Utilizing Wild Lumpfish Insights to Enhance Welfare and Performance of Lumpfish in Aquaculture

Sandra Ljósá Østerø and Kirstin Eliasen

PHOTO 1. *Faroese salmon farming cages. Photo by Sandra Ljósá Østerø.*

PHOTO 2. *Wild lumpfish liver. Photo by Kirstin Eliasen.*

Over the past two decades, the salmon farming industry in the Faroe Islands has experienced significant growth, positioning the archipelago as the fifth-largest Atlantic salmon (*Salmo salar*) producer globally, despite its population of only 55,000 residents. Similar to other Atlantic salmon producers, the industry faces challenges from sea lice (*Lepeophtheirus salmonis*), which pose a significant threat to both farmed salmon and wild trout populations. To combat sea lice infestations, the Faroese salmon farming industry has shifted away from chemical treatments toward non-chemical solutions, including the use of lumpfish (*Cyclopterus lumpus*) as cleaner fish.

In 2014, the Faroese salmon producer Hiddenfjord became the first to deploy lumpfish as cleaner fish in salmon cages, marking the beginning of their use in the Faroe Islands' aquaculture industry. Since then, lumpfish have become an integral part of salmon farming, serving as natural cleaners to control sea lice infestations. Despite their widespread use, high mortality rates and welfare concerns have raised questions about their long-term sustainability. This has led to a decline in lumpfish use in both the Faroe Islands and Norway (Østerø *et al*., 2024).

As lumpfish use in salmon farming was still in its early stages, the initial years were marked by trial and error, with farmers and researchers refining their approaches through hands-on experience. The small size of the Faroe Islands (Photo 1) allows for close collaboration between the industry, public institutions, and researchers, enabling the swift exchange of knowledge and the rapid implementation of solutions to industry challenges.

Learning from Wild Lumpfish

Most lumpfish used in the Faroe Islands as cleaner fish are sourced from wild-caught broodstock, meaning they are essentially non-domesticated. With limited knowledge on lumpfish biology and husbandry, researchers naturally turned to wild lumpfish for guidance. Early in their use as cleaner fish, there were no established welfare indicators for lumpfish, leading to the need for species-specific assessments.

Having accurate species-specific welfare indicators is crucial for ensuring the health and well-being of farmed fish. Many general welfare parameters used in aquaculture are derived from other species, which may not always be suitable for lumpfish. As a practically non-domesticated species with unique biological and behavioral traits, lumpfish require specialized indicators tailored to their needs.

The Spectrum of Liver Colors

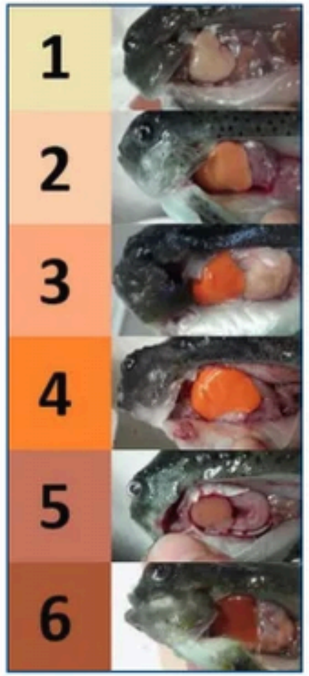
Shortly after the introduction of lumpfish in the Faroe Islands in 2014, regular welfare checks were implemented to assess their health and condition, leading to the gradual development and refinement of suitable Operational Welfare Indicators (OWIs) based on observations and research.

