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Latvia – Lithuania

**“Latvian and Lithuanian conjunction - Improvement of Baltic salmon and pikeperch rearing methods for more sustainable, resilient and healthy fish populations”
(SPPwelfare)**

Guidelines for data gathering for FHIM

Deliverable D.3.1.1.

Institute of Food Safety, Animal Health and Environment "BIOR",
Latvia 2024

Document is produced by the Institute of Food Safety, Animal Health and Environment "BIOR" within INTERREG project SPPwelfare "Latvian and Lithuanian conjunction - Improvement of Baltic salmon and pikeperch rearing methods for more sustainable, resilient and healthy fish populations"

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The project is implemented within the Interreg VI-A Latvia-Lithuania Programme 2021–2027. More information about the programme on the www.latlit.eu and the official website of the European Union www.europa.eu.

The project implementation period is from March 1, 2024 till February 28, 2026.

Total project budget is 497 146.00 EUR. funding of European Regional Development Fund is 397 716.80 EUR. The total eligible project budget of the scientific institute "BIOR" is EUR 293,000.00 EUR, where co-funding of European Regional Development Fund is 234 400.00 EUR and state co-financing is 20% (EUR 58,600.00 EUR).

This project is co-financed by the European Union.

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Introduction

The Fish Health Index is essential for assessing the health status of juvenile salmon, zander and other fish species in hatcheries. These guidelines outline the creation of a comprehensive index incorporating physiological, behavioral, and environmental parameters. The index will be calculated using methodology and will provide a quantitative measure of fish health. By implementing this index, hatchery managers can improve fish welfare, optimize production, and prevent disease outbreaks.

These guidelines are necessary for synchronized data collection in both project countries. These guidelines include a description of the necessary data and methods for data collection. The form for data collection is elaborated and added as ANNEX I and ANNEXII.

The assessment of Fish Health Index is essential for:

Optimizing rearing conditions: Determining optimal environmental factors for fish health.

Evaluating hatchery performance: Assessing the overall health of fish populations in different hatcheries.

Supporting welfare assessment: Providing a quantitative measure of fish well-being. Standardized Fish Health Index for assessing the health status of juvenile salmon and zander in hatcheries, will enhance the production of healthy stocks for restocking purposes. Fish farm managers and farmers have to be confident that the natural fish stocks are replenished with healthy juveniles. **Early disease detection:** Identifying health issues before they become major problems.

Life Cycle of Wild Salmon

In the wild, salmon life cycle begins with spawning in late autumn in rivers. In Latvia and Lithuania mainly from September to November (Plikšs, Aleksejevs, 1998). Female salmon select a spawning site, often at the tail end of a large pool with a gravel substrate. This gravel provides a steady stream of oxygen-rich water, crucial for the proper development of salmon eggs. Using her tail, the female digs a nest (called a redd) in the gravel, where she lays her eggs. The male, swimming alongside her, releases milt (sperm) to fertilize the eggs, which are then covered with gravel by the female. A female salmon can lay over 1,500 eggs per kilogram of her body weight (Karlson et al, 1994) or 2 000-40 000 egg per fish (Plikšs, Aleksejevs, 1998). Eggs are deposited in the gravel of the riverbed and hatch in early spring. Upon hatching, the young salmon, known as alevins. These alevins are partially transparent and remain hidden in the gravel, feeding off their attached yolk sacs for nourishment. After about 4 to 6 weeks, they emerge from the redd as fry, which are about 2 cm in length. These fry have all eight fins, which they use to maintain their position in fast-flowing streams and to maneuver in the water (Karlson et al, 1994; Plikšs, Aleksejevs, 1998).

Once the yolk sacs are depleted, the fry rise to the surface to gulp air, filling their swim bladders to achieve natural buoyancy. They then feed on microscopic life in the stream, growing quickly during their first year to a length of 5 to 8 cm before transforming into parr (Karlson et al, 1994).

Parr are identifiable by their vertical markings and single red dots, which serve as camouflage. These parr remain in the river for 1 to 4 or 5 years, depending on water temperatures and food availability, feeding on small aquatic insects. When they reach a length of 11 to 18 cm, they undergo a springtime transformation into smolts. This process, known as smoltification, involves developing a silvery sheen and darkening the edges of their pectoral and caudal fins. Internally, they undergo changes that enable them to survive in saltwater. Special gill cells allow them to regulate salt and water balance, essential for their transition to the ocean environment (Plikšs, Aleksejevs, 1998). Smolts swim downstream, imprinting the scent of their native river, which they will recall when returning to spawn. In late spring, they head out to sea in shoals. As adults, wild salmon grow rapidly at sea, feeding on small fish and crustaceans. The Baltic salmon is limited to the Baltic Sea and is considered a geographically isolated population of salmon (Karlson et al, 1994 Plikšs, Aleksejevs, 1998).

After spending one to four years at sea, salmon return to their natal rivers to spawn. Those returning after one year are called spawners. Hormonal changes trigger their migration back to freshwater, where they cease feeding and rely on their fat reserves. After spawning, these adult salmon, now known as kelts, are weak and depleted. Some

kelts manage to return to the sea to regain their strength and may spawn again, although only about 5% survive the journey back to spawn a second time (Karlson et al, 1994).

Salmon rearing for restocking

Aquaculture of salmonids consist of two groups based on the rearing target: rearing for restocking and rearing for consumption. In Latvia and Lithuania salmon are reared only for restocking purposes.

Restocking, or stocking, means the repeated injections of fish into an ecosystem where a population of that species already exists, sourced from an external population. These stocked species may be either already native to the recipient water body or exotic to it but previously introduced (Cowx, 1998). Stocking is generally recognized as an important tool to compensate for the loss of productivity and biodiversity, as well as to increase and/or maintain fish stocks.

