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Field measurements of cage deformation using acoustic sensors

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ABSTRACT

As aquaculture continues to supply an increasing share of the worldwide seafood demand, it will become critical for farmers to maximize their efficiency. Presently, the majority of marine finfish are produced in gravity type net pens which can deform when they are subjected to currents. The water velocity loading affects the overall net shape which results in net cage volume loss and consequently, increases fish stress and decreases growth rates.

In this study, an acoustic method is utilized to monitor the deformation of a small-scale fish cage deployed in currents. Twelve acoustic sources and four hydrophones were deployed on and around a small scale net pen for 60 days to monitor the net cage movement and volume. Local current velocities were recorded using two current meters, one inside and one outside the net pen. Three volume approximation techniques were examined, using the positions of the acoustic sources to predict net chamber volume as it responded to the currents. A numerical model of the system was then configured, set with loads under similar water velocities and results between field measurements and the model were compared.

The use of acoustic sources and hydrophones to monitor cage deformation was shown to accurately monitor net deformation. Field measurements compared well to numerical model predictions, with errors ranging from −3.8% to 32%, depending upon the number of acoustic sources employed in the volume calculations. At low water velocities, six acoustic sources were found to accurate predict the net pen volume. In higher currents, a minimum of nine acoustic sources was recommended.

1. Introduction

It is well established that aquaculture will continue to supply an increasing share of worldwide seafood production in the coming decades (FAO, 2010). Aquaculture products account for roughly 46% of the total seafood supply and are expected to continue to grow by 6.6% a year. The majority of marine finfisher presently raised in gravity type net pens. These cages typically consist of a floating polyethylene or steel collar that supports a net chamber weighed down by localized or distributed weights at the bottom. Nets deform when they are subjected to water movements generated by currents. The water velocity loading affects the overall net chamber geometry which results in net chamber volume loss. This, in turn, may negatively impact the fish welfare as loss of cage volume has been shown to cause stress in fish, resulting in low growth rates and higher cases of infection due to sea lice and other infestations (Ortuno et al., 2001; Rowland et al., 2006; Harper and Wolf, 2009).

The extent to which nets deform when subjected to a water velocity has been extensively researched (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; Osienski, 2013). Deformations of model scale net chambers under varying flow regimes have been tested in flume tanks (Lader and Enerhaug, 2005). In tank trials, total net volumes were found to be reduced by up to 35% in steady flow velocities of 0.5 m/s (Lader and Enerhaug, 2005; Lee et al., 2005). Full-scale field measurements of net deformations, which contain commercial farmed fish at typical culture densities under various flow conditions, are scarce and the ones that exist have large uncertainties in the measurements (see, for instance, Lader et al., 2008). Furthermore, conducting reliable in situ measurements of net deformation of full scale grow-out systems during wave and current exposure is even more challenging. The large amount of water enclosed in present industry size cages (for example, a standard size system in Norway is approximately 45,000 m^3) makes it difficult to monitor the net response in rough seas and high-current conditions. Having in situ data of net

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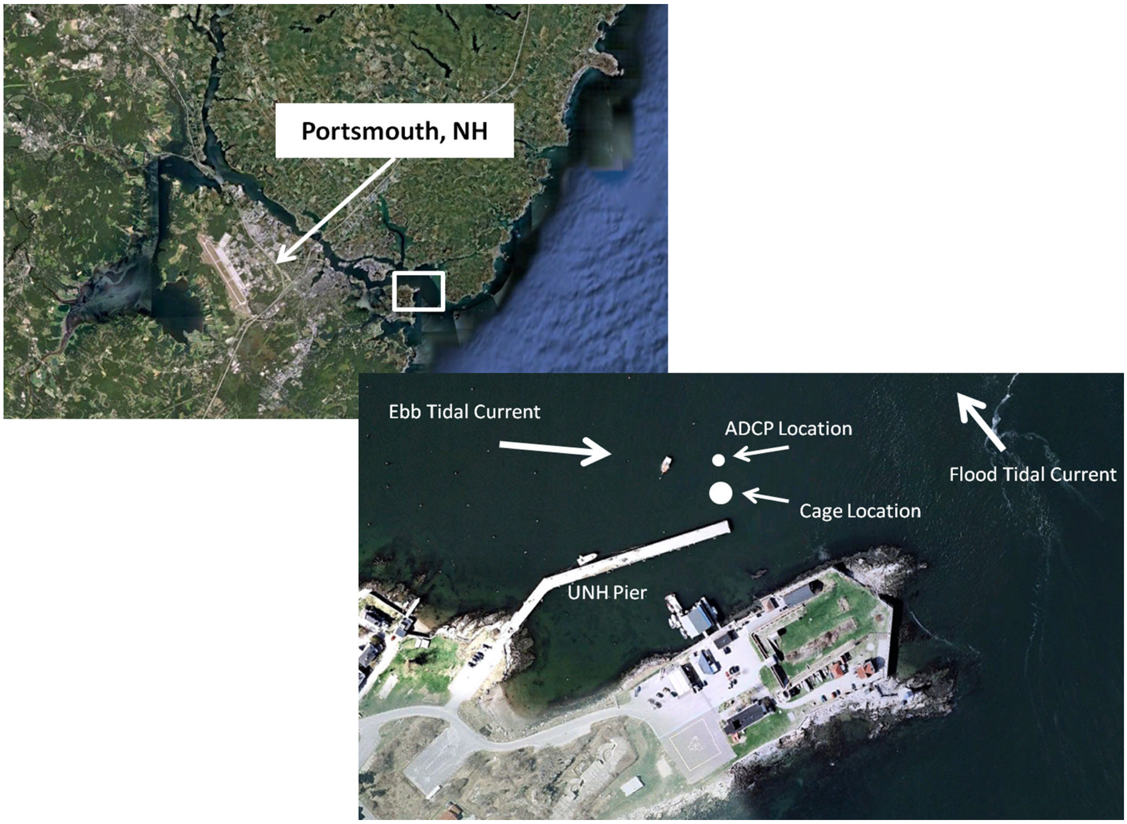