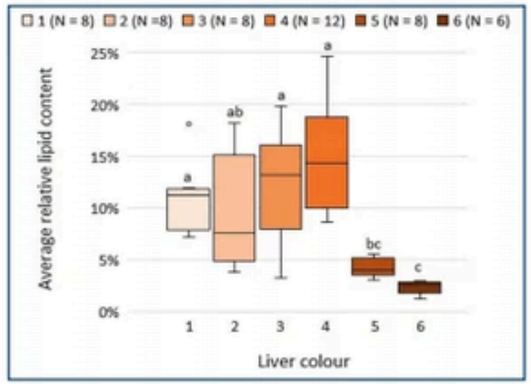
During welfare checks, researchers observed that lumpfish in a sea cage with a high survival rate had bright orange livers. Given the limited knowledge available on liver color in lumpfish, they turned to wild populations for insights. By examining the liver colors of farmed and wild lumpfish—assumed to be in optimal health—they aimed to identify potential correlations between pigmentation and overall well-being. The findings revealed that wild lumpfish consistently had bright orange livers, suggesting a link between liver pigmentation and overall well-being (Photo 2).

This discovery led to a study by Eliasen *et al*. (2020), which demonstrated that liver color—ranging from pale to bright orange to dark reddish-brown—reflects key biological differences and can function as an OWI and help farmers improve lumpfish welfare and survival (Figure 1).

The study found that lumpfish with bright orange livers had higher levels of carotenoid pigments like astaxanthin and canthaxanthin, essential for immune function and overall health. In the wild, lumpfish obtain these pigments naturally from their diet, which is rich in crustaceans. However, in salmon cages, they rely on formulated feed, which may not always provide enough of these important nutrients.

On the other hand, lumpfish with dark reddish-brown livers had lower energy reserves, particularly stored fats (lipids), which play an important role in their overall condition and welfare (Figure 2). These fish were likely under nutritional stress, causing them to break down their own liver fat for energy. The study also found that lumpfish with darker livers had smaller livers in relation to their body size, further linking liver color to overall condition and energy storage.





TOP, FIGURE 1. *Liver color scoring system. From Eliasen* et al. *2020.*
BOTTOM, FIGURE 2. *Lipid content (%) in relation to liver color. From Eliasen* et al. *2020.*

Changes in liver color can therefore provide valuable insights into lumpfish health. A transition from bright orange to dark reddish-brown often signals nutritional deficiencies or metabolic stress, while a change to pale livers may indicate underlying disease. Regular liver color assessments offer a practical OWI, helping farmers make decisions on feeding strategies and husbandry practices. By closely tracking these shifts, farmers can intervene early to improve lumpfish welfare, survival rates, and their overall efficiency as cleaner fish.

Body Condition

The body condition of fish can be estimated using standard length-to-weight relationships to evaluate their growth and condition. Traditionally, the body condition of lumpfish in salmon cages has been based on length-weight relationships from lumpfish in salmon cage environments (Gutierrez Rabadan *et al*., 2021, Eliasen *et al*., 2020, Rey *et al*., 2021, Engebretsen *et al*., 2024). However, from the onset of welfare monitoring in the Faroe Islands, farmers and researchers relied on data on lengths and weights of wild lumpfish, provided by the Faroe Marine Research Institute from their longstanding pelagic surveys. This reference has played an important role in identifying discrepancies in growth patterns, highlighting areas for improvement in husbandry and welfare practices.

A study by Østerø *et al*. (2024) found that wild lumpfish caught around the Faroe Islands exhibit a positive allometric growth pattern, meaning they gain proportionally more weight as they grow longer. In contrast, lumpfish in salmon cages displayed slightly negative allometric growth, where weight did not increase in proportion to length. Additionally, other commonly used standard weight references for farmed lumpfish showed an even more pronounced negative allometric growth pattern. These differences in growth patterns are displayed in Figure 3. The differing growth patterns may be due to the long-standing use of wild lumpfish as a reference for body condition in the Faroe Islands. This ongoing comparison may have contributed to efforts to maintain growth patterns closer to those seen in the wild.