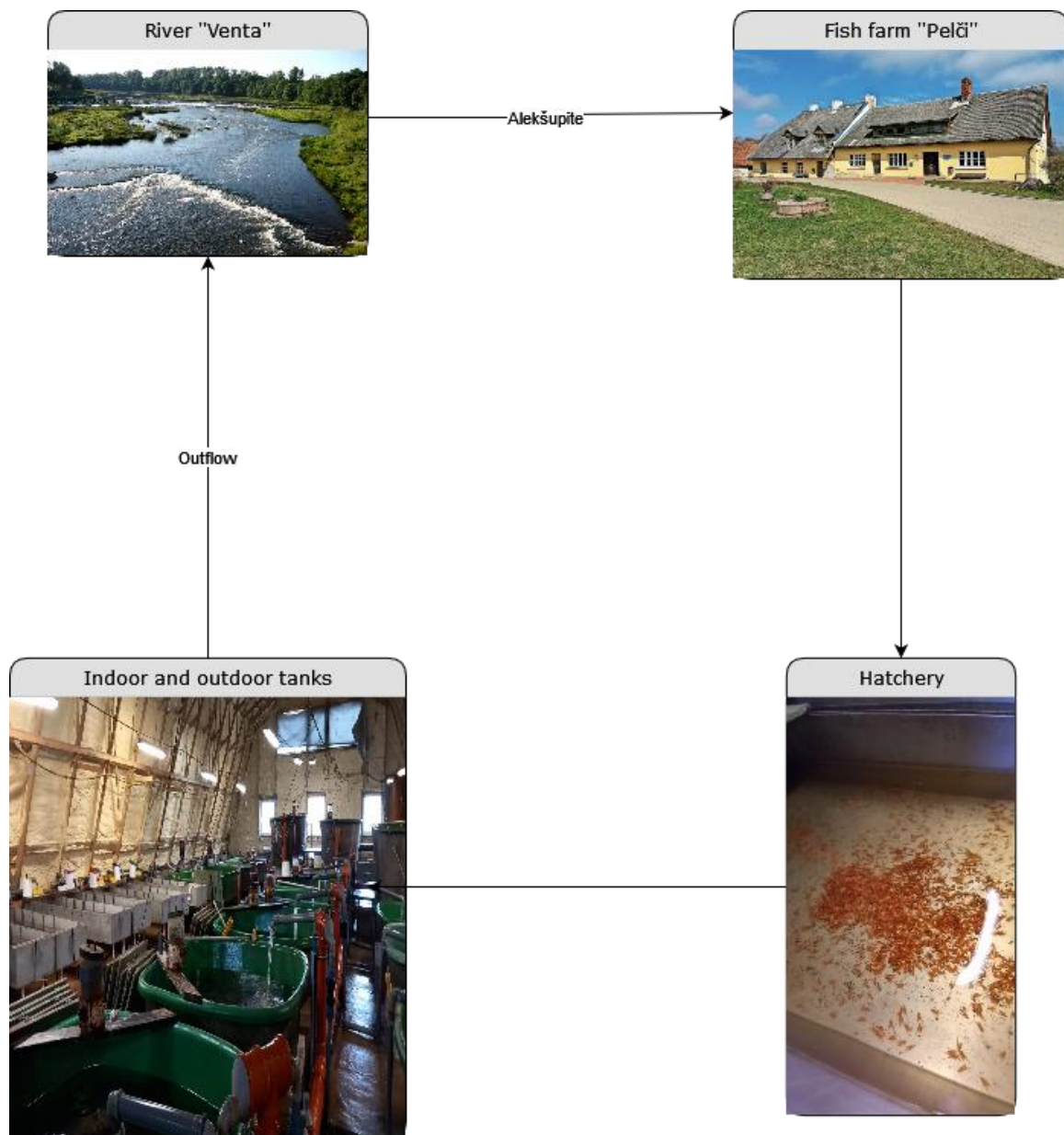


Fig. 1. Water exchange in flow-through hatchery-smolt farm

The artificial breeding of salmonids in Latvia has a rich history of nearly 140 years, though it faced interruptions during the First and Second World Wars. In Lithuania first salmon smolt releases made in 1998 (WGBAST ICES 2020 https://pub.epsilon.slu.se/22415/1/bajinskis_j_et_al_210217.pdf).

Baltic salmon (*Salmo salar* L.) is a top predator in the Baltic Sea. Salmon is among the most valuable fish and has been a primary target for fisheries, a key profession for the Baltic population since the Stone Age. According to Kulmala et al. (2013), Baltic salmon plays a crucial role in reducing sedimentation, regulating food webs, and maintaining the overall ecological balance of ecosystems. Additionally, the cultural services provided by salmon today are estimated to be more significant than the economic value of commercial salmon catches.

To mitigate the impact on migratory fish resources caused by river damming, river bed straightening, water quality degradation etc. annually rivers are restocked with hatchery-reared salmon juveniles and smolts.

Flow-through (FTS) and Recirculation (RAS) systems are used for salmon rearing (Bergheim et.al.2009; Brengbale 2022). FTS system is used in Latvia fish farms, including ff Pelči. Such farms normally rearing fish in the indoor fish farm from hatching till smolt. Water temperature is the same as in nature: from 1 °C in winter to 24 °C in summer. One year old smolt size in such rearing system usually is 15-25 g.

Recirculating Aquaculture systems (RAS) for salmon smolt and juveniles rearing is used in Lithuania. RAS is a technology where water is recycled and reused after mechanical and biological filtration and removal of suspended matter and metabolites. RAS is fully controled system and possibility to maintain hight quality of water and higher temperatures throughout the winter season has also made possible production of larger smolt; i.e. one year old smolt size is 60- 100 g.

In Latvia salmon broodstock fishery for restocking purposes occurs in the same rivers where the fish are born and released. Eggs are collected by stripping in the autumn and then incubated in hatcheries until they hatch in the spring. The hatching and juvenile development take place in flow-through systems using natal river water. After incubation, salmon smolts are released in the same river: salmon reared in Pelči are released in Venta River (Restocking Program 2024, Purvina et al., 2019). The number of restocked fish varies each year, depending on the success of broodstock fisheries and the specific conditions of the annual farming process. The average weight of salmon smolts 1+ released is 20 grams in the Venta River. Salmonids are released into the wild in the spring when river water temperatures reach 8 °C (Restocking Program 2024).

