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Current induced net deformations in full-scale sea-cages for Atlantic salmon (*Salmo salar*)

Pål Lader *, Tim Dempster, Arne Fredheim, Østen Jensen

SINTEF Fisheries and Aquaculture, NO-7465 Trondheim, Norway

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Abstract

Net deformations of sea-cages in two full-scale commercial Atlantic salmon (*Salmo salar)* farms (Varaldsøy, Norway, Hestur, Faroe Islands) were determined in relation to incoming currents of varying velocities. Ambient currents were measured with acoustic current meters, and net deformation behaviour and cage volume reductions were found by using depth sensors (pressure sensors) placed on strategic locations at the net cage. Cages deformed in current flow largely through lifting of the bottom netting and deformation of the front and back walls. Currents and therefore net volume reductions differed between the two farms: at Varaldsøy, the most critical current/deformation combination was 0.13 m s^{-1} and an estimated 20% cage volume reduction, while at Hestur, current speeds of 0.35 m s^{-1} caused a corresponding 40% cage volume reduction. Substantial net deformation and cage volume reductions may have significant implications for both fish production and welfare. Development of a real time net volume indicator could assist farmers in maintaining adequate cage volumes for optimal production and serve as an indicator of the optimal timing for net replacement if biofouling levels contribute significantly to deformation.

Keywords: Fish farm; Sea-cage; Net; Deformation; *Salmo salar*

1. Introduction

Marine net aquaculture cages of various constructions are used widely in coastal waters to produce almost 2.5 million tons of fish each year (FAO, 2006). Significant sea-cage industries exist in Norway, Chile, China, Japan, Indonesia, Scotland, Ireland, Canada, Greece, Spain, Australia and the Faroe Islands, with a wide variety of species cultured. While a variety of net cage types have been developed, 'gravity' nets, or those that retain their shape based on gravity and a series of weights (Ryan, 2004), are the dominant net cage type in use worldwide. For example, in 2004 in Norway, 870 Atlantic salmon (*Salmo salar*) and sea trout farm concessions were active and 285 concessions farmed other species such as cod, halibut and arctic char (Norwegian Fisheries Directorate, 2004). All used gravity nets to hold the culture species.

Due to their construction, gravity nets deform when they are subject to horizontal water movements generated by currents; both the overall net shape and mesh configuration changes. The extent to which nets deform when subject to a current has been modelled (e.g. Aarsnes et al., 1990; Fredheim, 2005; Huang et al., 2007; Lader et al., 2003; Li et al., 2006; Tsukrov et al., 2003; Zhao et al., 2007) and deformations of small-scale versions of nets under varying flow strengths and different mooring weights have been tested in flow tanks (Lader and Enerhaug, 2005). In tank trials, total net volumes reduced by up to 35% under current strengths of 0.5 m s^{-1} (Lader and Enerhaug, 2005; Lee et al., 2005). Full-scale field

* Corresponding author. Tel.: +47 92 68 07 05; fax: +47 93 27 07 01.
E-mail address: pal.lader@sintef.no (P. Lader).

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measurements of the deformations experienced by nets which contain commercial farm fish at typical culture densities under various flow conditions are scarce.

When exposed to current, a net cage changes shape by deflection and deformation (Fredheim, 2005). The extent of the change depends on the current velocity, the original shape and construction of the net cage, the

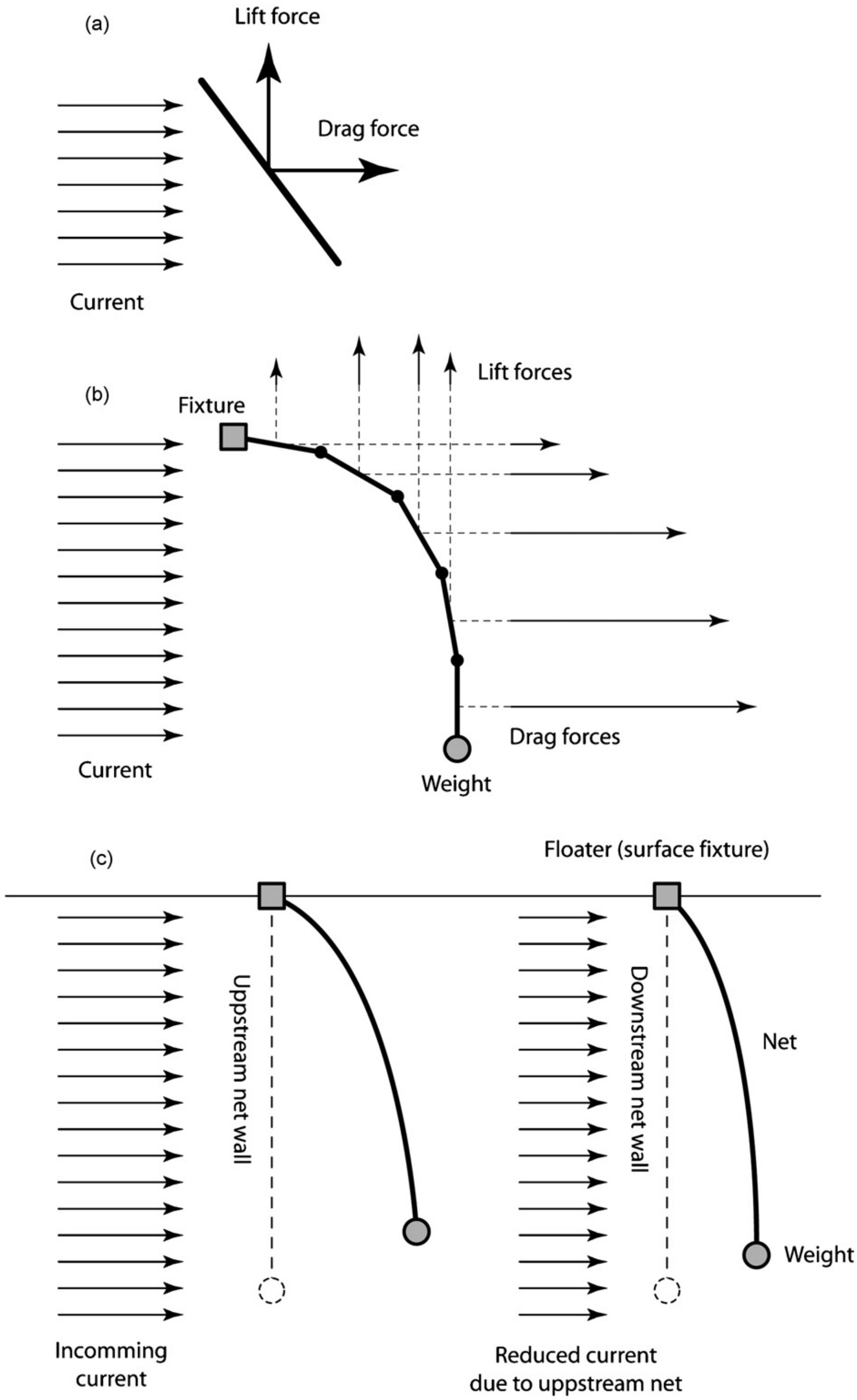

Fig. 1. Forces on net elements (a, b) and the principal deformation of a gravity cage in current (c).