Food provisioning on our planet is progressively challenged by population growth, resource scarcity and climate change. Aquatic resources are of major importance to cover nutritional needs, foremost protein, especially in countries of the Global South. While capture fisheries production stagnates, further growth of aquaculture production is often considered as last resort to increase aquatic yields. But, the aquaculture sector faces imminent challenges to realize sustainable intensification.

**F A C T S**

**Why do we need aquaculture?**
We need aquaculture to **ensure equal, sustainable and resilient food systems** in the future. Aquaculture, especially the culture of marine organisms (mariculture) has the potential to grow food independent from key resources (e.g. land, freshwater and mineral fertilizer) that limit agricultural food production.

**What is the problem?**
Aquaculture practices often focus on the **monocultures of carnivorous species** (e.g. finfish and crustaceans). These practices are considered as **unsustainable** because of their dependence on fishmeal and fish oil as **feed input**. Additionally, highly intensive aquaculture has negative environmental impacts such as, habitat loss, eutrophication and disease transmission to wild species.
Aquaculture species and production systems

Aquaculture is the farming of aquatic organisms like fish, crustaceans (e.g. crabs), molluscs (e.g. mussels and snails) and other invertebrates (e.g. sea cucumbers and jellyfish), as well as reptiles, amphibians, aquatic plants and algae. There is an immense variety of potential aquaculture species. However, merely a fraction is fully studied and only a handful nearing full domestication (e.g. Salmon and Carp). The broad spectrum of cultured species is reflected by the numerous categories of production systems, which can be classified according to four main criteria:

Criteria
1) Type of enclosure
2) Rate of water exchange
3) Culture density
4) Feed input

System divisions
Ponds, tanks, raceways, cages, pens
Static, open, semi-closed, recirculating
Intensive, semi-intensive, extensive
Fed aquaculture, enhancing natural feed, none-fed aquaculture

Examples of systems for fed aquaculture

Table 1: Comparison of system features

<table>
<thead>
<tr>
<th></th>
<th>Ponds</th>
<th>Raceways</th>
<th>Floating cages</th>
<th>RAS</th>
<th>Aquaponics³</th>
<th>IMTAs³</th>
<th>Line culture⁴</th>
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</tr>
</tbody>
</table>

¹e.g. feed production, water pumping and boat engines; GHG = Greenhouse Gases; ²e.g. clearing of natural habitat, disease transmission and eutrophication; ³Information regarding Aquaponics and IMTAs: see next page; ⁴Cultures of none-fed species such as mussels and algae

Images
Is sustainable aquaculture intensification possible?

The most crucial sustainability concerns in aquaculture pertain farming intensity and feed input. To rise to its full potential, with regards to enhancing global nourishment, a rethinking of current aquaculture practices is needed: Instead of high intensive monocultures of carnivorous species, which require other fish as feed-input, more species from the lower end of the food chain (such as herbivorous fish, molluscs, invertebrates and algae) should be targeted more often. Overall, the share of so called non-fed species needs to grow.

Non-fed aquaculture

Farming marine primary producers (e.g. algae) and plankton feeding-animals (e.g. mussels and jellyfish) represents the most resource efficient aquaculture approach. These organisms provide the bulk of marine biomass and feed on naturally occurring nutrient sources by which they even clean the water.

Besides lowering the trophic-level of aquaculture species, an advanced use of nutrient cycles by mimicking natural ecosystems can enhance the efficiency and yield of aquaculture systems. Mixed culture approaches like Integrated Multitrophic Aquaculture (IMTA) and Aquaponics illustrate promising solutions.

Aquaponics

- **Land-based** systems combining the aquacultural production of fish with a hydroponic plant culture
- The effluent/excretions from the fish provide nutrients for plant growth
- Water recirculates within the system, allowing minimal freshwater use

IMTAs

- Feed residues and excretions from the fed species are reused along a cascade of other species that fill different trophic positions along the food chain
- IMTA can provide economic rewards (e.g. more efficient feed use and species diversity) and mitigate environmental impacts (less discharge)

References


Mission of ZMT
At ZMT the research about sustainable aquaculture combines natural- (NS) and social sciences (SS) to enable socio-ecological system approaches. The NS side investigates candidate species from lower trophic levels (e.g. sea cucumbers, jellyfish and macroalgae) and synergistic co-culture options in IMTA systems. SS looks at societal and institutional changes to provide a better understanding of future aquaculture concepts and their role for global food security and nutrition.

Current ZMT projects
Food for the Future (F4F): Culture and utilization of jellyfish biomass, primarily as alternative animal protein source for food and feed
Sea Grapes (Green Caviar): Optimizing aquaculture practices for the high-value edible macroalgae C. lentillifera
Pilot-scale IMTA studies on Zanzibar and in Indonesia
Science communication: Winner of the University Competition 20/21 – Bioeconomy (see QR-Code below)

Take home messages
→ Aquaculture will be important to ensure global nourishment and food systems resilience in the future
→ Current approaches are often considered as unsustainable due to dependency on fishmeal and fish oil and negative environmental impacts
→ Non-fed aquaculture is among the most resource-efficient forms of animal protein production
→ Next to lowering the trophic level of cultured species, multi-species approaches such as IMTA and Aquaponics forebode the vastest sustainability gains