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Magnitude and causes of mortality of Atlantic herring *(Clupea harengus)* induced by crowding in purse seines

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Extended Abstract

Introduction

Releasing, or "slipping", all or part of a catch has traditionally been used as a method for catch regulation in purse seine fisheries. During the last decades it has been documented that the mortality of fish crowded to densities experienced in the later phases of purse seine fishing may be substantial (Lockwood *et al.*, 1983; Huse and Vold, 2010; Marçalo *et al*., 2006; Marçalo *et al*., 2007; Marçalo *et al*., 2010; Mitchell *et al*., 2002). Norwegian purse seine fisheries for Atlantic herring (*Clupea harengus*) are the largest and among the most profitable fisheries in Norway. Reports from the fishing grounds and anecdotal evidence suggest that slipping in these fisheries is a relatively common practice, particularly when herring occur in dense schools or large amounts of small herring are mixed with larger ones on the fishing grounds. Previous experiments have further shown that herring is sensitive to gear contact (Misund and Beltestad, 1995; Suuronen *et al.*, 1996a) and it is therefore likely that slipping mortality is a problem also in these fisheries.

Methods

To investigate the effects of crowding on Atlantic herring (*Clupea harengus*), large scale field experiments were conducted off the Norwegian coast between 2008 and 2012. These were carried out under conditions comparable to those experienced under commercial fishing and used methods originally reported in Huse & Vold (2010). Eight different experiments involving one control group and two or three test groups that were crowded to different densities were made. Each group was monitored for five days. Physiological assessments and quantification of scale loss were also carried out to investigate the mechanisms causing the observed mortality. For further details of the methodology see Tenningen et al (2012).

A quantitative field study of scale loss was performed by simulating crowding herring in a net at different densities. Herring were caught by a purse seine and carefully transferred into four net pens. One was kept as a control, while the other three were crowded for ten minutes at three different densities (79.8, 203.5 and 367.1kg.m3). At the final phase of the crowding, fish were sampled for photographic and histological assessment. The degree of scale loss was calculated by image analysis. For further details of the methodology see Svalheim (2012).

