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SPECIES DIVERSIFICATION IN **AQUACULTURE**

Executive Summary:

This document presents an analysis of the state of species diversification both at global and Caucasus and Central Asian regional levels; and provides a technical basis to discuss approaches to promote species diversification in aquaculture in the CACFish competence area. Currently, aquaculture represents one of the world's most diverse farming system in terms of farming technologies and the number of species farmed, and the growth in the aquaculture sector over the past 50 years has seen a rapid increase in the number of species cultured. A recent survey of species diversity in the Central Asian and Caucuses region revealed that across the region, a total of 42 species are recorded as cultured (commercial or pilot scale production). The introduction of new culture species to a country is not always a simple procedure. Notably, as the private sector tends to concentrate on farming the more established species where they can be assured of the most benefits - derived from stable technology platforms, established markets, developed value chains and production economies of scale. This documents also addresses the key drivers of species diversification in aquaculture and associated guiding principles or issues that should be addressed when considering the introduction of a new culture species.

Effective approaches to species diversification in aquaculture in the CACFish competence area would contribute to sustainable sectoral growth, poverty alleviation and support the realization of the Sustainable Development Goals.

Suggested action by the Committee:

- Consider the analysis of the state of species diversification both at global and Caucasus and Central Asia region levels,
- Consider key drivers of species diversification in aquaculture and associated guiding principles or issues; and
- provide any further advice and/or guidance for the promotion of species diversification in aquaculture.

INTRODUCTION

1. The aim of this document is to present an analysis of the state of species diversification both at global and Caucasus and Central Asian regional levels; and provide a technical basis to discuss approaches to promote species diversification in aquaculture in the CACFish competence area.

2. The diversity of global climate and environmental conditions has given rise to a rich and diverse number of species that can be used in aquaculture. Aquatic species are now cultured in freshwater, brackish-water, and marine and inland saline waters. As the global aquaculture sector grows, species diversification is increasingly being viewed as a mechanism to promote sustainability, and to mitigate against production risks associated with climate change, disease outbreaks, market fluctuations and other uncertainties (Harvey et al., 2017[1]). Currently aquaculture is the world's fastest growing food sector. In 2018, aquaculture production accounted for nearly 50 percent of total human-consumed aquatic products, equating to a total global production of 114.5 Million tonnes (FAO, 2020[2]). Of this production, 82.1 million tonnes comprised aquatic animals and 32.4 million tonnes comprised aquatic algae. Aquatic animal production was dominated by inland aquaculture (51.3 Million tonnes) with the remaining 30.8 Million tonnes being derived from mariculture.

3. Aquaculture represents one of the world's most diverse farming system in terms of farming technologies and the number of species farmed, and the growth in the aquaculture sector over the past 50 years has seen a rapid increase in the number of species that can be cultured. In 1950, 73 species that were reported as farmed. Since 1950, the number of species cultured increased eight fold, and in 2018, global production was attributed to 466 species or 622 "specimen items"[3] (Cai et al., 2022[4]). Despite the rapid increase in the number of species that are reported as cultured, the majority of production can be attributed to a relatively few number of species. Indeed, in a review of species diversity in aquaculture, Cai et al. (2022[5]) developed a diversity index of "effective number of species" (ENS) which took into consideration the volume or share of production for each species with respect to a country's total aquaculture production. Of 438 species reviewed, the effective number of species being cultured was only 47, indicating that production was dominated by a few species with minimal production being reported for the majority of the species reported. Indeed in 2018, global finfish culture production was dominated by just 27 species, which combined, comprised over 90% of total finfish production (FAO, 2020).

4. Species diversity at a national level varies considerably between countries and is influenced by many factors. A high level of species diversification is often associated with the larger producer countries that have establish production sectors across a diverse group of species. For example, in 2018, China and Bangladesh produced 66.1 million MT and 2.4 Million MT aquaculture products respectively. China reported the total number of species cultured as 85 and an ESN value of 27.7; the respective total species and ESN value for Bangladesh were also relatively high at 31 and 13.9 respectivly. From a global perspective, China reports by far the highest aquaculture species diversity indices. The high level of diversity is due to a number of factors. These include the country's long

[1] Harvey, B., Soto, D., Carolsfeld, J., Beveridge, M. & Bartley, D.M. eds. (2017) Planning for aquaculture diversification: the importance of climate change and other drivers. FAO Technical Workshop, 23–25 June 2016, FAO Rome. FAO Fisheries and Aquaculture Proceedings No. 47. Rome, FAO. 166 pp.