Fig. 1. The location of the UNH cage. The cage was placed approximately 30 m off the UNH pier in Portsmouth Harbor. Tidal water velocities reached 0.6 m/s. The ADCP was located approximately 10 m from the cage.

chamber dynamics is critical to better understand the response of these flexible systems and provide data sets that can be used to verify and calibrate numerical model predictions and laboratory experiments.

In this study, an integrated approach to monitor and predict the deformation of a small-scale gravity type net pen was employed included the use of in situ acoustic sensors, dynamic numerical models and volumetric calculation techniques. Twelve acoustic sources and four hydrophones were deployed on and around a small scale net pen for 60 days to monitor the net chamber movement and volume to relatively strong currents (up to 0.6 m/s). Local current velocities inducing drag loads were recorded with an acoustic Doppler current profiler (ADCP) outside the net pen and modular acoustic velocity sensor (MAVS) current meter inside the net pen. The positioning acoustic array data sets were then processed to estimate net chamber volumes using three calculation methods at steady state water velocities. Cage volume calculations from the field data sets were then compared to numerical model predictions under the same environmental conditions.

2. Experimental setup

The research was conducted at the University of New Hampshire (UNH) Judd Gregg Pier Facility in New Castle, NH (Fig. 1). The test cage was moored between two granite blocks approximately 30 m from the end of the pier and in a water depth of 9 m. A combination of acoustic sources and hydrophones, produced by Hydro-acoustics Technology Inc. (HTI), were utilized to monitor net chamber movement based on the ability to triangulate numerous positions of the net pen within a known, referenced space. The HTI system utilized twelve acoustic sources (pingers), monitored by four hydrophones, surrounding the net pen. Twelve pingers were selected to obtain the best special resolution of a cylindrical shape and balance the challenges of data acquisition, management and processing associated with this experiment. The pingers have dimensions of 2.5 cm × 1.0 cm and were programmed to ping every 2–3 s. Each pinger used was configured with a slightly different period so its location could be identified. Four equally spaced pingers were attached to the bottom rim. Eight pingers were distributed equally around the middle circumference of the net chamber.

The HTI receiver collected data from the pingers through the hydrophones, and transferred it to a computer for storage and analyses. Computer algorithms then triangulate the positions of the pingers (x, y, z positions of points on the net chamber) with a time stamp. This method has been used in the past to study fish distribution within offshore cages (Rillahan et al., 2009, 2011). Pingers were not placed around the cage surface rim as the location of the top rim could be indentified via fixed hydrophone location. More information on the HTI system, its accuracy and possible uses can be found in Ehrenberg and Steig (2002). Note that pressure sensors and accelerometers were initially considered for use in place of the acoustic sources for net cage deformation monitoring. However, pressure sensors are limited to only providing a depth measurement with no resolution of the horizontal position of the net chamber. Accelerometers also have potential, but the cost of models with little low frequency drift can be prohibitive.

The acoustic hydrophones were mounted on aluminum posts bolted to each corner of the platform (Fig. 2). Two hydrophones, placed at opposite corners of the cage frame, were positioned at a depth of 2.5 m. The remaining two were set to 0.65 m below the surface. This configuration allowed for the optimum resolution of the acoustic source position. Attaching the hydrophones to the cage framework also eliminated any measurement errors