Comparison of temperature and salinity from *NorKyst800* with observations

Temperature and salinity estimates from *NorKyst800* were generally consistent with observations at farm locations and sentinel cages, although regional and short-term deviations occurred. The Pearson correlation coefficient (r) between temperatures reported for farm locations and corresponding *NorKyst800*-modelled temperatures was $r = 0.95$, with reported values being on average 0.04 °C higher than modelled, 74 % of reported values being within ± 1 °C of modelled values and 93 % within ± 2 °C (N > 400,000 observations). We had measurements of temperature and salinity at 1 and 3 m depths for 6 sentinel cage locations in one fjord region in June 2016 and 43 sentinel cage locations in three fjord regions in June 2018. The correlation between *NorKyst800*-modelled temperature at 3 m depth and temperature measurements at 3 m depth was $r = 0.93$, with measured temperatures being on average 1.6 °C higher than modelled (N = 49). Higher temperatures than modelled were mainly observed in inner parts of fjord areas sampled in 2018 following a period with unusually high air temperatures, where the deviations were around 2 °C. A corresponding regional and short-term difference between farm-reported and *NorKyst800*-modelled temperatures showed that this deviation was not reflecting a persistent regional anomaly. The correlation between *NorKyst800*-modelled sea surface salinity and salinity measurements at 1 m depth was $r = 0.89$, with measured values being on average 0.1 salinity units lower than modelled (N = 49). At a regional and short-term scale (a single fjord region and sampling time), the deviations varied from the measurements being 2.7 salinity units lower to 3.7 salinity units higher than modelled.

Temperature measurements at 1 and 3 m depth were strongly correlated ($r = 0.94$, N = 49) with temperature at 3 m on average being 0.4 °C lower than at 1 m. The correlation between salinities at 1 and 3 m was $r = 0.86$, with salinity at 3 m on average being 1.2 salinity units higher than at 1 m.

Additional analyses of associations between lice levels and salinity and temperature

The environmental model that accounted for salinity-dependent infectivity and included a statistical nonlinear temperature effect (Eqs. 9c, 15a) provided worse predictions of salmon louse infestations than the baseline model for all years 2018–2020 (measured as mean absolute prediction error). The largest errors of the environmental model compared to the baseline model were found for sentinel cages in Hardangerfjorden (5.2–6.6 °E, 59.6–60.4 °N), which represented 41 % of the sentinel cages in 2018–2020 and 44 % in 2012–2017 and was the only fjord region where experiments were conducted all years in the study period. We therefore focussed the subsequent analyses on this region.

Observed lice levels in sentinel cages in Hardangerfjorden in years 2012–2017 were lower than predicted by the baseline model at low salinity and at high temperature (Fig. S1, left column). The environmental model corrected for these trends, so that prediction errors from this model correlated with neither salinity nor temperature in 2012–2017 (Fig. S2, left column). In years 2018-2020, however, observed lice levels were not lower than predicted by the baseline model at low salinity and the association with temperature was less clear than in the previous years (Fig. S1, right column). By correcting for salinity and statistical temperature effects, the environmental model strongly underestimated lice levels at low salinity and at high temperature in 2018–2020 (Fig. S2, right column).

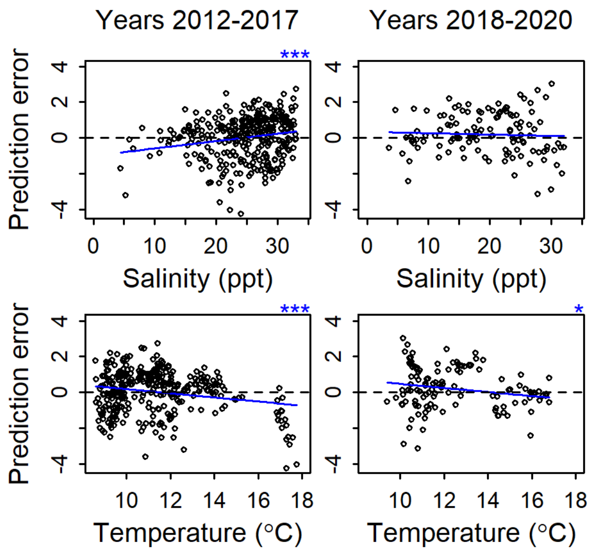

Figure S1. Baseline model prediction errors for sentinel cages in Hardangerfjorden (5.2–6.6 °E, 59.6–60.4 °N). Prediction errors are observed – predicted lice per fish per sentinel cage, on scale ln(N + 0.033). Prediction errors are shown as function of salinity (upper row) or temperature (lower row) and for years used to fit the model, 2012–2017 (left column), and for the test data years, 2018–2020 (right column). Blue lines show smooth regression lines fitted to the prediction errors. Blue asterisks show statistical significance of linear correlation (* $0.01 < p < 0.05$; ** $0.001 < p < 0.01$; *** $p < 0.001$).

