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A review of access and benefit-sharing measures and literature in key aquaculture-producing countries

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Abstract

Countries increasingly use access and benefit-sharing laws as a tool for the conservation and sustainable use of biological resources and associated traditional knowledge. These laws generally require the recipient of resources/knowledge to obtain the provider country's prior informed consent before collection, use or transfer and to share the benefits from their use with the provider. The aim of this literature review is to comprehensively analyse access and benefit-sharing laws and literature about the top five aquaculture-producing countries – China, India, Indonesia, Viet Nam and Bangladesh – to identify research trends and gaps in relation to accessing and sharing the benefits of aquaculture genetic resources and associated traditional knowledge. Using a systematic quantitative literature review methodology, we found only 5% of the literature examined the implications of access and benefit-sharing for aquaculture and these only related to publications about India's arrangements. While the other countries had literature about their legal measures and literature about informal genetic resource sharing practices in aquaculture, none of them connected the two research topics. None of the countries had literature analysing the implications of access and benefit-sharing in relation to traditional knowledge associated with aquaculture. We conclude that given these are the top global producers accounting for up to 80% of all aquaculture products, urgent research is needed to fill the literature gaps to assess whether access and benefit-sharing as a legal/policy tool is achieving conservation and sustainable use goals for aquaculture genetic resources.

Key words: access and benefit-sharing, aquaculture genetic resources, convention on biological diversity, Nagoya Protocol, traditional knowledge.

Introduction

Humans face the enormous challenge of being able to provide food and livelihoods to a population well over 9 billion people by 2050. Aquaculture is the fastest growing food production sector, growing 5.3% between 2001–2018 and currently playing a critical role for the food, nutrition and employment of millions of people (FAO 2020a). The global share of aquaculture in Asian countries was 88.7% (~72.8 million metric tonnes, Mt) in 2018 (FAO 2020a) with eight out of the top 10 aquaculture producers found in Asia. Employment in aquaculture was concentrated primarily in Asia (96% of all aquaculture engagement), followed by the Americas (1.9%) and Africa (1.9%) (FAO 2020a). To support the expected growth in production levels of over 30% by 2030 that is required for improved food security and livelihoods (FAO 2020a), the aquaculture sector has an increasing need for selective breeding programmes to improve efficiency and reduce pressure on wild sources of fingerlings (Olesen *et al.* 2015). Access to (e.g. collecting, using and sharing) aquatic genetic resources and intangible aspects such as digital sequence information and traditional knowledge is essential for increased research and development needs related to selective breeding, biotechnology and conservation initiatives (FAO 2020b). These resources and knowledge, however, are becoming subject to the complex array of national and international biodiversity and trade regimes that restrict their free use

and exchange and require sharing of the benefits from their use with the provider of the resources/knowledge. These regimes include access and benefit-sharing (ABS).

The ABS legal concept, originally articulated in the 1992 *Convention on Biological Diversity* (CBD), generally requires a recipient of a genetic resource and/or traditional knowledge associated with genetic resources, to obtain the provider country's prior informed consent (usually through a permit) before accessing the resource and often with conditions. The recipient must share the benefits from the use of the resource with the provider in a fair and equitable way according to mutually agreed terms (usually by way of contract). Some countries have implemented the concept using different procedures such as Brazil's registration system that captures end-users of genetic resources and knowledge with pre-defined activities that trigger benefit-sharing, rather than consent procedures at the time of collection or use (da Silva & de Oliveira 2018).

Since the CBD entered into force in 1993, there have been ever increasing analyses of laws regulating access to genetic resources and sharing the benefits from their use for conservation, global food and health security (e.g. Kamau *et al.* 2015; Dedeurwaerdere *et al.* 2016), particularly in relation to the agriculture and pharmaceutical sectors (e.g. Chiarolla *et al.* 2013). Only recently, however, has the collection, use and sharing of genetic resources and associated knowledge for aquaculture become a focus of the regulation debate in response to the increasingly important role of aquaculture for global food production. For example, Rosendal and Andresen (2016) investigated the views of Norwegian aquaculture actors about access to improved breeding materials and the effect of regulatory regimes including ABS. Only one study provides a broad review about how ABS regimes relate to, and affect the use and exchange of, aquaculture genetic resources (Humphries *et al.* 2018).

Other international agreements that shape national laws concerning the use and exchange of aquaculture genetic resources are:

- *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', which operationalises the CBD's ABS framework and establishes significant innovations including rules for traditional knowledge associated with genetic resources and measures for cross border monitoring and compliance);
- *Agreement on Trade-Related Aspects of Intellectual Property Rights* ('TRIPS'), which sets minimum standards of protection for a range of intellectual property including patents and copyright that are increasingly becoming relevant to aquaculture (Humphries 2015); and
- *United Nations Convention on the Law of the Sea* ('UNCLOS'), which applies to living resources within and beyond national jurisdictions and is currently the subject of negotiations for a legally binding instrument on the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction (Humphries 2017; UN 2019).

Significantly, the Nagoya Protocol provides that when developing and implementing ABS measures, Parties must 'consider the importance of genetic resources for food and agriculture and their special role of food security' (article 9 (c)). This does not go so far as imposing an obligation for special measures (e.g. simplified access procedures), but it does require Parties to consider special treatment for access to and sharing the benefits from the use of genetic resources and traditional knowledge for food and agriculture, including aquaculture (Greiber *et al.* 2012).

Aquaculture has demonstrated exponential growth in the Asian region, which depends on the sector for livelihoods, economic development and food security. The share of aquaculture in Asian fish production (excluding China) increased to 42% in 2016, up from 19.3% in 2000 (FAO 2020a). China is by far the highest food fish producing nation globally (57.9% of global finfish aquaculture production), followed by India (8.6%), Indonesia (6.2-6%), Viet Nam (5.0%) and Bangladesh (2.9%) (FAO 2020a). Most of the aquaculture production in Asia is focused on inland aquaculture, which provides 51.3 Mt, primarily finfish (91.5%), with much smaller amounts of crustaceans (7%) and molluscs (0.5%) (FAO 2020a). Over 38% of aquaculture in Asia is focused in marine and coastal areas (30.7Mt) composed mainly of molluscs (56%), crustaceans (19%) and finfish (24%) (FAO 2020a). The top seven seaweed-producing countries are all from Asia (China, Indonesia, South Korea, Philippines, North Korea, Japan and Malaysia) and together produced 99.2% of the global production of 32.4 Mt in 2018 (FAO 2020a).

The overall aim of this review is to identify research trends and gaps in literature relevant to ABS of aquaculture genetic resources and associated traditional knowledge in key aquaculture countries. Specifically, it aims to address the following research questions: (i) what is the state of ABS measures and literature about these measures in each country; and (ii) to what extent does the literature examine the implications of ABS measures for the conservation and sustainable use of aquaculture genetic resources and associated traditional knowledge?

The criteria for selecting the case studies for the review were Asian countries that are: (i) in the top 10 producing countries for either farmed aquatic animals (fish, crustaceans, molluscs, etc.) and/or aquatic plants; and (ii) which also have dedicated ABS laws or draft ABS laws (Table 1). Following an explanation of the methods in

Section 2, Section 3 outlines the state of aquaculture, ABS measures and ABS literature for China, India, Indonesia, Viet Nam and Bangladesh. Section 4 is a comparative discussion about trends and gaps in the ABS literature concerning genetic resources and traditional knowledge for use in aquaculture in these countries.

