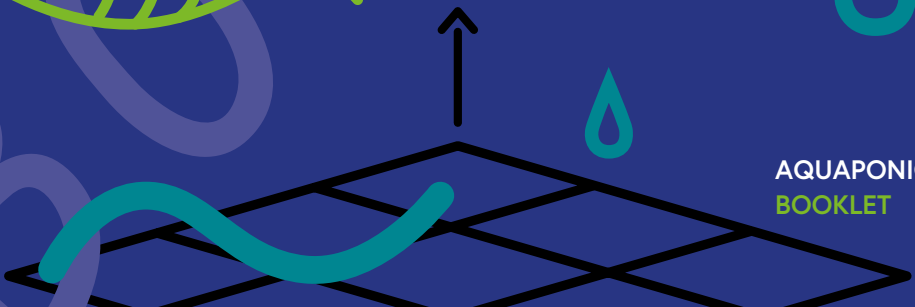
ENGLISH

AQUA CULTURE HYDRO PONICS

INGENIOUS SYMBIOSIS



AQUAPONICS VR
BOOKLET

WELCOME TO THE AQUAPONICS IN VIRTUAL REALITY.

You have farmed fish and tomatoes in the virtual farm or are going to try it? This booklet contains comprehensive background information on aquaculture and aquaponics, as well as instructions for playing the game.

CONTENT

Imprint

concept and text
→ Dr. Hendrik Monsees & Dr. Fabian Schäfer
design und illustration
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funding
→ BMBF. Federal Ministry of Education and Research

AQUA CULTURE HYDRO PONICS

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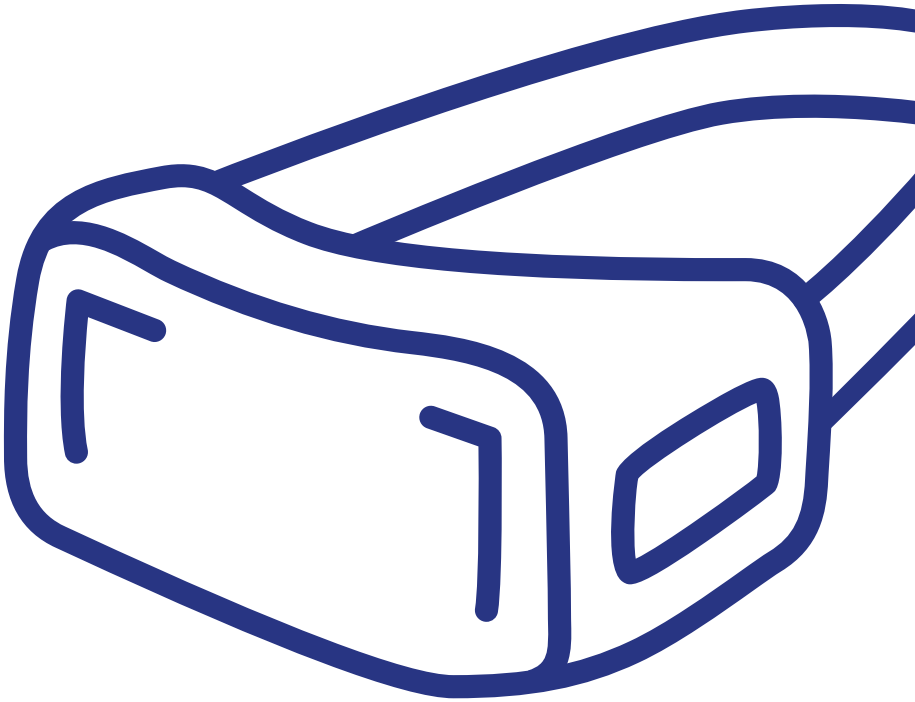
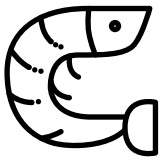


COMBINED FISH AND PLANT PRODUCTION IN AQUAPONICS

AQUAPONICS VR BOOKLET

Aquaculture is the controlled farming of aquatic organisms.

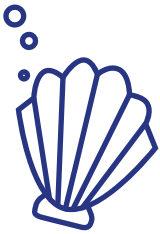


WHAT IS AQUACULTURE?