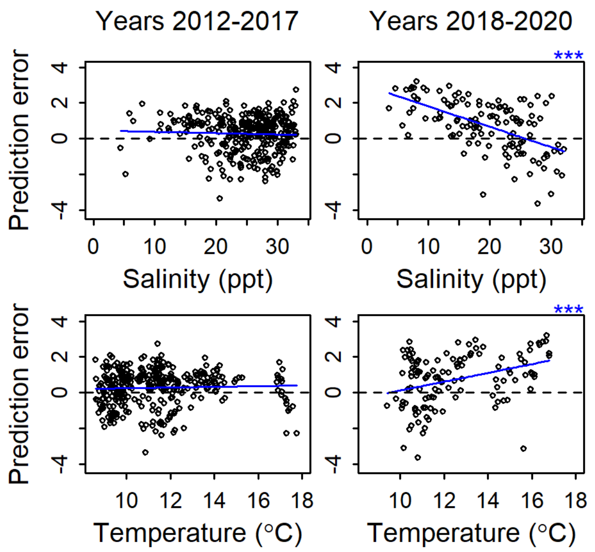

Figure S2. Environmental model prediction errors for sentinel cages in Hardangerfjorden (5.2–6.6 °E, 59.6–60.4 °N). Prediction errors are observed – predicted lice per fish per sentinel cage, on scale ln(N + 0.033). Prediction errors are shown as function of salinity (upper row) or temperature (lower row) and for years used to fit the model, 2012–2017 (left column), and for the test data years, 2018–2020 (right column). Blue lines show smooth regression lines fitted to the prediction errors. Blue asterisks show statistical significance of linear correlation (* $0.01 < p < 0.05$; ** $0.001 < p < 0.01$; *** $p < 0.001$).

The changing relationship between lice levels and salinity is also seen by plotting the observed lice per fish in sentinel cages against salinity (Fig. S3, upper row). In years 2012–2017, lice levels were lower at salinity below 20 ppt than at salinity above 20 ppt, in Hardangerfjorden as well as in the data set as a whole. In years 2018–2020, the relationship was reversed, with highest lice levels at low salinity. The relationship with temperature looks quite similar in the two periods, which probably reflects the large effect temperature has on processes such as egg production rate. Note that temperature effects on egg production and developmental rates were accounted for in both the baseline model (Fig. S1) and the environmental model (Fig. S2), but that the environmental model in addition accounted for temperature-dependent infestation rate and a statistical association between temperature and lice infestations.

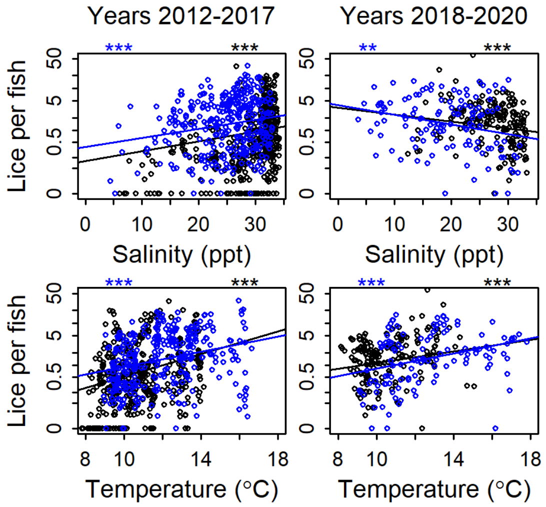

Figure S3. Observed number of salmon lice per fish in each sentinel cage plottet against salinity (upper row) and temperature (lower row) for years 2012–2017 (left column) and 2018–2020 (right column). Blue points represent sentinel cages in Hardangerfjorden (5.2–6.6 °E, 59.6–60.4 °N) and black points all other regions. Lines show linear regression lines for Hardangerfjorden (blue) or all data (black), with corresponding statistical significance indicated by asterisks (* $0.01 < p < 0.05$; ** $0.001 < p < 0.01$; *** $p < 0.001$).

Can the changing relationship between temperature and salinity and lice infestations be explained by errors in *NorKyst800*-modelled temperature and salinity? According to the comparison between *NorKyst800*-modelled and measured temperature, modelled temperature could deviate by up to around 2 °C at a regional and short-term scale. Salinity deviated by nearly 4 ppt for one region and time-point. The measurements from Hardangerfjorden in 2018 suggested that temperature and salinity may have been underestimated by *NorKyst800* during sentinel cage experiments in this region and period. A possible underestimation of temperature at temperatures above 13 °C, where the environmental model underestimated lice infestations in Hardangerfjorden in 2018–2020 (Fig. S2), would lead to an overestimation of lice infestations by the environmental model – that is opposite to what was observed. A possible underestimation of salinity by 4 ppt would lead to an overestimation of lice infestations by 36 % (i.e., 0.3 on ln-scale). In comparison, the observed lice levels at low salinity were about 3–7 times higher than predicted by the environmental model for Hardangerfjorden in years 2018–2020 (i.e., around 1–2 on ln-scale, Fig. S2). We conclude that errors in *NorKyst800*-modelled temperature and salinity may have contributed to, but seem unlikely to be the main cause of, the changing relationship between lice infestations and temperature and salinity.