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African Aquaculture: Genetic Resource and Traditional Knowledge Access and Benefit Sharing Measures

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ABSTRACT

Genetic resources are the building blocks for aquaculture breeding programs, biotechnology and conservation. The Convention on Biological Diversity and the Nagoya Protocol are international frameworks for access and benefit sharing (ABS) concerning: (a) the collection and use of genetic resources and associated traditional knowledge; and (b) sharing the benefits of their use with the provider. ABS laws in African countries increasingly apply to resources and knowledge used throughout the production chain for aquaculture, including genes and gene sequences. This paper reviews ABS legislation and peer-reviewed publications in Kenya, Malawi, Tanzania, Uganda and Zambia (leading aquaculture countries with ABS laws) to identify key knowledge gaps for ABS and aquaculture. Using a systematic quantitative literature review method and a qualitative analysis, the main findings are that despite established ABS laws in many of the reviewed countries, there are no analyses on the positive or negative effects of these laws for the conservation, sustainable use of genetic resources, digital sequence information and traditional knowledge relevant to aquaculture and the equitable sharing of benefits from their use. These knowledge gaps may significantly undermine the sharing of resources and knowledge necessary for ecologically sustainable aquaculture development in Africa, which is crucial to food security and livelihoods.

KEYWORDS

Access and benefit sharing; aquaculture genetic resources; Convention on Biological Diversity; Nagoya Protocol; traditional knowledge; Africa; digital sequence information

1. Introduction

Biological and genetic resources are the building blocks for aquaculture breeding programs, conservation research, biotechnology and commercial development. Africa produces approximately 2.7% of global aquaculture output (FAO 2020), however, aquaculture genetic resource sharing for sustainable aquaculture development, food security, economies and livelihoods is becoming increasingly important for this region (FAO 2020). In 2018, aquaculture accounted for 18% (2.2 million tonnes) of total fish production in Africa (FAO 2020), with Egypt being the highest producer in the region (1.5 million tonnes, ranked 6th globally) (FAO 2020). Between 2005 and 2018 the continent's total aquaculture output tripled and production continues to grow to ease pressure on wild stocks in capture fisheries (FAO 2020). The development of genetically improved strains that are faster growing and more resilient to disease and environmental stress will be critical to achieving the sustainable growth of sustainable aquaculture sectors.

Historically, many aquatic genetic resources have moved freely in the Africa region through informal exchanges (e.g. Eknath and Hulata 2009). African countries were strong supporters of the concept of access and benefit sharing (ABS) during the negotiations of the 1992 *Convention on Biological Diversity* (CBD) to ensure that low-income biodiverse-rich countries were not exploited for their genetic diversity and denied access to their own resources and commercial products produced by users of the resources and knowledge in other countries (Coolsaet and Pitseys 2015). To this end, the CBD acknowledged the sovereign rights of countries to their genetic resources, encouraged countries to facilitate access to their resources and required countries to ensure the fair and equitable sharing of benefits of the use of the resources with the provider (article 15). Aquaculture genetic resources and associated traditional knowledge in African countries will become increasingly subject to restrictions on their collection,

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use and movement for the purposes of aquaculture development, depending on how these countries implement their national ABS regimes. To date, there has been little analysis about the relevance of ABS to aquaculture research, development and commercialization in African countries, which depend on aquatic animals and plants for food security and livelihoods.

The CBD and its implementing agreement, the 2010 *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity* (Nagoya Protocol) set up a framework for: access to genetic resources and traditional knowledge (including prior informed consent and mutually agreed terms); benefit sharing (contractual agreements including monetary and non-monetary benefits); and monitoring and compliance. The idea is that access to genetic resources must be subject to the prior informed consent of the provider country that is party to the CBD (unless otherwise determined by the Contracting Party) and where granted, access must be on mutually agreed terms (CBD article 15). In effect, countries often manage access arrangements through administrative procedures (e.g. permits or registers). Contracting Parties to the CBD must also aim to share in a fair and equitable way the results of research and development and the benefits arising from commercial and other use of genetic resources with the provider country (CBD article 15). Countries often manage benefit sharing through contractual mechanisms. The original ABS concept under the CBD was an attempt to promote an incentive for users of genetic resources to compensate the providers who bear the cost of conserving and providing the biological resources (Janssen 1999). Despite decades passing since the first countries implemented these administrative and contractual ABS arrangements, there is little published evidence about the extent to which ABS achieves its conservation and sustainable use objectives (Robinson 2014; Laird et al. 2020).

The Nagoya Protocol attempted to clarify many aspects of implementing the ABS concept. These included clarifying the trigger of "utilisation" for benefit sharing (articles 2(c), 5 and 6) and special considerations (e.g. simplified mechanisms) for using genetic resources for noncommercial research purposes (article 8). It requires States Parties to "consider the importance of genetic resources for food and agriculture and their special role for food security" (article 8(c)), which would include aquaculture. Despite clarifying the nature of genetic resources captured under ABS obligations (article 2(e)) and rules for traditional knowledge associated with genetic resources (articles 7 and 12), significant challenges remain for implementing the intangible aspects of genetic resources, particularly digital sequence information (DSI) and traditional knowledge associated with genetic resources. Depending on the way a country implements its national policy and laws, compliance with ABS measures may not only affect the use of genetic material for commercial development of aquaculture strains but also other aquaculture research, including taxonomic and conservation investigations.

Both information and knowledge about genetic resources are gaining attention because the physical materials can be used with that information and knowledge without necessarily engaging the ABS equity and benefit sharing provisions (Lawson et al. 2020). This is inequitable because the information and knowledge are often integral to utilizing the resources. This has been long debated for traditional knowledge (e.g. Robinson et al. 2018) and only recently this has started for DSI (a placeholder term for information about genetic resources) (Bagley et al. 2020). This is complex as the CBD applies broadly to knowledge at the ecosystem, species and genetic levels (article 8(j)), whereas the Nagoya Protocol is confined to traditional knowledge associated with genetic resources (article 7). Other agreements may also shape the way a country approaches traditional knowledge, such as the *United Nations Declaration on the Rights of Indigenous Peoples,* that recognize the right to maintain, control and protect traditional knowledge (and cultural expressions) and the manifestations of their sciences, technologies and cultures including human and genetic resources (article 31). There are several other forums developing frameworks relating to traditional knowledge such as the World Intellectual Property Organisation's Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore. At present there is a large gap in research that specifically addresses how countries manage the use of information and knowledge relevant to aquaculture research and development under their ABS regimes.

The ABS concept has now spread to a range of other United Nations forums as a key strategy for the conservation and sustainable use of genetic resources within their mandates under specialized instruments. These include:

- the World Health Organization's Pandemic Influenza Preparedness Framework concerning certain virus genetic resources;
- the Food and Agriculture Organization's International Treaty on Plant Genetic Resources

for Food and Agriculture (Plant Treaty) concerning limited plant genetic resources; and
- the proposed implementing agreement under the United Nations Convention on the Law of the Sea (UNCLOS) for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction.

