculture, the approach taken to implement biosecurity measures, the information type used to inform the text and the inclusion of the precautionary approach.

#### Inclusion of biosecurity risks in texts of frameworks

The biosecurity risks associated with seaweed farming in Tanzania were identified in the framework texts, using a list of categorised risks, as listed in Campbell et al. (2019a) and Kambey et al. (2020). Risks were identified in texts of the frameworks, and quantified under five categories including ecological, environmental, ecosystem, economic, social and farmer welfare.



# National biosecurity strategy component analysis

Using the methods in Kambey et al. (2020), sixteen possible components of a national biosecurity strategy were used to analyse the selected frameworks for the Tanzanian seaweed industry. Each of the components were identified in the texts and quantified to understand their use in current prominence in national biosecurity strategy.

#### **Results**

Thirteen frameworks were selected for analysis based on their inclusion of the biosecurity concept and/or their relevance to the seaweed aquaculture industry in Tanzania. Eight of these frameworks are implemented by the GoT across the mainland, and the remainder are implemented by the RGoZ across Zanzibar (Table 1). These frameworks were then systematically analysed for general biosecurity themes, inclusion of specific biosecurity risks and the relevant components of a national biosecurity strategy. Eight frameworks implemented by GoT on the mainland focus mainly on the improvement of seaweed farming and production, increasing the production of the higher valued K. alvarezii and K. striatus, safeguarding indigenous fauna and flora, protecting habitats and addressing environmental issues such as pollution. The remaining five frameworks implemented by RGoZ across Zanzibar aim to promote research into the causes of diseases, the effects of epiphytes on seaweed, adaptation of cultivation to move into deeper water in order to cultivate in cooler water to mitigate disease and epiphyte outbreaks, and improvements to farm infrastructure to avoid seaweed breakage and loss in rough weather conditions.

#### Thematic analysis

Thematic analysis of the frameworks showed that only 31% were legally binding (Table 1). Seaweed aquaculture was explicitly mentioned in 69% of the frameworks, while the remaining referred to all aquaculture and fisheries activities in general terms. The Environmental Management Act (GoT 2004) included information regarding only general aspects of biosecurity, but is not specific to seaweed. More specific biosecurity approaches relating to disease prevention or control measures were mentioned in 31% of the frameworks. The Environmental Management Act (GoT 2004) included penalties in their approach to preventing the introduction of poisonous or pollutant material to the aquatic environment. None of the frameworks analysed explicitly mentioned the use of precaution in measures to minimise the risk of introducing pests and/or diseases to a seaweed cultivation region or site. Four of the frameworks (31%) explicitly included the precautionary approach to minimise the introduction of invasive species, while the remaining frameworks did not mention any precautionary biosecurity measures.

#### Inclusion of biosecurity risks in texts of frameworks

Thirty-five possible risks posed as a result of pests, diseases and non-native species, as used in an analysis by Kambey et al. (2020), were grouped into five categories that included wider environmental impacts, changes in ecological interactions, impacts on ecosystem processes, economic impacts to the farm, societal impacts and direct impacts on farm workers welfare (Table 2). Out of the 35 identified risks, only six (17%) were specifically included across five of the thirteen frameworks. Habitat loss was included in both the Tanzania Mariculture Guidelines Sourcebook (GoT 2001) and Seaweed Strategic Development Plan (GoT 2005). The introduction of toxicity to the environment was included in the Environmental Management Act (GoT 2004). Changes in ecological interactions through herbivory were included in the Seaweed Strategic Development Plan (GoT 2005). Production loss due to pests and diseases was included in the Zanzibar Research Agenda (RGoZ 2015). Loss of income due to the effects of pests and diseases was included in the Seaweed Cluster Initiative (Msuya, 2006). The communication of biosecurity risks with farmers was included in the ZaSCI (2006), specifically through epidermal reactions to the "ice-ice" disease. Out of the total risks, 28 (83%) were not included in the selected biosecurity frameworks.

