NASCO	**Council** ***How to protect wild salmon against sea lice with the use of new technologies and post-smolts***	**CNL(21)48rev** **Agenda item: 5(a)**

How to Protect Wild Salmon Against Sea Lice with the Use of New Technologies and Post-Smolts

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Background

Salmon lice (*Lepeophtheirus salmonis*) severely impact both wild salmon and the farmed salmon industry. In addition to the wildlife and welfare responsibility of the fish farmers, the enormous additional costs associated with lice counting and different lice combating methods are reasons for the huge interest and effort being invested to find solutions that successfully combat the parasite.

Because of the risk of resistance, the use of medical lice treatment is not preferred or common, and the different non-medical lice combating methods can roughly be divided between methods where lice are removed from the fish and methods that prevent lice from attaching to the salmon. In the first group, lice can be removed from salmon using methods involving handling the fish, such as mechanical delicing. Most of these methods include crowding and pumping of salmon that may cause severe welfare issues (Overton *et al*. 2019). Examples of methods where handling is not involved include the use of cleaner fish that eat lice and the use of lasers. Preventive methods used to various degrees include functional feed, genetic selection and vaccines. However, more successful, and common, is the use of different cage and tank systems that are constructed in such a way that lice do not enter the systems.

Semi-closed systems and post-smolts

Semi-closed systems (Figure 1) are examples of preventive methods where a physical barrier between the fish and its environment prevent lice from entering the system and fish from escaping from the system. Water is pumped into the system from depths under the lice level.

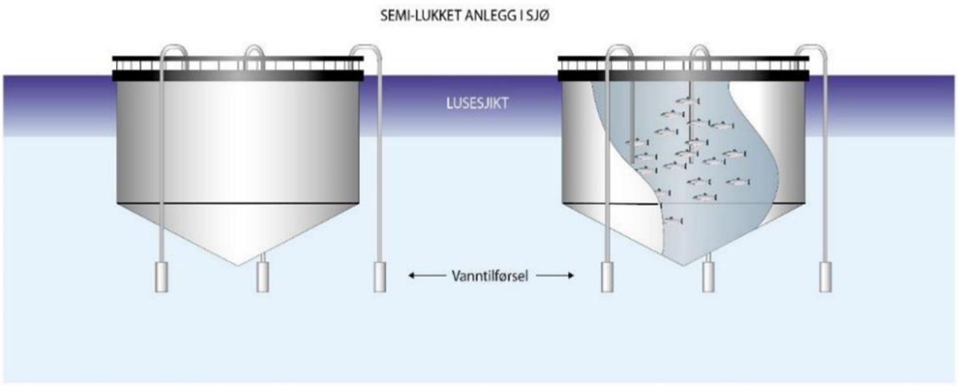

Figure 1. *Principal function of semi-closed systems.*

Semi-closed systems are so-far used for post-smolts, i.e. large smolts up to approximately 1,000 g that are already adapted to sea water. This leads to one more advantage of the systems, in that salmon are kept away from the open sea for longer, and therefore longer periods away from lice and risk of escapees. Post-smolts kept in land-based RAS (recirculation in aquaculture) facilities until they are approximately 1,000 g are also kept away from the open sea for longer. By putting large smolts of up to 1 kg into the net pens, the time spent in the open sea can be reduced from the traditional 16 – 22 months to 10 – 11 months. This way of producing fish is an alternative to the traditional method where 70 – 100 g fish are transferred to open net pens for ongrowing (Figure 2).

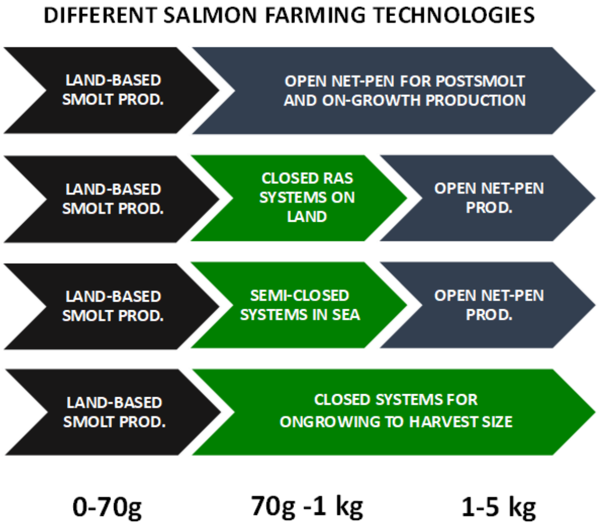

Figure 2*. Different production protocols for salmon. The upper arrow represents the traditional way where a 70 – 100 g smolt is transferred to open net pens for ongrowing. The two middle arrows represent production of post-smolts in either RAS or semi-closed systems before transfer to open net pens. The last arrow represents the system where salmon are kept on land for the whole life cycle.*