While these instruments do not yet have direct relevance to aquaculture genetic resources, they may have future relevance if they are included in the Plant Treaty's multilateral ABS system because the definition of "plant genetic resources for food and agriculture" (article 2) is broad enough to include aquatic plants. Similarly, the UNCLOS implementing agreement will concern marine genetic resources that may be relevant to aquaculture breeding or biotechnology. Few articles have explored the implications for future use and exchange of resources relevant to aquaculture under these instruments (e.g. Humphries 2017).

African countries have been particularly vocal during ABS discussions and framework negotiations because of their high biodiversity and dependence on biological resources and traditional knowledge for food and livelihood security (Coolsaet and Pitseys 2015). To promote regional guidance and capacity building for policy development, they adopted the African Model Legislation for the Protection of the Rights of Local Communities, Farmers and Breeders, and for the Regulation of Access to Biological Resources in 2000 (Organisation of African Unity 2000). Fifteen years later, the African Ministers for the Environment adopted strategic and practical guidelines for the coordinated implementation of the Nagoya Protocol in African countries (African Union Commission 2015b). Active participation in ongoing discussions of ABS issues, including how to manage DSI, has been strengthened by various initiatives, including the African Union Commission's establishment of the Continental Coordination Committee on Biodiversity and an online coordination tool (African Union Commission 2018).

The aim of this article is to review the ABS legal measures and peer-reviewed ABS publications in leading African aquaculture producing countries—Kenya, Malawi, Tanzania, Uganda and Zambia—to determine key research gaps for ABS and aquaculture. It uses a systematic quantitative literature review and a qualitative review of the literature and a doctrinal analysis of ABS measures in the reviewed countries to identify gaps in analysis of: (a) the implications of ABS for aquaculture activities or aquaculture sectors; and (b) the regulation of intangible aspects of ABS—DSI and traditional knowledge—of relevance to aquaculture research and development.

The criteria for selecting the case studies for the review were African countries that: (a) are significant African aquaculture producers; and (b) that have dedicated ABS laws (Table 1). Some of the top aquaculture producing African countries, such as Egypt and Nigeria, do not have dedicated ABS measures at the time of writing and are beyond the scope of this review.

Section 2 outlines the methods and Section 3 outlines the state of aquaculture, ABS measures and ABS literature for Kenya, Malawi, Tanzania, Uganda and Zambia. Section 4 discusses gaps in ABS literature concerning genetic resources, DSI and traditional knowledge for use in aquaculture in these countries. The paper concludes that the significant gaps risk undermining policy development for the conservation and sustainable use of aquatic genetic resources in aquaculture and proposes key areas for further research and analysis.

2. Methods

This is a mixed method review. It first uses a systematic quantitative literature review (SQLR) method (e.g. Pickering and Byrne 2014) to assess the literature on

Table 1. World aquaculture production by low-income food-deficit countries in Africa (FAO 2020; * FAO 2019 data for 2017).

Country	Combined animal/plant production (t) in 2018*	National ABS legislation
Uganda	103,737	National Environment Act 1995 National Environment (Access to Genetic Resources and Benefit Sharing) Regulations 2005 Guidelines for Accessing Genetic Resources and Benefit Sharing in Uganda 2007 Uganda Copyright and Neighboring Rights Act 2006 [concerning traditional knowledge] Industrial Property Act 2014 [concerning traditional knowledge]
Kenya	15,120	Environmental Management and Coordination Act 1999 Environmental, Management and Coordination Act (Conservation of Biological Diversity and Resources, Access to Genetic Resources and Benefit Sharing) Regulation 2006 The Protection of Traditional Knowledge and Cultural Expressions Act 2016
Tanzania	15,522	Environmental Management Act 2004
Zambia	24,300	Protection of Traditional Knowledge, Genetic Resources and Expressions of Folklore Act 2016 (No. 16 of 2016)
Malawi	9014	Environment Management Act 1996 (as amended 2017)

ABS in the African region, followed by a traditional narrative review of the literature on ABS and aquaculture in each country. By systematically identifying peer-reviewed literature from online databases and quantifying the data, the SQLR summarizes the status of the literature so that the results are reliable, quantifiable and reproducible, thereby highlighting knowledge gaps and reasons why more research is needed to fill them.

2.1. Data collection

Stage 1 involved searching five commonly used databases for this field (Proquest, Scopus, Web of Science, Google Scholar, HeinOnline) for articles relating to ABS published between January 1980 and February 2021. The initial search terms were [("access and benefit* shar*") AND ("genetic resources" OR law OR legislation OR policy OR "transfer agreement" OR biosecurity OR biosafety OR "intellectual property" OR "traditional knowledge")]. The search was restricted to peer-reviewed journal books, articles, book chapters and early access papers published in English. It excluded gray literature, newspaper articles, white papers and conference proceedings because of challenges with analyzing the credibility and quality of gray literature (e.g. Benzies et al. 2006). The search results from all five databases were entered into a single Endnote library (n = 1201). Duplicate references and unrelated or irrelevant articles (n = 520) were excluded such as where ABS is only mentioned in the discussion as a need for further research or where ABS is only used in keywords and/or references. The library was further refined to only include ABS articles for the five review countries—Uganda, Kenya, Tanzania, Malawi and Zambia (n = 18).

The second stage was a specific country-level search for the five review countries to obtain an overview of genetic resource and/or traditional knowledge collection, use and sharing relevant to aquaculture in each country (Stage 2 "national libraries"). This involved using Google and the online databases Proquest, Web of Science, Scopus, and Google Scholar to search all peer-reviewed publications (books, articles, book chapters). In each case, the search term was [Country Name AND (ABS OR "access and benefit sharing" OR "genetic resources" OR "intellectual property" OR "traditional knowledge" OR biosecurity OR biosafety)] between January 1980 and February 2021. Only two publications were identified after the removal of duplicates and papers that did not mention ABS.

All references were combined from the Stage 1 library (ABS references of the five review countries) and the national libraries for each country in a single Endnote library (n = 20), which excluded duplicates from both libraries. The individual country-level libraries form the basis of the country-specific literature reviews: Uganda (n = 7), Kenya (n = 9), Tanzania (n = 1), Malawi (n = 0) and Zambia (n = 3).

3. Research on key African aquaculture producing countries with ABS measures

Out of the 20 papers that related to the collection, use and/or transfer of genetic resources or traditional knowledge in the five review countries, none of them analyzed the implications of ABS for the aquaculture sector (see Table 2). The analyses of four of these publications included intellectual property considerations, six examined traditional knowledge in relation to ABS but none mentioned the relationships between DSI and ABS. None of the publications examined intellectual property or traditional knowledge associated with aquaculture genetic resources. The majority of the publications concerned Uganda and Kenya, with only three for Zambia and one publication for Tanzania, while Malawi had no peer-reviewed publications concerning ABS.