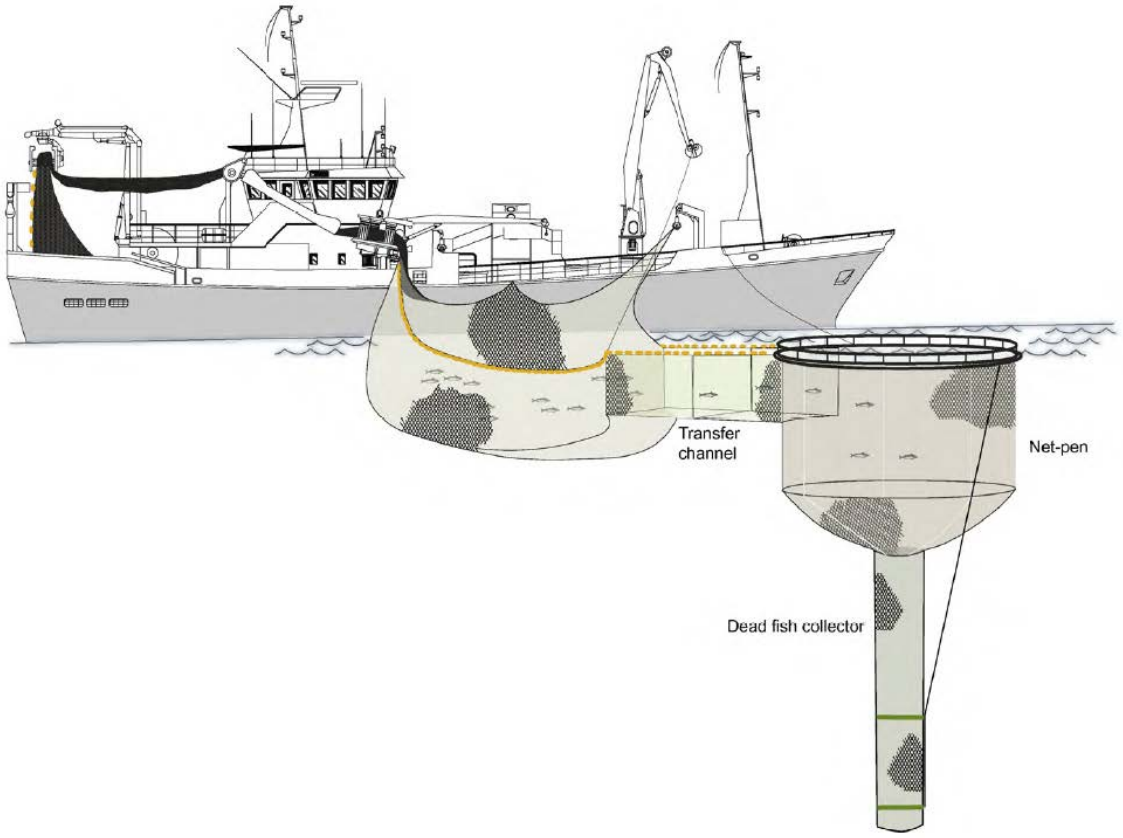

Figure 1 – Crowded fish were transferred from the purse seine into net pens to monitor their post capture mortality (from Huse & Vold, 2010).

Results

The mortality observed in each experiment was directly correlated with crowding density, although the level of mortality varied somewhat between experiments (Figure 2). Crowding densities below 100 kg m^{-3} did not result in any additional mortality compared to the control groups, while the mortality after severe crowding (>400 kg m^{-3}) exceeded 50 %. The mortality was size and condition related, where smaller herring and herring with a lower condition factor were more vulnerable. An important aspect of the experiments was to mimic commercial fishing conditions as closely as possible and to avoid unnecessary handling and transportation of the fish. All the experiments were, however, also conducted under relatively good weather conditions and the mortality rates may be different during other seasons and conditions.

From the quantification of scale loss, it was clear that the crowded groups had significantly more scale loss than the control (Figure 3). However, there were no significant differences in scale loss between fish exposed to different crowding densities. Moreover, the majority of herring in all groups experienced less than ten percent scale loss.

Histological assessment showed that herring normally has three to four layers of scales overlapping each other (Svalheim, 2012). These scales are loosely attached in the scale pocket, where one-third to one-half of the scale is protruding. Crowded herring still had intact scale pockets even when the scales were lost. This suggests that the osmoregulatory capabilities of the skin may not have been severely compromised by the scale loss.