Methods

This is a mixed method review, using a Systematic Quantitative Literature Review (SQLR) method (Pickering & Byrne 2014) to review ABS literature in the five reviewed countries and a traditional narrative review for the literature on ABS and aquaculture in each country. The SQLR systematically identifies peer-reviewed literature from online databases and quantifies the data, summarising the status of the literature so that the results are reliable, quantifiable and reproducible. By providing a commentary on the literature, the SQLR highlights knowledge gaps and reasons why more research is needed to fill them. The data collection methodology is described in more detail below and is summarised in Figure 1.

Given the paucity of literature about ABS measures in the reviewed countries, we also conducted a doctrinal legal analysis of the relevant ABS legislative instruments in each country (and draft legislation in China). We obtained consolidated legislation (including amendments) through the database WorldLII and/or the relevant country's parliamentary website.

Table 1 Asian countries selected for review with data on their animal and plant production in Mt (million tonnes)

Country	Animal (Mt)	Plant (Mt)	Primary ABS Legislation
China	49.90	18.50	Regulation of Access to Genetic Resources and Benefit-sharing 2017 (draft)
India	7.07	0.0053†	Biological Diversity Act 2002 Biological Diversity Rules 2004 Guidelines on Access to Biological Resources and Associated Knowledge and Benefits Sharing Regulation 2014
Indonesia	5.40	9.30	Regulation of the Minister of Environment No. 34/MenLHK/ Setjen/Kum.1/2017 on Recognition and Protection of Local Wisdom in The Management of Natural Resources and the Environment (including provisions for utilisation of traditional knowledge associated with genetic resources)
Viet Nam	4.10	0.019†	Law on Biodiversity 2008 No. 20/ 2008/QH12 Decree No. 65/2010/ND-CP on Detailed Regulations and Guidelines for Implementation of Some Article of the Law on Biodiversity (provisions on ABS annulled by Decree No. 59/2017 article 28) Decree No. 59/2017/ND-CP on the Management of Access To Genetic Resources and The Sharing of Benefits Arising From Their Utilization (substituting provisions in Articles 18, 19 and 20 of the Decree No. 65/2010/ ND-CP) Decree No. 155/2016/ND-CP on Penalties for Administrative Violations Against Regulations on Environmental Protection
Bangladesh	2.40	No data	Biodiversity Act 2017

Data are from FAO (2020a) and FAO (2019) and their ABS legislation.
†Production that is not in the world ranking of top ten producers.

Data collection

For the stage 1 'global library', we searched five commonly used databases for this field (Scopus, Web of Science, ProQuest, Google Scholar and HeinOnline) for articles relating to ABS published between January 1980 and December 2019. Our initial search used the search term [(''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")]. We limited our search to journal articles, books, book chapters and early access papers published in English. We excluded grey literature, editorials, comments, reviews, white papers and conference proceedings because some of the characteristics of this literature make it difficult to search systematically, including analysing the credibility and quality of website information (Benzies *et al.* 2006) We entered the results from the databases into a single Endnote library (n = 1287). We then excluded duplicate references and unrelated or irrelevant articles (n = 520). Examples of exclusions are (i) non-academic articles, for example grey literature; (ii) articles where ABS is only mentioned in passing (e.g. for further research); and (iii) articles where ABS is only used in keywords and/or references. The final global library contained 757 articles. This library was used to examine global patterns and identify references analysing ABS measures at the national level (n = 290), which was then further refined to determine ABS references for the five review countries (n = 90).

In addition to the stage 1 global search on ABS, we also conducted specific country-level searches for the five focus countries to obtain an overview of genetic resource and/or traditional knowledge collection, use and sharing relevant to aquaculture in each country where ABS was mentioned

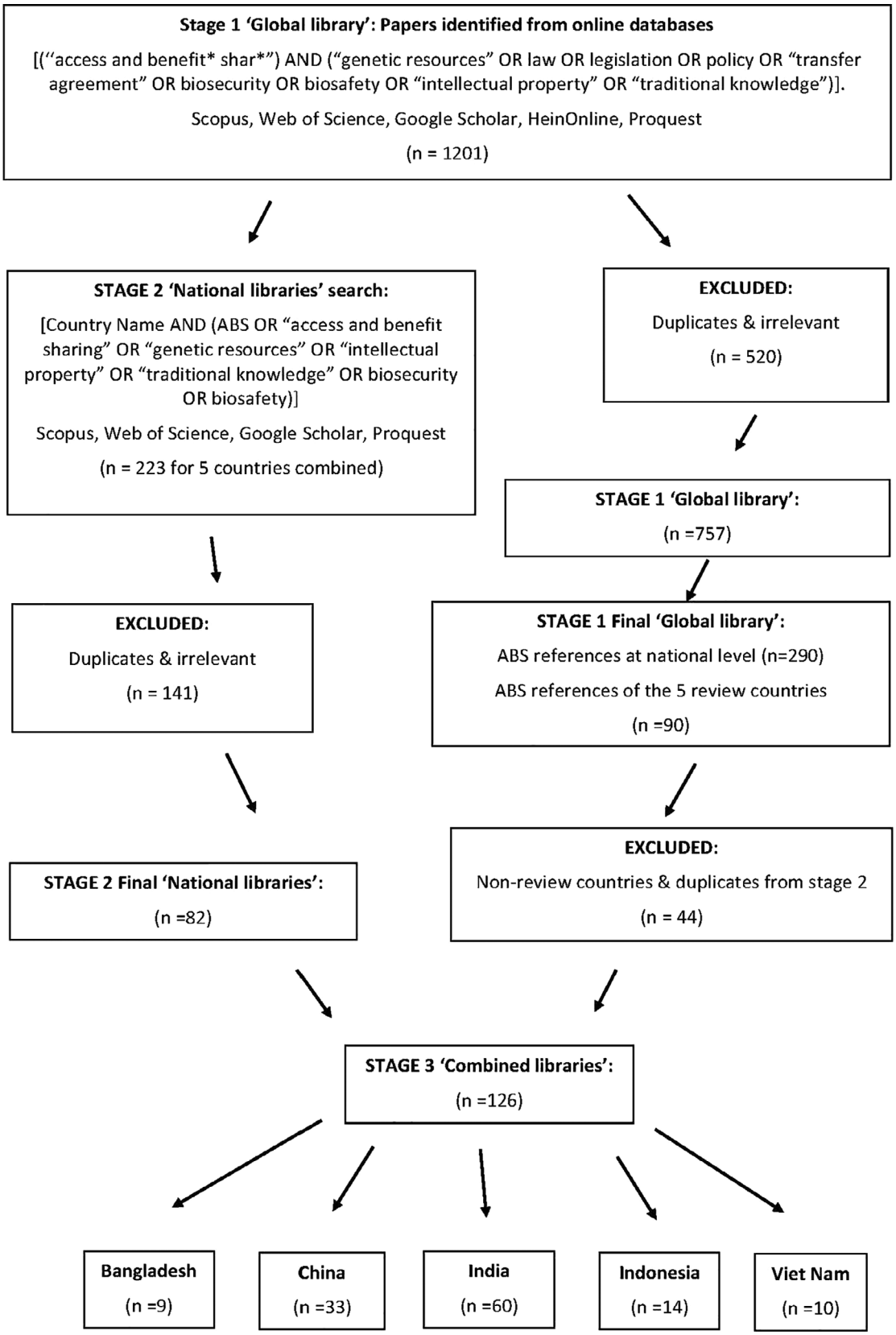

Figure 1 Preferred Reporting Items for Systematic Review Recommendations (PRISMA) flow chart outlining the process for compiling this review (modified from Moher *et al*. 2015). *n* = number of articles.