In Lithuania restocking ir carried out in Nemumas and Šventoje River basins.

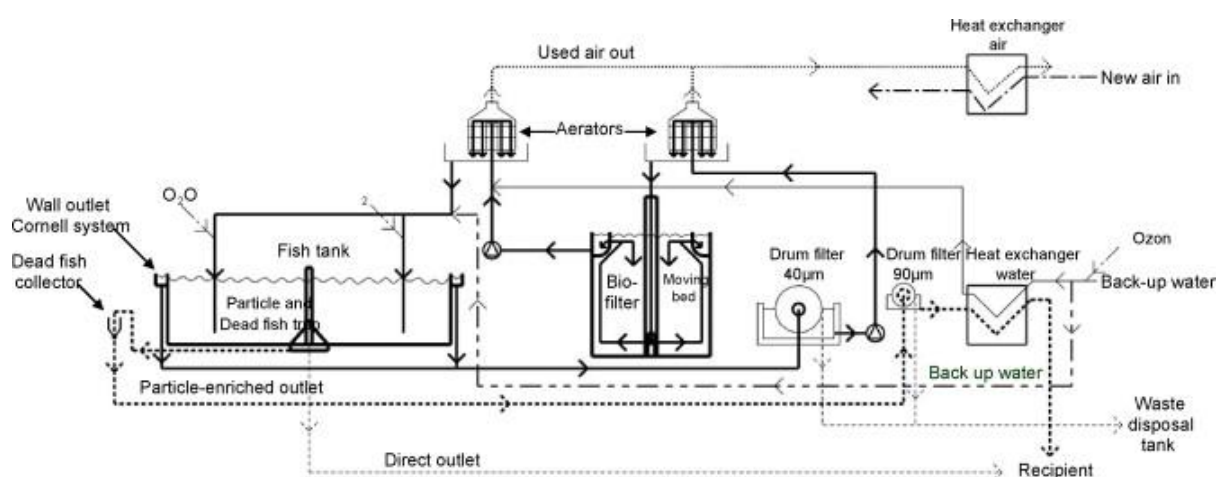


Fig. 2. A modern RAS for production of salmon smolt constructed 2008 in Northern Norway (courtesy of Hobas Ltd.). (Bergheim et al., 2009)

Fish rearing for restocking is a time consuming and expensive event, therefore it is strongly recommended to release healthy, well fed, unstressed fish, with height survival options.

Fish health indicators

Animal health and welfare are two closely linked concepts. For this criterion, good health refers to the absence of disease or injury, as well as an animal's ability to carry out its physiological functions at natural (normal) levels. Welfare, on the other hand, refers to the physical and mental condition of an animal in relation to its living conditions, as well as its ability to adapt to its environment. It is crucial to emphasize that welfare involves more than just freedom from harmful stimuli, it also includes exposure to positive experiences that enhance the well-being of fish. It is especially important to rear healthy, viable fish for release into natural waters to supplement and enhance fish stocks.

The indicators must represent a compliance species-specific health and welfare requirements of the fish.

Two different rearing systems are used for salmon juveniles rearing from egg to smolts Latvia uses the FTS system, Lithuania - RAS system (Fig.1 and Fig.2.).

Rearing condition (environmental condition)

Temperature

Temperature regulates the metabolic rate of salmon, including feeding activity, oxygen demand, growth rate etc. Atlantic salmon grow best at an optimal temperature of about 14°C (Jensen *et al*, 2011). Salmon can survive in temperatures ranging from 0 to 20°C, provided they are supplied with water that is saturated with oxygen. However, most life-stages: eggs, alevins, fry, smolts, and sexually mature fish, have limited temperature tolerance for normal development. In Latvia's rivers water temperature fluctuates from slightly about 0 °C in winter up to 25 - 26°C in summer. A similar temperature is also recorded in FTS fish farms (ff Pelči). Therefore, temperature measurement should be performed in FTS 3 times per day (morning, midday, and evening) and should be calculated mean daily temperature. The temperature in the RAS system is maintained artificially and should be measured and recorded at least once per day. The measurements should be documented using the standard form employed by the fish farm (no special form is required).

Oxygen (mg/L)

All life stages of salmon have a high demand for oxygen. The relative oxygen consumption (mg O₂/kg fish/min) of the salmon increases with temperature, activity, feed consumption and stress level, while it decreases with increasing body size. The oxygen saturation as a guideline should be maintained above 70% to maintain full appetite and growth but subsequent research on the impact on fish welfare may show that higher levels are required.

The level of dissolved oxygen (mg/L) in water depends on temperature, salinity, and the partial pressure of oxygen in the air that is in contact with the water. Salmonids are a species with high oxygen demands. Aquaculture experience shows that they require a minimum of 6-8 mg/L (80-70% saturation) of dissolved oxygen, as measured in the water outflow. While fish can adapt to suboptimal oxygen levels for short periods, maintaining optimal oxygen levels is essential for achieving good growth rates, as well as favorable economic and welfare outcomes in aquaculture (Mitāns (<https://fishing.lv/cope/viskas/akvakultura5.html>)).

Dissolved oxygen and oxygen saturation measurements should be measured daily with a calibrated probe. The measurements should be documented using the standard form employed by the fish farm (no special form is required).

Water pH

Water pH stands for the “power of hydrogen”. pH value is between 0 and 14. For fish welfare pH should be from 6 to 9 (<https://likumi.lv/ta/id/60829-noteikumi-par-virszemes-un-pazemes-udenu-kvalitati>). If the pH is too high or too low, decrease quality of spawn, growth rate, the aquatic organisms living within acid or alkaline water it is stressed and slowly die. pH can also affect the solubility and toxicity of chemicals and heavy metals in the water.

pH measurements should be registered daily using a calibrated probe. The measurements should be documented using the standard form employed by the fish farm (no special form is required).

