Interreg South Baltic
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Universität Rostock
Traditio et Innovatio

AQUALOOP PILOT PROTOCOL
"NEMATIC – Increasing the nutrient efficiency of commercial aquaculture through increased application of circular economy concepts"



AquaLoop - *Aquaculture expert floor for circular economy practice,* Interreg South Baltic
Sep 2023 - Aug 2026

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I. INTRODUCTION

The transition to circular aquaculture in the South Baltic region is essential for addressing key environmental, economic, and social challenges. By promoting more efficient resource use, reducing waste, and closing nutrient loops, circular aquaculture contributes to the green transition while supporting regional resilience and competitiveness. It is fully aligned with European sustainability objectives and regional policy frameworks, providing a pathway towards a more sustainable and resource-efficient aquaculture sector.

The Interreg South Baltic project **AquaLoop - *Aquaculture expert floor for circular economy practice*** aimed to develop, promote, and support the implementation of circular aquaculture in the South Baltic region, with a particular focus on nutrient loop closure and the valorisation of aquaculture by-products to foster responsible production and consumption.

To achieve these objectives, the project developed and demonstrated innovative circular aquaculture solutions while strengthening the capacities of current and future professionals, businesses, and consumers to support the sector's transition. The consortium brought together universities, municipalities, industry associations, and SMEs, creating a strong partnership that combined research, education, stakeholder engagement, and practical industry application. This multidisciplinary approach was fundamental to developing and implementing circular economy solutions that can be effectively adopted in practice.

A key element of the project's approach was the close cooperation between partners in the joint development of tailored solutions to strengthen human resource capacities. This was achieved through the design and implementation of **three cross-border pilots** within the range of activities jointly called **PilotLoops**, which tested innovative methods and tools while demonstrating practical approaches to circular aquaculture under real-life conditions in the South Baltic region.

I.1. PilotLoops – Circular aquaculture South Baltic pilots

Three pilots tested and demonstrated innovative production methods aimed at reducing waste and water use, while generating valuable by-products and lowering environmental impacts. The work involved in-depth analysis and close cooperation with associated partners, enabling the exchange of data and practical solutions and supporting testing from lab to farm scale. This collaboration was supported by the use of commercially relevant technologies and enabled a continuous exchange of data and solutions. In addition, the project delivered jointly developed protocols to support further uptake by enterprises. These outputs also provided important input for the project’s training and support activities, helping to ensure that the results could be effectively applied in practice.

- **AquaLoop Pilot 1 – TARAS - Testing Algae Applications in Recirculating Aquaculture Systems (RAS) to improve aquaculture circularity potential in the SB region**.
  Coordinating partner: University of Gdańsk (PL). The aim of the pilot was to further develop technology on cultivation of shrimps and specific strains of microalgae, for RAS facilities, processing water purification, while producing high-value algal biomass, and to demonstrate applications of the biomass produced.

- **AquaLoop Pilot 2 - NEMATIC - *Increasing the nutrient efficiency of commercial aquaculture through increased application of circular economy concepts.***
  Coordinating partner: University of Rostock (DE). The idea of the pilot was to research and test the unused residues from fish production. Specifically, the biochemical composition of the gonads, livers and skins of African catfish (*Clarias gariepinus*), rainbow trout (*Oncorhynchus mykiss*) and pikeperch (*Sander lucioperca*) will be investigated, and possible and practical potential paths of utilization will be tested.

- **AquaLoop PILOT 3 – FISHVISA - *Development of the Fish-Shrimp-Vegetables integrated system of aquaponics to showcase the potential of circular economy principles in RAS***,
  Coordinating partner: Klaipeda University (LT). The main activities were related to FISHVISA technology testing at the Marine Research Institute Fisheries and Aquaculture Laboratory. A small demo aquaponic system in a glasshouse was developed, and tested with rainbow trout, crayfish and salad, where crustaceans expect to use solid wastes, and vegetables use nutrients from fish and crustaceans, to develop a zero-waste RAS technology.

I.2. NEMATIC pilot – background and aim

Global aquaculture production has shown continuous growth over the past decades and is expected to play an increasingly important role in ensuring global food security. In contrast, aquaculture production in Europe has expanded at a considerably slower rate, with some countries even experiencing stagnation or declining production. Consequently, improving production efficiency and establishing new, economically viable aquaculture species are key priorities for the European aquaculture sector (FAO, 2024; FEAP, 2026).

The African catfish (*Clarias gariepinus*) represents a promising species due to its excellent feed conversion efficiency, rapid growth, high tolerance to intensive farming conditions, and suitability for production in recirculating aquaculture systems (RAS).

The culture of African catfish in RAS has become an established sector of European aquaculture, with an annual production exceeding 11,000 tonnes in 2024 (FEAP, 2026). Despite its production efficiency, the species exhibits a relatively low processing yield of approximately 40–43%, mainly due to its large head and anatomical characteristics. Consequently, 57–60% of the harvested biomass remains as processing by-products that are currently underutilized, despite containing valuable proteins and lipids.

Within commercial production, the gonads, liver and skin alone account for at least 20% of the harvested biomass, representing a substantial resource with significant potential for valorisation.

The African catfish is characterized by rapid somatic growth and early sexual maturation. Once sexual maturity is reached, nutrient allocation shifts from muscle growth towards gonadal development, reducing growth performance while supporting the production of high-quality eggs and sperm. This physiological transition is accompanied by increased metabolic activity, making efficient liver function essential for maintaining energy metabolism.

Furthermore, *C. gariepinus* possesses a suprabranchial organ that enables atmospheric oxygen uptake and allows short overland movements. These adaptations require a robust and physiologically specialized skin, suggesting considerable potential for the recovery of structurally and biochemically valuable compounds.

In addition to African catfish, rainbow trout (*Oncorhynchus mykiss*) and pikeperch (*Sander lucioperca*) supplied by the State Research Institute for Agriculture and Fisheries Mecklenburg-Western Pomerania (LFA MV), Institute of Fisheries, from Born am Darß and Hohen Wangelin facilities were investigated. Expanding the range of species enabled the assessment of the circular economy concept's applicability to the southern Baltic Sea aquaculture sector across the region's most important farmed fish species.

The NEMATIC pilot aims to improve both the environmental and economic sustainability of African catfish aquaculture by investigating the utilization of processing side streams that are currently discarded or only minimally used.

The project focuses on the gonads, liver and skin, with the following objectives:

- characterization of their biochemical composition, more specifically, lipid composition and fatty acid profiles;
- identification of high-value compounds suitable for food, feed, pharmaceutical or industrial applications;
- evaluation of potential processing pathways for the sustainable utilization of these by-products; and
- development of strategies to increase resource efficiency and circularity within the aquaculture of the South Baltic Region.

By transforming currently unused biomass into valuable products, the project seeks to improve nutrient utilization, reduce waste generation, increase the economic value of aquaculture production, and contribute to the objectives of the European circular bioeconomy.

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II. NEMATIC PILOT IMPLEMENTATION

II.1. Fish cultivation

The recirculating aquaculture system (RAS; Fig. 1) used for the production of three cohorts of African catfish (*Clarias gariepinus*; Fig. 2a) is located in the FishGlassHouse (FGH) at the University of Rostock on the campus of the Faculty of Agriculture, Civil and Environmental Engineering. The RAS is a commercially available production system that is also operated at commercial scale by the associated project partner Nutrition and Food, part of Bioenergie Lüchow. The system comprises nine culture tanks, a mechanical treatment unit for solids removal (sedimentation tank), a biological treatment unit (trickling filter) for nitrification, and a water conditioning unit to ensure stable water quality throughout the production cycle.

To enable continuous monitoring of fish performance and system operation, three successive cohorts of African catfish were stocked at different time points into three tanks each. Fish were reared until reaching an average target harvest weight of approximately 2.5 kg. The three cohorts were stocked on 23 January, 26 March, and 25 June 2024, respectively. The first and second cohorts completed their production cycle in December 2024, whereas the third cohort was maintained until March 2025.