[2] FAO (2020). The state of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

[3] "Species Items" include 466 individual species, 7 interspecific hybrids of finfish, 92 species groups at genus level, 32 species groups at family level, and 25 species groups at the level of order or higher (FAO, 2020).

[4] Cai, J.N., Yan, X. and Leung, P.S. (2022) Benchmarking species diversification in global aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 605. Rome, FAO *https://doi.org/10.4060/cb8335en*.

history and tradition in aquaculture, the diverse aquaculture resources, systems and technologies that have been developed, and a government that supports aquaculture development and species diversification. It also has competitive and diverse domestic fish and seafood markets that supports markets for multiple production species (Wang, 2001[5]).

5. High species diversity and ESN values are not always linked to high levels of production. Producers in countries that show high consumer preferences and markets for a diverse range of aquatic foods (e.g. Eastern and South-eastern Asia) are incentivised to diversify their product mix to maintain competitiveness in the market. Thus, high species diversity can also be attributed to low levels of production in smaller producer countries such as Singapore. In 2018, Singapore's production was reported at just 5 702 MT, and despite the limited production, the total number of species cultured was relatively high at 44 (ESN: 10.45). In contrast, countries that focus on supplying global export markets often have a correspondingly low species diversity. For example, Norway has an excellent bio-physical environment for salmon farming (*Salmo salar*), and has developed strong competitive and comparative advantages in farming the species. As a result, Norwegian producers tend to focus on improving production efficiencies and expanding their highly industrialised salmon production sector, and they tend not to focus on establishing new production species. Thus, despite significant production volumes (2018: 1.3 million MT), Norway's ENS is only 1.26, indicating that the effective number of species cultured is significantly lower than the global average (Global Median ENS: 2.37).

6. A survey of species diversity in the Central Asian and Caucuses region6 revealed that across the region, a total of 42 species were recorded as cultured (commercial or pilot scale production). Details are provided in Annex 1. These species were derived from 24 genera of which 39 were fish (teleost / elasmobranchs), one bivalve, one crustacean and one annelid. With 20 species under culture, Türkiye and Azerbaijan reported the greatest diversity in the number of species cultured. This was followed by Uzbekistan and Turkmenistan which reported 17 culture species, and Kazakhstan, Kyrgyzstan and Tajikistan which reported 12, 11 and 7 culture species respectively. The analysis of the "effective number of species" cultured in the countries in the region in 2018, indicate that while Azerbaijan recorded the lowest production in the region (478 MT) it recorded an ENS of 4.61 which was the highest in the region. In contrast, Armenia reported the third highest regional production (17 000 MT) but recorded an ENS of 2.69 which was the lowest in the region - the implication being that Azerbaijan's production while relatively low in volume, is based on a higher number of culture species than Armenia's. Nevertheless, it is interesting to note that all the countries in the region scored ENS values that are higher than the global median value (Regional values: 4.61 – 2.69; Global median value: 2.37), suggesting that from a global perspective, the regional production sector shows a relatively high level of species diversification.

7. Among those species cultured in the region, the sturgeons (*Acipenser* spp.) were the most commonly represented genus (5 species), followed by the Chinese and European carps (combined 5 species). It was established that the Siberian sturgeon (*Acipenser baerii*), the common carp (*Cyprinus carpio*) and the grass carp (*Ctenopnaryngodon Idella*) were cultured in all seven countries surveyed. Other commonly cultured species included the Russian sturgeon (*Acipenser guldenstaedti*), the beluga sturgeon (*Husa husa*), the African catfish (*Clarias garipinus*), the silver carp (*Hypophthalmichthys molitrix*), the rainbow trout (*Oncorhyncus mykiss*) and the Sevan trout (*Salmo ischchan*) – these species were reported as cultured in five of the seven countries surveyed.