3.1. Kenya

Fish farming in Kenya has grown rapidly since 2007 and now plays an increasingly essential role in improving national fish supply (Aloo et al. 2017) and local employment (KMFRI 2017). Aquaculture production grew from 4,218 metric tonnes in 2006 to 24,096 metric tonnes in 2014, equivalent to 15% of all fish production in Kenya (KMFRI 2017) but decreased to

Table 2. Country-specific ABS publications.

Country (total n = 20)	% of total papers	ABS law or policy	ABS and IP	DSI and ABS	TK and ABS	Implications of ABS for aquaculture
Kenya	45%	9	2	0	3	0
Malawi	0%	0	0	0	0	0
Tanzania	5%	1	0	0	1	0
Uganda	35%	7	2	0	2	0
Zambia	15%	3	0	0	0	0

IP = Intellectual policy, TK = traditional knowledge, GR = Genetic resources. DSI = digital sequence information.

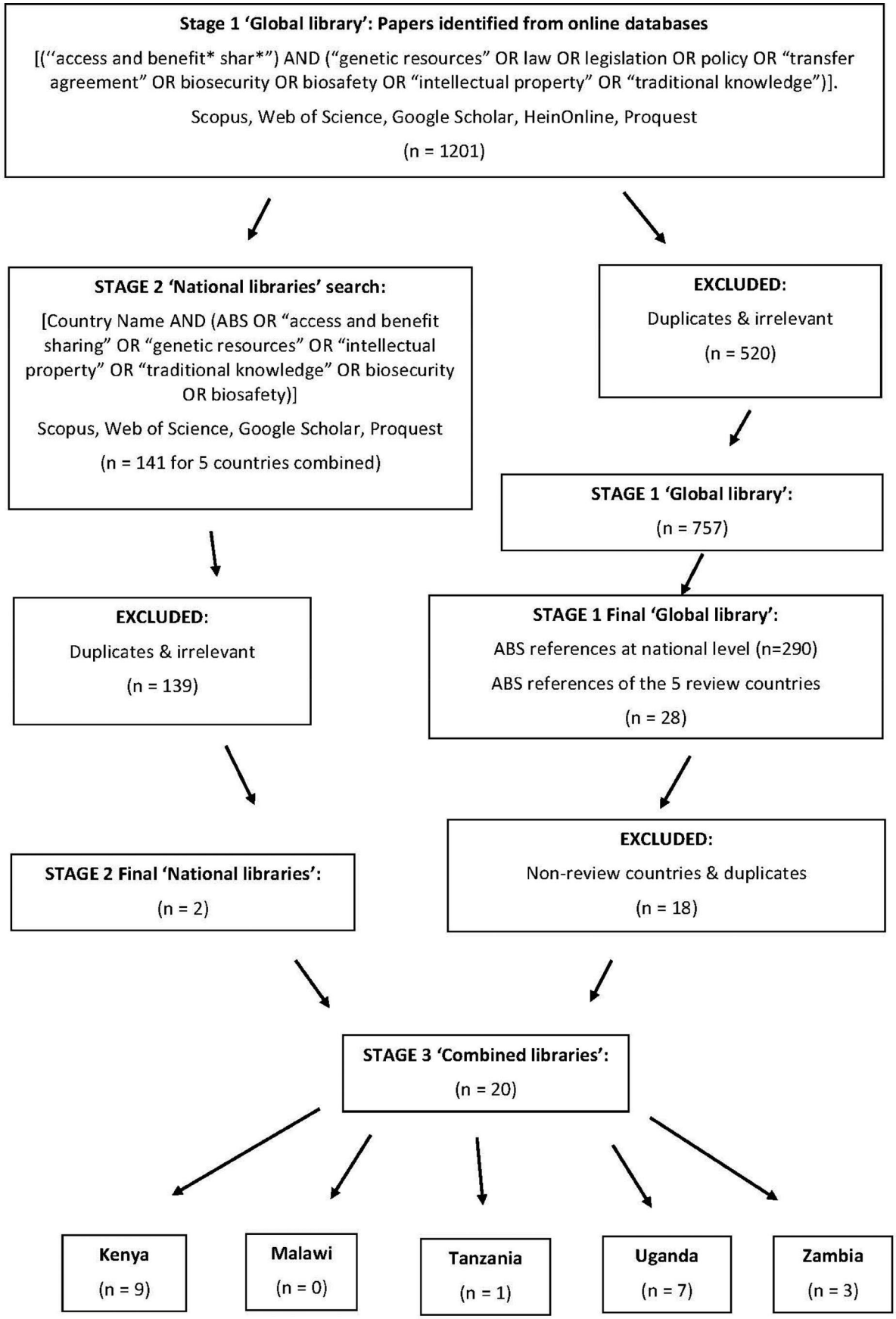

Figure 1. Preferred Reporting Items for Systematic Review Recommendations (PRISMA) flowchart outlining the process for compiling this review (modified from Moher et al. 2015). *n* = number of articles.

15,120 metric tonnes in 2018 (FAO 2021a, Table 1). Kenya is currently ranked the fourth largest aquaculture producer in Africa. While Kenyan aquaculture production has great potential, the sector remains underdeveloped for several key reasons, primarily land ownership conflicts, accessibility issues and a lack of clear guidelines and policies (KMFRI 2017). There is more freshwater production, including Rainbow trout (*Oncorhynchus mykiss*) in the cooler Mount Kenya region, while warm water aquaculture focuses on Nile tilapia (*Oreochromis niloticus*, 75% of production), African catfish (*Clarias gariepinus*) and other species (25% of production) (Opiyo et al. 2018). In 2016, the Kenyan fisheries and aquaculture sector comprised 0.8% of the GDP (KMFRI 2017). The sector directly employs more than 500,000 people and indirectly supports over two million others (KMFRI 2017).

Kenya has a range of legislation regulating ABS of its genetic resources, information and associated traditional knowledge (see Table 1). Under the *Environmental, Management and Coordination Act (Conservation of Biological Diversity and Resources, Access to Genetic Resources and Benefit Sharing) Regulation 2006*, any person who intends to obtain, possess or use *in situ* or *ex situ* Kenyan genetic resources, including derived products and intangible components, must obtain an access permit from the National Environment Management Authority (NEMA) (section 9(1)). The Regulation defines intangible components broadly to mean "any information held by persons that is associated with or regarding genetic resources within the jurisdiction of Kenya" (section 2). This includes traditional knowledge associated with genetic resources (Kenyan Government 2016) and is broad enough to potentially include genetic sequence information and other information associated with genetic resources. It applies to wild as well as domesticated (through selective breeding or biotechnology) terrestrial and aquatic genetic resources (Kenyan Government 2016). The ABS obligations apply to "obtaining, possessing and using genetic resources conserved, whether derived products and, where applicable, intangible components, for purposes of research, bio-prospecting, conservation, industrial application or commercial use" (section 2). They do not apply to various activities including approved research activities intended for educational purposes in Kenyan research institutions (section 3).