Water color

The color of the water where fish are reared in needs to be similar to the color of the water in the river. For both PP and LP usually the water color is light brown with the transparency remaining intact. If the water color is abnormal, for example green, it might mean that an issue has occurred in the water treatment facility or the river water has been contaminated. In return this tells us that the water is not safe for rearing purposes (ANNEX I). Water color changes should be registered in our provided form and should be inspected visually every day.

Water flow rate

Parr prefers higher water flow rates whereas fry prefer areas of low flow within rivers and these life stage requirements are typically considered in fish farms. The swimming capacity of Atlantic salmon depends on factors such as body size and metabolic scope (Grøttum & Sigholt 1998). Intensity of exercise has been found positively correlated with disease resistance (Takle et al. 2010) and improved cardio-vascular capacities (Jørgensen & Jobling 1994; Davison 1997).

The speed of water exchange is a valuable statistic. It gives us a hint of what is the current speed in fish tanks and should it be adjusted. The average necessary current speed for growing salmonids in fish tanks is 120 L/min^{-1} , which roughly translates to $20\text{-}40 \text{ cm s}^{-1}$, equivalent to $0.5\text{-}1.1$ fish lengths. In this current the fish are able to swim stably and are not under any sort of stress (Barbier et al, 2024). Water current should be measured as m s^{-1} used Water Velocity Meter at least 1 time per month (form in ANNEX I).

Lighting

Optimal photoperiod and light intensity are very important factors in the development of Atlantic salmon. Each life stage of fish needs a different photoperiod. Eggs and alevins should be kept in darkness, but parr, fingerlings and pre-smolts should be provided with light and appropriate photoperiod signals to ensure proper timing of events such as on-growing, smoltification and maintenance of homeostasis (ANNEX I). Lighting should be evaluated every day and registered in our provided form.

Fish group (herd or rearing tank) indicators

Mortality

Fish and egg mortality refers to the death of fish within a given fish group (rearing tank, or fish farm, or age group). Mortality, often measured over a specific period. Mortality in nature can occur due to various factors, including, environmental conditions, diseases, predation, and human activities such as fishing and pollution, however in fish farms it is diseases, handling and natural mortality. Understanding fish mortality is essential for managing and conserving fish populations in aquaculture.

Keep a daily count of dead and culled fish in each basin, remove them. Analyze the cause of death. Report the number and percentage of dead fish, as well as the cause of death, score the mortality. Mortality should be registered every day for each rearing tank and should be documented using the standard form employed by the fish farm (no special form is required).

Stocking density

The stocking density in a three-dimensional aquatic environment is measured by the weight of fish per cubic meter of water. Stocking density is important for salmon due to the complicated chemical interface between fish and the surrounding water. If salmon have insufficient amounts of water, they begin to suffer due to the lack of available oxygen, as well as high stocking densities lead to higher levels of disease, increased mutual aggression, decreased growth, diminished nutritional uptake, reduction in food conversion efficiency, fin erosion, gill damage, immunosuppression (Ashley, 2007).

However stocking density is a major factor affecting salmon welfare, its effects derive from interaction with many other various factors, and it is difficult to establish maximal and minimal values or optimal stocking densities that would guarantee safety in welfare. As it is difficult to set appropriate levels, instead of determination of optimal stocking density for salmon to use other indicators, such as fin damage, other injuries, growth rate, behaviors expressed and overall health.

We do not highlight Stocking density as an indicator of welfare, but keep it as an important parameter for daily records in hatcheries.

Stocking density should be registered as kg fish per m³ (form in ANNEX II).

Illnesses

Fish diseases are significant cause of increased mortality in fish farms. Early identification of diseased fish at early stages is a crucial step to prevent spread of infection disease. Fish disease diagnosis suffers from some limitations that need high level of expertise to

be resolved. Fish farmers and fish veterinarians, involved in the project has long-term experience and advanced education, therefore they are responsible for disease control (form in ANNEX I).

Notifiable disease outbreaks

The prevention of fish diseases is essential for the betterment of the fisheries industry, the improvement of farming production, and the increase in fish resources. Disease outbreaks are a significant constraint to aquaculture production, including fish rearing for restocking. In case of notifiable disease outbreaks fish group is excluded from the study in this project and all activities in fish farm must be carried out in accordance with the decision of the competent authorities: [Food and Veterinary Service Republic of Latvia](#) and [State Food and Veterinary Service](#) in Lithuania (form in ANNEX I).

Individual health indicators

For successful salmonid rearing and ensuring good welfare, maintaining an optimal nutritional status is essential. For individual assessment 100 fish were anesthetized and evaluated.

MS 222 (also known as TMS, tricaine methanesulfonate) is a fish anesthetic used for the temporary immobilization of fish, amphibians, and other aquatic cold-blooded animals (poikilotherms) around the world. MS-222 has long been recognized as a valuable tool for the proper handling of these animals during manual spawning (fish stripping), weighing, measuring, marking, surgical operations, transport, photography, and research. In Latvia it is used as the main anesthetic while working with fish. It is used in combination with water and it's mixed within a holding container. Normally the dose is 60mg/1L of water but it can be adjusted accordingly during the induction process. (Katz et al, 2020)

Clove oil is an effective, local and natural anesthetic. Many hatcheries and research studies use clove oil to immobilize fish for handling, sorting, tagging, artificial reproduction procedures and surgery and to suppress sensory systems during invasive procedures. Clove oil may be more appropriate for use in commercial aquaculture situations. Improper clove oil use can decrease fish viability, distort physiological data or result in mortalities. In Latvia we use clove oil for the anesthesation of European river lamprey. 3 drops of clove oil extract is mixed with 300ml of water, the solution is mixed and lamprey are inserted in the container. (Javaheri et al, 2012)

The anesthetic agent in use by our Lithuanian PP's is called **2-phenoxyethanol**. **2-phenoxyethanol** is a highly effective anesthetic in fishes. It is used in commercial

fisheries in all parts of the world. Phenoxyethanol is relatively inexpensive and remains viable in long-term exposure and is also easily available compared to other anesthetics. Our Project partners use this anesthetic in doses of 0.5mg-1mg/L. (Varkey et al, 2014)

Fish weight

Weight can be measured from a number of fishes (e.g. all fish in a catch), from the individual fish.