(stage 2 'national libraries'). These searches were done using Google and the online databases ProQuest, Web of Science, Scopus and Google Scholar. 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 April 2020. The 'national libraries' included all peer-reviewed publications (articles, book chapters, conference papers and books). There were a total of 223 publications after duplicates and irrelevant papers were removed. We excluded publications that did not focus on genetic resource and/or traditional knowledge collection, use and/or transfer. For example, for the genetic resource papers we excluded articles focusing on aquaculture production methods, feed, waste, disease, effects of aquaculture on ecosystems and experiments on genetic resources, for example growth performance. For the traditional knowledge papers, we included papers on traditional knowledge and ABS and traditional knowledge systems broadly relevant to aquaculture, including observations about species distributions, behaviour, production methods and fisheries/aquaculture management.

We manually entered all references from the global library (ABS references of the five review countries) and the national libraries for each country to a combined Endnote library ($n = 126$), which excluded duplicates from both libraries. The individual country-level Endnote libraries form the basis of the country-specific literature reviews: Bangladesh ($n = 9$), China ($n = 33$), India ($n = 60$), Indonesia ($n = 14$) and Viet Nam ($n = 10$).

ABS measures and research in key aquaculture-producing countries

Of all of the ABS law and policy publications reviewed in stage 1 ($n = 757$), only 38% (290) mentioned national laws or their implementation and most of these were not detailed analyses. The bulk of articles examined the relevant international agreements and general challenges with the ABS concept such as how to manage information separately from the physical material (e.g. Lawson *et al.* 2020) or how to manage traditional knowledge associated with genetic resources (e.g. Robinson & Raven 2020).

Each of the countries reviewed analysed the development and implementation of ABS policy and law to varying degrees. The five countries in the review can be divided into two categories:

- those with detailed ABS laws and institutional arrangements – India, Viet Nam and Bangladesh; and
- those with *ad hoc* biodiversity laws and dedicated ABS laws under development – China and Indonesia.

Out of the 126 papers that related to the collection, use and/or transfer of genetic resources or traditional knowledge in the five review countries, 93 (74%) specifically related to ABS law/policy but only six (5%) examined the implications of ABS for aquaculture. Of the 93 papers on ABS measures, 25 (21%[1]) examined intellectual property and 29 (23%) examined traditional knowledge in the national context. For the 33 papers that do not mention ABS measures but which relate to aquaculture genetic resources, 29 (23%) examined informal genetic resource use sharing practices in aquaculture. Three quarters of all the papers concerned India (48%) and China (26%), with relatively few for Indonesia, Viet Nam and Bangladesh.

This section briefly outlines for each reviewed country: the state of aquaculture and the country ABS laws that apply to aquaculture sectors; and the literature review results.

China

Aquaculture and ABS

China has a long history of aquaculture dating back more than 2000 years. Large-scale commercial farming began after the founding of the People's Republic of China in 1949. Today, China is the largest aquaculture-producing country in the world (FAO 2020a). In 2018, China produced almost 50 million of the 82 Mt of farmed aquatic animals, 61% of global production (FAO 2020a). The rapid development of aquaculture in China has not only contributed to improved food supply but has also generated employment and income for the Chinese people. In 2018, aquaculture accounted for just under 5 million jobs, particularly in rural areas (FAO 2020a). The traditional polyculture and integrated fish farming system, well known worldwide, has been challenged by the culture of high-value species using monoculture systems with high commercial feed input (Edwards 2006). Aquaculture genetic resources are obtained from natural breeding (e.g. spontaneous spawning) or different degrees of intervention from semi-artificial breeding (e.g. hormone-induced fish to spawn on their own) to artificial breeding (e.g. stripping eggs and sperm from the fish using in vitro fertilisation, or artificial insemination or more complex physiological or genetic interventions) (FAO 2017; Gui *et al.* 2018; Beirão *et al.* 2019).

China is a party to the Nagoya Protocol but does not yet have dedicated ABS legislation. In 2017, the government released the Regulation of Access to Genetic Resources and Benefit-sharing (Draft Regulation). It applies to genetic resources, derivatives and traditional knowledge of local communities (Chinese Government 2017) that 'exist within

[1]Percentages in this paragraph relate to the category/topic as a percentage of the entire body of literature examined in section 3 (126 papers).

the People's Republic of China and other waters within its jurisdiction' (articles 1 and 2).

Under the current Draft Regulation, the trigger for authorisation appears to be the activity of 'access'. While all access to genetic resources and associated knowledge would be subject to: (i) the prior informed consent of the holders of the resources/knowledge; (ii) ABS agreements; and (iii) registration or approval procedures (article 18), there would be simplified arrangements for domestic users (article 19). Both access and utilisation of genetic resources by foreign entities must be conducted within Chinese territory with Chinese collaborators (article 20). One exception to the registration and approval procedures would be access and use of genetic resources by 'farmers, pastoralists and fisherman according to their traditional way of life' (article 30). This may include aquaculture farmers. Significantly, draft article 27 provides that the subsequent transfer of genetic resources and traditional knowledge accessed before or after the Regulation enters into force will require registration and approval under the Draft Regulation. This means that aquatic genetic resources currently accessed may retrospectively be subject to ABS obligations if the Draft Regulation becomes law.

Literature review results

With 33 publications, China has over a quarter of the literature relating to the use and sharing of genetic resources and traditional knowledge (26%) in all the reviewed countries (Table 2). Of these, 22 consider ABS law and policy, including 16 that propose development of ABS legislation and/or policy in China (e.g. Qin 2009; Wu & Xue 2017).

Zheng (2019) provides a current assessment of the complexity and uniqueness of the Chinese national circumstances when developing its ABS measures, including the complexity of administrative responsibility for various categories of genetic resources such as agriculture and fisheries departments and traditional knowledge. Xue and Cai (2009) examine the patchwork of existing legislation that relates to procedures for access to genetic resources, finding that most are inconsistent and lacking for some categories including fish genetic resources. One publication focused on the implications of legislative approaches of ABS of foreign countries on China (Qin 2008). While eight publications explore the potential effect of the ABS legal concept on China's genetic resources if legislation were implemented in China (e.g. Wenying & Wanchun 2007; Vernooy & Ruiz 2013; Blackburn *et al.* 2014), none of them related to genetic resources for use in aquaculture.

Only one article (Cai 2017) explores the relationship between ABS and intellectual property in China. The author argues that China (as a biologically rich country with cutting-edge biotechnology) needs to positively involve intellectual property laws when developing biodiversity arrangements. The author notes some limitations of protection of biological diversity through intellectual property and suggests developing ABS regulations, requiring disclosure of origin in patent legislation and joint partnerships with Chinese institutions for biodiscovery among other things.

Out of the 22 publications on ABS, surprisingly few (four) examine traditional knowledge and ABS despite China's long history of aquaculture and traditional medicine. Most relate to traditional medicinal plants and farmer knowledge of crop species (e.g. Fu *et al.* (2018); Yang *et al.* 2018b; . There were no articles on ABS of traditional knowledge associated with aquaculture genetic resources.