Kenya has detailed and elaborate permit, benefit sharing and monitoring systems (Kenyan Government 2014). To obtain an access permit, a proposed user of genetic resources must demonstrate that the research activity facilitates sustainable management and utilization of genetic resources for the benefit of the people of Kenya (section 11(1)). The proposed user must also have the prior informed consent and a benefit sharing agreement with relevant private and government resource access providers, including local communities (section 9(2)). The permit holder must involve Kenyan citizens in the permit activities (section 20). Benefit sharing agreements must include both monetary and non-monetary benefits unlike other countries where it is generally optional to choose one or both (section 20). The Kenyan legislation is highly prescriptive about the form of benefits from both use of the physical sample as well as the traditional knowledge under an agreement. After obtaining an access permit, if a person wishes to transfer the biological resources outside the country, they must negotiate and sign a Material Transfer Agreement with a relevant lead agency in Kenya (section 18). These must spell out important terms and conditions of transfer, use and benefit sharing. Kenya has separate legislation—the *Protection of Traditional Knowledge and Cultural Expressions Act 2016*—that protects traditional knowledge and requires prior informed consent, the procedure of which would be specified in the registration documents (unique to each community) (section 10).

There are nine publications examining the development of ABS policy and law in Kenya but no articles that examine the implications of ABS for aquaculture. There are no articles on traditional knowledge or DSI associated with aquaculture genetic resources. The Kenyan government has acknowledged that there are challenges for engagement with the authorization system and to improve stakeholder understanding, it released a toolkit to guide users, providers and lead agencies through the processes (Kenyan Government 2014).

Angwenyi (2009) examined the development of ABS measures in Kenya in response to CBD obligations (the Nagoya Protocol was not in effect at the time). She noted that negotiated benefits from the use of resources may make an immediate difference to local communities through infrastructure development, for example, and when accumulated they can make a major difference in poverty alleviation and environmental sustainability in regional areas (Angwenyi 2009). Significantly, she stressed the importance of incorporating into policy-making the dramatic differences in the ways biological resources are used by the various sectors and recommended that the current generic framework be elaborated in different and flexible ways for different sectors, research

and activities (Angwenyi 2009). There are no subsequent publications indicating this has been done for the aquaculture sector in Kenya. Boga (2015) compared the authorization process for bioscience research before and after the ABS measures were implemented from a scientist's perspective. Before the measures, permits took about a month to obtain and post-ABS measures, over six months (Boga 2015). Requirements for multiple prior informed consent including from communities demanding immediate benefits from the use the resources, he argued, deters growth in research and hinders the management and conservation of Kenya's ecosystems and biodiversity (Boga 2015).

Three publications focused on intellectual property and ABS in Kenya. Kamau (2009) and Atsali (2020) examine traditional knowledge under Kenyan law, including options for protecting the knowledge under intellectual property regimes, while Munyi (2015) analyzed whether the plant variety protection regime in Kenya is compliant with international obligations. Atsali (2020) conducted a survey of awareness by specific counties of ABS laws and analyzed the suitability of using intellectual property regime for ensuring returns on community-based assets. They found that the surveyed county governments were unaware of the *Protection of Traditional Knowledge and Cultural Expressions Act 2016* despite it being their responsibility to manage initial registration, preservation, conservation, financial resources and facilitating access and sharing of information for traditional knowledge. They found the Kenya Copyright Board is developing draft implementation guidelines for the legislation to assist national and county governments to meet their obligations. In relation to patents, the authors found that the Kenya Industrial Property Institute is developing amendments to the *Industrial Property Act 2001* to require disclosure of the source of genetic resources and traditional knowledge in patent applications to ensure that communities benefit from their use. They found, however, that the absence of guidelines on examining biological inventions and depositing microorganisms for patent purposes has caused confusion for examiners and stakeholders and resulted in technically prohibiting the granting of patents to applicants. There were no articles considering intellectual property, ABS and aquaculture biological resources or traditional knowledge and aquaculture.

Watai et al. (2015) argued that the ABS regime in Kenya is fragmented and causes: (a) confusion about which institution is competent to grant PIC; (b) lengthy timeframes for issuing permits; (c) high transaction costs; and (d) legal uncertainty. This means that the lack of publications providing evidence of the effect of ABS on Kenyan aquaculture through the use and exchange of aquatic genetic resources and/or traditional knowledge is a significant gap that may hinder the continued growth of Kenya as one of the leading aquaculture producers in Africa. Despite the laws being in place for 14 years at the time of writing, there is a gap in evidence about whether ABS has a beneficial impact on the conservation and sustainable use of aquaculture genetic resources. Such evidence would be crucial for taking a flexible and nuanced approach to ABS for the diverse sectors in Kenya as envisaged by Angwenyi (2009).

3.2. Malawi

Aquaculture production in Malawi grew rapidly between 1980 and 2001 by 7.4% (Chirwa et al. 2017) and in 2018 produced 9014 tonnes (FAO 2021b, Table 1). Despite several aquaculture projects over the past 50 years, growth is limited when compared with other countries and does not meet the demand for fish in Malawi (Mussa et al. 2020), demonstrating an enormous potential for growth in the sector. Aquaculture fish production consists of 93% tilapia (*Oreochromis shiranus, O. karongae* and the indigenous *Tilapia rendalli*), 5% catfish (*Clarias gariepinus*) and 2% exotic species such as common carp (*Cyprinus cario*), black bass and rainbow trout (*Onchorhynchus mykiss*) (Chirwa et al. 2017). Aquaculture is primarily subsistence farming with a few commercial producers and is almost exclusively composed of pond culture (Mussa et al. 2020).

The Malawi government set up a legislative framework for ABS of genetic resources and traditional knowledge under the *Environment Management Act 1996* and the Procedures and Guidelines for Access and Collection of Genetic Resources in Malawi (Malawi Government 2015), which are non-binding Guidelines for implementing ABS in Malawi. The Act establishes an Authority and requires it to make measures for regulating access, benefit sharing, protection of Indigenous property rights and the regulation of trade in biodiversity (section 67). Malawi has not yet implemented legally binding regulations providing the process and detail of ABS obligations. The Act requires measures to regulate access to genetic resources for non-citizens or nonresidents of Malawi (section 67(2)(a)). "Access" means "obtaining, possessing and using biological and genetic resources conserved including traditional knowledge whether derived from products, intangible components or parts thereof for purposes of research, bio-prospecting, conservation, industrial

application or commercial use" (section 2). This broad scope would encompass nearly all uses of aquaculture genetic resources and associated knowledge in Malawi and might also extend to DSI, although the scope is unclear. While the Act requires the Authority to prescribe measures to "ensure effective equitable sharing of benefits and sustainable business mechanisms for the transfer of biotechnology" (section 67(2)(c)), the Guidelines do not prescribe in detail any benefit sharing obligations.