# National biosecurity strategy component analysis

Sixteen components of a national biosecurity strategy, used in the analysis of Indonesian frameworks by Kambey et al. (2020), were identified in the thirteen possible frameworks from Tanzania (Table 3). Four biosecurity components (25%) were identified in two of the frameworks; these included regulations on transport or movement of seaweed, regulations concerning introduction of exotic seaweed species, quarantine measures established for imported seaweed and import regulations related to the introduction of diseases. These components were each identified in the RGoZ (2010) and GoT (2003b). Both frameworks stipulate that: "any introduced aquatic species should get a permit so as to safeguard indigenous fauna and flora, protect habitat and protection of animals, plants and human diseases" (GoT 2003b; RGoZ 2010). The remaining 11 frameworks did not explicitly include any of the listed national biosecurity components in their texts.



Table 1 Frameworks identified related to biosecurity and/ or the seaweed farming industry in Tanzania

Framework	Relevant region*	Force of framework	Inclusion of seaweed	Biosecurity approach	Information type used	Use of precaution
Tanzania Mariculture Guidelines Source Book (GoT 2001)	TZ	Not binding	Explicit	None	None	No
Fisheries Act No. 22 of 2003, Tanzania (GoT 2003b)	TZ	Binding	Not explicit	Prevention	Expert opinion	Yes explicit
Environmental Management Act (GoT 2004)	TZ	Binding	Not explicit	Penalties	Expert opinion	Yes explicit
Seaweed strategic development plan (GoT 2005)	TZ	Not binding	Explicit	None	Experience-based	No
Seaweed Cluster Initiative (2006)	ZNZ	Not binding	Explicit	None	Experience based	No
Tanzania National Research and Development Policy (GoT 2010b)	TZ	Not binding	Explicit	None	None	No
Fisheries Act No. 7 of 2010 (GoT 2010a)	ZNZ	Binding	Not explicit	Prevention	Expert opinion	Yes explicit
Zanzibar Agricultural Transformation Initiative (RGovZ 2010)	ZNZ	Not binding	Explicit	None	None	No
Aquaculture Development Strategy and Plan of (RGovZ 2014)	ZNZ	Not binding	Explicit	None	None	No
National Fisheries Policy of Tanzania (GoT 2015)	TZ	Binding	Not explicit	Prevention	Expert opinion	Yes explicit
Tanzania Research Agenda (Priorities) (2016–2020) (GoT 2016)	TZ	Not binding	Explicit	None	None	No
Zanzibar Research Agenda (2015–2020) (RGoZ 2015)	ZNZ	Not binding	Explicit	None	None	No
Tanzania Aquaculture Development Strategy (GoT 2018)	TZ	Not binding	Explicit	None	None	No

TZ, Tanzania mainland; ZNZ, Zanzibar (including the islands of Unguja and Pemba)

#### Discussion

Biosecurity is an important aspect in managing crop loss, food insecurity and loss of community livelihood. In agriculture, it has been estimated that introductions of plant species across borders may introduce invasive species, which in 2003 was estimated to account for losses of approximately US\$ 400 billion globally (Desonie 2007). Although published reports of diseases and pests in seaweed aquaculture are numerous (Ward et al. 2019), management strategies included in policies to implement biosecurity in the seaweed industry have remained sparse (Campbell et al. 2019a; Kambey et al. 2020). In Tanzania, biosecurity issues regarding the marine plants have not been integrated into policies and strategies, which although this is in line with other producing countries (Kambey et al. 2020; Mateo et al. 2020), if improved could result in practices which help safeguard the Tanzanian seaweed industry.

# **Current status of biosecurity frameworks available to the seaweed industry in Tanzania**

The frameworks identified in the current study are divided according to which part of the Tanzanian Republic they belonged to, i.e. mainland or Zanzibar. There was no framework identified which was applicable to both

mainland and Zanzibar explicitly. This is a result of two operating governments: one for the union (the Government of Tanzania, GoT) and one for Zanzibar (Revolutionary Government of Zanzibar, RGoZ). This is an important aspect for the development of a national biosecurity strategy for an industry, which geographically spans both areas (Fig. 1). Not only do farms exist across these regions, but the industry is actively trading, moving and managing crop and produce between them (Msuya pers. comm), which means protocols for both governments should be aligned and a clear communication plan put in place. One solution to developing frameworks for the seaweed industry could be to take an "adaptive governance" approach to biosecurity, where the spatial difference is embraced by continued devolved and regional management. Using this approach, the geographical distance to industry is minimised, communication paths are shorter, meaning miscommunication is minimised, and alignment is achieved through agreements between the devolved governments (Cook et al. 2010).