[5] Wang, Y. 2001. China P.R.: a review of national aquaculture development. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. Aquaculture in the third millennium, pp. 307–316. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20–25 February 2000. NACA, Bangkok and FAO, Rome.

[6] FAO Regional workshop on aquaculture diversification (culture of new species), targeting small-holder farmers and extension agents that was held in Tashkent, Republic of Uzbekistan, 28-29 March 2023

DRIVERS OF SPECIES DIVERSIFICATION

8. Harvey et al. (2017[2]) identified the following seven primary drivers for aquaculture diversification:

i. Market demand

As the global population and wealth increases, the demand for fish and fish products will increase, and the concomitant increase in wealth is likely to increase demand of new species and products.

ii. Climate change

Climate change presents issues of uncertainly to aquaculture development and diversification. Depending on the location, climate change may significantly alter biophysical environments, and negatively impact culture species.

iii. Desire for increased resilience

Producers need to deliver a consistent supply of quality products. When production is distributed evenly between multiple species, there is an overall reduction in the risks to the farming operation should there be a production failure in one or more of the production species. By increasing the species mix, farmers can increase the resilience of their production systems and ensure continued economic returns during periods of uncertainty.

iv. Consumer demand

Consumers will want to continue to eat fish that they are accustomed to and at affordable prices. Tastes and demand may change providing opportunities to introduce new species and products.

v. Environmental concerns

The environmental impacts accruing to aquaculture are of increasing concern to both the industry and to consumers. Aquaculture competes for both natural resources (i.e., water, energy, and food) and with other human activities (urban or tourism development). Of particular concern is the widespread intensification of large-scale monoculture aquaculture production systems that, despite being a major contributor to food supplies, are sometimes associated with environmental sustainability issues. Increasing species diversity and the development of polyculture systems based on interspecific compatibility or complementarity can improve resource use, nutrient retention, and production efficiencies.

vi. Profit

Farmers will naturally focus on those species, hybrids and production systems that are the most productive and economically efficient in terms of generating the greatest economic return to their farming operations. Producers will naturally be inclined to support the introduction of novel species or species hybrids that increase production efficiencies and profits.

vii. Competitive advantage

Pioneer farmers and earlier adopters can be incentivised to introduce new culture species and technologies to gain a competitive advantage in terms of securing initial market share for their products. In some cases, initial price advantages accrue to the introduction of new products to the market.

9. The above-mentioned drivers comprise a combination of market forces and consumer demand, a desire for increased competitiveness, profits or resilience, and address climate change and environmental sustainability issues. These drivers may operate independently, or perhaps more often in a cross-cutting manner. For example, while climate change may impact the production efficiency of a species, reducing the resilience of the farming system to environmental shocks, high market demand

for the species will drive the farmers to identify alternate species that can maintain market share while addressing the climate change induced production constraints.

APPROACH IN PROMOTING SPECIES DIVERSIFICATION IN AQUACULTURE

10. The introduction of a new culture species to a country is not always a simple procedure. The private sector tends to concentrate on farming the more established species where they can be assured of the most benefits - derived from stable technology platforms, established markets, developed value chains and production economies of scale. Farmers often view the development or adoption of new culture species as high risk and costly, and with the possibility of having to allocate resources and effort into research and development, there is often an inherent reluctance to diversify on-farm species composition (New, 1999[7]) and in many cases, a lack of incentives to do so (Harvey et al., 2017[2]). Due to the high establishment costs and financial risks associated with species diversification, the public sector is often viewed as the primary driver for supporting species diversification. However, many publicly funded interventions to develop new species have proven less successful than anticipated as they are often driven by research interests, poor species choice, or a lack of consideration for their commercial viability. Indeed, arguably other 'dimensions' of aquaculture development, such as governance, value chain development, markets and marketing, social and environmental impacts, human resources, and financing have received less focus, becoming at some point the weak link that prevented the achievement of results of any significance. Furthermore, Pullen (2017[8]) cautions that an over-estimation of future markets; over-capitalization of start-ups; over-estimation by farmers of expected production and an under-estimation of costs; over-promotion by administrators and parties with vested interests; and inadequate science-based appraisals often leads to failure. If such realities are ignored, aquaculture diversification programmes are unlikely to succeed and will simply consume scarce economic, social and human resources.