Throughout the experimental period, fish were fed commercially available diets specifically formulated for African catfish (Alltech Coppens). Feeding followed the manufacturer's recommended protocol, with daily feed rations automatically adjusted according to the estimated biomass of each cohort to account for growth during the production cycle. This feeding strategy ensured that nutrient supply closely matched the physiological requirements of the fish while maintaining standardized production conditions across all cohorts.

Figure 1. Recirculating aquaculture system (RAS) operated in the NEMATIC pilot facility at the FishGlassHouse (FGH), University of Rostock. The system consists of nine culture tanks (left) and a water treatment unit (right) including a sedimentation tank for mechanical filtration and a trickling filter for biological treatment.

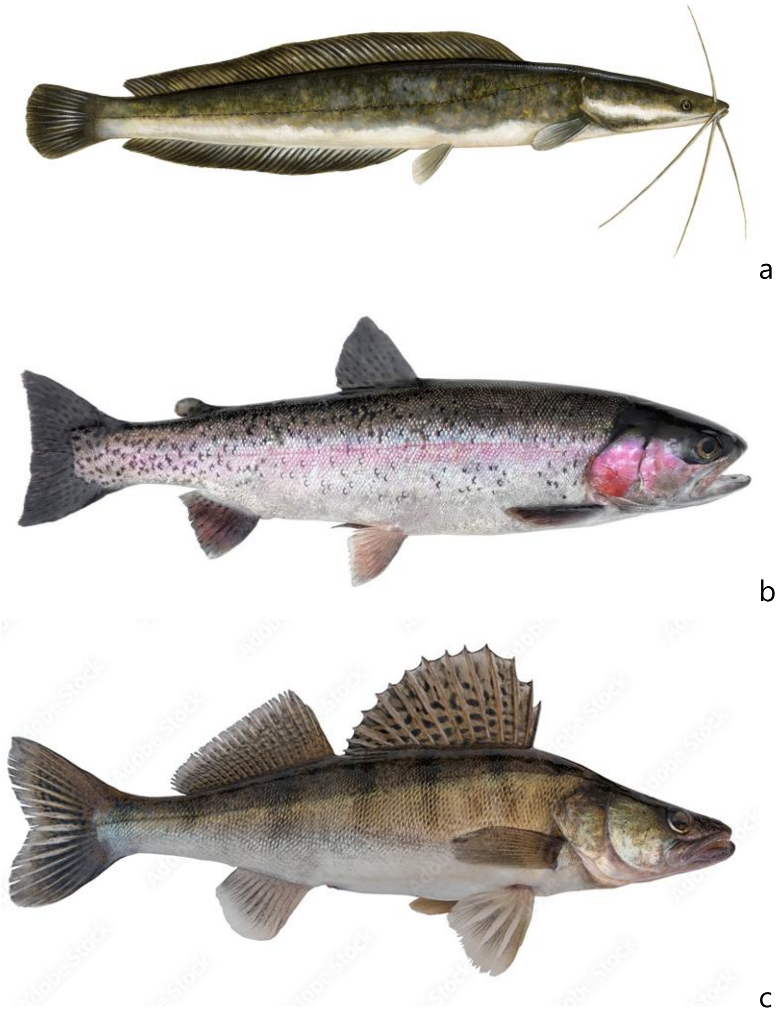


Figure 2. Freshwater fish species investigated within the project: a) African catfish (*Clarias gariepinus*), b) rainbow trout (*Oncorhynchus mykiss*), and c) pikeperch (*Sander lucioperca*). Image sources: WWF Switzerland (https://www.wwf.ch/de/fischratgeber/wels-afrikanischer-wels-europaeischer-wels), Angelmagazin.de (https://angelmagazin.de/zielfisch/regenbogenforelle/), and Adobe Stock (Asset ID 282412169).

The two other fish species investigated in the project, rainbow trout (*Oncorhynchus mykiss*; Figure 2b) and pikeperch (*Sander lucioperca*; Figure 2c), were reared at the facilities of the State Research Institute for Agriculture and Fisheries Mecklenburg-Western Pomerania (LFA MV). For subsequent sampling and analysis, three subsamples of five individual fish each were transferred from the respective rearing facilities to the laboratory at the University of Rostock at regular intervals.

II.2. Fish sampling

Sampling was conducted at three-week intervals for all three fish species. At each sampling point, three subsamples, generally originating from different culture tanks, were collected, with five individual fish per subsample. Fish were anaesthetized and euthanized in accordance with applicable legal requirements prior to sampling and subsequent analysis.

For each individual fish, the following biometric and physiological parameters were recorded: sex, total length, total body weight (whole, ungutted), liver weight, gonad weight, visceral fat weight, skin weight, and fillet weight. Tissue samples from the gonads, liver, and skin were collected from each individual, immediately frozen, and stored at −20 °C until further sample preparation and analysis.

In total, 615 African catfish (*Clarias gariepinus*), 180 rainbow trout (*Oncorhynchus mykiss*), and 210 pikeperch (*Sander lucioperca*) were sampled during the study period.

II.3. Fish performance

The collected data demonstrate that the three fish species differ substantially in growth performance (Fig. 3a, 4a and 5a) due to their distinct ecological adaptations. These differences are reflected in both culture duration and target harvest weight.

The data further indicate that liver development, expressed as the hepatosomatic index (HSI), plays an important role in achieving the respective growth performance (Fig. 3b, 4b and 5b). Similarly, the species differ in the timing of reproduction, as reflected by changes in the gonadosomatic index (GSI) (Fig. 3c, 4c and 5c).

The ratio of skin weight to total body weight (Fig. 3d, 4d and 5d) reflects not only the proportion of enclosed biomass but also species-specific skin requirements, which are influenced, among other factors, by the ecological niche occupied by each species.

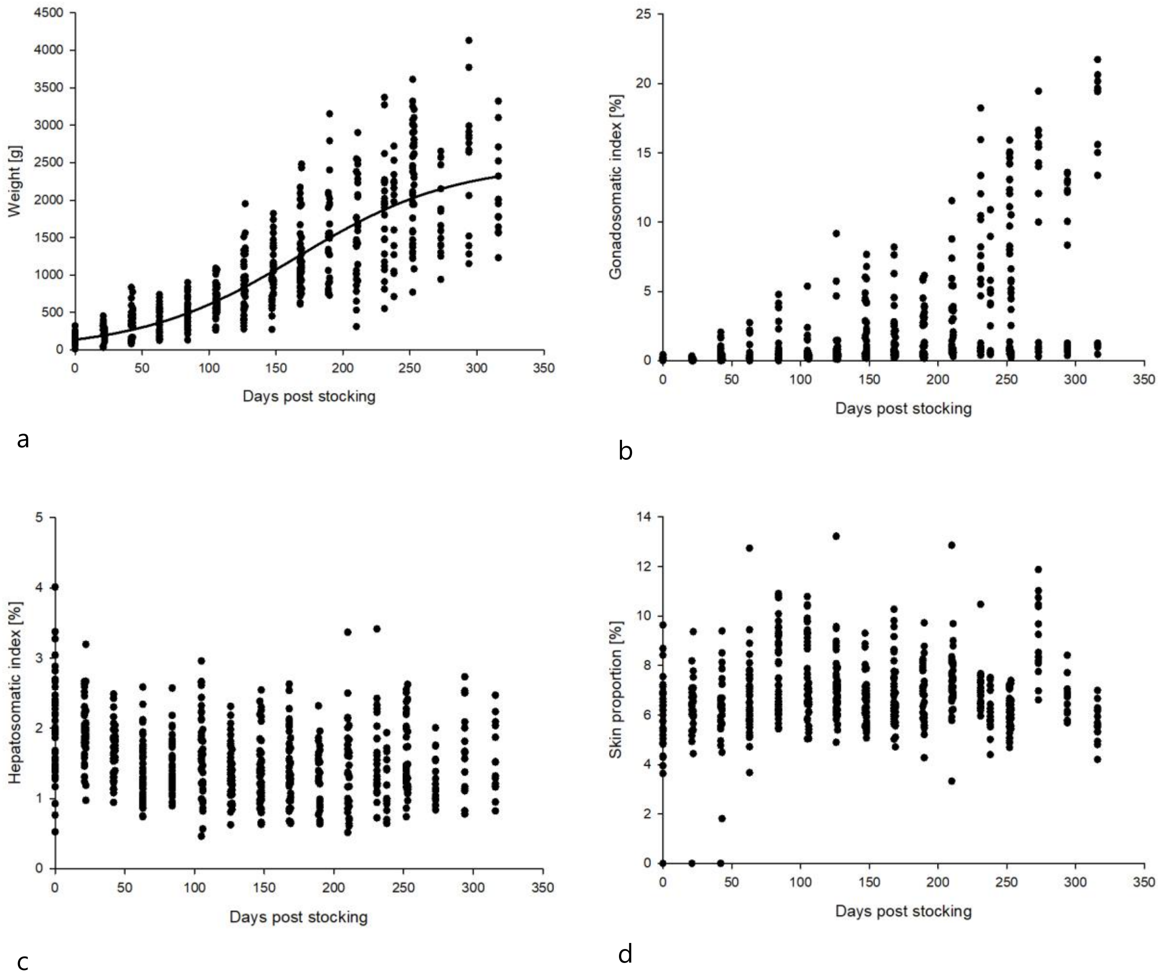
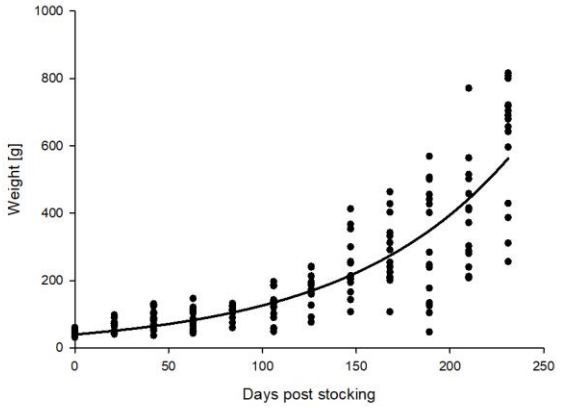