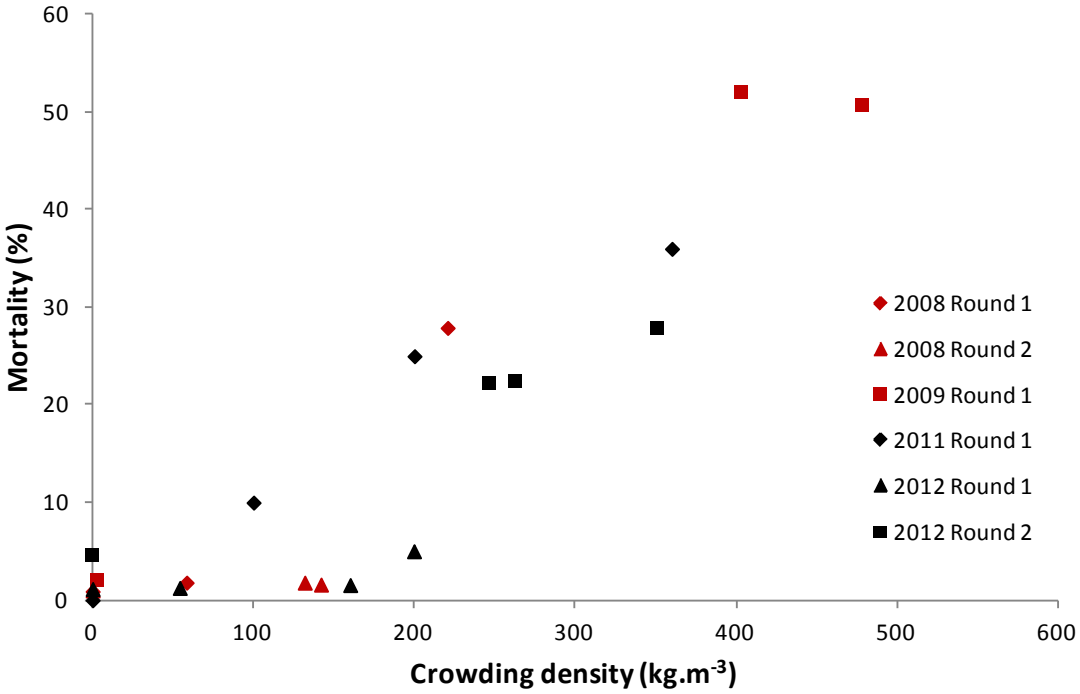

Figure 1: The relationship between crowding density and mortality in North Sea herring (red) and Norwegian spring spawning herring (Blue) (adapted from Tenningen et al. 2012).

Physiological analyses initially showed significant increases in cortisol and lactate, as well as chloride, sodium and potassium ions, in the blood of crowded fish (Tenningen et al, 2012). Lactate returned to control levels two days post-crowding, whereas cortisol and blood ion levels continued to increase during the 4-5 day monitoring period. Furthermore, plasma glucose appeared to be substantially reduced at the end of the trial, indicating that the herring were incapable of restoring homeostasis and were approaching physiological exhaustion.

Discussion

These results suggest that slipping from purse seines in a late phase of hauling may produce unacceptably high rates of unaccounted fishing mortality. However, herring seem to tolerate crowding well at lower densities, indicating that release in an earlier phase may be acceptable if the fishing practices are modified to consider the welfare of the catch and promote the survival of released fish. To achieve this, it is important to understand the potentially fatal mechanisms during the capture process.

For pelagic species, such as the clupeids and scombrids, scale loss and skin injuries have often been proposed as the primary causes of death after contact with fishing gears (Pawson and Lockwood, 1980; Misund and Beltestad, 1995; Suuronen *et al.*, 1996a, 1996b; Mitchell *et al.*, 2002; Marçalo *et al.*, 2010). Quantification of scale loss in this study, however, indicated that this factor alone could not account for the observed mortality in these experiments.