The main intent of quaculture is to provide food for human consumption. However, aquaculture can serve other purposes, such as the production of animals for stocking for recreational fisheries (e. g. carp and trout), for conservation and re-introduction of endangered species (e. g. sturgeons) or the production of algae for fuel or pharmaceuticals. Depending on the cultured species, the juveniles for on-growing are produced by directed reproduction with a broodstock or by capturing juveniles in the natural environment.

Is aquaculture the same as fish farming?

There really is not the one aquaculture, since a lot of different species are being farmed. Besides fish, molluscs, crustaceans, algae and aquatic plants are produced in aquaculture. The term "fish farming" therefore only describes a part of the entire aquaculture.



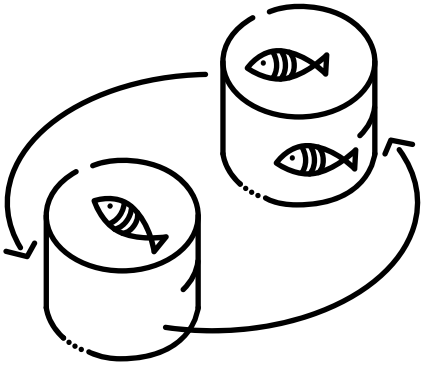
Aquaculture takes place in a lot of different production systems, like recirculating systems, net pens, ponds or flow-through systems.

↖ Ponds
↑ Capture fisheries
↓ Recirculaing aquaculture systems

WHAT IS THE ROLE OF AQUACULTURE?

In many places, aquaculture has a long tradition going back hundreds or even thousands of years. When it comes to the supply of fish, seafood and other aquatic organisms, aquaculture long had a tangential role in comparison to capture fisheries. Due to stagnating catch levels of the fishing fleets, the increasing population and product demand, the sector is experiencing a swift rise since the 1980s.

Aquaculture is considered as the fastest growing sector of food production worldwide. In 2018, over 114.5 Million tons of fish, crustaceans, molluscs, algae and aquatic plants were farmed. Today, over halve of the global consumption originates from aquaculture. And the demand is increasing. Every human on our planet eats over 20 kg per year.



In Germany…

…the aquaculture sector is eking out a niche existence. With less than 40.000 tons annual production only around 3% of the national consumption can be supplied.

PRODUCTION SYSTEMS

A lot of different production systems are being used in aquaculture. Their interactions with the environment differ between the systems. Generally, systems are either defined as open (more or less uncontrolled exchange with surrounding environment) or closed (controlled exchange), but several intermediate stages also exist.

In Germany, aquaculture is dominated by the farming of carp in ponds, trout in flow-through systems and mussel farms on the shores. Recirculating systems only play a minor role.

Net pens

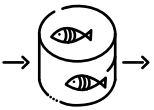
Mainly fish are fattened in net pens. The nets allow for a constant exchange with the surrounding water body (open systems).

Ponds

From a simple hole in the ground to large pond areas, this traditional and near-natural method with many variants and intensity levels is very important on a global level (open systems).

Algae and plants

Algae and plants are farmed in a variety of culture systems, e.g. concrete pools, nets or photobioreactors.



Flow-through systems

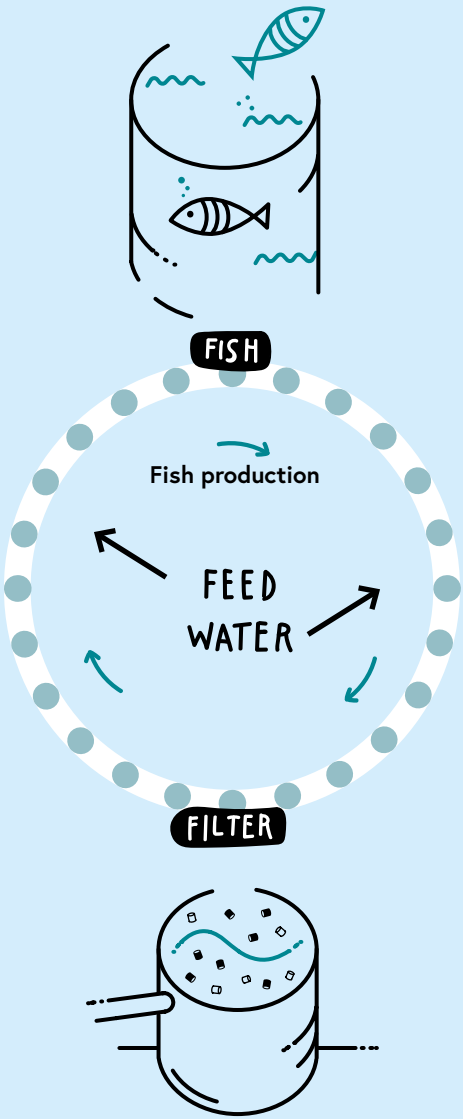
These are usually concrete basins or channels with a constant flow-through of water (open or semi-closed systems).