Figure 3: Performance data of African catfish: a) growth curve over the production periods; b) gonadosomatic index (GSI); c) hepatosomatic index (HSI); and d) skin ratio.



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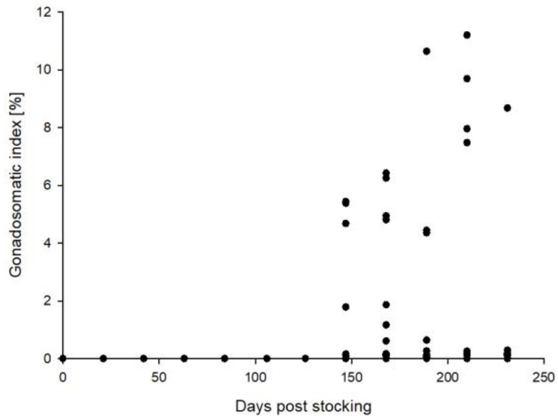

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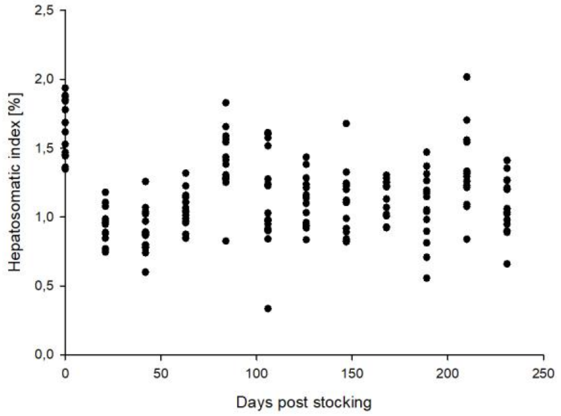

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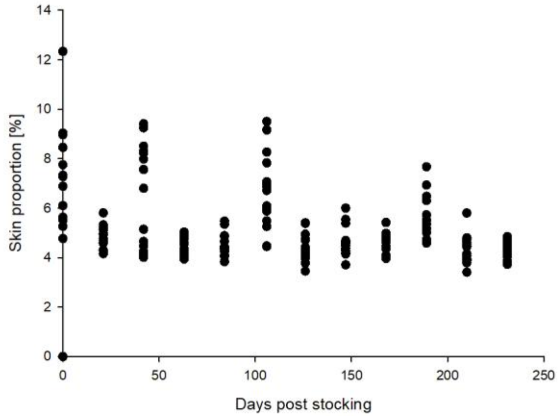

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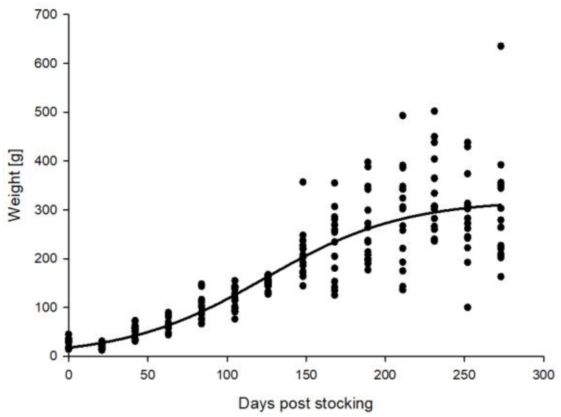
Figure 4: Performance data of rainbow trout: a) growth curve over the production periods; b) gonadosomatic index (GSI); c) hepatosomatic index (HSI); and d) skin ratio.



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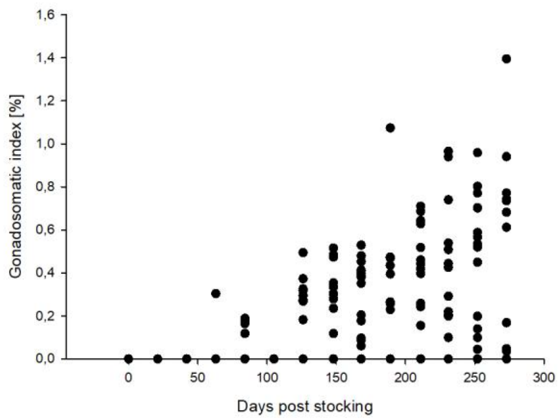

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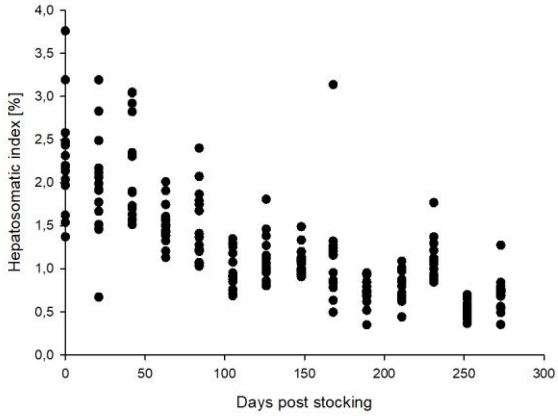

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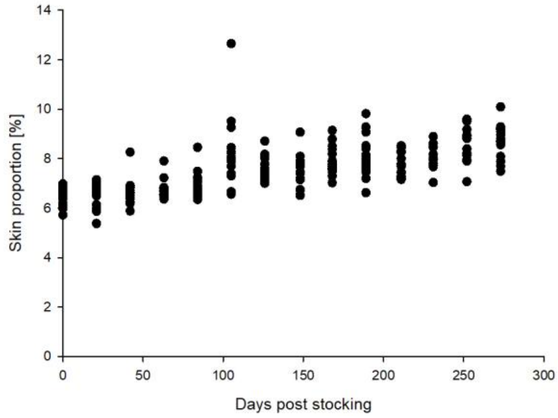

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Figure 5: Performance data of pikeperch: a) growth curve over the production periods; b) gonadosomatic index (GSI); c) hepatosomatic index (HSI); and d) skin ratio.

