Aquaculture and biodiversity in global food systems

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Abstract

A One Health approach will be essential to ensure future food systems can address the trade-offs between interventions needed to produce more food of higher nutritional value, with a smaller ecosystem footprint. This will involve consideration of hazards that link or spread between different supply chains, taking a whole-systems approach. Here, we consider how biodiversity maps to aquaculture across the One Health space. Aquaculture poses ecosystem health risks through the biodiversity impacts of disease spread, non-native introductions, farm-level pollution and habitat damage. Less well recognised, biodiversity also links strongly to animal/plant health, through increased risk of hazards (pathogen and pest diversity can create significant stock health challenges) but also by providing opportunities – genetic diversity underpins stock fitness and mixed-species farming improves resilience. Application of One Health principles will allow aquaculture to grow sustainably, but this needs the buy-in of policymakers, farmers and the scientific community.

Food systems of the future will need to take a One Health approach – recognising that food, humans and their environment are inter-related entities. Without this, it will not be possible to produce more food of higher nutritional value under increasingly challenging conditions while at the same time reducing food's environmental footprint and addressing social inequity. This will involve dealing with the many hazards associated with food value chains, from those that limit supply – such as pests or chemical contamination – to environmental degradation from unsustainable practices or societal problems such as conflict-driven interruptions of food supply. Unfortunately, these hazards are mainly addressed within individual food sectors such as maize farming or beef husbandry, without attention to how they could link or spread between supply chains. This misses the opportunity to look at the bigger picture, to identify pervasive hazards or cross-sectoral impacts. To be effective in fixing food systems, we need to take a whole-system, or 'One Food', view (Bremner *et al*, 2023).

Food systems conversations are often focussed on the readily visible practices of land-based agriculture. But blue foods, and aquaculture in particular, play an important role in the global food mix and need to be part of the conversation. Total aquatic animal foods are presently estimated to constitute 15.3 percent of global crude animal protein, with aquaculture (the farming of aquatic animals and plants) representing 7.5 percent of the global total (Boyd *et al*, 2022), but these low figures mask the significance of aquatic protein for peoples in some regions of the world and aquaculture production is projected to grow by 17 percent by 2023 compared to 2022 and to break the 100 million tonnes live-weight equivalent in 2027 (FAO, 2024). In 2022, at 94.4 million tonnes, global animal aquaculture production surpassed wild capture fisheries for the first time in history (FAO, 2024), making the farming of fish and other species a noteworthy source of human intervention with consequences for aquatic environments.

Taking food from rivers, lakes and seas has implications for biodiversity and environments (Mitra *et al*, 2024), just as it does on land. In an ideal world, food production would be environmentally negligible at worst and nature-positive at best. That this is demonstrably not the case is one of the reasons why our food systems are dysfunctional and require One Health solutions. Yet there are additional ways in which biodiversity is connected to food production in the One Health space and biodiversity maps to the animal/plant health pillar as well as it does to environment/ecosystem health one (Figure 1).