11. As developing new culture species tends to be time consuming and financially costly, for many countries, introducing new species for which the production technologies have been established represents an easier and more cost-effective development strategy. In this regard, it is essential for policy-makers, planners and the private sector to assess the development resources available to them when assessing prospects for the successful introduction of a new culture species. It is also important to note that there is no one-size-fits-all aquaculture development strategy. Some countries may pursue species diversification for a more resilient aquaculture sector, while other countries may concentrate on developing aquaculture species with the greatest socio-economic benefits, for example to support food security and poverty alleviation (Cai et al,, 2022[5]).

12. In view of the inherent difficulties in successfully introducing new culture species, Pullen (2017) developed a series of guiding principles or issues that should be addressed when considering the introduction of a new culture species. These can be summarised as:

- Diversification demands information - aquaculture is a technology driven production sector and there is a need to gather information and identify knowledge gaps to establish the potential for a successful species introduction.
- Diversification should be compatible with local ecosystems and not negatively impact aquatic biodiversity. The Precautionary Principle should be adopted, and where alien species are

[7] New, M. 1999. Global aquaculture: current trends and challenges for the 21st century. World Aquaculture, 30(1): 8–13.

[8] Pullin, R.S.V. (2017) Diversification in aquaculture: Species, farmed types and culture systems. In: Harvey, B., Soto, D., Carolsfeld, J., Beveridge, M. & Bartley, D.M. eds. 2017. Planning for aquaculture diversification: the importance of climate change and other drivers. FAO Technical Workshop, 23–25 June 2016, FAO Rome. FAO Fisheries and Aquaculture Proceedings No. 47. Rome, FAO. 166 pp.

proposed for introduction, an assessment of the risks to biodiversity should be undertaken (FAO, 1996[9]). The risks of adverse impacts should include: damage to aquatic and terrestrial biodiversity, escapes from farms, and the possible spread of aquatic diseases.

- Diversification should anticipate, adapt to and mitigate the effects of climate change. The advantages and disadvantages of any proposed diversification should be assessed in terms of adaptation, mitigation, resilience and vulnerability to climate change.
- Diversification should comply with national and international codes of conduct, conventions and laws. These would include certification schemes, market standards, the FAO Code of Conduct for Responsible Fisheries and the Technical Guidelines that apply to aquaculture. In addition, the diversification should comply with all obligations under relevant international conventions, including, inter alia: the Convention on Biological Diversity (CBD); the Ramsar Convention, and the United Nations Convention on the Law of the Sea (UNCLOS). It should also comply with national legislation on biosafety, biosecurity, and the conservation and the use of biodiversity and natural resources, including land and water.
- Diversification should be profitable and products acceptable in domestic and/or export markets, and analyses should take into consideration the risks of market shifts. It is important that there are no taboos, image and reputational problems for the proposed farmed aquatic products. Assessing profitability requires making a detailed business plan, including realistic appraisals of the following: availability and cost of sites and systems; variable production costs, especially feed and seed; best, worst and most probable ranges of expected prices; competitiveness with other products; harvesting.
- Diversification should minimize risks from pathogens and predators. There is a need to assess risks from pathogens, parasites and predators, and to ensure that there are no insurmountable health, survival and product quality risks from existing or possible pathogens, parasites and predators.
- Diversification should be planned in consultation with all stakeholders and be attractive to farmers. The likely adoption by farmers should be assessed, and governability and sustainability issues taken into consideration. The sustainability of a diversification intervention should be assessed using biological, ecological, economic and social metrics.
- Diversification should be compatible with other responsible food producing sectors. The diversification should avoid conflict with other food producing sectors.

