Improving a Low Profile Dredge Using Computational Fluid Dynamics and Flume Tank Testing

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In collaboration with

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1.0 EXECUTIVE SUMMARY

Project Title: Improving a Low Profile Dredge Using Computational Fluid Dynamics and Flume Tank Testing

Year Awarded: 2017

RSA Priorities Addressed By This Research: **Scallop RSA High Priority #2** – Bycatch Research

Industry Partners: Charlie Quinn - Quinn Fisheries, Eddie Welch – F/V Westport (flume tank)

This goal of this project was to improve a low profile dredge (LPD) by using a combination of flume tank testing and computational fluid dynamics (CFD) simulations. Coonamessett Farm Foundation (CFF) tested a variety of LPD prototypes using traditional paired dredge gear trials between 2012 and 2015. However, while the LPD proved to be a promising design, none of the tested prototypes consistently reduced flounder catch while maintaining scallop catch. To make continued refinement of the LPD more efficient and cost effective, we incorporated flume tank testing and CFD analysis into our design strategy.

The LPD was conceived as a modified turtle deflector dredge (TDD) that would further reduce flatfish bycatch by reducing the vertical distance to the top of the dredge, allowing flatfish to more easily swim over the dredge (**Figure 1**). The height of the dredge was lowered to make it easier for fish to swim over the oncoming frame. The original LPD prototype (LPD v1) had the depressor plate attached along the top side of the struts, resulting in a depressor plate angle of 22 degrees (**Figure 1A**). A second version of the LPD (LPD v2) was designed to improve performance by dropping the depressor plate between the struts to increase the angle of the depressor plate to 45 degrees, matching the angle in standard-height dredges like the TDD (**Figure 1B-C**).

Reidar's Manufacturing built a set of dredge frames and a dredge bag scaled to 1/6th of the standard dredge size that could be used in flume tanks at scaled speeds that match speeds used in the commercial scallop fishery (**Figures 2 & 3**). The dredge models were tested in the flume tank at the Marine Institute Centre for Sustainable Aquatic Resources (CSAR) at Memorial University in Newfoundland. Tests of dredge frames were conducted with and without a scaled dredge bag attached. A range of speed and wire scope combinations were tested, and the bale angle was measured for the full range of speeds and wire scopes for each dredge using a calibrated camera on a trolley. Fluorescent dye tablets, yarn telltales, and scaled scallops were used to visualize the flow and any turbulence behind the dredge frames.

As part of the funded project, the use of CFD analysis was validated with comparisons to flume tank tests (**Figure 4**). Since the project was completed, data from at-sea trials was compared to model particle studies to determine if CFD models can predict the results from gear trials (**Figure 5**).

2.0 PRELIMINARY RESULTS AND DISCUSSION

(1) **Objective 1** - Develop a modular scaled dredge to examine the impacts of changing the geometries of scallop dredges.

We successfully designed and built a set of 1/6th scale dredge frames (**Figure 2**) and a dredge bag (**Figure 3**) that can be used in flume tanks at scaled speeds that match speeds used in the commercial scallop fishery. We plan to continue using these dredges in future projects.

(2) **Objective 2** - Test the scaled dredge in multiple configurations in a flume tank at scaled speeds that match realistic fishing speeds.

The flume tank tests went very smoothly. We were able to test all of our dredge frames at a range of speeds, with and without a dredge bag attached. Measurements of warp tensions, catenary shapes, and bale angles provided important data for understanding the functional differences between the dredge frames. The use of dye tablets, yarn telltales, and small scaled scallops allowed us to effectively visualize differences in flow patterns as we altered the speed of the tests for each dredge (**Figure 4**).

(3) **Objective 3** - Simulate the performance of different dredge configurations using CFD models.

We modeled flow around multiple dredge frames in the Flow Simulation package for SOLIDWORKS using CAD drawings of full-sized dredges. Simulation output was examined using animated cut plots of turbulent energy and simple particle studies. The results of the CFD simulations successfully highlighted details about dredge hydrodynamics that were observed during flume tank tests (**Figure 4**). Furthermore, we were able to easily test new ideas for improving the LPD by changing depressor-plate angles and lengths in the CAD drawings of full-sized dredges.