The study found that a significant proportion of lumpfish in salmon cages were underweight or emaciated compared to wild lumpfish. Figure 4 illustrates the proportional distribution of lumpfish across three body condition categories—good condition, underweight, and emaciated—using (a) a length-weight regression by Gutierrez Rabadan *et al*. (2021) and (b) a regression based on wild lumpfish from the study by Østerø *et al*. (2024). The distribution based on wild lumpfish aligns well with observations from the Faroe Islands, where lumpfish generally display good body condition in hatcheries and at deployment but where body condition declines after deployment in salmon cages. Incorporating body condition standards based on wild lumpfish, can help farmers better to detect underweight or emaciated lumpfish (Photo 3). Regular monitoring of growth patterns allows for early intervention when signs of poor health arise, ultimately improving survival rates and the effectiveness of lumpfish as cleaner fish. Using wild lumpfish as a reference for body condition ensures that farmed lumpfish are assessed against their natural growth patterns, offering a more accurate benchmark for detecting and addressing poor body condition.

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Wild Lumpfish as a Benchmark in Research

The approach of using wild lumpfish as a reference in Faroese research is not limited to liver color and body condition. Other lumpfish studies have applied this method to improve knowledge of lumpfish welfare and husbandry. Research comparing wild and farmed lumpfish has also been used to assess differences in nutritional requirements, feeding behavior and natural shelters (Photo 4). These studies help refine feeding strategies and management practices in aquaculture.

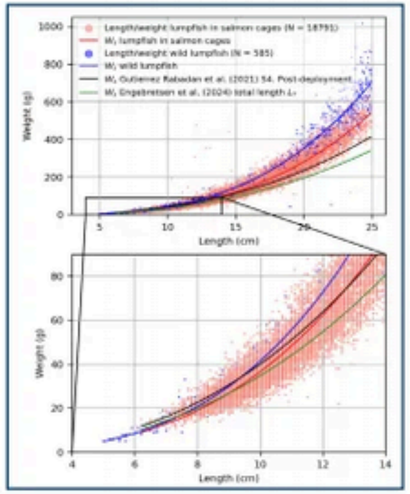
Seaweed Shelters

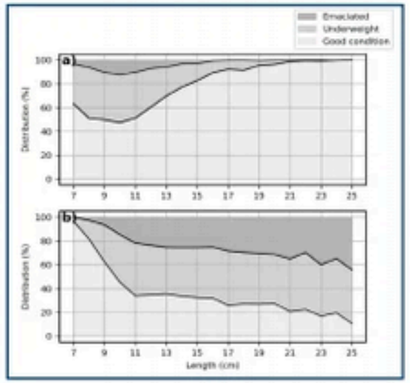
Recent research in the project Lumpfish & AkvaNest (FHF Norwegian Seafood Research Fund project 901781) has explored the potential of using natural seaweed shelters to improve lumpfish welfare and cleaning efficiency. The study found that while the seaweed shelters did not significantly alter lumpfish activity or lice consumption rates, they did harbor fewer pathogenic bacteria compared to traditional plastic shelters. This suggests that natural seaweed habitats may provide a healthier environment for lumpfish, potentially reducing infection pressure and stress-related mortality.