The Malawi government has been prolific in considering and promulgating new environmental protection and national resources management policies and legislation (e.g. Makanje 2019) but has not yet aligned these with ABS. As such, Malawi has no peer-reviewed publications dealing specifically with the issue of ABS of biological diversity in Malawi. There are no English articles concerning ABS of aquaculture genetic resources, nor any articles explaining the implementation of the ABS power in 2017.

3.3. Tanzania

While Tanzania has a relatively large aquaculture sector, there is enormous untapped potential for production growth (Mwaijande and Lugendo 2015). In 2018, Tanzania reported 15,522 tonnes of animal aquaculture production mostly from freshwater (96%) (FAO 2021c, Table 1). There are approximately 22,500 fish ponds used for aquaculture with the entire sector (fresh and marine waters) generating considerable employment—15–20,000 people in the seaweed sector, 14,000 in freshwater fish farming and 3,000 in mariculture (Tanzanian Government 2016). About 75% of aquaculture production is tilapia with fish produced from aquaculture generally consumed locally. Other common aquaculture species are rainbow trout (*Oncorhynchus mykiss*) and catfish (*Clarias* spp.) in freshwater and milkfish (*Chanos chanos*), prawns (*Penaeus* spp.) and seaweed (*Eucheuma spinosum, Kappaphycus cottonni* and *E. striatum*) in marine areas (Tanzanian Government 2016). Shoko et al. (2011) and Chenyambuga et al. (2012) state that aquaculture in Tanzania is still a subsistence activity practiced by small-scale rural farmers who have low social, cultural and economic status and limited access to technology, markets and finance. These fish farmers use small ponds ranging in size from 150–500 square meters. There is some larger-scale cage farming in Lake Victoria and larger shrimp production ponds along the coast (Tanzanian Government 2016).

The mainland (excluding Zanzibar) ABS obligations have been implemented through the *Environmental Management Act 2004* empowering the Minister to make regulations for ABS of genetic resources (section 66). Despite this power to make the regulations, ABS is not specifically regulated in Tanzania. The CBD *National Report* from Tanzania reports that regulation is being prepared to implement to CBD and Nagoya Protocol commitments by 2020 (Tanzanian Government 2015, Targets 16 and 18). There are, however, other legislative schemes that need to be considered when accessing and using biological materials (such as the *Fisheries Act 2003*).

The *Fisheries Act 2003* asserts sovereignty over "[a]ll biological resources and their intangible products whether naturally occurring or naturalized within fisheries" (section 51(1)). The term "fishery" is defined to mean "every area, locality or place or stations in or which fishing gear is used, set or place or located and also the area, tract or stretch of water in or from which fish may be taken by such fishing gear" (section 2). The effect of the *Fisheries Act 2003* is to apply to any taking of fish in Tanzania (except Zanzibar) and this is covered by a permitting system (section 51(4)). There do not appear to be any benefit sharing arrangements in the context of ABS.

There are significant research gaps concerning ABS law and policy analysis in Tanzania, with only one peer-reviewed publication. Stangeland et al. (2008) trace developments in traditional medicine and legislation concerning the conservation and use of biodiversity in Tanzania. They recommend more studies on domestication and sustainability of use of medicinal plants and the effect that biodiversity legislation may have once the laws are fully operational and implemented. This is the only publication for Tanzania concerning traditional knowledge and ABS and there are no articles relating to ABS concerning traditional knowledge or biological resources in aquaculture.

3.4. Uganda

In 1953 modern aquaculture in Uganda was initiated to increase the amount of animal protein in the diet of rural families (Kasozi et al. 2017). Aquaculture peaked in the late 1960s with roughly 11,000 ponds in operation. During this peak there was increased technology adoption by farmers and government-based research into carp culture, tilapia hybridization, and predator control (Kasozi et al. 2017). Most of these ponds were abandoned in the 1980s as a result of the

protracted political instability, significantly impacting aquaculture development in the country (Kasozi et al. 2017). Aquaculture in Uganda grew at an annual rate of 300% between 1999 and 2010 with aquaculture production in 2018 reaching an estimated 103,737 metric tonnes (FAO 2021d, Table 1). This increased production was mainly due to the increase in commercial aquaculture producers using high density fish culture technologies and better management of communal ponds and water bodies (Kasozi et al. 2017). As Uganda is a landlocked country, it is completely reliant on freshwater fish aquaculture. The main species produced in Uganda are Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus)*. Other important fish in different areas of the country include common carp (*Cyprinus carpio*) and redbelly tilapia (*Tilapia zillii*) (Dalsgaard et al. 2012; FAO 2021d).

Uganda implemented a dedicated national ABS framework in 2005 (see Table 1). The *National Environment (Access to Genetic Resources and Benefit Sharing) Regulations 2005* applies broadly to *in situ*, *ex situ*, wild and domesticated genetic resources, derivative products (including chemical compounds and progeny), information associated with genetic resources (including genetic sequence information) and local knowledge about genetic resources held by local communities and individuals (sections 2 & 4). Obligations are triggered at the time of access, which means "the obtaining, possessing and using of genetic resources, their derivative products, and intangible components for purposes of research, bio-prospecting, conservation, industrial application or commercial use" (section 2). This means that a broad range of genetic resources, information and knowledge relating to aquaculture breeding, development and conservation collected after 2005 would be subject to Uganda's extensive restrictions on the use and transfer of genetic resources, knowledge and information outlined below. The obligations do not apply to those genetic resources that are merely transiting through Ugandan territory (section 23).

The access procedure involves negotiations and agreements with multiple agencies, communities and individuals. A proposed user must obtain the prior informed consent of resource access providers to access and export genetic resources (including associated information and knowledge) and negotiate benefit sharing agreements (called accessory agreements) with each provider—lead agency, local community or owner (section 10). If the resources are located in an area managed by a local community, the accessory agreement must be with the applicant, lead agency and local government representing the local community (section 13).

An applicant must carry out an Environmental Impact Assessment if access is likely to have a significant impact on the environment (section 16). If there is no adverse impact, the proposed user must negotiate a "materials transfer agreement" with the lead agency for access and/or export of the resources (section 14). The ABS Regulation has detailed provisions about the clauses that the agreement must contain, as well as detailed provisions on the benefit sharing requirements for accessory and materials transfer agreements. After submitting the consent and accessory agreements, materials transfer agreement, environmental impact assessment certificate and a detailed project proposal, the Uganda National Council for Science and Technology may issue an access permit authorizing the applicant to access or export the genetic resources and impose any terms and conditions it considers necessary (section 19). Uganda also has legislation relevant to the sharing and protection of traditional knowledge under the *Uganda Copyright and Neighboring Rights Act 2006* and mandatory disclosure of innovations that contain any element of traditional knowledge associated or not with Ugandan genetic resources under the *Industrial Property Act 2014* (section 10(3)(b)(i)). These rules demonstrate the extensive procedures that a farmer or researcher must follow when collecting, using and transferring aquaculture genetic resources.