China, however, has the most publications (11) that relate to the collection, use and transfer of aquaculture genetic resources (informal practices, not specifically referring to ABS). Publications relate to the source of seed, fingerlings and/or broodstock for genetic improvement including for carps (Jeney & Jian 2009), molluscs (Guo 2009), scallops (Guo & Luo 2016) and crabs (Sui *et al.* 2011; He *et al.* 2014). Several chapters in the book edited by Gui *et al.* (2018) describe fish farming practices including genetic resource exchanges associated with freshwater species (e.g. Li & Xia 2018; Xie *et al.* 2018; Yang *et al.* 2018a). Ren *et al.* (2018) examine how rice–fish farmers preserve genetic diversity of local common carp through local exchanges and developments. They demonstrate that

Table 2 Country-specific publications concerning ABS and aquaculture

Country	Total # papers	% of papers	ABS law or policy	ABS and IP	Implications of ABS for aquaculture	Informal GR sharing practices in aquaculture	TK and ABS
China	33	26%	22	1	0	11	4
India	60	48%	58	20	6	2	18
Indonesia	14	11%	7	4	0	3	7
Viet Nam	10	8%	4	0	0	6	0
Bangladesh	9	7%	2	0	0	7	0
Total	126		93	25	6	29	29

GR, genetic resources; IP, intellectual policy; TK, traditional knowledge.

thousands of small farmer households interdependently obtained fry and parental carps for their own rice–fish production, resulting in a high gene flow and large numbers of parent carps distributed.

There is a significant gap in the literature about the effect on the China's aquaculture sector and the global aquaculture sector if China implements its Draft Regulation. If China was to implement retrospective ABS legislation, there could be restrictions on the collection, exchange and new and continued uses of previously collected aquaculture genetic resources and associated traditional knowledge by locals (albeit through simplified administrative mechanisms) and by foreigners, who need to collaborate with locals in their breeding and development programmes. It may also have broad implications for global aquaculture production if China decides to restrict access to, or require benefits from the use of, its germplasm which it has distributed throughout the world.

India

Aquaculture and ABS

India has a long history of aquaculture, dating from the fourth century. Currently, India is the second largest aquaculture producer in the world, behind China, with global contribution in 2018 of 8.7% (FAO 2019a). The major contribution comes from freshwater aquaculture, whose share has gone up from 46% in the 1980s to over 88% in recent years (Kasozi *et al*. 2017; FAO 2019a). India earned about US$ 5 billion in 2015–16 through aquaculture exports (10% of total export and 20% of agriculture export) (Muthiah 2017). Carp culture is the largest component of freshwater aquaculture in India (FAO 2019a) and in recent years, there has been rapid development of techniques of seed rearing and grow-out culture of carps with assured supply of quality seed (Kasozi *et al*. 2017). India has invested heavily in research and technological advancements to improve fish production and meet projected demand (Muthiah 2017) through mobilising farmers/stakeholders, technological innovations and policy/support mechanisms (see de Jong 2017; Kasozi *et al*. 2017; Adhikari *et al*. 2018).

India's Central Parliament passed the *Biological Diversity Act in 2002* (ABS Act) and issued rules for implementation under the *Biological Diversity Rules 2004*. In response to the implementation of the Nagoya Protocol, the Central Parliament gazetted its *Guidelines on Access to Biological Resources and Associated Knowledge and Benefits Sharing Regulations* 2014, which has detailed provisions about procedures and benefit-sharing formulas for certain types of access. India implements the ABS Act through a three-tier institutional mechanism, with the National Biodiversity Authority (NBA) at the national level, State Biodiversity Boards (SBBs) at the State government level and the Biodiversity Management Committees (BMCs) at the local level (Indian Government 2017).

The ABS Act applies broadly to wild and domesticated *in situ* and *ex situ* biological resources and associated knowledge 'occurring in India' (sections 2 & 3), including traditional knowledge, although it is unclear whether it applies to digital sequence information and resources located in private conditions or collections. For foreigners (non-citizens, non-residents and organisations not registered or incorporated in India), there is an extensive process for prior informed consent in the form of a benefit-sharing agreement with the NBA for using resources and knowledge for commercial, research, bio-survey and bio-utilisation purposes (section 3), unless they are collaborating with approved Indian institutions (section 5). There is a simplified process of notification to the SBBs for Indian nationals for the above purposes, other than for 'commercial utilisation', transferring the results of research or applying for intellectual property protection (sections 6, 7). 'Commercial utilisation' does not include conventional breeding or traditional practices in use in any agriculture, horticulture, poultry, dairy farming, animal husbandry or bee keeping (section 2(f)). A plain reading of animal husbandry would include aquaculture; however, it is unclear whether the culture of aquatic plants would be included. benefit-sharing agreements are only required for use by foreigners, with benefits flowing to the NBA, the BMCs and/or benefit claimers, who are 'the conservers of biological resources, their by-products, creators and holders of knowledge and information relating to the use of such biological resources, innovations and practices associated with such use and application' (section 2(a)).

Literature review results

India has the largest body of literature (60 articles) relating to the ABS of genetic resources of all the countries examined (47%) (Table 2). There are 58 articles examining ABS measures and two relating to informal collection, use and transfer of aquaculture genetic resources (without specifically referring to ABS). Of the 58 articles on ABS, 20 relate to intellectual property and 18 relate to traditional knowledge associated with genetic resources.

Prajeesh (2017) examines the internationally recognised certificates of compliance in India, which demonstrate compliance with India's ABS measures, including one related to green algae for its commercial potential, one related to prawn materials and another related to yellow clam materials for obtaining intellectual property rights. The author argues that India is leading the way in issuing certificates and making them available to the ABS Clearing House. Pushpangadan *et al*. (2017) argues that India was the first country that experimented with a benefit-sharing

model that implemented the spirit of the CBD's traditional knowledge provision. Muzaka and Serrano (2019), however, note the few benefit-sharing agreements that have been concluded with communities lack community involvement in the approval process. The authors argue that India's approach to ABS has been shaped not by local community needs to share in the benefits of the use of their resources and knowledge but by the commitment of the Indian state to the development of a biotechnology sector that is competitive in global markets.

Twenty of the ABS articles relate to intellectual property (e.g. Aggarwal & Satpute 2014; Elsy & Ram 2015; Dhanaraj & Sharma 2020), all but one relating to terrestrial animal and plant genetic resource ABS. Ramanna-Pathak (2015) analyses the impact of intellectual property protection and access to resources in India's shrimp aquaculture sector. The author explores India's need for access to foreign-improved breed material and technologies but also the need to create incentives for local companies and institutions to invest in genetic material. The paper outlines policy options for India that ensure a balance between intellectual property protection over and access to aquatic resources.

Eighteen articles relate to traditional knowledge (e.g. Torri 2011; Varma 2017), mostly in relation to plant genetic resource ABS. Pushpangadan *et al.* (2017) propose 'the first' model of benefit-sharing that supports traditional knowledge. They conclude the major challenge facing policy makers in India is to give adequate attention to the administrative as well as the legal aspects of intellectual property, benefit-sharing procedures and conservation and sustainable use of biodiversity and associated traditional knowledge. Demunshi and Chugh (2010) explore the role of traditional knowledge in marine bioprospecting, primarily in pharmaceutical, nutraceutical, cosmeceutical and bioenergy sectors, but did mention progress in aquaculture without further elaborating examples.

Of the 58 ABS articles, six examined the implications of ABS laws on aquaculture genetic resources. Ramanna-Pathak (2012) provides an example of benefit-sharing of seaweed (*Kappaphycus alvarezii*) aquaculture genetic resources and highlights criticisms of India's administrative approach, including failing to consult with or distribute monetary benefits to the communities entitled to benefit-sharing. Three other publications (Jacob & Reddy 2015; Thomson & Achalender 2015; Valderrama *et al.* 2015) investigate the *Kappaphycus alvarezii* example and analyse the socio-economic development of the community growers from the perspective of implementing India's ABS laws and how fair and equitable sharing of benefits between providers and users can be achieved.