II.4. Fatty acid composition

Fatty acids are supplied to cultured fish through dietary oils and, depending on feed composition and species-specific requirements, are incorporated into the fish biomass as well as into individual organs and tissues.

To assess the potential utilisation of fatty acids from currently underutilized organs and tissues, such as gonads, liver and skin, fatty acid analyses were conducted to determine both the absolute quantities and the fatty acid composition of the different by-product streams. The data presented for African catfish and rainbow trout are currently being prepared by the project team for scientific publication and will be made available on the project platform following publication.

In African catfish, total fatty acid content in the liver varied considerably between sexes, ranging from 126.9–221.3 µg/mg dry weight in females and 26.8–69.2 µg/mg in males. In the gonads, total fatty acid content ranged from 153.6–202.0 µg/mg dry weight in females and 72.8–122.5 µg/mg in males. Particularly high concentrations were found in the skin, with values of 282.0–356.1 µg/mg dry weight in females and 143.2–308.2 µg/mg in males.

In rainbow trout, total fatty acid content in the liver ranged from 78.3–269.2 µg/mg dry weight. The skin showed an even wider range, with total fatty acid concentrations of 36.7–432.4 µg/mg dry weight.

The fatty acid profiles of both African catfish and rainbow trout demonstrated substantial concentrations of the nutritionally important long-chain polyunsaturated fatty acids EPA and DHA.

A preliminary economic assessment indicated that the recovery of fatty acids from these by-products could have a positive economic impact. However, this potential depends on sufficient market acceptance of the recovered materials. At present, there is still some market reluctance towards raw materials derived from by-products, potentially due to the perception that they are of lower quality. The results presented here indicate that this assumption is not necessarily justified, as the analysed tissues contain substantial amounts of potentially valuable fatty acids, such as omega-3 fatty acids.

II.5. Potential by-products

As potential raw materials for by-products, the gonads, liver, and skin of the fish were examined in greater detail.
As discussed in the previous chapter, the quantity and composition of fatty acids in the three aforementioned organs or tissues were analyzed. In principle, fatty acid extraction is feasible; however, several prerequisites must be met. One of the most important prerequisites is the availability of a sufficient quantity of source material, as further processing is generally labor-intensive, while the use of machinery only becomes economically viable above a certain processing volume.
To provide an indication of the quantities that could be available for processing based on the results obtained, the production of African catfish, for example, with an average individual harvest weight of 1.5 kg and an annual production volume of 500 tonnes, would generate approximately 40 tonnes of gonads, 8.5 tonnes of liver, and 35 tonnes of skin.
For rainbow trout and pike-perch, the corresponding quantities would be approximately 5.5 and 5.0 tonnes of liver, and 25 and 35 tonnes of skin, respectively. In both species, the gonads were not yet fully developed when the fish reached their initial market size and are therefore considered unsuitable for further utilisation.
For the further utilisation of these materials, an extensive search of the scientific literature and online sources was conducted to identify potential applications. Based on the findings, practical implementation of the identified approaches was subsequently investigated, either in-house or with the support of external experts. In addition to analyzing the fatty acid composition of the three sample materials, the broader biochemical composition of the gonads and skin was also considered.
With regard to the gonads and liver, it was assumed that various bioactive molecules, such as enzymes, may be present. However, a general screening approach without clearly defined target compounds was considered too uncertain and, due to financial constraints, could not be implemented. Consequently, this approach could not be pursued further.
The utilisation of fish skin as a medical device presented a different challenge, as patent-related restrictions apply to its use as a wound dressing. These restrictions prevented this approach from being pursued further at the moment.

Ultimately, the following options were investigated experimentally: the extraction of collagen from the skin of African catfish and the production of leather from African catfish skin.
In addition to the original approaches, an idea emerged during the course of the project to dry the heads of African catfish and evaluate their suitability as dog treats.

Collagen extraction

The process of collagen extraction described by Montero and M.C. Gómez-Guillén (2000), which was applied during the project, follows the listed key steps:

1. Pre-treatment:
    a. Fish skin is cleaned to remove impurities like scales (not necessary for African catfish), fat, and any attached tissues like meat. This is often done through washing with cold water (Fig. 6).

Figure 6: Preparation of the skin, weight of this piece was 33.5 g.

b. The cleaned skin is then soaked in a mild alkaline solution (e.g., NaOH 0.1M) to remove non-collagenous proteins and other organic substances, such as fats and pigments (Fig. 7). This step is important for isolating collagen and ensuring the purity of the final product.

Figure 7: Just after the skin was placed inthe NaOH; after 24h in NaOH, mucus and other tissues are dissolved in the solution; skin weight is now 44.8 g.

2. Demineralization:
   a. The skin is treated with a diluted acid solution to solubilise the collagen and demineralize the material (e.g. scales, bones, etc.). This step is not needed for African catfish skin.
3. Collagen Extraction:
   a. The collagen is extracted by soaking the fish skin in the acid solution for a specific period (typically several hours to days) at a controlled temperature (Fig. 8). This helps solubilise the collagen into the solution. We used 48 to 72 h and a temperature of 4° to 20°C (30°C is not working).

Figure 8: Same piece of skin now in 0.5 M acetic acid. The 44.8 g are in 1L solution

b. In some cases, enzymatic treatments can be used.

4. Filtration and Centrifugation:
   a. The collagen solution is filtered to remove any remaining impurities or undissolved material (Fig. 9). Centrifugation can also be used to separate soluble collagen from the rest of the mixture.

Figure 9: We filtrated with a cheese cloth

5. Purification:
   a. The collagen extract may undergo further purification steps, such as dialysis, to remove excess acids, salts, and low molecular weight impurities.
   b. The purified collagen is typically concentrated through precipitation (e.g., by adding salts) or through ultrafiltration (Fig. 10).

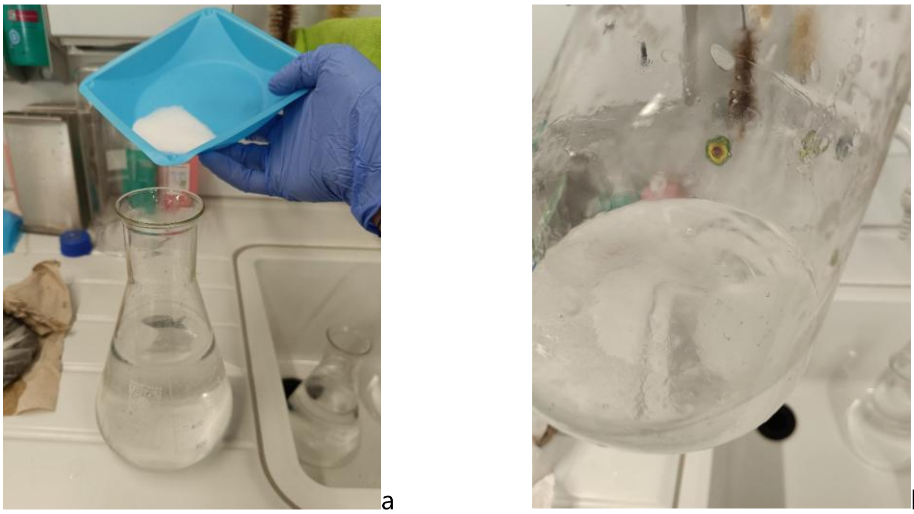

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Figure 10: a) we did precipitation but without the purification step, b) we cleaned the precipitate 3 times with distillate water

6. Collagen Drying:
   a. Once the collagen has been purified, it can be dried to create a collagen powder (Fig. 11). This is often done by freeze-drying (lyophilization), which preserves the collagen's structural integrity and allows it to be stored for long periods.