There are no articles concerning the relevance to or impact of ABS measures on aquaculture sectors, research and breeding. Only seven analyzed ABS policy and law in Uganda, two of which related to intellectual property and traditional knowledge. There are no publications referring to traditional knowledge associated with aquaculture and how the ABS measures may impact local communities.

Access to genetic resources in Uganda was first comprehensively examined by Tumushabe and Mpeirwe (2003). They explored the high reliance on genetic resource exploitation in Uganda, including its economic benefits (US$550 million) and importance to subsistence lifestyles, as well as the extensive informal exchanges of *in situ* and *ex situ* biological resources (Tumushabe and Mpeirwe 2003). Elliot (2008) provided an updated overview by examining the progress of ABS policy development in Uganda, with particular focus on the newly implemented *Access to Genetic Resources and Benefit Sharing Regulations (2005)*. Wekundah (2012) and Gilbert (2020) examined ABS policy in Uganda from the perspective of intellectual property and traditional knowledge. Gilbert

(2020) conducted a pilot project in several districts to identify traditional farming knowledge and practices and to record, collect, organize and register the traditional knowledge with the aim of creating new intellectual property rights through scientific validation and collaborative research and development. There were no articles relating to traditional knowledge and aquaculture. Finally, there are no publications about whether the implementation of ABS in Uganda is achieving its biological resource conservation and sustainable use objectives and whether it is supporting the fair and equitable sharing of benefits from their use with providers, including traditional knowledge holders.

3.5. Zambia

Zambia is a landlocked country with 20% of its land covered by water, subsequently all aquaculture involves freshwater fish farming. Aquaculture production grew in Zambia from less than 5% of the total fish supply in 1995 to more than 20% in 2014, equivalent to 11.56% annual growth (Kaminski et al. 2018). The total aquaculture production was 24,300 metric tonnes (about 27% of total fish production) in 2018 (FAO 2021e, Table 1). Tilapia farming makes up 99% of the aquaculture market with Nile tilapia (*Oreochromis niloticus*), three spotted tilapia (*O. andersonii*), longfin tilapia (*O. macrochi*), and redbreast tilapia (*Tilapia rendalli*) the most common species (Namonje-Kapembwa and Samboko 2018). Aquaculture production falls into two major types: (i) extensive small-scale local production resulting from government and donor-aid programs, which are supported by government-run services and; (ii) recent commercial-scale operations run by a few lead firms supported by market-led capital investments (Kaminski et al. 2018). While small-scale producers only contribute 11% of production, a significant challenge for growth is the availability of good quality fingerlings and high transport costs associated with the extensive travel required to purchase them (Namonje-Kapembwa and Samboko 2020).

In 2016 the Zambian government enacted its *Protection of Traditional Knowledge, Genetic Resources and Expressions of Folklore Act 2016* (No. 16 of 2016) (ABS Act). Under the Interim National Report on the Implementation of the Nagoya Protocol 11 July 2018 (Zambian Government 2018), the Zambian government reported that while the ABS Act and institutional arrangements for implementing the Protocol are in place, the Commencement Order and the regulations to fully operationalize the arrangements are not yet in force. It is also developing the governing instruments including Memoranda of Understanding and guidelines. Local courts administer customary law (*Local Courts Act* (Zambia), section 12), which is recognized as part of the ABS framework under the Act.

The ABS obligations relate broadly to aquatic genetic resources used for any purpose "in any field of human activity" (presumably including conventional breeding), including the information components of the genetic resources (such as DSI) (see section 2). It regulates the protection of traditional knowledge as a category of intellectual property as well as traditional knowledge associated with genetic resources as subject matter of ABS. Traditional knowledge is defined broadly under the act (section 2) and could include knowledge concerning the use of aquaculture genetic resources, depending on the context. A person would need the prior informed consent of a traditional community holder or a government agency acting on behalf of the holder before accessing the knowledge (section 18). The Act recognizes traditional community rights in relation to their resources including an exclusive right to regulate access and share the benefits from the utilization of their resources (section 27).

An access agreement, is a pre-requisite for obtaining an access permit issued by the Patents and Companies Registration Agency established in accordance with the *Patents and Companies Registration Agency Act.* This Agency is authorized under the ABS Act to approve access agreements with the genetic resources and traditional knowledge holders (sections 2 and 28(2)) and issue permits for access to genetic resources (section 33). Access agreements are between the permit holder and the resource or knowledge holder (section 41) who is the traditional community (individual or group) who has a right over the resource or knowledge in accordance with customary laws and practices (section 2). The access agreement constitutes both the consent for access as well as the terms for benefit sharing with the holder of the resource or knowledge (section 41).

As a condition of access to genetic resources, if a permit holder seeks to acquire intellectual property protection over the all or part of the accessed resource, the permit holder must negotiate a new access agreement with the traditional community unless the original access agreement allowed for the acquisition (section 36(k)). Where protection is sought, the permit holder must recognize the origin of the genetic resource in the patent claim. When collecting the genetic resources, the permit holder must be accompanied by

an authorized person from the Agency or an appropriate institution designated by the Agency (section 32(5)). Further, research based on a genetic resource accessed in accordance with a permit must be carried out in Zambia with the participation of Zambian citizens designated by the Agency, unless the authority holder has approval otherwise (section 32(6)).

Despite the extensive ABS framework in Zambia, there are only three peer-reviewed publications that examine ABS law and policy. None of the publications relate to intellectual property or traditional knowledge and none of them examine the implications of ABS on aquatic genetic resources.

Simwanda and Mwila (2003) and Elliot (2008) provided a background to ABS in Zambia including discussion of the use of genetic resources, bioprospecting, institutional responsibilities, and relevant laws and policies. Chomba and Nkhata (2016) examined how the theory of property rights offer a perspective for understanding and managing benefit sharing arrangements for socio-ecological systems, using the Barotse floodplain of Zambia as a case study. While the authors mention the CBD and its concept of benefit sharing, the focus of the paper is not on ABS but on benefit sharing arrangements in natural resource governance (fisheries). The article, however, has useful insights into the complex community access arrangements for fish in different bodies of water that could be relevant considerations for future cases of ABS. None of the publications analyze the 2017 ABS legislation.

4. Discussion

Each of the reviewed countries are at various stages of aquaculture development. Aquaculture production in Uganda is one of the highest in Africa, however, the limited supply of quality seed is a key barrier to growth in the sector (Stangeland et al. 2008). Kenya has one of the fastest growing populations in the world, indicating that demand for fish products will continue to rise with the potential for significant expansion in aquaculture production (Aloo et al. 2017). Similar to Uganda, current challenges for expansion in Kenya include a shortage of good quality seed from the few government seed production centers and no program for quality certification (Aloo et al. 2017). There is similarly enormous untapped potential for growth in sustainable aquaculture in Tanzania (Mwaijande and Lugendo 2015), Zambia (Kaminski et al. 2018) and Malawi (Watai et al. 2015) where consumption of fish outstrips domestic supply. Key to this growth in production is access to genetic material, information and traditional knowledge to set up robust breeding programs that produce quality stock.