3.0 SPECIAL COMMENTS

This project was the first of its kind, and it was highly successful. Observations of dredge behavior in the flume tank were illuminating to all present, and the flume tank tests provided the information needed to assess the validity of using CFD simulations to examine dredge hydrodynamics. CFD simulations are not routinely used when developing fishing gear modifications, even though they are routinely used in other industries. This project demonstrated that these methods could be successfully used to design dredge frame modifications for a fraction of the price of at-sea trials using a mix of flume tank testing and CFD simulations. Because components of the dredge frame, including the depressor plate and cutting bar, can be easily altered in CAD drawings, new modifications can be rapidly tested for a fraction of the cost of at-sea trials, highlighting useful designs and eliminating designs that show little promise.

This research is part of a long-existing program of gear development and scallop dredge research at CFF. The TDD is its most well-known scallop dredge design, and the advancements in flume tank testing and computer simulations made during this project were natural successors to earlier

experiments conducted at the same flume tank during the development of the TDD. CFF has a strong collaborative relationship with commercial fishermen, and two members of the CFF Gear Advisory Panel traveled to Newfoundland at their own expense to participate in the flume tank testing and offer their expert opinions.

Although this work was not conducted during the funded project period, we have since compared the output of more complex particle studies to data collected during at-sea trials. Particles that matched the densities of sea scallops and benthic fish were placed in front of the dredge frame at heights ranging from -2 to 10 cm (scallops) or 30cm (fish) (**Figure 5**). Scallops and fish were classified as going into the dredge bag, over the dredge, or toward the twine top based on the trajectory around the dredge frame and between the dredge frame and the end of the twine top. Trends in the output from CFD particle studies match those observed in the field during paired gear studies.

Figure 1. (A) First low profile dredge prototype (LPD v1) with a 22° depressor plate (B) Standard-height turtle deflector dredge (C) Redesigned low profile dredge (LPD v2) with a 45° depressor plate. The depressor plates are highlighted in red.

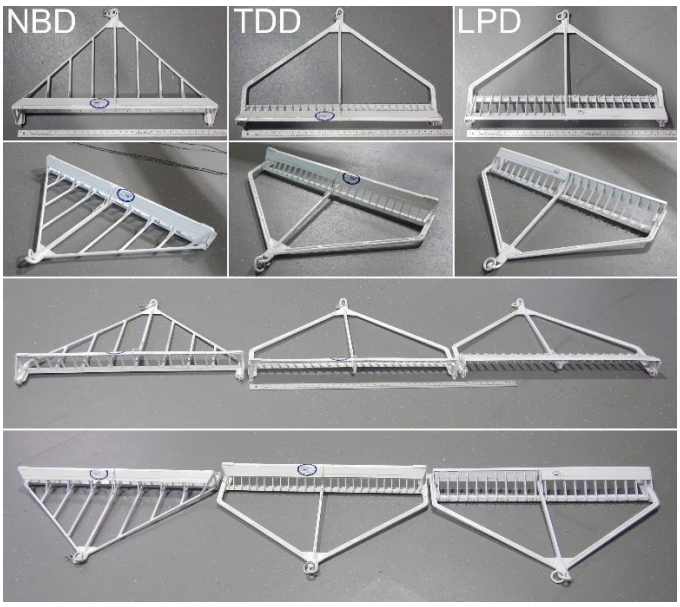

Figure 2. Scaled dredges used for flume tank testing. All dredges were built to 1/6th scale. A meter stick is shown for scale. The LPD is shown with the 22-degree (LPD v1) and 45-degree (LPD v2) depressor plates to highlight the difference between these configurations.