(Bivalve) Mollusc farming

Often, long ropes or baskets are used for farming of bivalve molluscs at the shores, which feed by filtration of the surrounding water (open system).

Recirulating systems

The animals are being farmed in tanks. The rearing water is treated in filter systems and recirculates back into the tanks. The closed system allows for a high level of control.



↑ Recirculating systems

AQUACULTURE IN THE FUTURE

The demand for fish and seafood is increasing. At the same time, the global supply from capture fisheries is stagnating or decreasing. Aquaculture can help meeting this challenge. The expansion of the sector however, needs to be shaped sustainably in order to minimize over-exploitation of resources.

→ With good management, the extensive pond farming in traditional aquaculture systems is considered as a near-natural method, compatible with the environment and also providing valuable ecosystem services. However, due to limited availability of water and land, as well as conflicts with environmental protection, the potential for growth is low.

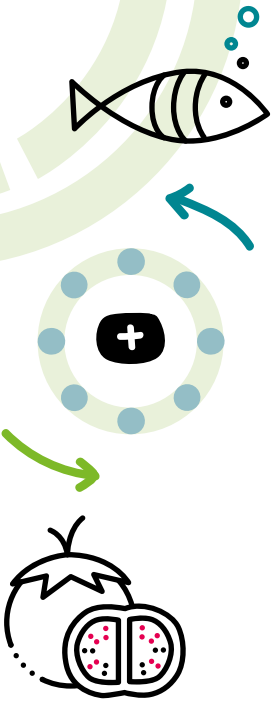
→ Expansion of aquaculture can be realised by (semi-)closed recirculating systems, technical innovations, environmentally friendly feed sources and short transport links. Recirculating systems can be integrated into existing production chains to e. g. use synergies (supply of water, heat, energy) or recycle nutrients.

trendsetter

The metabolites released by fish in recirculating systems can be used as plant fertiliser for example. The research and implementation of such concepts is considered as trendsetting.

II AQUAPONICS

Aquaponics combines the rearing of fish in an aquaculture facility with the cultivation of plants in a hydroponics system.



AQUACULTURE

Aquaculture is the controlled production of aquatic organisms, such as fish, molluscs or crustaceans. Production can take place in open systems, such as ponds or net pens – but also in closed systems, in so-called recirculating aquaculture systems, which are a part of aquaponic systems.

HYDROPONICS

Hydroponics describes the soilless cultivation of plants. In these systems the roots are supplied with all important nutrients by a nutrient solution. The roots can either directly grow in the nutrient solution, be washed around or sprayed with a nutrient solution or even supplied by a hose and drip irrigation.

By combining these two production systems, valuable resources, such as water and fertiliser, can be saved in plant production due to the dual use from the water in fish production.

WHY AQUAPONICS?

Currently (2020) there are already around 7.8 billion people on earth and the United Nations (UN) are forecasting an increase to 9.7 billion by 2050. This is associated with increasing pressure on the ecosystems on land and under water due to the fact that more and more resources are needed for the creation of new living space or arable land, as well as for the production of food.