Weigh measurements are to be made in grams (g). For FHIM individual weight of 100 fish should be registered in form (ANNEX II).

Fish length

Different types of length measurements are used by fishermen, scientists and fish farmers:

Total Length (TL) – The length of a fish as measured from the tip of the snout to the tip of the tail. It is the greatest length of the fish. If fish having a forked tail, for example, the two lobes are moved to the position which gives the maximum length measurement (whichever may be the longer lobe is used) (Fig3).

Fork Length (FL) – The length of a fish as measured from the tip of its snout to the fork of the tail. (median rays of its tail) (Fig3).

Standard length is the greatest length of a fish from its anterior extremity to the hidden base of its median tail fin ray (where these meet the median hypural plate) (Fig3).

For salmon juveniles Fork length should be used.

Length measurements are to be made in metric scales (e.g. cm or mm) on special fish measuring board.

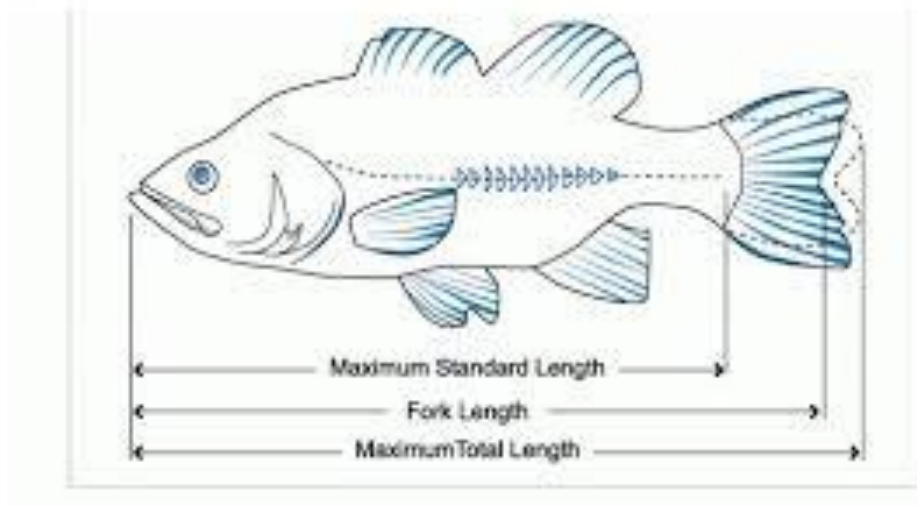


Fig. 3 Fish length measurements

(https://www.fsl.orst.edu/geowater/FX3/help/9_Fish_Performance/Measures_of_Fish_Length.htm)

Condition factor

For successful salmonid rearing and ensuring good welfare, maintaining an optimal nutritional status is essential. This can be measured by the condition factor, a key indicator of fish health. A decline in the condition factor (CF) typically signals insufficient welfare. Emaciated or malnourished fish, being smaller, are quickly outcompeted in the competition for food and struggle to feed as the required feed size increases with their growth. Early detection of emaciated fish is crucial, as salmon can suffer from poor welfare for an extended period before eventually dying. Moreover, they can act as vectors for transmitting diseases to healthier fish.

This measurement can be automated, but if done manually, it should be performed as frequently as possible, especially during high-risk periods such as smoltification, fasting, stressful conditions, and feeding deficits. The condition factor will vary with the life stage and season, but for smolts and fish up to harvest, it should generally range between 1 and 1.6. A CF value below 0.9 typically indicates emaciated fish, while a very high K value may suggest vertebral deformities, which should be closely monitored.

Generally, CF decreases during winter and spring, and increases during summer and autumn. Periods of good growth typically increase K (Juell et al. 1994; Endal et al. 2000), while periods of poor growth reduce K (e.g. Juell et al. 1994; Einen et al. 1999). Within a

population, low CF individuals tend to be emaciated fish while 'normal' K values indicate good health, and very high CF values often indicate deformed individuals.

$$CF = \frac{M(100)}{g^3}, \text{ where}$$

CF - fish condition factor

M – fish weight (g)

g - fish length (cm)

The condition factor has to be assessed monthly and before release in nature (ANNEX II).

Smoltification state

Smoltification, or parr-smolt transformation to smolt, is a complex process driven by the endocrine system, involving developmental changes in the biochemistry, physiology, morphology, as well as in behavior of juvenile salmon. These are energetically costly changes that weaken immune defenses (Pontigo et al 2016), but prepare the fish for downstream migration and marine life (Stefansson et al 2008).

Salmonids start life in freshwater, where they are hyperosmotic, leading to water gain and salt loss through the gills. To maintain homeostasis, they excrete excess water as diluted urine and actively uptake salts via the gill epithelium. In seawater, the situation reverses; salmon become hypoosmotic, losing water and gaining salts. They compensate by drinking seawater, reducing urine, and actively secreting salts through specialized gill cells called ionocytes (Clarke et al 1996).

Photoperiod and temperature are critical environmental cues for smoltification in Atlantic salmon. In the Northern Hemisphere, smoltification completes by spring, initiating migration at 8-10 °C (Jonsson and Ruud-Hansen 1985).

The parr-smolt transformation also involves several endocrine systems. Growth hormone (GH), cortisol, and thyroid hormones increase in response to photoperiod and temperature, regulating growth, metabolism, and osmoregulatory mechanisms (McCormick 2001, Madsen et al 1995). GH and cortisol enhance salinity tolerance by upregulating key osmoregulatory transporters (Hwang et al 2011). Thyroid hormones influence olfactory imprinting, metabolism, morphology, and behavior (McCormick 2013), while prolactin generally inhibits smolt development. Elevated thyroid hormones are observed during migration and in response to environmental changes (McCormick et al 2003).