In addition to the geographical separation of frameworks, none of the binding frameworks was found to specifically include seaweed, and most were outdated with dates ranging as far back as 2001. Any seaweed-specific (at least mentioning seaweed) frameworks were non-binding, and were developed by organisations other than the governmental departments (mostly NGOs, academia or donor-funded projects). As a



 Table 2
 Summary of the biosecurity risks included in selected national frameworks in Tanzania

Category	Biosecurity instrument	TMGS \$ (2001) (	SSDP E (2005) A	SSDP EM NFPT (2005) ACT(2004) (2015)	1	Ι,	SCI Z (2006) (2	ZATI R (2012) (2	Ι,	TNRDP (2010)	ADSPZ (2014)	TADS (2018)	FA TZ (2003)	FA
					2	2020)		2	2020)					(2010) I
	Sub-component													
Environment	Pest/pathogen								I					
	Pest/pathogen vector	ı	- 1		ı	ı		- 1	ı		ı	ı		ı
	Biodiversity	`	` <u>`</u>		ı	ı		-	ı	·	ı	ı		ı
	Habitat loss or change	`	\ \		I	1		1	ı			1		
	Decrease in native species abundance	1	1		I	ı		1	I			ı		
	Decrease in threatened or endangered species	1	1		I	1		1	ı			1		
	Toxicity		`		I	ı		1	I		ı	ı		ı
	Introduction of new host species for pest/pathogen	1	ı		I	ı		1	I		ı	ı		ı
Ecological	Predation	1	- 1		I	ı		1	I		ı	ı		ı
interactions	Herbivory	,	` \		I	1		- 1	ı			ı		
	Competition		- 1		ı	ı		-	ı		ı	ı		ı
	Hybridisation of commercial and wild	1	- 1		I	ı		-	ı		ı	ı		ı
Ecosystem	Nutrient regime changes	1	1		I	1		1	ı			1		
Processes	Hydrological cycle changes	1	1		I	1		1	ı			1		
	Food web changes	ı	- 1	1	I	ı	- 1	-	ı		ı	ı		ı
	Physical disturbance	1	- 1	1	I	ı	- 1	-	ı		ı	ı		ı
	Effect of control measures	1	ı		ı	ı		1	I		1	ı	·	ı
	Effects of climate change on pests/pathogens/non-native	1	1		I	1		1	ı			ı	·	
Economics (of	species and/or impacts Production			1	`				I			ı		
Seaweed	Infrastructure/facilities/property	ı	- 1		I	ı		- 1	I	·	ı	ı		ı
industry)	Control and management costs	1	1		1	1		- 1	ı			ı		
	Trade losses/loss of market share	1	1		I	1		- 1	ı			ı		
	Trade restrictions	ı	-	1	I	ı			I		ı	ı		ı
	Adverse consumer/buyer reaction	1	-	1	ı	1	1	1	ı		ı	1		ı
	Tourism	1	1		ı	ı		1	ı		1	1		
	Shipping (including vessels and waterways)	1	- 1		I	ı	- 1	1	I		ı	ı		ı
	Fisheries	1	- 1	1	ı	ı		-	ı		ı	ı		ı
	Aquaculture (other than seaweed)	1	1		I	1		1	I		1	ı	ı	
	Restoration/replanting costs to farm	1	1		ı	1		- 1	ı			ı		
	Health care costs	ı	- 1		I	ı		-	ı		ı	ı		ı
	Ecosystem services	1	1		I	1		- 1	ı		1	ı		
	Food safety	1	1		I	1		1	ı			ı		



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Category	Biosecurity instrument	TMGS (2001)	SSDP (2005)	EM NFPT ACT(2004) (2015)	PT ZRA 15) (2015– 2020)	SCI (2006)	ZATI (2012)	RPT (2015– 2020)	TNRDP (2010)	ADSPZ (2014)	TADS (2018)	FA TZ (2003)	FA ZNZ (2010)
	Sub-component												
Social and cultural	(Any mention of pests from farms or spread of non-natives impacting social and culturally important people/sites etc.)	ı	1	I	I	I	ı	I	I	I	I	ı	ı
Farm workers	Communication of biosecurity risks	ı	1	I	I	>	1	ı	ı	ı	1	1	
welfare	Lost income	I	1	I	I	>	1	ı	ı	ı	1	ı	
	Working with infected crop	ı	1	I	ı	1	1	ı	ı	ı	I	ı	