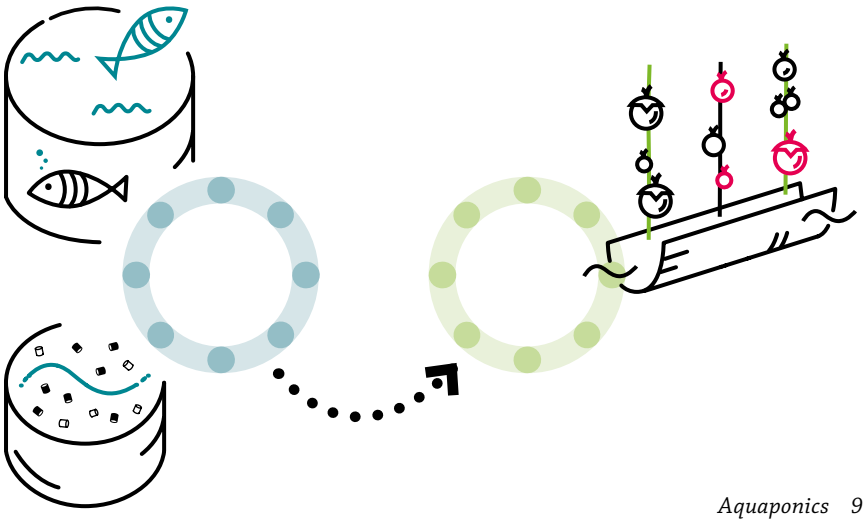
Aquaponics is one of the most efficient food production systems when it comes to the consumption of water, feed and fertiliser, and space requirements. The yield per area is significantly higher compared to conventional production systems (for fish e.g. in ponds, for plants e.g. cultivation in soil on a field). Particularly with regard to advancing climate change, aquaponic systems could contribute to the fact that fewer resources and valuable arable land are available for food production.

However, the investment costs for the construction of aquaponic systems are often high and the associated risk means that there are currently only a few commercial systems worldwide. In the hobby area, however, a large number of different systems can be found.

HOW IT WORKS

In aquaponic systems, fish are produced in closed recirculation systems. Due to the treatment of the water from the fish production with the help of mechanical and biological filters, these systems have very low water requirements. Thereby, nutrients, such as nitrate, potassium or calcium, are enriched in the process water.

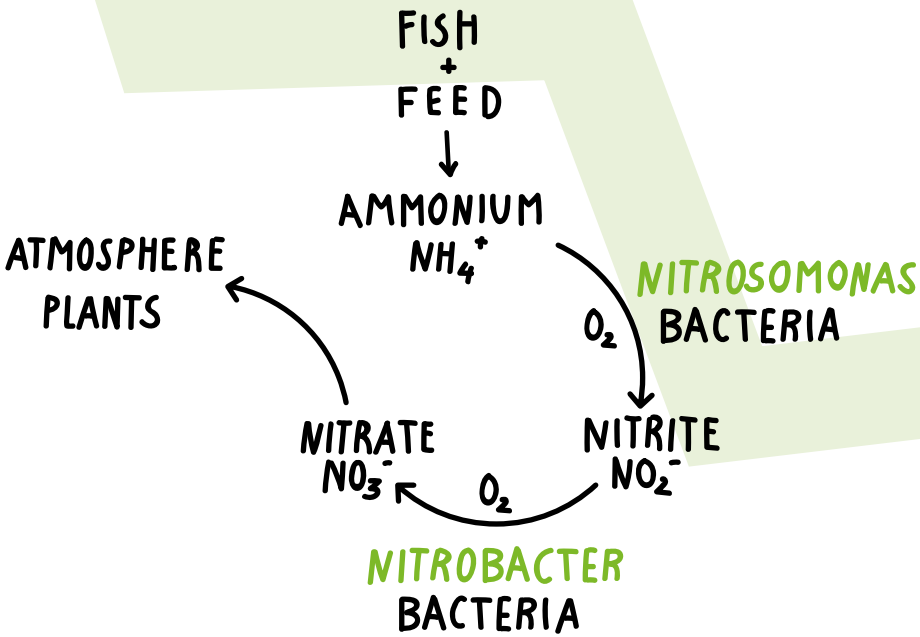
The nutrient-rich waste water, that is generated when cleaning the filters or when draining the water from the fish tanks, is usually disposed into the sewer system. In aquaponic systems, however, this enriched water is recycled by using it in the connected hydroponics unit (soilless cultivation of plants) for the production of plants, such as tomatoes, lettuce or herbs. This saves nutrients and especially water and conserves natural resources in food production.