Two further articles relate to informal collection, use and sharing of aquaculture genetic resources in India. Singh (2015) sets out practices of the collection of seed and broodstock from the rivers and lakes of the Indian Himalayas and more recent use and exchanges from pond-raised brooders. Kasozi *et al.* (2017) argue that India has good supply of quality seed and techniques of seed rearing of carps have been rapidly developed over recent years, but the government should diversify with emphasis of seed production of other valuable species like catfish and murrels. They point out there are many policy initiatives to boost aquaculture growth including the establishment of seed hatcheries and the dissemination of technological know-how to farmers in exchange for sharing indigenous technical knowledge with researchers (Kasozi *et al.* 2017).

While India is the only reviewed country with literature concerning the implications of ABS specifically for aquaculture (mainly seaweed), there remain significant research gaps. The continued growth of the aquaculture sector to reach the government's production and economic targets will require, among other activities, improved seed quantity and quality for a range of animal, plant and microorganism genetic resources. While there is literature about breeding and biotechnology advances, there is no mention of any permit, reporting, tracking, or monitoring requirements for any aquaculture organisation/genetic resource users in the country. The importance of traditional knowledge associated with plant genetic resources is well documented in India (Pushpangadan *et al.* (2017). There is, however, no published information on the actual traditional knowledge associated with aquaculture species and practices and/or ABS of the associated traditional knowledge.

Indonesia

Aquaculture and ABS

Indonesia is currently the third largest aquatic animal aquaculture producer (5.4 Mt) in the world behind China and India, and the second largest aquatic algae producer (9.3 Mt) behind China (FAO 2020a). Indonesia's rapid growth in the farming of tropical seaweed species (*Kappaphycus alvarezii* and *Eucheuma* spp.) has been the major driver in the global increase in seaweed production since 2010 (FAO 2020a). Excluding the principal marine production from seaweed (almost 70% of total aquaculture production), freshwater aquaculture dominates the sector (65% of animal production) followed by brackish water ponds (33%) and marine animal production (1%) (FAO 2019b). In 2017, freshwater finfish species, including tilapia, catfish and carp, dominated production (BPS 2018).

Although Indonesia ratified the CBD in 1994 and the Nagoya Protocol in 2014, it does not yet have dedicated ABS laws for its genetic resources. There is a patchwork of legislation that applies to the collection and use of its biodiversity with the key being *Law Number 5.1990 on*

Conservation of Living Resources and their Ecosystems. Indonesia has not yet finished drafting the Revised Law Number 5/1990 to bring it in line with the Nagoya Protocol (Mardiastuti 2019).

The *Regulation of the Minister of Environment No. 34/MenLHK/Setjen/Kum.1/2017 on Recognition and Protection of Local Wisdom in The Management of Natural Resources and the Environment* contains rules on obtaining data about traditional knowledge and genetic resources. This includes a requirement for negotiating an agreement with the community, complying with the community's local protocol for obtaining consent and agreeing to share profits under a benefit-sharing agreement (article 24).

Literature review results

Indonesia has 14 publications relevant for the review but there is evidence of a greater number of articles in Bahasa Indonesian (see, e.g., Mardiastuti 2019) (Table 2). Of the publications in English, seven specifically relate to the development of ABS law and policy (of which all seven related to traditional knowledge ABS and four related to intellectual property), and three relate to informal aquaculture genetic resource use and sharing. None of the articles specifically relate to ABS measures in relation to aquaculture genetic resources and traditional knowledge.

Most of the seven articles on ABS measures investigate the challenges and the need for implementing ABS regulations in Indonesia (e.g. Latifa 2015). Mardiastuti (2019) highlights challenges for implementing ABS regulations in Indonesia, including unclear institutional arrangements specifying which authorities have responsibility, a lack of data management relating to genetic resources and traditional knowledge, a lack of ABS checkpoints for monitoring and compliance of genetic resource movements and a lack of specific ABS regulation. She suggests a reason for the delay in amending Indonesia's biodiversity law is that it requires a merging of draft laws under the responsibilities of different Ministries. She points out examples of biopiracy of Indonesia's resources and knowledge and concludes that Indonesia will continue to miss out on international collaborations for bioprospecting and commercial use of its resources and knowledge unless the institutional arrangements and regulation are in place.

There were seven papers relating to traditional knowledge and ABS measures (e.g. Kusniati *et al.* 2016). All of the ABS papers concerning intellectual property (four) also focused on traditional knowledge (e.g. Susilowati & Hermono 2017). Rohaini (2016) argues that in order to establish ABS in Indonesia, there are other factors that first need to be addressed. These include lack of public awareness of the relevance of ABS, lack of written evidence and Indigenous people's data, lack of regulation to protect the knowledge and the need to recognise the rights of indigenous communities over knowledge and resources. Susanti *et al.* (2020) examine the proposed draft Intellectual Property Law on the Protection of Traditional Cultural Expressions. They argue that the state is concerned with protecting traditional knowledge and cultural expressions for its intellectual property and commercial values, while the local communities are more concerned with preserving and promoting it as national cultural heritage, emphasising their inherent spiritual, cultural identity and social-bonding values. They argue the draft protection law may fail because, among other reasons, it overlooks indigenous community rights, customary law and the circumstance that Indonesian users are excluded from the proposed benefit-sharing condition despite being the largest user of Indonesian traditional knowledge. They argue among other things that the law should encourage sharing of knowledge between indigenous communities and ensure that the common use of biological and other resources relating to traditional knowledge remains free. Irawan (2017) recommends among other things, also pursuing non-legal efforts such as tracking, preserving, documenting and digitising the knowledge in a traditional knowledge database.

Indonesia only had three publications about the informal collection, use and exchange of aquaculture genetic resources (e.g. Yi *et al.* 2018). Fachry *et al.* (2018) point out that in Indonesia, the source of fingerlings is highly concentrated, where small-scale hatcheries are clustered in the Buleleng Regency in Bali (95% of hatcheries) and Situbondo in East Java (88% of hatcheries). These areas export large numbers of fingerlings, for example 2.5 billion milkfish from Bali in 2016, which supports around 1 Mt per annum of milkfish global production. The article focuses on biosecurity issues rather than biodiversity (ABS) issues; however, it is a good example of the literature gap when considering the effect of ABS on global supply and use of aquaculture genetic resources. Valderrama *et al.* (2015) explore the spread of the seaweed *Kappaphycus alvarezii* through tropical countries around the world including Indonesia.

There is a significant gap in literature analysing the potential impacts of ABS on different methods of seaweed production and other genetic material sharing, which is crucial for Indonesia as the second largest global producer of seaweed (FAO 2019b). Such analyses are especially important to inform the current policy development on ABS arrangements that will apply to Indonesia's biological resources. None of the literature has made the connection between aquaculture traditional knowledge and Indonesia's ABS measures for traditional knowledge, which may be crucial to the conservation and sustainable use of Indonesia's genetic diversity as well as livelihoods, particularly in relation to seaweed production.

Viet Nam

Aquaculture and ABS

In 2018, total aquaculture production in Viet Nam was 4.1 Mt (FAO 2020a). This was made up primarily of freshwater aquaculture (2.7 Mt, 66%), while brackish and mariculture made up 33% (1.04 Mt). Viet Nam produces a range of species with black tiger shrimp (*Penaeus mondon*), clams (*Meretrix lyrata* and *M. meretrix*), groupers (*Ephenelus* spp.) and sea bass (*Lates calcarifer*) the most important brackish and marine species. Other marine and brackish species include white shrimp (*Litopenaeus vannamei*), oyster (*Crassostrea spp., Pieria martensii*), cockles (*Anadara granosa*), mud crabs (*Scylla paramosaim*) and cobia (*Rachycentron canadum*). Important freshwater species include carps (*Cyprinus carpio*), catfish (*Pangasius bocourti* and *P. hypopthalmus*), giant freshwater prawns (*Macrobrachium rosenbergii*) and tilapia (*Oreochromis niloticus*) (FAO 2006; Nhu *et al.* 2011; Nguyen 2009).