/ means availability of biosecurity risk in the framework, \_ means lack of biosecurity risk in the framework

Ministry of Livestock and Fisheries development, RGoZ (2015) Zanzibar Research Agenda (2015–2020) SCI- Seaweed Cluster Initiative, RGoZ (2012) Zanzibar Agricultural Transformation Initiative, (2005) Seaweed Strategic Development Plan, GoT (2001) Tanzania Mariculture Guidelines Source Book, GoT (2004) The Environmental Management ACT, GoT (2015) National Fisheries Policy RGoZ (2014) Aquaculture Development Strategy and Plan for Zanzibar, GoT (2018) Tanzania Aquaculture Development Strategy, GoT (2003b) Fisheries Act No. 22 Tanzania (2003), GoT (2010b) Fisheries Act No. 7 Zanzibar (2010) GoT (2016) Research

result, there are no clearly defined, or practically implementable, measures for controlling diseases on seaweed farms under either the GoT or RGoZ governments. However, through research projects and communication of farmers' knowledge through co-operatives, different measures to control diseases of farmed seaweeds have been informally practiced (e.g. moving into deeper water, placing farms near seagrass beds where there are higher nutrients and visual health checks of planted propagules) (Largo et al. 2020). This small-scale action is only available to farmers directly involved in research or capacity building projects, such as the SeaPoWer initiative (Brugere et al. 2020), which provided farmers with an opportunity to learn how to use tubular netting in deeper water where crop health is less affected. Continued small-scale and short-term funded action is limited, though in its effect on a larger regional or national-scale without the support of governmental frameworks to mandate such changes.

Even in the case of the national biosecurity strategy established to control the introduction and export of plants, which includes "aquatic flora" (seaweeds), seaweed farmers continue to transfer crops from one region to another without considering the existing regulations, showing that, even in the case of a regulated measure for control, without the buy-in from the industry practitioners to protect themselves from such impacts, policies can remain unsuccessful. Therefore, without the involvement of farmers, processors, buyers and exporters in the development of an adaptive governance approach to biosecurity, there will be little incentive for implementation on a national scale (Cook et al. 2010; Reed and Curzon 2015).

# Biosecurity themes in national frameworks

In Tanzania, legally binding biosecurity regulations for the aquaculture industry are few, and there is a lack of clarity on which ones are required to be implemented by an individual farmer. For example, farmers may plant diseased propagules, and take propagules from one place to another without assessing the disease risk, hence potentially negatively affecting seaweed production (Rusekwa, pers. comm.). The frameworks that mention precautionary approaches to controlling diseases (e.g. import regulations, quarantine measures for aquatic flora, regulations for exotic aquatic flora and regulations on transport or movement of aquatic flora) are not explicit to all farmers, since the word "seaweed" is not mentioned directly in these frameworks, instead the word "aquatic flora" is used. However, the Director of Aquaculture in the Ministry of Fisheries, in collaboration with local authorities, has the mandate to regulate the collection, sale, import and export of aquatic floral products (GoT 2003b; RGoZ 2010). The GoT (2003b) explicitly prohibits the transportation of



**Table 3** Biosecurity components included in national biosecurity frameworks

Biosecurity component	Inclusion in biosecurity frameworks
Established aquatic seaweed health regulations	_
2. Competent authority responsible for implementing existing regulations	_
3. System for reportable (notifiable) diseases	_
4. System for inspecting and certifying aquaculture operations	_
5. Established disinfection procedures	_
6. Other sanitary pathogen control measures	-
7. Statutory contingency plans in place in the event of an outbreak	-
8. Seaweed surveillance diagnostic, etc./personal training capabilities	-
9. Regulations regarding seaweed aquaculture site selection for minimising disease spread	-
10. Introduction of crop cycle separation of seaweed as a management principle	_
11. Regulations concerning stocking density	_
12. Regular disease surveillance	_
13. Import regulations related to diseases	GoT (2003b), GoT (2010b)
14. Quarantine measures established for imported aquatic flora	GoT (2003b), GoT (2010b)
15. Regulations concerning introduction of new (exotic) aquatic flora	GoT (2003b), GoT (2010b)
16. Regulations on transport or movement of aquatic flora	GoT (2003b), GoT (2010b)