NUTRIENT CIRCLE

The fish feed contains proteins, carbohydrates and lipids that are required for the fish's metabolism (e.g. growth, energy production). When nitrogenous compounds are broken down, ammonium (NH_4^+) is formed as a metabolic end product and is primarily excreted through the gills. Depending on the pH, a part of the ammonium is present as fish-toxic ammonia (NH_3). The decomposition of uneaten feed and faeces (excrements) and their microbial degradation also increases the ammonium/ammonia content in the process water.

The ammonium is converted into harmless nitrate via nitrite, as intermediate stage in recirculating systems by various biological filters, such as drip-, moving bed- or sand bed-filters, by certain types of nitrifying microorganisms. The conversion of ammonium to nitrite is done e.g. by the genus Nitrosomonas. The second step, the conversion of nitrite to nitrate, is e.g. carried out by the genus Nitrobacter. The formed nitrate represents the end product of the nitrification and consequently accumulates in the process water of the closed recirculation system.



FISH AND PLANTS

In aquaponics, fish species, such as Nile Tilapia, are produced. The natural habitat of these cichlids is Africa. As omnivores, they have lower demands on the feed quality. Additionally, they are robust against fluctuations in rearing conditions (temperature, nutrient content in the water, etc.) and grow rapidly.

Especially when rearing fish in greenhouses, the tolerance towards temperature fluctuations is a great advantage, as temperatures of over 30°C can be reached at times with intense sun exposure, but tight temperature regulation / air conditioning is very costly and not very sustainable. Other freshwater fish, such as African sharptooth catfish and various carp species, are successfully reared in aquaponic systems.

Cold water aquaponics is being tested in a few places (e. g. trout in Scandinavia). When selecting the plants, in principle all species that are grown in hydroponics can also be used for aquaponics. However, the specific nutrient requirements have to be considered. For example, fruit-bearing plants with a high nutrient demand, such as tomatoes, cucumbers or pumpkins, need significantly more nutrients than leafy plants, such as lettuce or herbs. Accordingly, in addition to economic aspects, the conditions of the respective aquaponic facility should also be taken into account when selecting the plants.

ECONOMIC IMPORTANCE

Currently (2020) there is still no widespread, commercial use of aquaponic systems for the sustainable production of food.

→ The main reasons are associated with high investment costs, inadequate standardization, the scarcity of trained staff and the associated risks when planning and financing such systems.

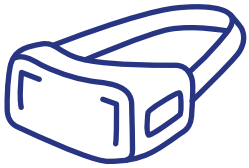
→ Several commercial systems have been set up in Europe in recent years. Today, there are a large number of small and medium-sized producers in the USA, who often produce on a sideline basis. However, there are no precise estimates on the global production volumes of aquaponic systems.

→ Compared to conventional systems, production can currently still be classified as extremely low.

→ Particularly promising for future commercial systems are decoupled aquaponic systems that enable optimal control of all production parameters and that were developed at the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB).

VR GAME AQUAPONICS

Virtual reality (VR) is a computer generated reality in 3D.



↗ VR glasses

The Aquaponic VR game…

…was designed in such a way that users without prior knowledge are able to discover the relationships and the functional principle of aquaponics.

THE AQUAPONICS VR GAME

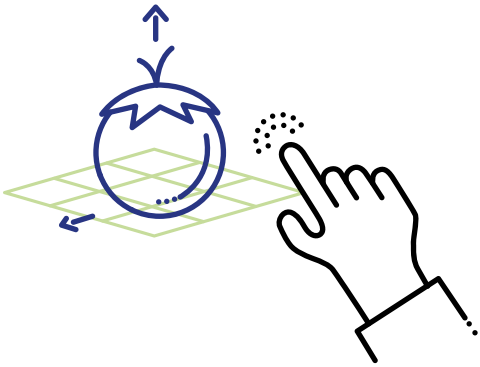
During the game, a narrater guides through the game so that the users can experience the interactions in virtual reality and do not miss any important stations.

This provides an overview of the entire system, but also insights and information on specific system parts, such as the biofilter and of course the fish and tomatoes. The users interact in the virtual space in an aquaponic facility as fish farmers and gardeners, and carry out simple tasks, such as feeding and harvesting. At the same time, background information is transferred.