One of the most significant indicators is assessment and classification of smoltification stages. In our previous research we have adopted a system of classifying the smoltification stages from 1 to 3, where 1 is a parr, 2 is a presmolt and 3 is considered a smolt. This type of classification is needed to better understand the maturation levels within the fish farm.

A parr is given the 1st grade, because it's the least mature type of a salmonid. In this stage the parr have distinguishable par bars, they are darker in color and really active. During smoltification a parr will lose its parr bars (Dark, vertical bars on its side) and defined countershading, making them appear more silvery and bringing them into the next stage - presmoltification.

A presmolt (grade 2) is the beginning of smoltification in young parr. They undergo changes in their osmoregulatory ability, due to anatomical changes in their gills, kidneys and gut. Their parr bars start to disappear and they mature into smolts.

A smolt (grade 3) is defined by its silvery color and streamlined anatomy. In this stage they are mature enough to leave their natural freshwater basins and migrate into the open sea.



Fig. 4. Smoltification state: 1-Salmon Fry, 2-Salmon Parr, 3-Salmon Smolt

Fin condition

Salmonids has two pectoral fins, two pelvic fins, dorsal fin, anal fin, the adipose fin and the caudal fin. The fins of salmonids are some of their most important features. The two

sets of paired fins (pectoral and pelvic) are used to navigate, balance and hunt in water bodies. The adipose fin is a small fleshy fin located between the caudal fin and the dorsal fin, it serves no known purpose. The caudal fin is mainly used as a means of propulsion, but it is also used by the female salmon to dig their redd during reproduction.

Fin condition is used as one of important fish welfare indicator, because fin's damages occur in aquacultural systems only. Fin damages are characterized by shortening size, frayed rays, disturbing of fin tissue, lesions, and necrosis creation (Kima et.al, 2013). Possible causes are aggressive behavior of fish, height stocking density, mistakes in feeding management, inappropriate rearing system, low water quality, careless handling with fish and bacterial infections. Mostly, dorsal, and pectoral fins are damaged in salmonids. Fin erosion has become a concern in fisheries management because of aesthetic and fish survival issues. Fin necrosis level is divided in 3 levels dependency of how large part of fin is lost: D0- fins with no damages; D1- ofin loss to 30%; D2- fin loss from 30% to 70 %; D3 fin loss more than 70%.

Fin damage has to be assessed individually by manually scoring the severity and prevalence of fin damage.

Individual fish should be scored, by examining the dorsal, caudal, and anal fins, left and right pectoral and pelvic fins. Fin condition should be assessed every month (form in ANNEX I).

Other pathologies

Gill condition

Reduced gill function impairs the fish's ability to exchange gasses, excrete waste products, and maintain osmotic balance. Gill problems can be caused by bacterial, parasitic, viral, and fungal pathogens, as well as poor water quality. Chronic gill disease increases stress sensitivity, reduces growth, and can lead to high mortality rates.

The severity of gill damage can be assessed on-site by examining fresh gill smears under a microscope. Once amoebic gill disease (AGD) is diagnosed via histological analysis, it can be scored based on the presence of pale, mucoid lesions on the gills. The severity is rated on a scale from 0 (no infection) to 5 (severe infection) (Taylor et al., 2009).

Operculum (gill cover - branchiostegal membrane) necrosis

Bone deformities are a common issue in fish farms worldwide, with the operculum being one of the first craniofacial bones to develop during the embryonic stage. This bone is

prone to various developmental and acquired abnormalities. Opercular shortening is one of the most widespread conditions in young salmonids and other species, sometimes affecting up to 80% of a population. (Sandoval, 2020)

In species that depend on the operculum to assist in moving water over the gills, a decrease in the efficiency of this mechanism places additional stress on respiration and excretion. Although salmonids possess a respiratory reserve, opercular shortening inevitably undermines this, leading to increased blood flow (hyperaemia) as a compensatory response. The shortening can occur on both sides (bilateral) or one side (unilateral) and may result from erosion and remodeling or simply from incomplete development (hypoplasia). Bone formation (osteogenesis) requires a high oxygen supply, so anything that disrupts oxygen-rich blood flow to the developing tissue can cause abnormalities. (Sandoval, 2020)

Beyond reducing respiratory efficiency, opercular shortening exposes the underlying gill tissue, making it more susceptible to mechanical damage and infection. In the affected population, these changes can result in reduced food intake, inconsistent mortality rates, and can also impact the appearance of the final product for consumers. The factors contributing to these deformities vary, including environmental conditions such as high incubation temperatures, pH levels, low dissolved oxygen, gas supersaturation (causing gas bubble disease), heavy metals, salinity, light exposure duration, and high bacterial levels. (Sandoval, 2020)

Genetic factors can also contribute to a high incidence of opercular abnormalities, as seen in triploid Atlantic salmon. Nutritionally, insufficient levels of fatty acids, proteins, ascorbic acid (vitamin C), and retinoic acid (vitamin A) can lead to opercular shortening. Other contributing factors include teratogens like malachite green, high biomass, potentially leading to high bacterial load, and elevated proteolytic enzymes that can erode the trailing edge of the operculum. (Sandoval, 2020)

Pathology should be registered as YES/NO monthly. (ANNEX II)

Skeletal deformities

Skeletal deformities in fish refer to abnormal changes in the usual development of bones and/or cartilage, resulting in structures that are histologically and anatomically different from their normal form. These deformities vary in their location, shape, and impact. They can occur in any of the three main regions of a fish's body—head, trunk, or tail—and differ in severity based on factors such as the cause, the fish's age, and the type of affected tissue, whether bone or cartilage. The extent of these deformities can disrupt key physiological functions like swimming, reproduction, growth, disease resistance, and

defense against predators. In severe cases, they may lead to reduced weight gain or even death in young fish. Such deformities are commonly observed in both wild and farmed fish, with high occurrences in fish hatcheries, leading to significant economic losses in aquaculture due to the unsellable appearance of affected fish. Additionally, skeletal deformities are considered potential indicators of environmental pollution or poor aquaculture practices.