The production of post-smolts is relatively new and much research is being done to secure fish welfare and robustness in the systems and to ensure that the fish are suited to life at sea when they reach the appropriate size. Also, producing post-smolts on land means that the fish need to adapt to brackish water or salt water on land. This requires knowledge of fish biology and responses in this phase, including appropriate smoltification protocols. Also, knowledge about RAS technology to ensure fish health and welfare is required.

Cases from Research

In the presentation examples from our research concerning post-smolt welfare and performance in RAS and semi-closed systems will be shown.

Our experience with the semi-closed systems we have been investigating is that the functionality regarding lice infestation is very good. The lack of lice is also scientifically documented (Nilsen *et al*. 2017a). In a newly completed MSc thesis, where six generations of salmon were followed in one semi-closed system, it was concluded that in three out of six generations the growth was better in the semi-closed system compared to a reference cage. However, after the fish were moved out from the semi-closed system and into open net pens, fish from four out of six generations performed better when they originated from the semi-closed system than if they came from the reference net pen. The lice infestation was also lower in the fish originating from the semi-closed system, even if lice were present in the area at the time of the experiment (Øvrebø 2020).

Recently, a study was completed in which we followed a group of 200,000 smolts from a RAS facility, into a semi-closed system and finally out to an open net pen (Espmark *et al*. 2020). The main conclusions from this study were that growth (Specific Growth Rate and Thermal Growth Coefficient) was better during the time that the fish spent in the semi-closed system compared to both the RAS phase and the three months that we followed the fish in the open net pen. It was also documented that skin health improved during the stay inside the semi-closed system, shown by histology and gene expression analyses. We believe that a slight increase in temperature inside the system improved growth and that good water quality facilitated skin health and growth.

To secure survival and good welfare after sea transfer, it is important to ensure that the post-smolts are robust. Karlsen *et al*. (2018) showed that post-smolts are low in immune genes for a period of approximately one month after sea transfer (Figure 3). At the same time, skin histology and gene expressions for skin health also indicated reduced epidermis quality. Four months after sea transfer, both immune genes and skin quality improved (Karlsen *et al*. 2018). These results show that post-smolts are naturally vulnerable just after sea transfer and should thus be handled as little as possible, especially during the window of low immunity and poorer skin health.

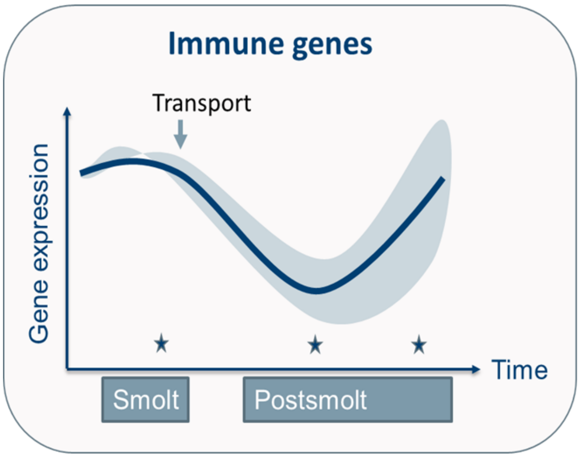

Figure 3. *Expression of group of immune genes are naturally low in the period between smolt and post-smolt (Karlsen* et al. *2018).*