CONCEPT AND AIMS

The main goal of the Aquaponic VR application is to make the complex biological and technical background of the integrated fish and plant production in an aquaponic facility accessible and touchable for a large number of user groups and the interested public through a virtual reality (VR) simulation.

Such tangible experiences can contribute to a better understanding and increase of the acceptance of these forms of production. However, such experiences are usually tied to a specific location and are only accessible in exceptional cases. With the help of VR technology, this can be transported in a realistic way.



↑ VR game

Dahrendorf award

The Ralf-Dahrendorf-Award for the European Research Area, which the Federal Ministry of Education and Research awarded for the first time in 2019, honors outstanding achievements in European networks. This honors projects by scientists in EU research projects and their motivation to put the results in dialogue with society. The winning projects can receive funding for their creative science communication ideas. The award is also intended as an incentive for other European researchers to let interested citizens participate in the exciting results of their research projects and to get more people excited about research topics. The Ralf-Dahrendorf-Award was first awarded on May 14, 2019 at the conference on the European Research Area in Berlin - also to the aquaponics project »INAPRO« of the IGB.

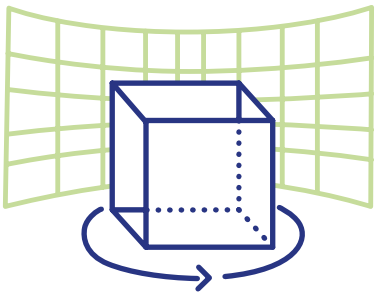
Ralf-Dahrendorf-Preis
Für den Europäischen Forschungsraum

SAFETY INSTRUCTIONS FOR USING THE AQUAPONIC VR

GAMING AREA

The gaming area is limited by a grid, please do not move or reach through this virtual grid, as you could collide with objects or people.

⚠ Avoid fast and powerful movements in general to protect yourself from accidents and to avoid damaging the VR system.



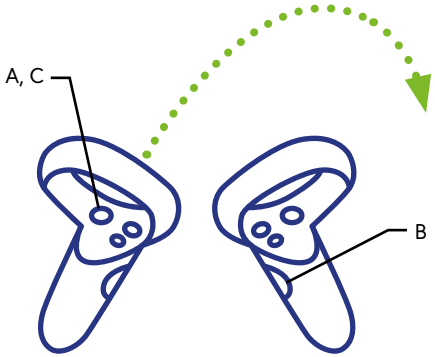
↑ Gaming area

USE OF CONTROLLERS

A – Moving
Please avoid walking independently in the virtual reality application, use the joystick of the left controller to teleport to a new location (see »Teleporting«).

B – Grabbing
With the help of the right controller you can grab objects such as the fish feed by closing your hand.

C – Teleporting
If you push the movable button of the left controller forward, you can determine your next location with the light beam that appears. The teleportation is triggered by releasing the button. If a green beam appears, it means that the movement is possible. If the beam is red, this movement cannot be carried out.



↑ left and right controller

APPENDIX

REFERENCES, USEFUL LINKS AND FURTHER INFORMATION

Ralf-Dahrendorf-Award for the European Research Area

bmbf.de/de/ralf-dahrendorf-preis-fuer-den-europaeischen-forschungsraum-7420.html

AquakulturInfo (German only)

aquakulturinfo.de

Research project CITYFOOD

cityfood-aquaponics.com

IGB Aquaponics

igb-berlin.de/en/aquaculture-and-aquaponics

IGB Aquaponics in VR

igb-berlin.de/aquakultur-und-aquaponik → Downloads

Research project INAPRO

inapro-project.eu

Statistisches Bundesamt (German only)

destatis.de

FAO 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rom.

fao.org/3/ca9229en/ca9229en.pdf

Fisch-Informationszentrum (FIZ, German only)

fischinfo.de

CUBES Circle

cubescircle.de

Fischbestände Online (German only)

fischbestaende-online.de

Aquaponics Knowledgebase

cfakb.igb-berlin.de

IGB Leibniz-Institut für Gewässerökologie und Binnenfischerei

AQUAKULTURINFO

Bundesministerium für Bildung und Forschung

Ralf-Dahrendorf-Preis Für den Europäischen Forschungsraum

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