GoT (2003b) Fisheries Act No. 22 Tanzania (2003), GoT (2010b) Fisheries Act No. 7 Zanzibar (2010)

seaweeds (defined in the text as aquatic flora) from, or into, the country without permission; therefore, there is an existing tool for controlling the introduction of invasive cultivars, at the point of import. However, as there is no domestic processing industry, the government implements this regulation through the price negotiations between buyers from overseas processing companies who export the seaweed crop, and a portion of the profit is collected from the seaweed farmers during this sale. Although the international buyers also pay a fee to the government during the sale, ultimately the overall price is determined by the buyer. Under this process, the government is aware of what crop is exported, and that the buyer can provide farming materials, including imported propagules from abroad or across regions, as a part of this price negotiation. However, there have been no supporting biosecurity measures introduced by the government to limit the introduction of exotic cultivars. In addition, seaweeds are being transported from one site to another nationally without permission, which also risks the transmission of disease and pests from one area to another, as has been seen across aquaculture sectors globally (Lafferty et al. 2015; Ingle et al. 2018).

Legislations that do not yet exist for the seaweed industry are already in place for some terrestrial agricultural sectors of Tanzania, and include detailed biosecurity legislations for specific crop commodities. For example, regulations for the coffee industry, written by the GoT (2003a), specifically regulated the prevention and control of coffee plant pests and diseases. Another industry-led example is the Sisal Industry Regulation (GoT 2011), which aims to control pests and diseases of the sisal plant and improve

seedlings through meristematic tissue culture technology to maintain brood stock quality. A collaborative approach is also taken in the partnership between Australia and ten African countries, including Tanzania, to look at the relationship between plant biosecurity and food security called the Australia-Africa Plant Biosecurity Partnership (AAPBP) (CABI 2017). This is another example where biosecurity is specifically recognised and is being addressed through an international capacity building project. Other sectors, like livestock and human health, already have well-defined biosecurity frameworks and management practices set in place, although end-users do not necessarily know how to effectively put them into practice (Henjewele 2015; Katz and Mramba 2015; GHSA 2016; Msami 2020). Even more advanced biosecurity proposals include the development of an electronic national inventory of dangerous pathogens working with laboratories that deal with "pathogens of concern" (Brizee et al. 2019). Therefore, although the seaweed industry in Tanzania does not yet have specific biosecurity regulations, other industries have already established mechanisms through policy and legislation, which could be reflected in future seaweed policy and legislation.

### Biosecurity risks in national frameworks

The biosecurity risks from pests, diseases and the spread of non-native species in the Tanzanian seaweed industry have been reported in research articles from as early as 1996



(Msuya et al. 1996; Lyimo et al. 2006, 2008; Zemke-White and Smith 2006; Eklöf et al. 2012), demonstrating recognition of existing biosecurity risks associated with production and processing. However, uptake of any practical management measures for these biosecurity risks remains quite low on a national scale in Tanzania. Biosecurity risks will exist for several actors in the Tanzanian seaweed value chain. For example, farmers and propagule handlers are the most likely to spread diseases and pests, as is seen in the agricultural sectors (FAO 2011). For example, farmers commonly practice the sharing of propagules between farms, villages, districts and even regions (e.g. K. alvarezii seeds from Zanzibar to Songo Songo Island) (Msuya and Porter 2014). In so doing, they may share diseased propagules or facilitate the re-planting of infected seaweed, a mode of transmission already observed elsewhere in the tropical seaweed industry (Hurtado et al. 2017).

Seaweed export companies like Zanzibar Agro-Seaweed Company Ltd. (ZASCOL), Zanzibar East Africa seaweed company (ZANEA) and C-Weed corporation have been attempting to minimise this practice by providing farmers with enough propagules or the required production volumes they buy, and have been importing alternative varieties of E. denticulatum, K. alvarezii and K. striatus from the Philippines when the existing Tanzanian varieties become unproductive (Lirasan and Twide 1993; Mshigeni 1998; Msuya 2005; Msuya et al. 2014; Largo et al. 2020). More recent examples of imported cultivars include the imported Kappaphycus varieties known locally as "Kikorosho" (variety of K. alvarezii) and "Kikarafuu" (K. striatus), and E. denticulatum (known in the Philippines, and thus in Tanzania, as "million million"). These new cultivars used to replace the unproductive varieties of *K. alvarezii* (cottonii) and E. denticulatum (spinosum) have already started to fail due to a complexity of issues including using the same propagules over a long time and climate change-related stress, resulting in a disease-susceptible crop (Hurtado et al. 2006; Vairappan et al. 2008; Hayashi et al. 2010; Msuya 2011b; Msuya and Porter 2014; Mulyaningrum et al. 2019; Ward et al. 2019). Despite the risk of introducing pathogens through such pathways being discussed globally in recent literature (Cottier-Cook et al. 2016; Badis et al. 2019; Campbell et al. 2019a, b), it remains unclear if quarantine procedures are followed during the importation of seed stock.