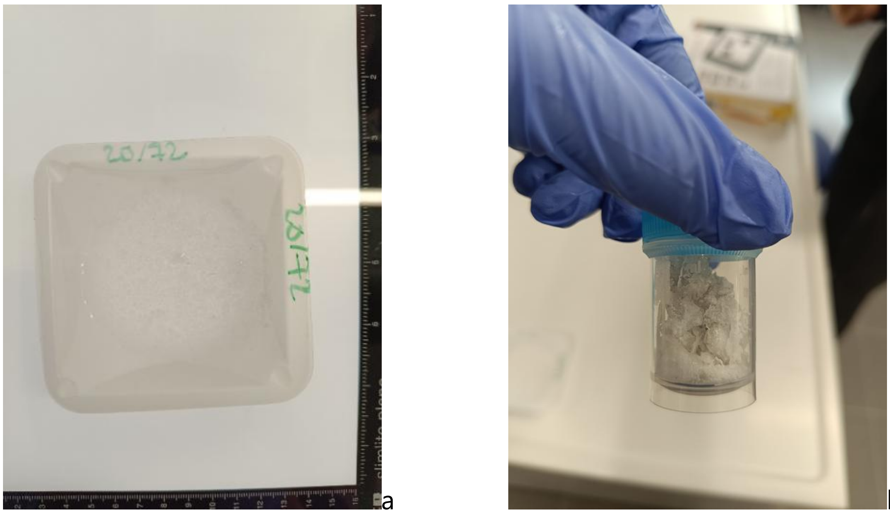

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Figure 11: a) Dried collagen, b) notice that this has impurities.

7. Characterization and quality control:
   a. The final collagen product is tested for purity, molecular weight distribution, and functional properties to ensure it meets the desired specifications.

Fish leather preparation

1. Preparing the fish skin
   a. Cleaning: Remove any flesh and fat from the skin using a blunt knife or scraper, de-scaling (if necessary)
   b. Rinsing: Wash the skin thoroughly in cool water.

2. Salt solution: soak the skin in a strong saltwater solution for several hours. This helps preserve and further clean the skin.

3. Tanning with oak bark
   a. Prepare the oak bark solution:
      i. Weigh the bark: For 500 grams of fish skin, use about 200 grams of oak bark.
      ii. Boil the bark: Simmer it in about 1-2 liters of water for 1–2 hours to extract the tannins. Let the liquid cool to room temperature and strain out the solids (Fig. 12).

Figure 12: Oak bark solution

   b. Tanning process:
      i. Immerse the skins in the tannin-rich solution.
      ii. Let them soak for 1–3 days, depending on the thickness of the skins. Stir gently every day to ensure even exposure.

   c. Monitor: The skin will darken as it absorbs tannins. Check periodically for flexibility and texture. (See results below)

4. Drying the Tanned Leather
   a. Rinse: After tanning, rinse the skins in cool water to remove excess tannins.
   b. Stretching:
      i. Lay the skin flat on a mesh or stretch it gently on a wooden frame (Fig. 13).
      ii. Use pins, clips, or small nails to secure the edges without tearing.

Figure 13: Skin flattened on a mesh

c. Air Drying:
   i. Dry in a well-ventilated, shaded area to prevent over-drying or cracking (Fig. 14).
   ii. Avoid direct sunlight.

Figure 14: Air drying of fish skin.

5. Softening the leather
   a. Moisturizing: Before it gets to dry, apply a small amount of natural oil (such as coconut oil) (olive oil worked better) to the leather (Fig. 15 and 16). Massage it in evenly to restore flexibility.
   b. Stretching again: Work the leather by bending and stretching it to further soften it.

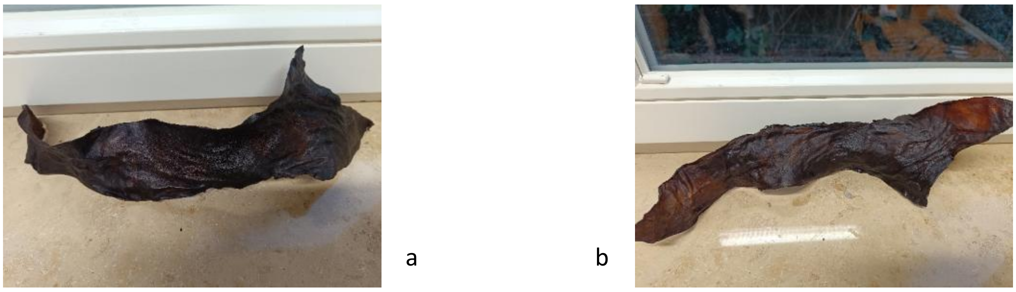

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Figure 15: a) African catfish skin 3 days in the tannin solution, b only coconut oil was applied (extremely hard)

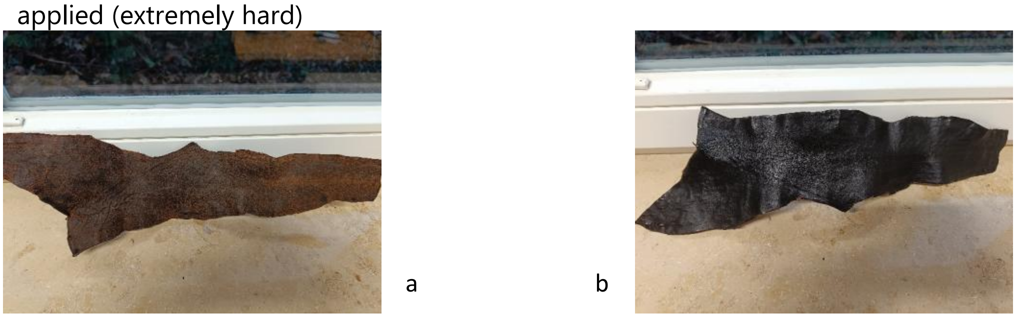

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Figure 16: a) African catfish skin 1 days in the tannin solution, b) Olive and coconut oil were applied (softer but still room for improvement)

Following several partly unsuccessful attempts to produce leather from African catfish skins in-house, the project established contact with an experienced artisan who has specialized in fish leather production for several decades. For the project, he professionally processed the catfish skins into leather using a purely plant-based tanning process.

The resulting leather is visually appealing, durable, and, considering its relatively low thickness, demonstrates high tensile and tear strength (Fig. 17). This successful processing demonstrates the potential of African catfish skin as a valuable secondary raw material and provides a promising basis for further development and potential commercial applications.

Figure 17: Fish leather made from African catfish skin, professionally tanned under controlled conditions.

Dried African catfish heads as a dog treat

The African catfish has a disproportionately large head, which has so far been largely unused. Since the head accounts for approximately 10–15% of the harvested fish and therefore represents a significant untapped resource, potential applications were investigated.
Market research identified dried catfish heads already being offered as dog treats at retail prices comparable to the value of an entire fish fillet. Based on this finding, a simple drying protocol was developed. The heads are dried in a drying cabinet at 60–65°C for five days and can subsequently be stored under dry conditions. In this context, utilising a cost-effective source of industrial waste heat would further advance the principles of the circular economy.
A consumer study was conducted at the Faculty of Agriculture, Civil and Environmental Engineering to assess dog owners' willingness to use the product and the dogs' response to dried catfish heads.
The results were encouraging: approximately 90% of the dogs showed clear interest or strong enthusiasm and consumed the product. Furthermore, smaller dogs were more likely to reject the dried heads. A change in the dogs' smell was noticed after consumption but was not considered negative by the owners. In most cases, the dogs' stools became firmer.
Approximately 80% of dog owners indicated that they would use the dried catfish heads again, primarily as an occasional treat rather than as a regular food product. Regarding willingness

to pay, approximately 28% of respondents indicated €1–3, 56% €3–5, and 14% around €10 per head.
Overall, the results demonstrate a clear economic potential for the valorisation of African catfish heads, which are currently largely regarded as a waste stream. Further development of this application could therefore contribute to improved resource efficiency, additional revenue opportunities, and increased value creation along the catfish production chain.