Many African countries have limited human and financial resources for implementing, supporting and enforcing their ABS systems (African Union Commission 2015a, 2015b). With only 20 publications specifically analyzing ABS law and policy in the reviewed countries and no publications addressing the implications of ABS for aquaculture sectors, there is a significant gap in biodiversity law analysis in these countries. There is no evidence about whether ABS measures have a positive or negative effect on the access, use and transfer of aquaculture genetic resources and associated information and knowledge, or whether they achieve their conservation and sustainable use objectives. Nor are there any documented examples in peer-reviewed literature of benefit sharing with the providers of these resources that promote fairness, equity and economic outcomes that support farming practices, livelihoods and communities.

In the reviewed countries there are no analyses about key questions of concern from the aquaculture sector including whether ABS would apply to private hatcheries as well as government facilities, the extent to which obligations apply to intermediaries (between users and providers) including multiplier facilities, the kinds of aquaculture research that fall within scope of ABS and the extent of information and knowledge that falls within scope. There is no analysis about whether the current and proposed permitting and contractual obligations restrict collection, use and transfer of resources and information that is necessary for ecologically sustainable growth that prevents inbreeding and disease and whether it hampers conservation research of native aquaculture species. The ABS laws in Malawi apply differently to nationals and non-nationals, whereas in the other reviewed countries the same obligations apply to both, raising questions about the effect of ABS on different stakeholders involved in aquaculture. With little published information about how ABS may operate in the reviewed countries, there may be uncertainty for users and providers, particularly as the sector is largely composed of small holders and small businesses who do not have access to information available to governments and larger corporations.

This section focuses on two key gaps in analysis concerning: (a) the conservation/sustainable use of aquaculture genetic resources; and (b) the intangible aspects of genetic resource use including DSI and traditional knowledge that are likely to become

increasingly important to research and development in aquaculture sectors.

4.1. Implications of ABS for the conservation and sustainable use of genetic resources relevant to aquaculture in the reviewed countries

None of the countries reviewed had published literature directly analyzing the implications of ABS for aquaculture activities or the aquaculture sectors. The country examples fall into two categories in relation to ABS. Countries with:

1. extensive and established ABS laws that have been in force for at least 15 years (Kenya and Uganda); and
2. laws setting out powers to implement ABS obligations but regulations to operationalize ABS are not yet fully in force (Tanzania, Malawi and Zambia).

The ABS laws in Uganda and Kenya have been in force since 2005 and 2006, respectively, so it is not surprising that these countries have the most literature (80%) about ABS measures of the countries reviewed. They have also attempted to reduce complexity of their institutional arrangements by having a "one-stop-shop" approach to genetic resource policy, law and decision-making. The National Council for Science and Technology is the Competent National Authority under the Ugandan ABS framework, which processes applications and oversees the lead agencies responsible for the particular category of genetic resource access such as the Ministry of Agriculture, Animal Industry and Fisheries in the case of aquatic genetic resources (Oiteno et al. 2017). In Kenya, the only designated Competent National Authority according to the ABS Clearing House website is the National Environment Management Authority, which coordinates all access applications and benefit sharing negotiations. While Boga (2015) outlines the difficulties researchers face with obtaining prior informed consent from a variety of agencies, the extent to which the one-stop-shop has simplified arrangements in recent years is not explored in the literature.

Given that Uganda and Kenya are two of the top aquaculture producers in Africa, it is surprising that there are no publications that analyze the effect of ABS measures on the collection, use, transfer and exchange of genetic resources, information and traditional knowledge associated with aquaculture. There is no published evidence that ABS as a concept and a legal tool in Kenya and Uganda has had any beneficial or adverse effect on the conservation and sustainable use of genetic resources generally or aquatic genetic resources specifically. Nor is there any discussion about the effect of additional red tape and constraints on the free sharing of broodstock, fingerlings and other genetic materials necessary for increasing genetic diversity and productivity in breeding programs in these countries. Their wide-ranging ABS measures capture physical materials, information and traditional knowledge relating to aquaculture breeding, biotechnology and conservation. They have significant permitting processes, contractual requirements to share the benefits from the use of materials, information and/or traditional knowledge as well as specific requirements for material transfer agreements if users wish to share them with subsequent users in their countries or overseas. These ABS laws are triggered at the time of access as well as utilization but there is no interpretation in the literature of how they may affect new and continuing uses of aquatic genetic resources collected before 2005 in Uganda and 2006 in Kenya. Nor are there comprehensive analyses of how the ABS laws work in practice, whether they are effectively implemented and the extent to which they are enforced.

In contrast to Uganda and Kenya, Tanzania and Malawi have only implemented legal powers for developing ABS rules but do not yet have regulations specifying how ABS would apply, including the subject matter, permit processes, benefit sharing requirements, monitoring and enforcement. This partially explains the lack of literature about formal ABS measures in these countries, but the analysis above demonstrates that there are informal frameworks that have been in operation for several years. There is a significant gap in the literature about informal exchange practices of genetic resources, information and traditional knowledge for use in aquaculture, and a lack of analyses about options for implementing ABS arrangements that may accommodate important food and livelihood sectors including aquaculture. Given that design of the content of ABS rules is imminent, these sorts of analyses would be crucial for policy makers to understand options for minimizing adverse effects on the aquaculture sector. Policy makers in these countries recognize the enormous potential for growth in aquaculture production that could meet the large gap in domestic demand for fish. The government agencies responsible for ABS implementation in these countries are environmental authorities and not authorities responsible for

aquaculture, increasing the risk that policy objectives for biodiversity and sustainable aquaculture development will not be taken into account.

The legislation in Zambia has more detail as to the infrastructure and rules governing ABS in that country, but the government has advised the CBD that the regulations required to fully operationalize the framework are not yet in force. The existing framework has broad reach to include physical materials, associated information and traditional knowledge associated with genetic resources for use in aquaculture. It has strong measures for protection of traditional knowledge as a form of intellectual property, which is reflected in the relatively large number of publications that relate to intellectual property and ABS for Zambia. It has a similarly broad temporal application as the laws of Uganda and Kenya because it applies not only at the time of access, but also at the time of utilization of the genetic resources. As with Uganda and Kenya, there is no analysis in the literature about if and/or how the laws may capture new and continuing uses of aquaculture genetic resources collected in Zambia prior to when the law enters into force. Increased red tape requiring permission to use and exchange resources and requirements to share the benefits from the use of aquaculture genetic resources may adversely affect continued production growth from current and future selective breeding programs to meet the gap in local demand in fish consumption and improve livelihoods. Zambia has not designated a Competent National Authority (primary decision maker for ABS matters) on the CBD's ABS Clearing House and there are no recent publications about the effectiveness of Zambia's institutional arrangements for ABS.

4.2. Intangible aspects of genetic resource use including information and traditional knowledge

None of the peer-reviewed publications relate to how the reviewed countries manage DSI under ABS and there is a significant gap in how they manage traditional knowledge associated with genetic resources as the discussion below indicates.