It is possible that low-cost biosecurity measures could be effectively applied to minimise and/or eradicate the discussed diseases risks, like those adopted by the milk and meat industries in Kenya, for example, sanitising containers used in transport and processing equipment with soaps and detergents (Nyokabi et al. 2018). In Tanzania, some seaweed farmers have adopted simple biosecurity measures already, such as drying ropes in the sun in-between harvest and re-seeding (Msuya, pers. comm.). However, with so few biosecurity activities being currently practiced on farms nationally, as well

as the lack of supporting policies, implementation of such measures could remain difficult. To support farmers through the development of biosecurity in the seaweed industry, national policies that strengthen biosecurity awareness and support farmers to invest in biosecurity practices, could help to build the capacity of both farmers and extension officers, which is essential in a successful national biosecurity strategy (Bondad-Reantaso et al. 2018; Campbell et al. 2019a).

# Components of a national biosecurity strategy in Tanzania

A majority of potential components in a national biosecurity strategy were not identified in existing frameworks (Table 3). The four national biosecurity components identified in existing frameworks for import regulations related to diseases, quarantine measures established for imported aquatic flora, regulations concerning introduction of new (exotic) aquatic flora and regulations on transport or movement of aquatic flora were found in two of the identified frameworks: the Tanzania GoT (2003b) and RGoZ (2010). Although the components were mentioned in these acts, there is very little detail regarding their application in seaweed farming, but rather the general biosecurity approach of the policy. In Tanzania, there is no established regulation for many components considered as key in a strong aquaculture biosecurity strategy: aquatic seaweed health, established disinfection procedures, site selection, monitoring or reporting of diseases and/ or pests (Bondad-Reantaso et al. 2005; Scarfe et al. 2008). There is also a lack of any government-supported procedures for extension officers to inspect or certifying seaweed farm operations, which also exist in other agricultural sectors such as forestry, sisal and coffee, for which there are inspections for the prevention, control and management of known diseases (e.g. GoT 2011, 2013). This type of support has been demonstrated to limit the impact of pests and diseases in other agricultural industries in Australia (Anderson et al. 2017). Currently, the Ministry of Fisheries and Livestock is best placed to establish similar national biosecurity strategies for the seaweed industry, as they already have the capacity for terrestrial crops, which have legally binding biosecurity regulations for importation or export of plants, and disease control and prevention. Without similar support, the impacts of diseases and pests of seaweeds which are affecting the national industry will remain undocumented, and without a strategic plan for limiting future outbreaks.

#### **Conclusions**

In Tanzania, there are existing biosecurity frameworks for aquaculture which are legally binding, but their scope is



limited to the fish farming industry, and inclusion of farmed seaweeds remains uncertain. The inclusion of biosecurity legislation regarding seaweed farming is lacking nationally, and any known biosecurity measures are currently informally practiced by farmers, which can result in an incoherent approach to managing biosecurity nationally. The Government of Tanzania already has well-established biosecurity policies specific to terrestrial plants (e.g. coffee and sisal), farmed fish and livestock (including piggeries and poultry), which are explicitly tailored to the industries. Such biosecurity frameworks do not exist that solely accommodate the specific challenges the seaweed industry faces. This analysis of existing frameworks also highlights the geographical disconnect between the two governments involved in the Tanzanian seaweed industry, i.e. the United Republic of Tanzania Government and the Revolutionary Government of Zanzibar. Both governments currently lack biosecurity policies, which explicitly cover seaweed farming, despite the industry spanning both administrative jurisdictions. However, both governments are in the process of revising their aquaculture policy strategies to include acts, which will cover seaweed farming and biosecurity more specifically. Therefore, this paper provides timely information on policy gaps and deficiencies to assist both governments in establishing coherent biosecurity policies, which could improve the control of diseases and pests that limit the productivity of the Tanzanian seaweed industry.

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