Skeletal deformities should be registered each time a check up of the fish is done. If any are present in the rearing conditions of the farm, then more actions are required. Each deformed fish should be photographed. (Eissa et al.)

Eyes condition

Fish eye anatomy is similar to other vertebrates, with three pairs of oculomotor muscles maintaining eye position. The cornea acts as a barrier to the external environment and is crucial for vision and protecting the inner eye. The lens provides a wide angle of view, and the fixed iris adapts to light changes. Common eye conditions include exophthalmia ("pop-eye"), often caused by gas bubble disease, and cataracts, which can result from nutritional deficiencies, UV exposure, parasites, and environmental changes. Eye injuries can also occur due to handling and netting during aquaculture procedures, with behavioral interactions like "eye snapping" in halibut leading to eye damage. Eye injuries make fish vulnerable to secondary infections and can impair feeding and avoidance behaviors. Eye damage can lead to secondary infections, stress, and poor welfare. Cataracts, in particular, can cause blindness, significantly impacting fish welfare. Eye injuries are commonly caused by handling practices, such as netting and pumping, as well as UV light exposure, behavioral interactions, and parasite infections. Reducing handling stress, controlling UV exposure, and managing parasite infections are critical for preventing eye damage. Minimizing aggression during feeding, careful design of handling equipment, and monitoring for eye injuries can reduce the risk. Limiting UV exposure and ensuring a balanced diet can help prevent cataracts. Fish eyes are highly vulnerable to damage due to the lack of eyelids and their protruding nature. Eye damage often indicates poor handling, disease, or environmental stressors (Noble et al., 2012). If a deformity is spotted then it should be registered in the provided form.

Literature:

1. Alaa E. Eissa, A.M. Abu-Seida, M.M. Ismail, N.M. Abu-Elala, M. Abdelesalam (2021) A comprehensive overview of the most common skeletal deformities in fish. *Aquaculture Research*, volume 52, issue 6, p. 2391-2402.
2. Anna Mercy Thoranam Varkey, Sajan Sajeewan. (2014) Efficacy of 2-Phenoxyethanol as an Anaesthetic for Adult Redline Torpedo Fish, *Sahyadria denisonii* (Day 1865). (Available at <https://onlinelibrary.wiley.com/doi/10.1155/2014/315029>)
3. Ashley, Paul J. "Fish welfare: current issues in aquaculture." *Applied Animal Behaviour Science* 104.3-4 (2007): 199-235. p212.
4. Bergheim, A., Drengstig, A., Ulgenes, Y., & Fivelstad, S. (2009). Production of Atlantic salmon smolts in Europe—Current characteristics and future trends. *Aquacultural Engineering*, 41(2), 46-52.
5. Clarke WC, Saunders RL, McCormick SD. 1996. Smolt production. In: Pennel W, Barton BA (eds). *Principles of salmonid culture*. CRC Press, Elsevier, Amsterdam, The Netherlands, Pp 517-567.
6. Davison W (1997) Training and its effects on teleost fish. *Comparative Biochemistry and Physiology* 94: 1–10.
7. Einen O, Mørkøre T, Røra° AMB, Thomassen MS (1999) Feed ration prior to slaughter – a potential tool for managing product quality of Atlantic salmon (*Salmo salar*). *Aquaculture* 178: 149–169
8. Emma Barbier, Frode Oppedal, Malthe Hvas. (2024) Atlantic salmon in chronic turbulence: Effects on growth, behaviour, welfare, and stress. *Aquaculture*, volume 582 (Available at <https://www.sciencedirect.com/science/article/pii/S0044848624000115>)
9. Endal HP, Taranger GL, Stefansson S, Hansen T (2000) Effects of continuous additional light on growth and sexual maturity in Atlantic salmon, reared in sea cages. *Aquaculture* 191: 337–349.
10. Erin M Katz, David K Chu, Keeriann M Casey, Katechan Jampachaisri, Stephen A Felt and Cholawat Pacharinsak. (2020). The Stability and Efficacy of Tricaine Methanesulfonate (MS222) Solution After Long-Term Storage. *J Am Assoc Lab Anim Sci*. 2020 Jul; 59(4): 393–400.
11. European Food Safety Authority (EFSA) (2008) "Animal welfare aspects of husbandry systems for farmed Atlantic salmon – Scientific Opinion of the Panel on Animal Health and Welfare" Annex to the EFSA Journal 736: 122 pp
12. Grøttum JA, Sigholt T (1998) A model for oxygen consumption of Atlantic salmon (*Salmo salar*) based on measurements of individual fish in a tunnel respirometer. *Aquaculture Engineering* 17: 241–251.