NEXT STEPS

13. In order to promote species diversification in the CACFish competence area, the following could be considered: (i) undertake a technical review to identify those species that show the greatest potential for development / introduction to countries in the region; (ii) Undertake feasibility studies for those selected species that show the greatest potential for adoption by countries / region; (iii) Based on the technical reviews and feasibility studies, develop a regional / country road maps for species diversification.

SUGGESTED ACTION FOR THE COMMITTEE

14. In view of all of the above, the Committee is invited to: (i) consider the analysis of the state of species diversification both at global and Caucasus and Central Asia region levels; consider key drivers of species diversification in aquaculture and associated guiding principles or issues; and (iii)) provide any further advice and/or guidance for the promotion of species diversification in aquaculture.

[9] FAO (1996). Precautionary approach to capture fisheries and species introductions. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome. 54 pp

ANNEX 1

Table 1. Aquaculture species diversity in the Central Asian and Caucuses

Culture species		**Country**						
Scientific name	**common name**	**Kyrgyzstan**	**Kazakhstan**	**Tajikistan**	**Uzbekistan**	**Turkmenistan**	**Azerbaijan**	**Turkiye**
Acipenser baerii	Siberian Sturgeon	-	C	PC	C	C	C	C
Acipenser gueldestaedtii	Russian Sturgeon	C		-	C	C	C	C
Acipenser nudiventries	Bastard sturgeon	-		-	-	-	C	-
Acipenser persicus	Persian sturgeon	-		-	-	-	C	-
Acipenser stellatus	Starry sturgeon	-		-	-	-	C	-
Acipenser zuthenus	Sterlet	-		-	-	-	C	-
Alburnus chalcoides	Danue bleak	-		-	-	-	C	-
Carassius carassius	Crusian carp	-		C	C	C	-	-
Channa argus	snakehead	-		C	C	C	-	-
Clarias garipiunus	African Catfish	PC		C	C	C	C	-
Coregonus lavaretus	Common White Fish	C		-	-	-	-	-
Coregonus peled	Peled	C		-	-	-	-	-
Ctenopnaryngodon idella	Grass carp	C	C	C	C	C	C	-
Cyprinus carpio	Common carp	C	C	C	C	C	C	C
Dicentrachus labrax	Sea Bass	-	-	-	-	RD	-	C
Salmo trutta macrostigma,	Red spotted trout	-	-	-	-	-	-	C
Huso huso	Beluga sturgeon	C	-	-	PC	C	C	C
Hypophthalmichthys molitrix	Silver carp	C	-	C	C	C	C	-
Hypophthalmichthys nobilis	Bighead carp	-	-	C	C	C	C	-
Mytillus galloprovincialis	Black Mussel	-	-	-	-	-	-	C
Oncorhyncus mykiss	Rainbow trout	C	-	C	C	C	C	C

Oncorhyncus mykiss	Turkish salmon (sea trout)	-	-	-	-	-	-	C
Oreochromis Mossambicus	Mosambique Tilapia	-	-	-	PC	C	-	-
Oreochromis niloticus	Nile Tilapia	-	-	-	PC	C	-	C
Penaus vannamei	White shrimp	-	C	-	-	RD	-	-
Polyodon spathula	American paddlefish	-	-	-	-	-	C	-
Rutilus frisii kutum	Caspian kutum	-	-	-	-	PCS	C	-
Rutilus rutilus	Roach	-	-	-	C	C	-	-
Salmo ciscaucasius	Caspian salmon	-	-	-	-	PCS	-	-
Salmo ischchan	Sevan trout	C	-	C	-	C	C	C
Sander lucioperca	Pike perch	-	PC	C	C	C	-	-
Silurus glanis	European catfish	-	-	-	C	C	C	C
Sparus aurata	Sea Bream	-	-	-	-	-	-	C
Thunnus thynnus	Bluefin tuna	-	-	-	-	-	-	C
Vimba vimba	Vimba bream	-	-	-	-	-	C	-
Balkhash marinka	Marinka	-	C	-	-	-	-	-
Hirudo spp.	medical leeches	-	-	-	-	-	-	C

Key

Commercial	C
Pilot commercial	PC
Candidate species - R&D	RD
Potential culture species	PCS