Recognizing that researchers using DSI may attempt to avoid ABS obligations that regulate access to material genetic resources, African countries have been highly vocal in a range of international forums about the need to find a solution under ABS frameworks (Kobayashi et al. 2020). The African Group has expressed its view that the phrase "genetic resources" encompasses DSI and should be subject to benefit sharing obligations (African Group 2019). It "sees merit in exploring the development of a benefit sharing approach for DSI that would attach to commercialized products and not hinder academic research" and notes that "in the absence of a benefit sharing solution many African countries … either already control access to DSI or have initiated measures to do so" (African Group 2019). The African Group is vocal in establishing a link between ABS, DSI and Sustainable Development Goals and have indicated that its acceptance of the Post 2020 Biodiversity Framework may hinge on whether the final document includes benefit sharing for DSI (Karger et al. 2019).

Uganda, Kenya, Zambia and Malawi all include information as the subject matter of ABS obligations, however, none of the legal frameworks explain what type of information could fall within the obligations and how the benefit sharing, traceability and reporting arrangements would work in practice. For example, a narrow scope or proximity to the genetic resource would be nucleotide sequence data associated with transcription (DNA and RNA) and progressively broader scope could include this information as well as proteins, metabolites, biochemical pathways and even information on ecological pathways (Houssen et al. 2020). According to a CBD study on DSI, determining the origin of information will depend on the proximity of information to the underlying genetic resource, which is possible for the narrow scope but impossible with subsidiary information such as ecological pathways and behavioral data (Houssen et al. 2020).

There is no peer-reviewed literature about how Uganda, Kenya, Zambia and Malawi governments interpret the information scope of their ABS laws and how their processes and infrastructure (e.g. contractual mechanisms, material transfer agreements, ABS checkpoints for compliance) might be adapted to tracing the movement of information as opposed to physical materials. None of the literature includes how these might work in practice for DSI relating to aquaculture breeding and biotechnology research. There is gray literature (outside scope of this review) about government positions on DSI at points in time, although the accuracy and currency of this literature may vary as the DSI policy debate evolves. For example, the African Group submission to the CBD on DSI and ABS noted that under the framework in Malawi, the use of "any forms of DNA/RNA sequences or sequence data in any format including in microbiological, digital or synthetic or in any other format associated with genetic resources to trigger benefit sharing obligations" (African Group 2019). It notes there is an obligation to make sequence data available online and that under ABS contracts there should be a clause

that the "government of Malawi has commercial rights or other further use rights in products or processes developed based on the research results or this DSI, and any use requires a contract of use with the Government of Malawi" (African Group 2019). Uganda's submission to the CBD on DSI proposes the use of metadata, DSI access and use agreements, incentives and capacity building as possible DSI policy approaches for consideration of the Conference of the Parties in 2022 (Ugandan Government 2021).

Recognizing the importance of traditional knowledge associated with genetic resources held by Africa's Indigenous Peoples and Local Communities, African countries have also been instrumental in promoting and protecting the role of traditional knowledge and rights of Indigenous Peoples and Local Communities in ABS forums (Coolsaet and Pitseys 2015). Despite this, there were only four articles that examined how Uganda, Kenya and Tanzania manage traditional knowledge under their ABS laws, none of which mentioned considerations for traditional knowledge associated with aquaculture genetic resources. The reviewed countries have diverse approaches to addressing the key challenge of how to ascertain the knowledge holder from whom prior informed consent is required. In Malawi, the government must ensure that prior informed consent has been obtained from the relevant community, whereas the procedures in Uganda allow for government and local community representatives to authorize access and conclude benefit sharing agreements. Kenya has a registration procedure for accessing traditional knowledge that is protected as a form of intellectual property. Knowledge holders are identifiable through the register, however even if knowledge is not registered, a person would still need to obtain the prior informed consent from the relevant holder before use. In Zambia, a person must obtain the prior informed consent from a community holder or a government agency acting on behalf of the holder, but it is unclear whether there are procedures for ascertaining the right knowledge holder.

Equally diverse are the country approaches to defining the scope of the traditional knowledge that falls within ABS obligations. The range of UN forums developing frameworks for traditional knowledge protection and use including human rights, intellectual property and biodiversity forums (see section 1) have a broad range of interpretations of the scope of traditional and local knowledge that fall within the various frameworks (Mulalap et al. 2020). In the case of biodiversity of aquaculture genetic resources, traditional knowledge may extend not only to uses of the materials for breeding purposes but also to broader ecosystem-human interactions. On a plain reading of the national laws of reviewed countries, Kenya, Uganda and Zambia have broad definitions of traditional knowledge, which are likely to include any knowledge associated with the management and use of aquatic resources including aquaculture and marine conservation. Malawi has a narrow focus, only applying to knowledge associated with the genetic resource. There is broader literature outside scope of this review about initiatives to improve awareness of the use of traditional knowledge from African countries, such as Biocultural Label Initiatives, which may assist with transparency and traceability in data repositories (Liggins et al. 2021). Until there is literature, however, about the how African ABS laws are intended to (or do) affect traditional knowledge associated with aquaculture activities, users may inadvertently misuse the knowledge without fair and equitable sharing of the benefits with the knowledge holders.

5. Conclusion

This paper reviewed the ABS measures and ABS literature for Uganda, Kenya, Tanzania, Malawi and Zambia using a systematic quantitative methodology. These countries were chosen because they are key aquaculture producing countries in Africa and have dedicated ABS laws. The main findings were that the literature was limited with key gaps on the implications of ABS for the conservation and sustainable use of genetic resources relevant to aquaculture and the management of intangible aspects of genetic resource use including DSI and traditional knowledge associated with aquaculture genetic resources. These significant gaps risk undermining effective biodiversity and aquaculture policy development because there is no published and peer-reviewed evidence about whether ABS is achieving its conservation, sustainable use and equity objectives in these countries for genetic resources generally, and aquatic genetic resources specifically.

The extent to which policy makers in each country are approaching ABS implementation for aquaculture sectors and the information they are basing their decisions on is unclear. Key questions include:

- To what extent have the reviewed countries accommodated the importance of genetic resources for food and agriculture, including aquaculture, and their special role of food security when developing and implementing their ABS measures in accordance with article 8(c) Nagoya Protocol (FAO 2021f)?
- Does ABS apply to all or only some aquaculture applications and research (e.g. selective breeding,

grow-out, sea ranching, biotechnology, conservation, taxonomy)?
- To what extent do ABS measures capture traditional knowledge associated with aquaculture (e.g. regarding genetic resources only or broader knowledge)?
- How do the countries manage DSI associated with aquaculture genetic resources?

Considering the growing importance of aquaculture in the reviewed countries for livelihoods and food security, there is a need for urgent research and analysis to address the practical positive and negative effects of ABS on the conservation and sustainable use of aquaculture genetic resources and how the intangible aspects of genetic resource could be managed to achieve equitable outcomes for the providers of resources and knowledge.

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