

## *How to protect wild salmon against sea lice with the use of new technologies and post-smolts*

*Åsa Maria Espmark  
Nofima, Sunndalsøra, Norway*

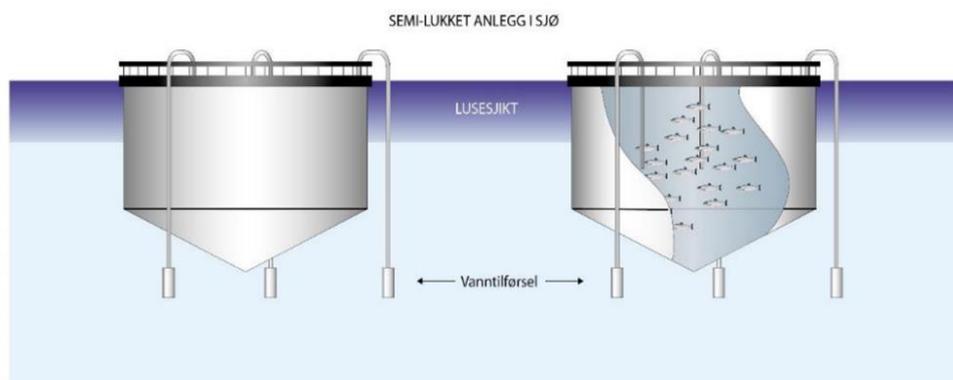
### Background

Salmon lice (*Lepeophtheirus salmonis*) is causing severe impacts on both wild salmon and farmed salmon industry. In addition to the wildlife and welfare responsibility of the fish farmers, enormous additional costs associated with lice counting, and different lice combating methods are reasons for the huge interest and effort being done 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 with methods including handling of 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.* 2018). Among the methods where handling is not included, the use of cleaner fish that eats lice and lacer are examples. Amongst preventive methods functional feed, genetic selection and vaccines have been used in various degrees. However, more successful, and common are 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-smolt

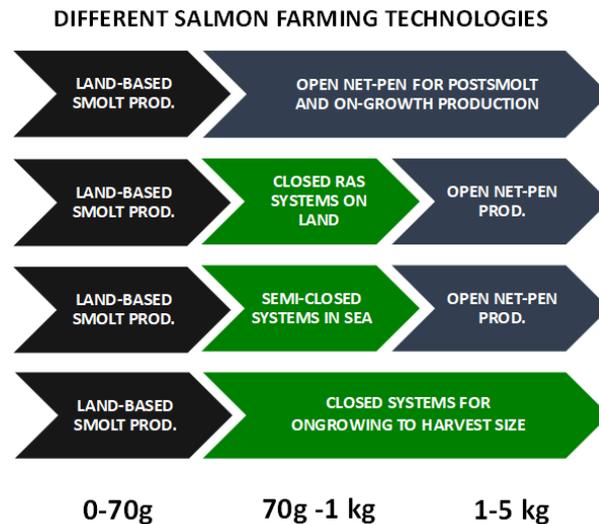
Semi-closed systems (Figure 1) are examples of preventive methods where a physical barrier between the fish and its environment prevent lice from entering the system and fish from escaping from the system. Water is pumped into the system from depths under the lice level.



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

Semi-closed systems are so-far used for post-smolt, that is seawater adapted big smolt up to approximately 1000 gram. This leads to one more advantage of the systems in that salmon are kept away from open sea for longer, thus longer periods away from lice and risk of escapees. Also, when keeping post-smolt in land-based RAS (recirculation in aquaculture) facilities until they are approximately 1000 gram, the fish are kept longer away from open sea. By putting

large smolts of up to 1kg to net pens, it would then be possible to shorten the time spend in open sea from the traditional 16-22 months to 10-11 months. This way of producing fish is an alternative to the traditional method where a 70-100 gram fish are transferred to open net pens for on-growing (Figure 2).



**Figure 2.** Different production protocols for salmon. The upper arrow represents the traditional way where a 70-100 gram smolt is transferred to open net-pens for on-growing. The two middle arrows represent production of post-smolt 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 the whole life cycle.

The production of post-smolt 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 fitted for life in sea when they reach the appropriate size. Also, producing post-smolt on land means that the fish need to adapt to brackish water or salt water on land. This requires knowledge about fish biology and responses in this phase, amongst others appropriate smoltification protocols. Also, knowledge about RAS technology to ensure fish health and welfare is required.