13. HELCOM (2011). Salmon and Sea Trout Populations and Rivers in the Baltic Sea – HELCOM assessment of salmon (*Salmo salar*) and sea trout (*Salmo trutta*) populations and habitats in rivers flowing to the Baltic Sea. Baltic Sea Environmental Proceedings No. 126A. Helsinki Commission, Helsinki. 79 pp
14. Hwang P, Lee T, Lin L. 2011. Ion regulation in fish gills: recent progress in the cellular and molecular mechanisms. *Am J Physiol-Reg I* 301, R28-R47.
15. ICES (2018). Report of the Baltic Salmon and Trout Assessment Working Group (WGBAST), 20–28 March 2018, Turku, Finland. ICES CM 2018/ACOM:10. 369 pp.
16. ICES (2020). Baltic Salmon and Trout Assessment Working Group (WGBAST). ICES Scientific Reports. 2:22. 261 pp. <http://doi.org/10.17895/ices.pub.5974>
17. ICES (2023). Baltic Salmon and Trout Assessment Working Group (WGBAST). ICES Scientific Reports. 5:53. 451 pp. <https://doi.org/10.17895/ices.pub.22800983>
18. ICES (2023). Baltic Salmon and Trout Assessment Working Group (WGBAST). ICES Scientific Reports. 5:53. 465 pp. <https://doi.org/10.17895/ices.pub.22800983>
19. Jonsson B, Ruud-Hansen J. 1985. Water temperature as the primary influence on timing of seaward migrations of Atlantic salmon (*Salmo salar*) smolts. *Can J Fish Aquat Sci* 42, 593-595.
20. Juell J-E, Bjordal A°, Ferno¨ A, Huse I (1994) Effect of feeding intensity on food intake and growth of Atlantic salmon, *Salmo salar* L., in sea cages. *Aquaculture and Fisheries Management* 25: 453–464.
21. Kulmala S., Haapasaari P., Karjalainen T.P., Kuikka S., Pakarinen T., Parkkila K., Romakkaniemi A. and Vuorinen P.J. (2013) TEEB Nordic case: Ecosystem services provided by the Baltic salmon – a regional perspective to the socio-economic benefits associated with a keystone species. In Kettunen et al. Socio-economic importance of ecosystem services in the Nordic Countries - Scoping assessment in the context of The Economics of Ecosystems and Biodiversity (TEEB). Nordic Council of Ministers, Copenhagen. Available also at: www.TEEBweb.org.
22. Lars H. Stien, Marc B. M. Bracke, Ole Folkedal, Jonatan Nilsson, Frode Oppedal, Thomas Torgersen, Silje Kittilsen, Paul J. Midtlyng, Marco A. Vindas, Øyvind Øverli and Tore S. Kristiansen (2013) "Salmon Welfare Index Model (SWIM 1.0): a semantic model for overall welfare assessment of caged Atlantic salmon: review of the selected welfare indicators and model presentation" 33 – 50.
23. Madsen SS, Jensen MK, Nhr J, Kristiansen K. 1995. Expression of Na(+)-K(+)-ATPase in the brown trout, *Salmo trutta*: In vivo modulation by hormones and seawater. *AM J Physiol Regul Integr Comp Physiol* 269, R1339-R1345.
24. McCormick SD, O'Dea MF, Moeckel AM, Björnsson BT. 2003. Endocrine and physiological changes in Atlantic salmon smolts following hatchery release. *Aquaculture* 222, 45-57.

25. McCormick SD, Sheehan TF, Björnsson BT, Lipsky C, Kocik JF , et al. 2013. Physiological and endocrine changes in Atlantic salmon smolts during hatchery rearing, downstream migration, and ocean entry. *Can J Fish Aquat Sci* 70, 105-118.
26. McCormick SD. 2001. Endocrine control of osmoregulation in teleost fish. *American Zoologist* 41, 781-794.
27. Noble C., Jones H., A., Damsgård B., Flood M. J., Midling K. Ø., Roque A., Sæther B.S., Cottee S.Y., (2012). Injuries and deformities in fish: their potential impacts upon aquacultural production and welfare. *Fish Physiol. Biochem.*, 38:61–83
28. Noble, C., Gismervik, K., Iversen, M. H., Kolarevic, J., Nilsson, J., Stien, L. H. & Turnbull, J. F. (Eds.) (2018). *Welfare Indicators for farmed Atlantic salmon: tools for assessing fish welfare* 351pp.
29. Plikšs Māris, Aleksejevs Ēriks (S.a.) "Lasis" (Available: <https://www.latvijasdaba.lv/zivis/salmo-salar-l/>)
30. Pontigo JP, Agüero MJ, Sánchez P, Oyarzún R, Vargas-Lagos C, et al. 2016. Identification and expressional analysis of NLRC5 inflammasome gene in smolting Atlantic salmon (*Salmo salar*). *Fish Shellfish Immun* 58, 259-265.
31. Purvina, S., Medne, R., Bajinskis, J., Kondratjeva, N. 2019. Success of long-term salmonid restocking in Latvia. *Environ. Exp. Biol.* 17: 31–32.)
32. S. Javaheri, H. Nekoubin. (2012). Effect of anesthesia with clove oil (review). (Available at https://www.researchgate.net/publication/228104108_Effect_of_anesthesia_with_clove_oil_if_fish_review)
33. Sandoval C. (2020). Short operculum - Gross pathology, (Available at <https://fishhistopathology.com/?p=2307>)
34. Stefansson SO, Björnsson BTh, Ebbesson LOE, McCormick SD. 2008. Smoltification. In: *Fish Larval Physiology*, 639-681.
35. Takle H, Castro V, Grisdale-Helland B, Helland S, Tørud B, Kristensen T (2010) *Aerob utholdenhetstrening for bedret hjertefunksjon og helse hos oppdrettslaks: oppfølging og videreutvikling av konseptet trening av fisk* (In Norwegian). Final Project Report for FHF, Norway. ISBN: 978-82-7251- 738-9. 46 pp.
36. Taylor R.S., Muller W.J., Cook M.T., Kube P.D., Elliott N.G. (2009). Gill observations in Atlantic salmon (*Salmo salar*, L.) during repeated amoebic gill disease (AGD) field exposure and survival challenge. *Aquaculture*, Volume 290, Issues 1–2, Pages 1-8.

ANNEX I

Form N1 Rearing condition and herd health indicators

General data		
Date:		
Fish farm name:		
Address:		
Phone number:		
Email:		
Fish farm:		
Growing system type:		
Rearable fish type:		
Growing type (intensive, extensive etc.)		
Water source		
Rearing condition (environmental condition)		
Temperature		
Dissolved oxygen		
Oxygen saturation		
Water pH		
Water color		
Water flow rate		
Lighting		
Fish group (herd or rearing tank) indicators		
Fish of group	herd	rearing tank
Rearing length (reared from... data)		
Egg mortality		
Fish mortality during the growing period		
Fish density		
Fish aggression		
Type of feed in use		
Feeding regimen		
Amount of feed per day		
Notifiable disease outbreaks		
Illnesses		
Anamnesis		
IPN		
Aeromonosis		
Flavobacteriosis		
Trauma		
Parasites		

ANNEX II

Form N2 Individual health indicators (n=100 fish)

[illegible]