Viet Nam's ABS legislation includes *Law on Biodiversity 2008* No. 20/2008/QH12 (the 'Act'); and *Decree No. 59/2017/ND-CP on the Management of Access To Genetic Resources and The Sharing of Benefits Arising From Their Utilization* (the 'Decree'), which substitutes ABS provisions in articles 18, 19 and 20 of the *Decree No. 65/2010/ND-CP*. The ABS regime applies to wild and exotic *in situ* and *ex situ* biological resources and their derivatives located in Viet Nam (Act article 3). ABS rules will only apply to exotic species that have been produced or cultivated in Viet Nam 'for a long time' (Decree article 3(10)). The scope is broad enough to encompass the physical aquatic genetic resources for use in aquaculture, although it appears not to cover the information components (as such genetic sequence information) as separate subject matter. The provisions cover traditional knowledge associated with genetic resources but Viet Nam does not yet have provisions protecting such knowledge (UEBT 2018).

Extensive ABS rules with prior informed consent on mutually agreed terms apply to foreign individuals or organisations seeking access to Viet Nam's biological resources for commercial or non-commercial purposes (Decree article 4.2). This includes registration for access, negotiation of a benefit-sharing agreement (which includes compulsory clauses for benefit-sharing), the Commune-level People's Committee's certification of the benefit-sharing contract and an access licence (Decree articles 7-11). There is a streamlined process for domestic individuals or organisations, who only require access licences and benefit-sharing contracts to conduct research and development for commercial purposes or if they want to transfer the resources outside Viet Nam (Decree article 4.3). The Ministry of Agriculture and Rural Development is responsible for granting licences to access to Viet Nam's aquatic biological resources (Decree article 6.1).

Literature review results

Viet Nam has the fewest publications of the countries reviewed with only 10 relevant articles or book chapters (Table 2). Only four publications related to ABS measures (none concerning intellectual property and traditional knowledge) and the remaining articles concerned informal exchanges of genetic resources. There were no publications concerning ABS of aquaculture genetic resources and associated traditional knowledge.

Nguyen and Tran (2018) examine the key elements of the 2017 ABS law and its implementation. They analyse some shortcomings within the regulations, legal system, institutional arrangements and capacity and awareness of stakeholders on ABS issues. This includes the grey area for the government entity responsible for handling ABS authorities. There are lists of aquatic breeds permitted for trade and production falling within the Ministry of Agriculture and Rural Development's responsibility but the Ministry of Natural Resources and Environment has responsibility for wild aquatic genetic resources (that may or may not end up being used for aquaculture purposes). The only other recent publication after the implementation of the law is Sirakaya (2019), which includes some of Viet Nam's ABS measures in the comparative analysis of 20 countries' laws. There is no mention in any ABS analyses of the relevance of ABS to the aquaculture sector.

Of the six publications that examine informal sharing arrangements for aquaculture genetic resources, Nguyen (2009) examines the patterns of use and exchange of the striped catfish, which is naturally distributed in the Mekong River and Chao Phraya River basins and cultured in several countries. Viet Nam's production has changed from using wild-caught seed in extensive systems to an intensified farming system entirely dependent on hatchery-produced seed to reduce pressure on wild fish populations. De Silva and Phuong (2011) and Bui *et al.* (2013) point out that Viet Nam's catfish hatcheries range from a room in a farmer's household to commercial-scale operations and Viet Nam has geographically integrated the location of seed production hatcheries with fry to fingerling rearing and grow-out farms to enable the sector to function more efficiently. Joffre *et al.* (2015) explore the use and movement of shrimp resources in integrated shrimp mangrove aquaculture. They recommend the development of a regulatory framework that optimises the financial benefits of the systems for farmers, without mentioning ABS. Nhu *et al.* (2011) examine the use and exchange of cobia resources that contribute to Viet Nam being the third largest producer of farmed cobia in the world (at the time). They recommend improvements to hatchery technology and fry transportation among other activities to accelerate future development of the species. There is a significant gap in research about how Viet Nam's ABS laws have/may impact these diverse informal

exchanges of aquaculture biological resources and whether ABS contributes to the conservation and sustainable use of these resources.

Bangladesh

Aquaculture and ABS

In 2018, Bangladesh produced 2.40 Mt of farmed aquatic animals (FAO 2019). Aquaculture increased dramatically from 0.12 Mt in 1985 to 1.95 Mt in 2014 (ca. 12% growth per annum) (FAO 2016) to 2.4 Mt in 2018 with 56% of the fish produced in Bangladesh now being farmed, mirroring the global trend away from capture fisheries (FAO 2020a). In 2014-15, Bangladesh exported 83,524 Mt, more than half of which were shrimp, and around 18.2 million people were employed in fisheries and aquaculture (FAO 2016). While aquaculture has grown significantly in Bangladesh, its full potential is yet to be released because of sub-optimal productivity, caused by lack of quality fingerlings among other things (Jahan *et al*. 2015).

Bangladesh manages ABS of its genetic resources and traditional knowledge under the *Biodiversity Act 2017* (the 'Act'). Bangladesh's ABS obligations appear to apply broadly to aquatic genetic resources, including those used for aquaculture. Section 35 gives the government power to exempt certain 'livestock' from the operation of the Act, which is marketed as a consumer good by notification in the official government gazette. It is unclear whether any aquaculture species have been exempted.

Similar to the Indian framework, the Act provides that without the previous approval of the National Biodiversity Committee, anyone (other than Bangladesh citizens, entities and residents) will not be allowed to:

- possess or collect any biodiversity or biological resources (literally bio-wealth) or traditional knowledge related to these;
- commercially use biodiversity or biological resources, bio-survey, bio-utilisation or bioprospecting related activities or research;
- collect data related to biodiversity and biological resources; and
- undertake activities related to obtaining biodiversity or biological resources (section 4).

This broad range of activities, some of which are defined under section 2, are likely to extend to aquaculture and breeding activities as well as other related activities including taxonomic research, grow-out and conservation. The National Biodiversity Committee has the power to approve or reject the application (within 90 days) and seek advice from a technical committee or other governmental organisation regarding the application or ownership regarding regional biodiversity or genetic resource related knowledge and use (section 7). Before approving an application, the Committee must consider evidence of prior informed consent from local authorities and legal claimants of resources, and has the power to require the transfer of biodiversity development related technology to local people and communities (section 30). There are monetary benefit-sharing provisions, including a contribution to the Biodiversity Conservation Fund, which must contribute to compensating individuals affected by the conservation of biodiversity rich traditional places' (section 36).

Literature review results

Bangladesh constitutes 7% (nine) of the reviewed papers (Table 2). Only two articles examined ABS laws in Bangladesh (Rahaman 2015; Karim 2017) but no articles examined the legal concept in relation biological resources and/or traditional knowledge relevant to aquaculture or intellectual property. The remaining articles (seven) focused on informal practices of use, sharing and quality of genetic resources without specifically referring to ABS.

Karim (2017) offers a detailed interpretation of the newly enacted *Biodiversity Act 2017* including its scope, procedures, exceptions and institutional arrangements. He identifies challenges of non-implementation, lack of enforcement and lack of impact on wildlife conservation of other conservation legislation in Bangladesh. He warns 'without a well-functioning institutional system, free from corruption, the success of the new law is doubtful. Rather, there is a potential risk that this new law may pave the way for "permit-raj over research" creating hindrance or uncertainty for future biological and conservation research that may not involve any commercial utilisation' (p. 102). Rahaman (2015) briefly discussed ABS in relation to plant genetic resources and traditional knowledge but we found no other publications specifically relating to ABS as a concept.