Training has been proven beneficial for survival, and one way to facilitate training is with water velocity (Castro *et al*. 2011). To secure system specific recommendations for swimming speed, Timmerhaus *et al*. (2021) performed an experiment where post-smolts were exposed to velocities of 0.5, 1.0, 1.8 and 2.5 body lengths per second. It was seen that weight increased linearly with velocity. However, the fish provided with a velocity of 0.5 body lengths per second were the longest but had the lowest condition factor compared to the other test groups. There was also a linear increase in muscle cell density, indicating that the weight increase was indeed an increase in muscle mass, caused by training. The welfare of the fish at the highest velocity (2.5 body length per second) was not good, shown by the increased number of severe skin damages at the highest velocity. Also, shoaling was observed after a few days with the highest velocities. The reason for this behavioural change is not clear but may be because the fish tried to form a hiding place from velocities or that uneven distribution of velocities in tanks may have resulted in places with lower velocities that were preferred places for the fish compared to places with a higher velocity. From this study it was concluded that recommended swimming speed in RAS for post-smolts is 1.0 – 1.5 body lengths per second (Timmerhaus *et al*. 2021), which is the same as for earlier recommendations from flow-through.

During ‘traditional’ salmon production, freshwater smolts are given a winter signal with 12 hours darkness and 12 hours of light to induce smoltification that results in sea water tolerance, and the fish is ready to be transferred to sea. The transformation of aquaculture, in that the fish are kept longer on land, has also resulted in the fish being introduced to sea water or brackish water while still on land. This has led to several different smoltification protocols, varying in salinity, duration and timing of winter signal, and even the absence of winter signal. Many of the different protocols used are developed from experience and without scientific proof. During the presentation we will show an example of scientific approach where we experimented with different salinities and photoperiods and how this influenced performance and welfare.

One advantage with closed aquaculture systems is the possibility of controlling water quality and thus performance and welfare. Full control of water quality requires good skills in water quality among workers, knowledge of how to obtain and keep optimal water quality and of how to prevent failures. Recirculating water needs to be treated to remove discharges such as ammonia and carbon dioxide that may be toxic to fish. In an experiment in RAS, Mota *et al.* (2019) showed a growth penalty with CO_2 concentrations from 5 – 40 mg / l (Figure 4), without any severe welfare effects. However, the effect on growth at concentrations lower than the recommended 15 mg / l, suggests that the CO_2 levels should be kept even lower in RAS. The authors suggest 12 mg / l in RAS (Mota *et al.* 2019).

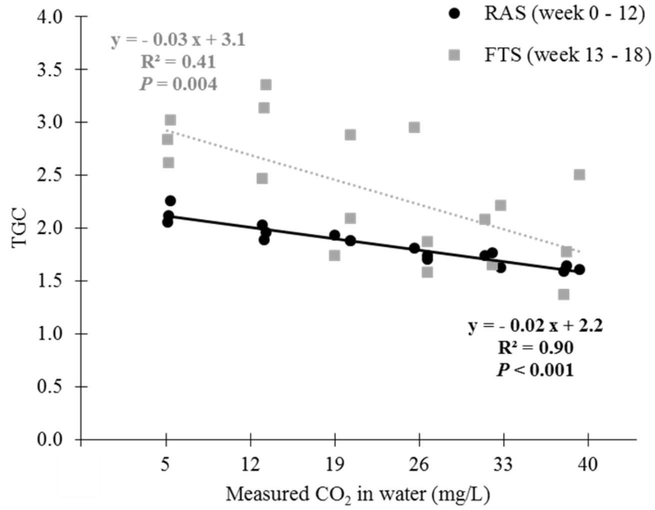

Figure 4. *Growth penalty caused by CO_2 during the RAS phase was carried over to the flow through on-growing phase (Mota* et al. *2019).*

Many farmers prefer to treat the RAS water with ozone to reduce colouration and increase visibility in the water. However, due to the production of bromines in ozone treated saline water that may be toxic for the fish, the risk of using ozone in saline water is higher than in fresh water. In fresh water, ozone significantly improves water clarity, diminishes bacteria counts, reduces dissolved metals and leads to increased salmon growth (Davidson *et al.* 2021). Salmon is sensitive to ozone in saline water, and Stiller *et al.* (2020) demonstrated that ozone concentrations, recommended for turbot (*Scophthalmus maximus*) and sea bass (*Dicentrarchus labrax*), turned out to be acutely lethal for salmon and was especially harmful to the gills.

To conclude, there is agreement that new technologies and production protocols are needed to prevent harmful effects on wildlife caused by aquaculture. There is a risk that new technological solutions are being developed more quickly than the research required to ensure that fish welfare is secured in the new systems. It is important that research and technological development work hand in hand so that the technologies are developed taking fish welfare into account.

Acknowledgements

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