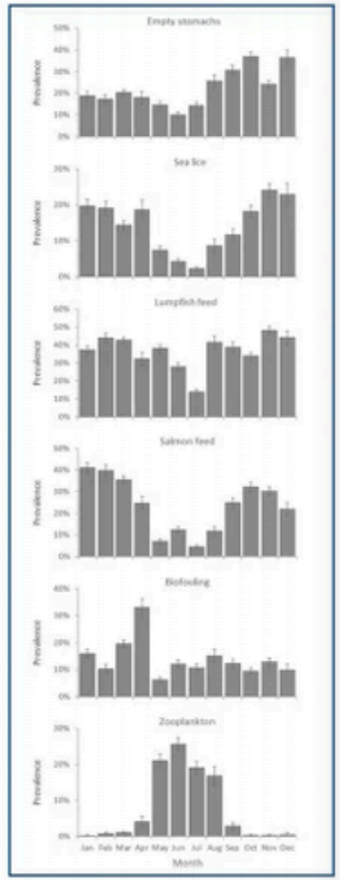
Feed and Feeding Behavior

The natural feeding behavior of wild lumpfish also plays a critical role in their effectiveness as cleaner fish in aquaculture. Lumpfish are opportunistic feeders, adapting their diet to whatever is available in their environment. In the wild, young lumpfish primarily feed on small crustaceans in coastal habitats before migrating to open waters as they mature. A study by Eliasen *et al.* (2018) showed that in salmon cages, lumpfish exhibit similar opportunistic behavior, consuming not only sea lice but also formulated feed, biofouling organisms, and seasonally available zooplankton (Figure 5, Photo 5). This adaptability can be both beneficial and challenging—while it may allow lumpfish to adapt to life in salmon cages in varied conditions, it also means that their delousing efficiency can fluctuate depending on the availability of alternative food sources.

A recent PhD study investigated nutritional deficits in lumpfish feeds by comparing wild and farmed populations, aiming to improve welfare and survival. The study revealed significant differences in lipid and protein levels between wild and farmed lumpfish, which directly impact their health and efficiency as cleaner fish. These findings contribute to the formulation of nutritionally optimized feeds tailored to the specific dietary needs of lumpfish, enhancing their robustness and effectiveness in aquaculture.







TOP LEFT, FIGURE 3. *Length-weight relationships. From Østerø* et al. *(2024).* BOTTOM LEFT, FIGURE 4. *Proportional distribution of body condition categories based on a) Gutierrez Rabadan* et al. *(2021) and b) wild lumpfish model. From Østerø* et al. *(2024).* RIGHT, FIGURE 5. *Monthly variation in the average prevalence of empty stomachs and in the average prevalence of food types in the lumpfish stomachs. From Eliasen* et al. *(2018).*

Conclusion

The use of wild lumpfish as a benchmark has significantly improved our understanding of lumpfish welfare and performance in aquaculture (Photo 6). Research on liver color, body condition, feeding behavior, and habitat preferences has highlighted the importance of using natural references when developing welfare indicators and management strategies for farmed lumpfish. By continuously refining husbandry practices based on wild lumpfish insights, farmers can enhance survival rates, optimize feeding efficiency, and improve the overall well-being of lumpfish in salmon cages. As long as lumpfish remain non-domesticated, using wild lumpfish as a benchmark continues to be a valuable approach. Their natural biological traits offer key insights into health, growth, and behavior, guiding the development of welfare indicators suited to farmed populations.

THE USE OF WILD LUMPFISH AS A BENCHMARK HAS SIGNIFICANTLY IMPROVED OUR UNDERSTANDING OF LUMPFISH WELFARE AND PERFORMANCE IN AQUACULTURE... . AS LONG AS LUMPFISH REMAIN NON-DOMESTICATED, USING WILD LUMPFISH AS A BENCHMARK CONTINUES TO BE A VALUABLE APPROACH.

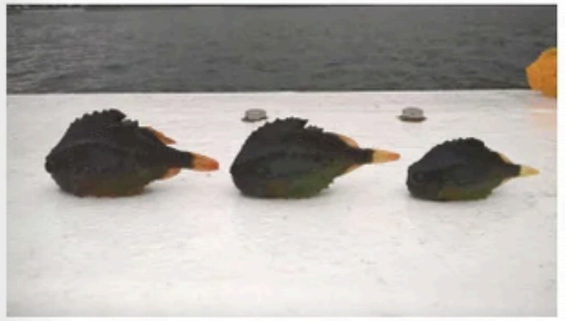


PHOTO 3. *Incorporating body condition standards based on wild lumpfish can help farmers detect underweight or emaciated cultured lumpfish. Photo by Kirstin Eliasen.*

PHOTO 4. *Research comparing wild and farmed lumpfish has been used to assess differences in nutritional requirements, feeding behavior and natural shelters. Photo by Kirstin Eliasen.*

PHOTO 5. *In salmon cages, lumpfish consume not only sea lice but also formulated feed, biofouling organisms, and seasonally available zooplankton. Photo by Sandra Ljósá Østerø.*

PHOTO 6. *Wild lumpfish. Photo by Kirstin Eliasen.*

Notes

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