Reference

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II.6. Experimental outcomes

The work carried out within the project Pilot NEMATIC generated valuable new data and insights, particularly through the focused data collection and the exploration of new research questions. At the same time, the project demonstrated that, despite promising ideas and approaches, not every aspect could be pursued through to completion. Personnel and financial constraints, as well as technical limitations, restricted the implementation of certain activities. In some cases, the required equipment or processes were either unavailable or designed exclusively for large-scale industrial operations and were therefore not compatible with the small material flows typically generated by research projects.
Nevertheless, several promising approaches were successfully pursued and the results were presented to associated partners and other stakeholders at specialist events, workshops, conferences, and professional meetings. This provided an opportunity to share the findings and discuss their potential for future applications.
In addition, three scientific publications are currently in preparation to disseminate the data and findings generated on African catfish and rainbow trout to the wider scientific community. This will further contribute to the transfer and long-term utilisation of the knowledge generated within the project.

II.7. Summary and Outlook

Sustainable aquaculture represents a viable approach to producing healthy food. At present, however, only a part of the biomass produced is utilised, whilst the remainder has to be disposed of at considerable effort and high cost.

The NEMATIC pilot has demonstrated, both theoretically and – to a certain extent – in practice, that there are viable ways of obtaining marketable by-products from these residual biomass streams. The next steps should therefore focus on the commercial utilisation of these by-products, as well as on gaining a better understanding of customer perceptions and market requirements, in order to tap into viable market opportunities.

Beyond the southern Baltic Sea region, examples such as Iceland demonstrate that the consistent implementation of circular economy principles and the utilisation of secondary streams can significantly increase the overall value of aquaculture products.

III. PILOT DEMONSTRATIONS

The AquaLoop project aimed to prepare school kids, students, and professionals for circular economy approaches, with a focus on aquaculture production and consumption. It sought to support their career development while contributing to both ecological and economic progress in the region. NEMATIC pilot specifically focused on all three target groups:

1. Secondary school youth from the Waldorfschule Rostock and other schools from Rostock and Northern Germany;
2. Students of the Aquaculture Master programme from the University of Rostock, students participating in the AquaLoop student exchange programme from University of Gdansk and Klaipeda University as well as other national and international students;
3. Researchers and academics, including partner institutions: University of Rostock, University of Gdańsk and Klaipeda University;
4. Representatives of NGOs, municipalities, public bodies;
5. SMEs, including employees of aquaculture businesses or individuals wishing to enter the aquaculture sector.

Training based on the pilot was performed within so called **TrainingLoop – Circular aquaculture training pool** activities of the AquaLoop project, whereas **study visits** to the facility were carried out as part of the **SupportLoop – Circular aquaculture stakeholder support** AquaLoop activities.

III.1. University of Rostock secondary school youth involvement in NEMATIC pilot

As part of the AquaLoop project, a 4-month lasting pilot activity was conducted at the NEMATIC pilot with a sixth-grade school class from Rostock. The project introduced students to the principles and practical operation of aquaponic food production using African catfish combined with basil and rocket salat cultivation. In addition to gaining a basic understanding of aquaponics, the students were actively involved in monitoring and assessing key parameters of the water connecting the fish and plant production systems.
From March to June 2024, a total of 30 school kids, one teacher, and two accompanying adults from the Waldorfschule Rostock visited the pilot on a weekly basis. The pupils were first introduced to the background and objectives of the AquaLoop project and to the basic concept of aquaponics. During the practical sessions, they germinated basil and rocket seeds themselves, subsequently transferred the seedlings into the experimental system, and monitored plant growth on a weekly basis in rotating groups (Fig. 18a).
In parallel, the pupils regularly assessed fish growth, also working in rotating groups. Growth performance of the African catfish was monitored by measuring both body length and weight (Fig. 18b). A third group was responsible for the weekly monitoring of key water-quality parameters at two locations within the recirculating system. Using handheld measuring equipment, the pupils determined water temperature, dissolved oxygen concentration, pH, and electrical conductivity (Fig. 18c). In addition, rapid test kits were used to measure the concentrations of the nitrogen compounds ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-).
Through this hands-on approach, the pupils developed a fundamental understanding of aquaponic systems while gaining more in-depth insights into fish biology, plant production

management, and the interactions between fish metabolism and water quality within a recirculating production system. The project also provided practical experience in observation, measurement, data collection, and the interpretation of biological and environmental processes.

The successful implementation of the school project confirmed the initial assumption that a positive perception of aquaculture and its products should ideally be fostered at an early age, rather than only addressing consumers once they reach adulthood. Early, hands-on engagement with sustainable aquaculture can help build knowledge, understanding, and acceptance of aquaculture as a resource-efficient approach to future food production.

a b c

Figure 18: a) Collection of plant growth data; b) collection of fish growth data; c) measurement of water quality parameters.

III.2. University of Rostock student's involvement in NEMATIC pilot

The pilot actively involved students from the University of Rostock, engaging 17 master students. This collaboration provided valuable support to the project while offering students hands-on experience in applied marine science and sustainable aquaculture.

Students participated in the daily operation and maintenance of the recirculating aquaculture system (RAS), including monitoring water quality, maintaining equipment, observing fish health, determining their mass, managing feeding, and documenting system performance. They also supported experimental work by assisting the biological sampling, such as gonad, liver and skin samples for further analysis.

III.3. AquaLoop cross-border student exchange program

The AquaLoop project established a cross-border student exchange programme between the three partner universities implementing the project pilots: University of Rostock (Germany), University of Gdańsk (Poland), and Klaipeda University (Lithuania). The initiative provided bachelor's and master's students in aquaculture and related disciplines with one week of hands-on training based on the three AquaLoop pilot activities. Through experimental and laboratory work linked to the TARAS, NEMATIC, and FISHVISA pilots (Fig. 19), students became familiar with partner institutions, circular economy approaches, and innovative aquaculture practices. The programme also included study visits to commercial aquaculture facilities.

Figure 19: AquaLoop cross-border student exchange program banner (banner credit: B. Dmochowska).

The NEMATIC pilot served as a practical training platform for exchange students from the University of Gdansk (Poland) and Klaipeda University (Lithuania), who visited the Faculty of Agriculture, Civil and Environmental Engineering at the University of Rostock in February 2025.

Under the guidance of the AquaLoop team, students were introduced to fish cultivation in recirculating aquaculture systems (RAS) and aquaponics production with an emphasis on process water utilisation. Through direct involvement in the pilot activities, students gained hands-on experience in experimental procedures and daily aquaculture operations. Their work included biological sampling of African catfish and Rainbow trout (gonads, liver and skin), leather production from fish skin, parasitological as well as molecular biology and genetics training. In addition, the students gained insight into semi-commercial applications of RAS technology through a visit to the State Research Institute for Agriculture and Fisheries Mecklenburg-Western Pomerania (LFA MV), Institute of Fisheries, Hohen Wangelin, a pikeperch hatchery doing research as well as seedling production (Fig. 20 and 21).

Figure 20: a) Students from Gdansk and Klaipeda sampling African catfish; b) Study trip to the State Research Center MV, Institute for Fisheries, Hohen Wangelin; c) pikeperch RAS.

"AquaLoop cross-border student exchange program"

PRACTICAL INFORMATION
for students from the University of Gdańsk Rostock and Klaipeda University visiting the University of Rostock

AquaLoop project team from the University of Rostock is very happy to host you in Rostock, Faculty of Agricultural and Environmental Sciences for the "AquaLoop cross-border student exchange program", part of the AquaLoop Interreg South Baltic project.

Please have in mind, the following practical information:

Program duration: February 23th – March 01st 2025 (agenda attached)
Program venue: Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-Weg 2, 18059 Rostock, Germany
Program start and meeting point: February 24th 2025 (Monday) 09.00 a.m. Lecture room (SR7) ground floor, LAG 1, Justus-von-Liebig-Weg 2, 18059 Rostock

Accomodation:
Appartmenthotel Rostock, Goethestraße 12, 18055 Rostock, Germany – there will be an arramgement for breakfast
https://appartement-hotel-rostock.de/
app. 100m from the Rostock main station and tram station
3 single rooms for each group (Uni Gdanks and Klaipeda University)
Check-in time: 14.00-20.00

University of Rostock will organize tram tickets for the whole week and will cover the expenses through the AquaLoop budget, individual student cards are required.
On Sunday (23.02.2025), either Laura Ballesteros-Redondo or Adrian Bischoff-Lang will pick you up at the Rostock main station and bring you to the hotel. On Monday, we will also pick you up at the hotel and take the tram to the Faculty.