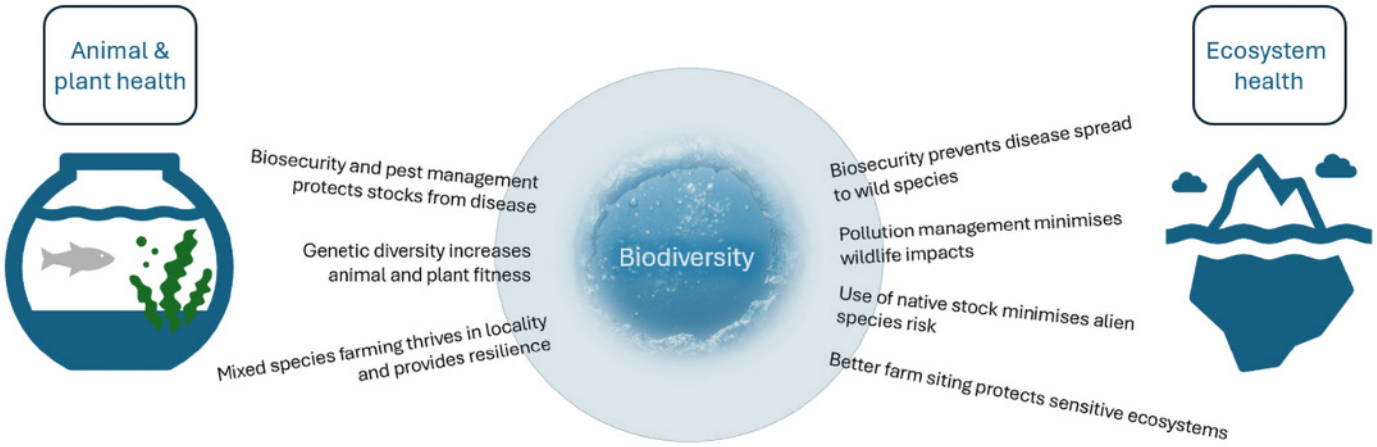

Figure 1. Biodiversity maps onto animal and plant health as well as ecosystem health (Source: Julie Bremner)

Generally, the concept of animal and plant health is seen through the lens of the fitness of the animals or plants making up an individual stock. But it can also be viewed in terms of the biodiversity of these stocks – animal and plant production will be 'healthy' when it utilises a diverse mix of species suited to the local growing environment. Aquaculture has a high level of species diversification compared with crop and livestock production. Crop production is estimated to consist of around 255 species globally and just a handful of these may provide much of the world's food (FAO, 2019; Khoury *et al*, 2023), while around 40 species of livestock are farmed and a small number provide the majority of global meat, milk and egg output (FAO, 2019). Aquaculture, on the other hand, although it also focusses on a handful of main species, involved 564 species farmed worldwide by 2024 (368 species of finfish, 88 species of molluscs, 62 species of crustaceans, 32 species of algae, 2 species of cyanobacteria, 7 species of marine invertebrates, 3 species of frogs and 2 species of aquatic turtles; FAO, 2024).

But it is not just about how many species are farmed globally, it is about how they are farmed. Intercropping – the practice of growing a biodiverse mix of plant species in close proximity to improve overall yield and resilience – is a well-known agroecological practice. Agroecology is as relevant to aquatic systems as it is to land-based agriculture. Mixed species or multitrophic aquaculture systems (combining species from different parts of the aquatic food web, such as bivalves and algae) can mitigate some of the impacts of single-species aquaculture, providing ecological stability (Ying *et al*, 2018). Indeed, combining bivalve and algae aquaculture can reduce biodiversity impacts compared with culturing higher-trophic-level species such as finfish because they do not require feed, the production of which largely comes from harvesting of wild animal populations (Boyd *et al*, 2022). However, agroecological practices must be managed intelligently for aquaculture for a variety of reasons including that introducing non-native, invasive species to a local environment comes with the risk of their pathogens spilling over to wild populations or hybridising with native species (Peeler & Taylor, 2011). As with food diversification on land, such practices must also consider market demand: just because multitrophic aquaculture can reduce environmental impacts and increase food system resilience, does not mean people will want to buy the products. These types of intervention will require adequate market evaluation. They also need consumer education and policy development that facilitates diversification while strengthening the use of well-established species (Cochrane *et al*, 2009).

One Health principles can deliver sustainable production in aquaculture, improving food and nutrition security, livelihoods and economic development, and the protection of natural resources (Stentiford *et al*, 2020). As aquaculture grows as an important global protein and nutrient source, sustainability measures must be applied rigorously. Farmers need ownership, but also to embrace nature-positive goals. Policy makers need to provide an enabling environment; within many aquaculture value chains, the uneven distribution of risk and reward is a disincentive for innovative and sustainable practices. And scientific research needs to provide the information to determine which species can provide the best combination of nutrition, nature protection and climate resilience.

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