Figure 3. Scaled 7-row apron dredge bag. (A) Tor Bendiksen of Reidar's Manufacturing hangs the bag on the New Bedford dredge (NBD). (B) Bag attached to the TDD during flume tank testing. (C) Bag attached to the LPD v2 during flume tank testing.

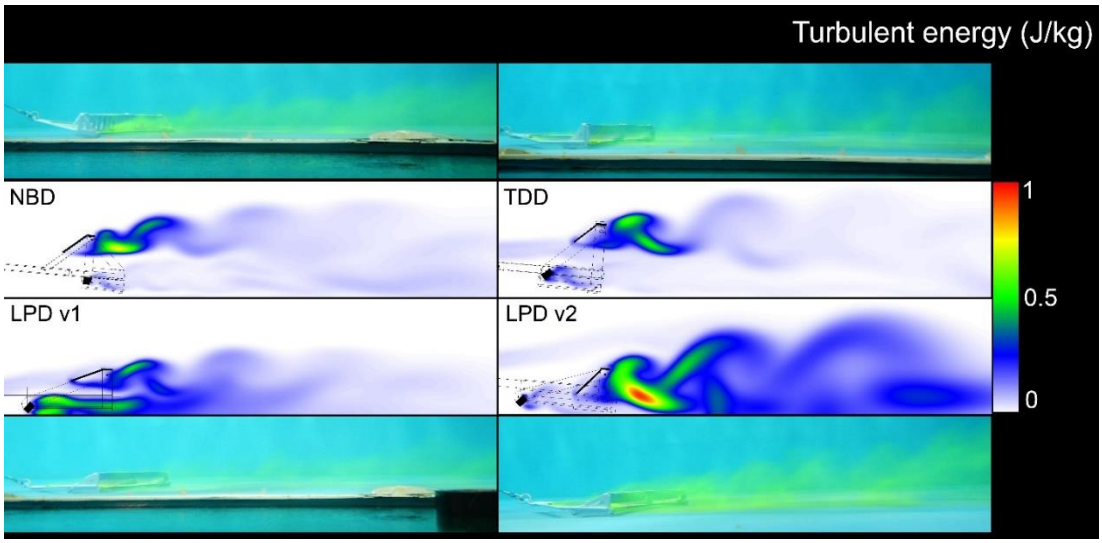

Figure 4. Representative turbulent energy cut plots from CFD models for each dredge type. Images of the dye streams behind each dredge during flume tank testing are also shown immediately above or below each cut plot.

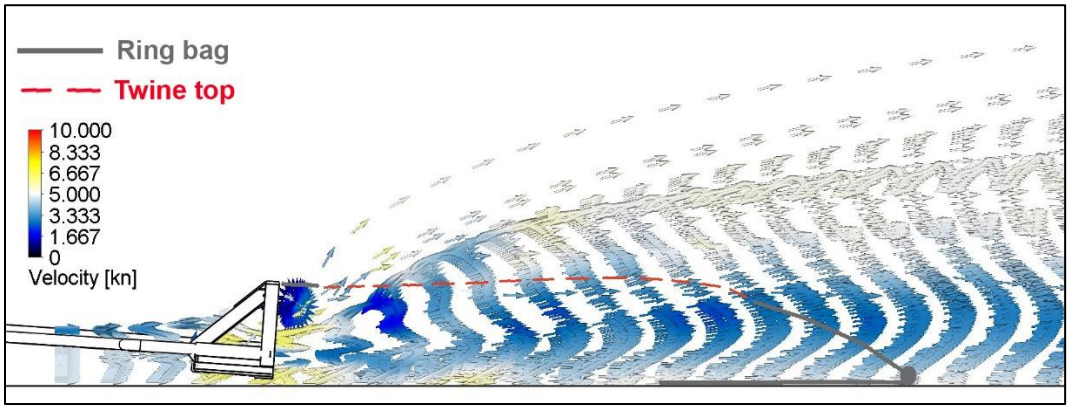

Figure 5. Example of particle study output in a CFD simulation for large (30-cm) fish when the TDD is towed at 5 kn.