Financial issues:

Participation in the "AquaLoop cross-border student exchange program", as well as travel and accommodation is arranged by the University of Gdanks or Klaipeda University in cooperation with the University of Rostock, and funded by the AquaLoop project funds.
Accommodation expenses are covered by the sending Universities in advance of your stay. Daily lunches as well as a joint dinner wil be arranged by the hosting university and covered by the project funds.

Other important issues:

Please note:

- you need to have an insurance coverage for Germany
- you must be present at the program for the entire program duration
- you will obtain consent forms for participation in the program from the University of Rostock before the program starts

Contacts

Contacts to the Program Coordinators at the University of Rostock are:
adrian.bischoff-lang@uni.rostock.de, mobile number 0049-160-5221069
laura-redondo@uni-rostock.de, mobile number 0049-1575-1923696

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Daily agendas in host institutions (may be subject to change)

University of Rostock agenda	
Day 1 – 23.02.2025 (Sunday)	• Arrival in Rostock via train from Hamburg and/or Berlin (Airport) • Pick up at the Rostock main station, transfer to the hotel and later pick up for a short Welcome Reception
Day 2 – 24.02.2025 (Monday)	• Safety instructions for working in the FishGlassHouse (FGH) and the labs • Introduction to the AquaLoop project and pilot 2: NEMATIC • Tour to the FGH and first routines
Day 3 – 25.02.2025 (Tuesday)	• AquaLoop Pilot 2 – Fish sampling (Fish anatomy, Extraction of liver, gonads, filet, skin and fat from African catfish an rainbow trout) • Aquaponics at the FGH • Production of fish leather
Day 4 – 26.02.2025 (Wednesday)	• Molecular biology and genetics of aquatic animals • Joint dinner at the Restaurant Trotzenburg (around 19:00/7:00 o'clock pm)
Day 5 – 27.02.2025 (Thursday)	• Study Trip to an aquaculture facility (State Research Center MV, Institute for Fisheries, Hatchery Hohen Wangelin) • Farewell Party in the afternoon at LAG 1
Day 6 – 28.02.2025 (Friday)	• Parasitological training in the FishLab
Day 7 – 01.03.2025 (Saturday)	• Departure from Rostock

Figure 21: AquaLoop cross-border student exchange programme and agenda at the University of Rostock for students from the University of Gdansk (Poland)and Klaipeda University (Lithuania).

The exchange programs demonstrated the value of the NEMATIC pilot as a training and knowledge-transfer platform, providing students with practical experience in innovative and sustainable aquaculture technologies. Feedback from both groups was exceptionally positive, with participants highlighting the opportunity to work with novel species and methodologies, gain insight into scientific research, and develop practical skills. According to feedback from the exchange program participants, one of the particular highlights was the tasting of catfish fillets at the barbecue, which was also attended by aquaculture students from the University of Rostock to promote networking among future aquaculture experts in the South Baltic region.

III.4. Demonstration to professionals

NEMATIC pilot was listed as one of the facilities to be visited as an example of potential circular-economy solutions. Pilot operation was demonstrated to the AquaLoop project partners representing public research and education institutions, NGOs, and companies: University of Gdańsk (Poland), Klaipeda University (Lithuania), Gulborgsund Municipality (Denmark), Fish Market Development Association (Poland), Scandinavian Aquasystems AB (Sweden), VKST (Denmark) and University of Rostock (Germany) (Fig. 22). The meeting and demonstration with aquaculture professionals in the academic and market sector provided valuable expertise and know-how for the pilot further adjustments.

Furthermore, the NEMATIC pilot was used with kindergarten groups (pre-school age), school classes of various age groups, and a large number of national and international students from a wide range of academic disciplines. In this context, particular mention should be made of the presentation of AquaLoop, its objectives, and the pilot as part of the Summer School Sustain MV. Participation took place in 2023, 2024, and 2025, as well as in 2026, one day after the official end of the project. These activities provided an excellent opportunity to introduce students to the concept of a circular economy in aquaculture.

Experts from the aquaculture and agricultural sectors, as well as politicians and decision-makers from regional and local authorities, also took the opportunity to visit the NEMATIC pilot. These visits enabled them to gain a better understanding of the underlying concept and the practical application of circular economy principles in aquaculture, while also highlighting the need for such approaches.

Figure 22: Group of AquaLoop partners, representatives of academia, research and business sector visited the NEMAIC pilot facility, during the AquaLoop Kick off meeting.

IV. PILOT RESULT DELIVERY AND COMMUNICATION

The NEMATIC pilot was extensively communicated throughout the project lifecycle through a wide range of regional, national, and international dissemination activities. To maximise the visibility of the pilot and ensure that its results reached diverse stakeholder groups, the project combined scientific dissemination, industry outreach, stakeholder engagement, and policy dialogue. The pilot and its outcomes were presented at AquaLoop partner and Advisory Board meetings, the AquaLoop International Conference in Bremerhaven, major international aquaculture conferences, Interreg cooperation events as well as regional and international workshops. These activities targeted researchers, aquaculture producers, industry representatives, SMEs, policymakers, public authorities, educators, students, NGOs, innovation support organisations as well as open public. In addition, the NEMATIC pilot was promoted through a range of communication materials, including posters, newsletters, scientific and popular publications, brochures, and other dissemination tools, ensuring broad awareness of the pilot's objectives, implementation, and results across multiple audiences.

IV.1. AquaLoop partner and Advisory Board meetings

Throughout the implementation of the NEMATIC pilot, project communication played a key role in presenting progress, gathering feedback, and refining pilot activities. In addition to numerous online meetings and technical consultations held throughout the project, updates on the pilot were regularly presented during AquaLoop partner meetings held in Rostock, Germany (November 2023), Klaipėda, Lithuania (April 2024), Copenhagen, Denmark (August 2024), Gdynia, Poland (April 2025), Aalborg, Denmark (October 2025), and Malmö, Sweden (June 2026) (Fig. 23).

These meetings brought together researchers and academics from the University of Rostock (Germany), the University of Gdańsk (Poland), and Klaipėda University (Lithuania), representatives of partner organizations including the Fish Market Development Association (Poland), Guldborgsund Municipality (Denmark), VKST (Denmark), and Aquasystems AB (Sweden), as well as members of the AquaLoop Advisory Board (Fig. 24) representing the Ministry of Agriculture of Lithuania, Business Lolland-Falster (Denmark), Aquamedic Poland, and the Technology Transfer Center (ttz) Bremerhaven (Germany), together with other relevant stakeholders.

These exchanges provided an important forum to discuss the progress of the PilotLoops, share implementation experiences, coordinate activities, and identify opportunities to strengthen the practical relevance and impact of the NEMATIC pilot. In particular, the meeting in Rostock included a visit to the NEMATIC pilot facility at the University of Rostock, where freshwater fish, such as African catfish, Tilapia or Common carp, are cultivated and circular aquaculture solutions, such as aquaponics were demonstrated to consortium members and stakeholders. At the time of the kick-off meeting, biological sampling of African catfish was not yet in progress. However, the FishGlasHouse has been in operation since 2015, and the NEMATIC pilot was thematically integrated into the existing facility.

The partner meetings, Advisory Board sessions, and regular online consultations generated valuable recommendations that were systematically incorporated into the further development of the NEMATIC pilot. Feedback focused on the general lack of knowledge regarding waste streams in fish production and the need to make further use of these potential raw materials, but also on increasing the practical applicability of the demonstrated solutions, improving the communication of pilot results to the aquaculture sector, and ensuring that research outcomes could be effectively transferred into training and support activities. Participants also highlighted the importance of demonstrating economically viable circular aquaculture practices, strengthening stakeholder engagement through study visits, workshops, and demonstration events, and comprehensively documenting lessons learned throughout pilot implementation.