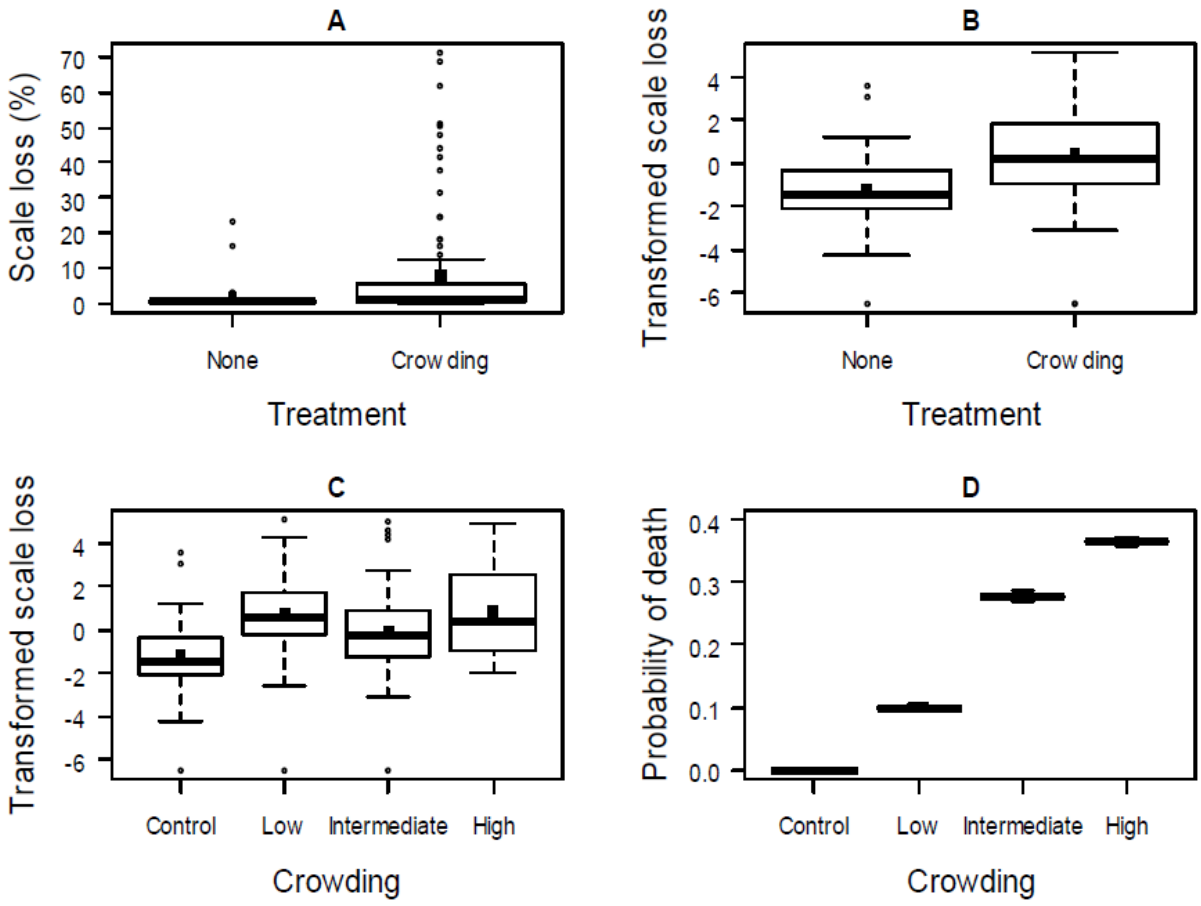

Figure 3: Crowding effect on mortality and scale loss, and the effect of condition factor and length on scale loss in herring, showing median, mean, min. and max. values (from Svalheim, 2012).

A: Box plot illustrating percent scale loss depending on treatment; crowded, control.

B: Same plot as in A, but with Box Cox transformed scale loss percentage.

C: Box plot illustrating difference in scale loss depending on different crowding density.

D: Probability of death at different crowding densities.

The increase in blood lactate shows that the initial stressors were sufficiently severe for the fish to become anaerobic during the crowding and, together with the observed reduction in available oxygen in the sea water, the significant reduction in available oxygen may also have had fatal consequences. It is therefore likely that there is more than one fatal mechanism during the slipping process with potentially synergetic effects. Oxygen starvation, scale loss and/or energy depletion are all possible explanatory variables for the observed mortality

Until more accurate instruments for pre-catch identification of fish schools become available to fishermen, slipping will be an unavoidable means to release excess catch or fish of unwanted size, quality and species. A future challenge is, therefore, to modify fishing practices and gear designs with the aim of minimizing slipping mortalities in the herring purse seine fisheries. These results provide important information about the crowding densities that can be tolerated in the purse seine fisheries for herring and will benefit future development of guidelines for purse seine slipping operations.