Seven publications explored informal use, sharing and quality of genetic resources for use in aquaculture. Karim *et al*. (2016) discussed the importance of improved seed quality for aquaculture in Bangladesh. Fish seed supply has grown substantially since the early 2000s reflecting the growth of aquaculture in Bangladesh. In 2016, 878 carp hatcheries (112 public and 756 private) had been established in the country, with than 98% of carp seed for aquaculture supplied by these hatcheries. Although this good network of hatcheries and reasonable supply of cheap seed had supported growth of aquaculture in Bangladesh, a common and emerging concern was that of poor seed quality (Belton & Azad 2012). The quality of seed in hatcheries had been deteriorating due to various factors, including inbreeding, inter-specific hybridisation, negative selection and improper broodstock management resulting in a low growth rate, high mortality, disease susceptibility and deformities, suggesting a need for collection of quality

broodstock from more diverse wild and domesticated sources (Sarder 2007).

Despite the importance of conservation and sustainable use of Bangladesh's aquaculture biological resources for the government's proposed growth in aquaculture, there is a significant gap in analysing the impact of ABS policy and law on the changing practices in Bangladesh around access to quality seed for breeding purposes. Addressing the significant gap in analysis about the relationship between traditional knowledge and ABS is crucial for the local communities that hold the traditional knowledge and determining the extent to which they receive benefits from its use in research and development of genetic resource products.

Discussion

What is the state of ABS measures and literature about these measures in the reviewed countries?

The number of publications explicitly examining ABS law and policy in the reviewed countries was disproportionate to the countries that have ABS measures in force. India had two thirds of the publications, reflecting the comparatively long period that its ABS laws have been in place (18 years). Viet Nam and Bangladesh had the fewest publications on ABS despite both having established dedicated ABS laws in 2017. Despite having no dedicated ABS laws in force for its genetic resources, China had the second highest proportion of papers about ABS measures (18%). This may be because China is both a key provider country (reflecting its rich biodiversity) and a user country, with its established biotechnology, industrial and commercial agriculture industries (Cai 2017).

Few of the publications examine the practical implications of ABS measures on various sectors including aquaculture. All three countries have relatively complex ABS measures that involve multiple layers of government in processing applications, obtaining prior informed consent and establishing mutually agreed terms. Each have simplified arrangements for prior informed consent and mutually agreed terms for local individuals, organisations and institutions. These similarities may reflect the fact that each of these is biodiverse-rich countries and is concerned about their genetic heritage leaving their country with little benefit to the country.

China's Draft Regulation that the government released for consultation in 2017 is not yet in force, perhaps reflecting the complexity of administrative responsibilities (Zheng 2019) but also the need to get the balance right for ABS measures that conserve and sustainably use its biodiversity as both a provider and user of biological resources. Significantly, there are no published analyses of the implications for China of the Draft Regulation's proposal for retrospective application to biological resources and traditional knowledge that fall within scope (purportedly endemic and exotic resources). This may have broader unexamined implications for the expected growth in global aquaculture development for both provider and user countries of China's aquaculture genetic resources (that relies on genetic improvement and research China's resources).

Nearly a third of publications about ABS measures examined intellectual property and traditional knowledge issues, usually in relation to each other. Publications about Indonesia in particular examined the topics together, reflecting the country's emphasis on the development, use and protection of traditional knowledge. India had by far the largest proportion of ABS articles that related to intellectual property (77%) and traditional knowledge (62%) of all the review countries. One explanation is the well-documented history of 'biopiracy' of traditional knowledge in India, where 'genetic resources and traditional knowledge is taken from biodiverse developing countries without permission' and often used to benefit the users without compensation to the providers (Kumar 2019). In an attempt to combat biopiracy, Viet Nam has a requirement to disclose the origin of genetic resources and/or traditional knowledge under their national legislation[2] and India and Bangladesh have strict requirements for obtaining the government's approval before claiming a patent over an invention incorporating its genetic resources or knowledge.[3] Publications examine whether China should introduce similar measures (e.g. Cai 2017). This review, however, found no literature analysing the extent of biopiracy in aquaculture sectors and how disclosure of origin measures has worked in practice for aquaculture genetic resources and associated traditional knowledge in any of the reviewed countries.

A common theme in publications on ABS was concerns about the effective implementation and/or enforcement of ABS measures in the countries reviewed. For example, Karim (2017) warned that if Bangladesh's new ABS legislation is managed in the same way as its other conservation legislation, there is little capacity for the government to implement its provisions. This was one of the few articles that considered whether ABS was achieving its conservation and sustainable use objectives. Most ABS articles focused on the economic and capacity building benefits that may accrue to the providers – be they government or Indigenous Peoples and local communities. None of the articles provided evidence about the capacity for the ABS concept

[2]Decree No. 59/2017/ND-CP on the Management of Access To Genetic Resources and The Sharing of Benefits Arising From Their Utilization article 14.3.

[3]Biological Diversity Act 2002 (India) section 6; Biodiversity Act 2017 (Bangladesh) section 6.

to contribute directly to conservation of biological diversity generally or aquaculture specifically.

A key challenge for implementing effective ABS measures in several of the reviewed countries related to institutional arrangements, in particular how multiple competent national authorities (CNA) with responsibilities for different genetic resources can more effectively coordinate policy development, access decision-making and benefit-sharing negotiations. For example, of all the countries, only Indonesia has a single CNA – the Ministry of Agriculture and Food and Drug Agency (Mardiastuti 2019). In contrast, Viet Nam has shared responsibilities with the Ministry of Agriculture and Rural Development responsible for genetic resources for food and agriculture (including aquaculture) and the Ministry of Natural Resources and Environment responsible for all others (Nguyen & Tran 2018). The sole CNA in India is the National Biodiversity Authority (established under chapter III *Biological Diversity Act 2002*). It is unclear who the CNAs are in Bangladesh and China because they have not been reported to the CBD's ABS Clearing House; however, there is some literature raising questions about the challenges China has for designating responsibility (Zheng 2019). For all the reviewed countries, there is relatively little literature about the effectiveness of approaches to institutional arrangements generally and no literature about how aquaculture genetic resources are effectively managed within these institutional arrangements.

To what extent does the literature examine the implications of ABS measures for the conservation and sustainable use of aquaculture genetic resources and associated traditional knowledge?

The key finding of this review is that there are no in-depth peer-reviewed analyses of the implications (positive or negative) of ABS measures for the conservation and sustainable use of aquaculture genetic resources and associated traditional knowledge in the top aquaculture-producing countries. All the reviewed countries have literature about informal collection, use and exchange of aquaculture genetic resources (see Table 2) but only six articles make the connection between these practices and ABS, all of which were from India. India has a long history of aquaculture and a current policy emphasis on aquaculture development (see section 3.2 above), so this focus is not surprising. The implications explored, however, only focused on the ability of Indian governments to distribute financial and other benefits to benefit claimers under the ABS institutional infrastructure, which could be an issue regardless of the sector it affects.