As a result, both the communication strategy and the technical implementation of the NEMATIC pilot were continuously refined throughout the project. The regular presentation of pilot results at consortium meetings, complemented by frequent online consultations between partners, enabled the timely exchange of knowledge, validation of experimental approaches, and implementation of adjustments in response to expert recommendations. This iterative process strengthened collaboration among project partners, improved the quality and relevance of the pilot activities, and enhanced the dissemination of results, ensuring that the final NEMATIC pilot reflected the collective expertise of the consortium and the guidance of the Advisory Board while contributing to AquaLoop's objective of promoting circular economy practices in aquaculture across the South Baltic region.

Figure 23: AquaLoop partner meetings held in Rostock, Germany, Klaipėda, Lithuania, Copenhagen, Denmark, Gdynia, Poland, Aalborg, Denmark, and Malmö, Sweden.

Figure 24: AquaLoop Advisory Board, including representatives of Ministry of Agriculture of Lithuania, the Technology Transfer Center (ttz) Bremerhaven (Germany), Aquamedic Poland, and Business Lolland-Falster (Denmark) (from left to right).

IV.2. AquaLoop International Conference

The results of the NEMATIC pilot were disseminated during the final AquaLoop International Conference "Strengthening Circular Economy and Valorisation of Side Streams in RAS Aquaculture", held on 25 February 2026 at Klimahaus in Bremerhaven, Germany, (with the possibility of online participation). As the final conference of the AquaLoop project, the event brought together more than 70 participants (Fig. 25) representing academia, the aquaculture industry, policymakers, public institutions, and students from across Europe, providing an excellent platform for communicating the outcomes of the NEMATIC pilot to a diverse international audience.

The NEMATIC pilot results were presented as part of the conference session "*Closing the Nutrient Loop & Byproduct Valorization*", which highlighted innovative approaches to improving the circularity of recirculating aquaculture systems. The presentation, entitled "By-products characterization and valorisation of African Catfish (*Clarias gariepinus* Burchell, 1822)" showcased the pilot's key findings concerning the weight-proportional distribution of African catfish suitable for human consumption, and the valorization of aquaculture side streams. The presentation demonstrated the high potential of circular economy during the catfish production in RAS, while also discussing economical requirements and benefits of these circular solutions. The pilot results were further communicated through the conference presentation materials, panel discussions, networking sessions, and the conference exhibition, enabling direct interaction with researchers, industry representatives, and policymakers interested in the practical implementation of circular aquaculture technologies.

The conference provided an important opportunity to disseminate the scientific and practical outcomes of the NEMATIC pilot, stimulate discussion on their applicability within commercial aquaculture, and gather feedback from key stakeholders. The strong engagement of participants and interdisciplinary discussions contributed to increasing the visibility of the pilot, promoting knowledge transfer beyond the project consortium, and supporting the wider uptake of innovative circular economy-based solutions for improving the sustainability and resource efficiency of recirculating aquaculture systems. For more details see the success story report on the project webpage (https://aqualoop.edu.pl/?p=3119).

Figure 25: AquaLoop International Conference participants, and NEMATIC pilot presentation title page.

IV.3. International branch conferences

The NEMATIC pilot was communicated to the international aquaculture community during the two largest European aquaculture conferences organized by the European Aquaculture Society (EAS) and the World Aquaculture Society (WAS), ensuring broad dissemination of its objectives, methodology, and research outcomes among key sector stakeholders.
The first dissemination activity took place during AQUA 2024 (Fig. 26)., held in Copenhagen, Denmark (August 2024), where NEMATIC was presented through an electronic poster and within an AquaLoop E-poster presentation introducing the project's circular aquaculture approach. The conference brought together researchers, aquaculture producers, technology providers, policymakers, students, and representatives of supporting industries from around the world, providing an international platform to raise awareness of the project's objectives and establish contacts with organizations interested in circular aquaculture solutions.

The communication of the NEMATIC pilot was further strengthened during Aquaculture Europe 2025, held in Valencia, Spain (September 2025) (Fig. 26). Building on the initial project presentation from the previous year, AquaLoop disseminated the scientific results of the NEMATIC pilot through the electronic poster entitled "*By-products Valorization of African Catfish (Clarias gariepinus (Burchell, 1822))*" (Fig. 26). The presentation showcased results obtained at the University of Rostock, focusing on the fatty acid content and composition of cultivated African catfish and its potential valorisation of side-streams. Together with three additional AquaLoop presentations covering the project's remaining pilots and educational activities, the NEMATIC pilot contributed to presenting AquaLoop as a comprehensive framework for implementing circular economy principles in aquaculture. The conference provided valuable opportunities to discuss the pilot findings with international researchers, aquaculture producers, technology developers, policymakers, and other sector stakeholders, increasing the visibility of the developed solutions, promoting scientific exchange, and supporting the wider uptake of innovative circular aquaculture practices beyond the South Baltic region.

Figure 26: NEMATIC pilot presentation at Aquaculture Europe 2024 and Aquaculture Europe 2025

IV.4. International conferences for different stakeholder groups

The NEMATIC pilot was promoted at international conferences in 2024–2025, enabling communication with diverse stakeholder groups, including researchers, educators, policymakers, industry representatives, NGOs, and the wider blue economy community. These events increased the pilot's international visibility and created opportunities for knowledge exchange and future cooperation.

In May 2024, the NEMATIC pilot was presented at European Maritime Day in Svendborg, Denmark, during a workshop on circular recirculating aquaculture. The event brought together maritime experts, policymakers, businesses, and innovation stakeholders, providing an opportunity to communicate the pilot's contribution to circular aquaculture and engage with the European blue economy community.

In September 2024, the project was showcased at the Eurofish Conference "The Fisheries and Aquaculture Sector – Ways to a Circular Economy**"** in Madrid, Spain. The conference focused on Decarbonisation of the fishing fleet, reduction of energy consumption in RAS; side- and waste streams within aquaculture; and side- and waste streams within fisheries, allowing the University of Rostock to present the NEMATIC pilot to researchers, marine science professionals as well as practitioners, highlighting its side stream-oriented activities.

In November 2025, the NEMATIC pilot was communicated during the Danish Bioeconomy Conference in Nykøbing Falster, Denmark, alongside other Interreg initiatives. The event gathered researchers, policymakers, industry leaders, and bioeconomy experts, providing a platform to present the pilot's role in supporting sustainable and circular aquaculture and to establish links with stakeholders working on bio-based innovation.

Together, these international events supported the dissemination of the NEMATIC pilot across Europe, reaching complementary target groups and strengthening cooperation between research, education, industry, and policy communities working towards sustainable aquaculture and the blue economy.

IV.5. Interreg program events

The NEMATIC pilot was actively communicated through AquaLoop's participation in major Interreg South Baltic events, providing opportunities to disseminate project results and engage with a broad international audience.
At the Interreg South Baltic Annual Event – Evolving Priorities: Navigating Challenges and Trends in the Interreg South Baltic Programme, held in Stralsund, Germany (September 2024), AquaLoop presented the NEMATIC pilot as part of the workshops and discussion. Through face-to-face discussions and presentations of the pilot activities, consortium representatives demonstrated how side stream production in recirculating aquaculture systems contributes to circular aquaculture and improved nutrient management. The event brought together Interreg project partners, program representatives, policymakers, and stakeholders from across the South Baltic region, providing an excellent platform for exchanging experiences, promoting project achievements, and discussing the transferability of the developed solutions.

IV.6. Online dissemination materials and communication channels

Throughout the project, the progress, activities, achievements, and results of the NEMATIC pilot were continuously communicated through a range of dissemination materials and communication channels. These included:

- project newsletters,
- project brochures,
- project posters,
- promotional publications.

All materials were made available through the AquaLoop project website and promoted via the project's LinkedIn platform, and University of Rostock website ensuring broad accessibility and regular updates for researchers, aquaculture professionals, policymakers, industry representatives, students, and the wider public. This continuous communication supported the visibility of the NEMATIC pilot, facilitated knowledge transfer, and contributed to the wider dissemination of its innovative approaches and outcomes.

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