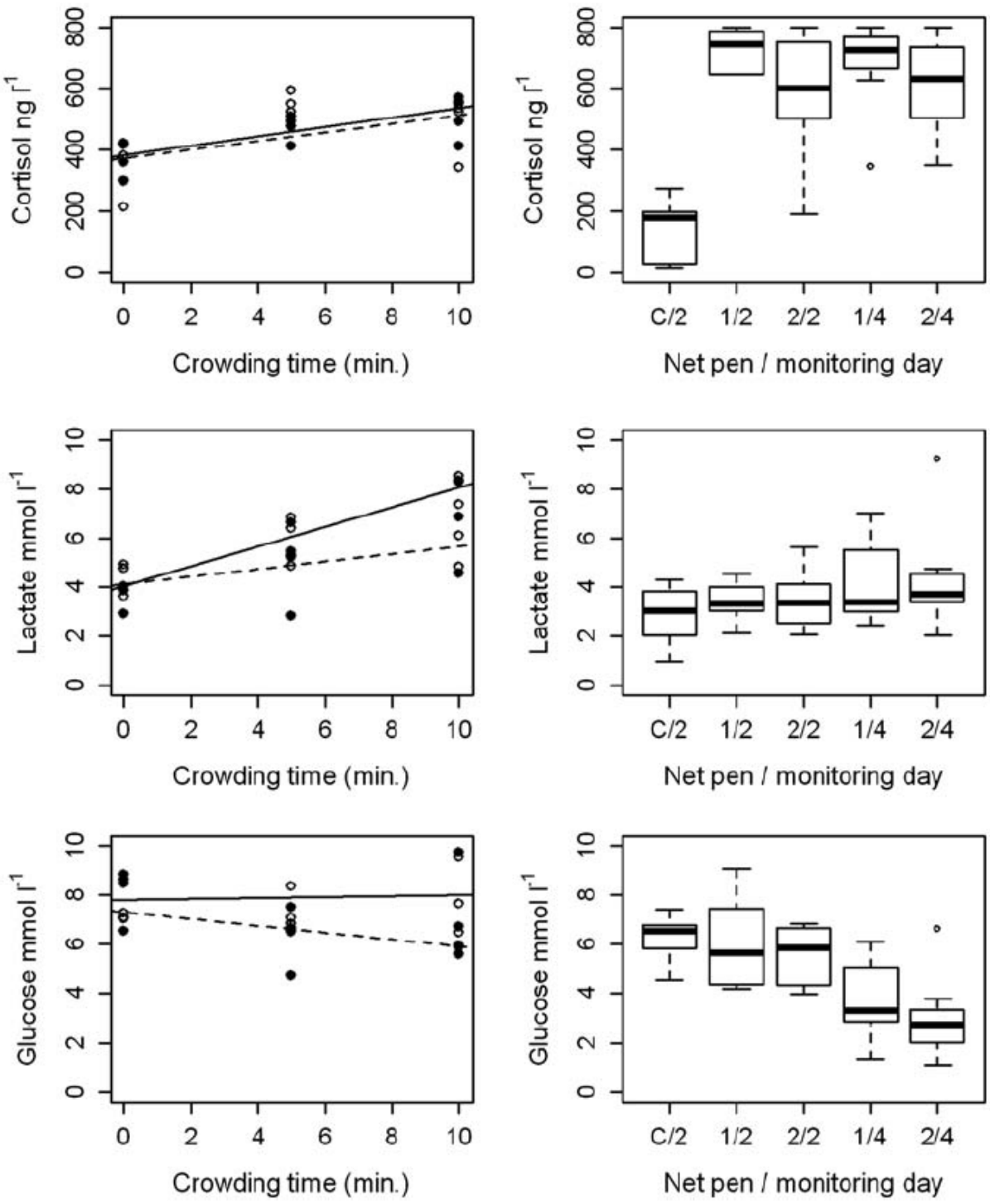

Figure 4. Cortisol, lactate, and glucose levels in the blood during the crowding phase (graphs in the left column) and during the monitoring period (graphs in the right column) in the crowded net pens and in the control net pen (C) on the second day of monitoring. (From Tenningen et al, 2012).

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