None of the countries had literature examining whether policy makers have considered the special importance of food and agriculture (including aquaculture) when developing and implementing their ABS measures in accordance with the Nagoya Protocol (article 8(c)). Nor did the publications explore the aquaculture sectors' unique characteristics when it comes to genetic resource and knowledge practices. These characteristics include aquaculture's need for exchanging large amounts of biological resources to address the sector's lag in domestication (compared with agriculture) and the difficulties for distinguishing between using resources for their genetic material, for example for breeding or biotechnology (usually attracting ABS), rather than for their products, for example grow-out or consumption (not usually attracting ABS) (Humphries 2016). Another key characteristic is the difficulty for determining the geographic origin of aquatic genetic material that moves freely between jurisdictions (Humphries 2016). India, Viet Nam and Bangladesh laws (and China's Draft Regulation) have broad scope of aquaculture genetic resources that would fall within ABS arrangements, including those that originated in their country as well as imported species. There is little analysis in the literature about the extent to which these countries could restrict access to aquaculture resources originating from other countries and implications for global movement of seed for breeding. There are also significant differences between aquaculture sectors for which ABS may have a different impact (e.g. farming for food production as opposed to growing biomass for pharmaceutical trials). Assessing the actual impact of ABS on aquaculture with empirical and other evidence is a significant gap in ABS literature and analysis.

What is surprising is the absence of analyses of proposed ABS measures in relation to China's aquaculture genetic resources and traditional knowledge, which has an even longer history of aquaculture and is by far the largest producer of aquaculture products worldwide (FAO 2020a). Explanations for this gap include (i) scholars publishing mainly in Chinese languages; and/or (ii) the lack of dedicated ABS law, which is still in draft form. However, existing legislation already has ABS elements and an *ad hoc* approach to ABS can lead to even greater uncertainty about the circumstances in which aquatic genetic resources can be accessed and benefits shared with the providers.

Viet Nam, Bangladesh and Indonesia do not have any articles that mention ABS in relation to aquaculture. While there are some analyses of ABS and aquaculture in other countries (e.g. Rosendal *et al.* 2013), a large gap in global literature is analysing the implications for different aquaculture sectors that have vastly different considerations for the use and exchange of reproductive materials. For example, there is a complete absence of publications analysing the effect of ABS on seaweed. China is the lead producer, followed by Indonesia (FAO 2019). World production has

more than tripled between 2000 and 2018, with Indonesia's production of tropical seaweed species being a major driver of growth in this period (FAO 2020a). Given its growing importance to food security, industrial applications and its role in reducing stressors of capture fisheries worldwide, an analysis of whether ABS achieves its goals for the conservation and sustainable use of seaweed genetic resources seems crucial.

None of the countries reviewed examined the implications of ABS on intangible genetic resources (e.g. digital sequence information – DSI). Each of the international ABS forums continues to debate how or if DSI should be the subject matter of ABS but have yet to reach agreement (Lawson *et al*. 2020). The issue is that many technology-poor countries are concerned that as technologies improve for biotechnological breakthroughs that do not require access to the physical materials, researchers will use DSI obtained for free from databases on which to base their commercial products, without the requirement for sharing the benefits from their use with the provider country. Each of the countries reviewed, with the exception of China and India, has fledgling biotechnology sectors generally and specifically in relation to aquaculture. Further, many of the countries have been vocal advocates to include DSI in the international framework (CBD 2019). Therefore, it is surprising that there are not more publications on DSI and ABS generally and for the aquaculture sector specifically.

Another key gap in literature is analyses about traditional knowledge associated with aquaculture and its relationship with ABS frameworks. Rosendal *et al*. (2013) suggest that this may be because of lower incidences of traditional knowledge in aquaculture compared with medicine and agriculture and fewer farmers' breeds of fish since the bulk of the world's fish farming is based on wild catches. However, discussions about the relationship between traditional knowledge and ABS in various international forums are demonstrating that there is a broader interpretation of the kind of knowledge captured within the ABS transaction (e.g. Mulalap *et al*. 2020). Such knowledge might not be restricted to genetic material use in the scientific sense but in the sense of broader knowledge systems and practices, such as marine management, and empirical evidence built over thousands of years. The significant gap in research about the relationship between ABS laws, intellectual property laws and traditional knowledge associated with aquaculture may perpetuate cases of biopiracy and accidental misappropriation of local and indigenous knowledge because users may not understand what type of knowledge is regulated.

As many countries increasingly rely on aquaculture for food and livelihood security, there is a sense of urgency to address the significant gaps in literature to assist actors in the aquaculture sector and policy makers to understand:

- the practical impact of ABS measures on aquaculture genetic resource collection, use and sharing and associated traditional knowledge;
- the extent to which ABS laws capture endemic, imported and genetically altered aquaculture genetic resources and the implications for sharing seed across jurisdictions that may fall within scope of several ABS laws;
- the level of awareness and compliance by actors of the aquaculture sectors in the review countries of their ABS obligations in relation to aquaculture genetic resources and traditional knowledge;
- which actors benefit from the use of aquaculture genetic resources and traditional knowledge and whether any of the benefits flow to the conservation of genetic resources *in situ*;
- how to manage information associated with aquaculture genetic resources (e.g. Digital Sequence Information), increasingly used in aquaculture biotechnology; and
- whether ABS as a concept has been effective in meeting the CBD's objectives of the conservation and sustainable use of aquatic genetic resources.

The international ABS framework has been in place for nearly 30 years and national implementation by the reviewed countries has been in progress for decades. Given these timeframes, from an academic point of view, there is little indication about why publications on informal genetic resource and traditional knowledge practices in aquaculture are skirting around ABS issues.

For the leading aquaculture producers China, India, Indonesia, Viet Nam and Bangladesh, which have varying capacities for implementing ABS institutional arrangements, policy and law, one option could be to cooperate and develop a regional approach to ABS, similar to the regional approaches in Europe (EU 2014), Africa (AU Commission 2015) and South America (Ormaza 2019). This may build capacity for sharing approaches and infrastructure that supports the conservation and sustainable use of aquaculture genetic resources. Other options include the development of multilateral ABS frameworks similar to the Plant Treaty, which do not require individual negotiations for access to and benefit-sharing of resources and associated knowledge for every transaction with providers of the resources/knowledge (who may be governments, communities and individuals depending on the scope of an ABS law). Instead, a multilateral system can have pre-arranged Standard Material Transfer Agreements or other mechanisms for facilitating access under simplified arrangements and requiring benefits from the use of resources or knowledge flow primarily to farmers in all countries, especially developing countries who conserve and sustainable use genetic resources for aquaculture (see, e.g., Plant Treaty article 13(3)). This review found no peer-reviewed

publications about why multilateral and other options have stalled in the case of aquaculture.

Conclusion

There is no doubt that aquaculture is expanding faster than any other food sector globally and that the countries in this review are leading the way (FAO 2020a). What is in doubt is whether ABS as a concept and as a legal mechanism is an effective tool for the conservation and sustainable use of aquatic genetic resources for use in aquaculture. The almost complete absence of analyses at the global and country levels about the practical implications (positive and negative) of ABS measures for the collection, use and sharing of aquaculture genetic resources, associated information (e.g. digital sequence information) and associated traditional knowledge is concerning for aquaculture's sustainable future. It is also concerning for the Indigenous Peoples and local communities who hold traditional knowledge associated with aquaculture that may be appropriated in the mistaken belief that traditional knowledge and aquaculture may not be captured by a given country's ABS framework.

There is an urgent need for aquaculture actors to understand their existing and proposed ABS obligations and for government policy makers to consider the unique characteristics and needs of the aquaculture sectors when developing and implementing ABS laws and policy. Despite the global ABS framework being in place for nearly 30 years, the conversation has only just begun about how to accommodate the importance of aquaculture genetic resources and knowledge for food livelihood security. Whatever local, regional or global solutions may be developed to take into account the relevance or impact of ABS measures on aquaculture sectors, a first step is to address the significant gaps in literature on the implications of existing and proposed national ABS measures that apply to the activities of farmers, breeders, researchers and other actors in aquaculture sectors.

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