### Cases from Research

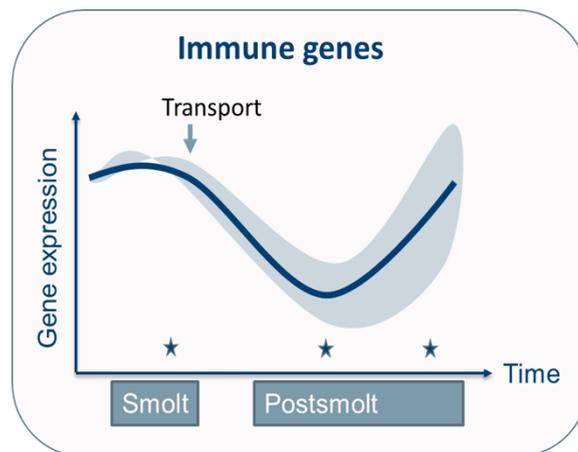
In the presentation examples from our research concerning post-smolt welfare and performance in RAS and semi-closed systems will be shown.

Our experience with the semi-closed systems that 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.* 2017). 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 for the semi-closed system even if lice in the area at the time of experiment were present (Øvrebø 2020).

Recently, a study was completed where we followed a group of 200 000 smolt 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 also after sea transfer, it is important to ensure that the post-smolt are robust. From an experiment Karlsen *et al.* (2018) showed that post-smolt are low in immune genes for a period approximately one month after sea transfer (Figure 3). At the same time with the low immune gene levels, also skin histology and gene expressions for skin health indicated reduced epidermis quality. Four months after sea transfer both immune genes and skin quality improved (Karlsen *et al.* 2018). These results shows that post-smolt 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.



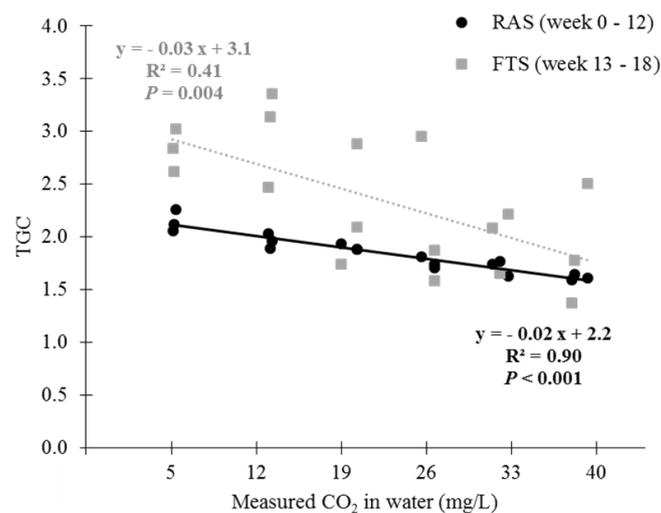
**Figure 3.** Expression of group of immune genes are naturally low in the period between smolt and post-smolt (Karlsen *et al.*, 2018)

Training has been proven beneficial for survival, and one way to facilitate training is with water velocity (Castro *et al.* 2011). In order to secure system specific recommendations for swimming speed, Timmerhaus *et al.* (2020) performed an experiment where salmon post-smolt were exposed to velocities of 0.5, 1.0, 1.8 and 2.5 body length per second. It was seen that the weight increased linearly with velocity, however, the fish provided a velocity of 0.5 body length per second, were the longest but had the lowest condition factor compared to the other test groups. It 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 some hiding places from velocities or that possible uneven distribution of velocities in tanks resulted in places with lower velocities that were more preferred places for the fish compared to places with higher velocity. From this study it was concluded that recommended swimming speed in RAS for post-smolt is 1.0 – 1.5 body length per second (Timmerhaus *et al.* 2020), which is the same as for earlier recommendations from flow through.

During “traditional” salmon production, freshwater smolt are given a winter signal with 12h dark and 12h 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 that the fish are introduced to sea water or brackish water while the fish are 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. A full control of water quality demands good skills in water quality among workers, how to obtain and keep optimal water quality, and 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. Mota et al., (2019) showed in an experiment in RAS a growth penalty with CO<sub>2</sub> concentrations from 5 – 40 mg/l (Figure 4), without any severe welfare effects. However, the effect on growth already at concentrations lower than the recommended 15 mg/l, suggests that in RAS the CO<sub>2</sub> levels should be kept even lower. The authors suggest 12 mg/L in RAS (Mota *et al.* 2019).



**Figure 4.** Growth penalty caused by CO<sub>2</sub> 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 the coloration and increase the 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 to use it in fresh waters. In freshwater ozone significantly improves water clarity, diminish bacteria counts, and reduced dissolved metals, in addition to lead to increased salmon growth (Davidson *et al.* 2021). Salmon is sensitive towards 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 acute lethal for salmon and was especially harmful for the gills.

To conclude, there is agreement that new technologies and production protocols are needed to prevent harmful effects on wildlife because of aquaculture. Development have come far to suggest technological solutions, and research have come a bit to ensure that fish welfare is secured in the new systems. It is important that research and technological development are working hand in hand so that the technologies are developed on the premises of the fish biology, and not the other way around.

### Acknowledgements

Research presented are funded by CtrlAQUA (Centre for Closed-containment Aquaculture) SFI (Centre for Research Based Innovation) (RCN project #237856/O30), and FishGLOBE (RFF project #259057).

## References

- Castro, V., Grisdale-Helland, B., Helland, S.J., Kristensen, T., Jorgensen, S.M., Helgerud, J., Claireaux, G., *et al.* 2011. Aerobic training stimulates growth and promotes disease resistance in Atlantic salmon (*Salmo salar*). *Comparative Biochemistry and Physiology A-Molecular & Integrative Physiology*, 160 (2), 278-290.
- Davidson, J., Summerfelt, S., Mota, V., Espmark, A.M.O. and Good, C. 2021. Effects of ozone on post-smolt Atlantic salmon *Salmo salar* performance, health, and maturation in freshwater recirculation aquaculture systems. *Aquaculture*, 533, 736208.
- Espmark, Å.M., Stiller, K., Shahzad, K., Reiten, B.G., Marchenko, Y., Gerwins, J., Radonjic, F.S., *et al.* 2020. Nytt S-CCS konsept for oppdrett av laks - Postsmoltproduksjon i FishGLOBE. Nofima rapport 42/2020 (In Norwegian).
- Karlsen, C., Ytteborg, E., Timmerhaus, G., Høst, V., Handeland, S., Jørgensen, S.M. and Krasnov, A. 2018. Atlantic salmon skin barrier functions gradually enhance after seawater transfer. *Scientific Reports*, 8, 9510.
- Mota, V., Nilsen, T.O., Gerwins, J., Gallo, M., Ytteborg, E., Baeverfjord, G., Kolarevic, J., *et al.* 2019. The effects of carbon dioxide on growth performance, welfare, and health of Atlantic salmon post-smolt (*Salmo salar*) in recirculating aquaculture systems. *Aquaculture*, 498, 578 – 586.
- Nilsen, A., Nilsen, K.V., Biering, E. and Bergheim, A. 2017. Effective protection against sea lice during the production of Atlantic salmon in floating enclosures. *Aquaculture*, 466, 41 – 50.
- Overton, K., Dempster, T., Oppedal, F., Kristiansen, T., Gismervik, K. and Stien, L.H. 2019. Salmon lice treatments and salmon mortality in Norwegian aquaculture: a review. *Reviews in Aquaculture*, 11, 1398–1417.
- Øvrebø, T.K. 2020. Growth performance and welfare of post-smolt (*Salmo salar* L.) reared in semi closed containment systems (S-CCS) – a comparative study. Master in Science thesis, Department of Biology, University of Bergen, Norway, 144 pp.
- Stiller K.T. Kolarevic J., Lazado C.C., Gerwins G., Good C., Summerfelt S.T., Mota V.C. and Espmark Å.M.O. 2020. The Effects of Ozone on Atlantic Salmon Post-Smolt in Brackish Water – Establishing Welfare Indicators and Thresholds. *International Journal of Molecular Sciences*, 21, 5109; doi:10.3390/ijms21145109.
- Timmerhaus, G., Lazado, C.C., Cabillon, N.A.R., Reiten, B.K.M. and Johansen, L.H. 2020. The optimum velocity for Atlantic salmon post-smolts in RAS is a compromise between muscle growth and fish welfare. *Aquaculture*, 532, 736076.