Design and Testing of a Low-Impact Scallop Dredge

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Introduction:

It is acknowledged by nearly everyone working on the ocean that fishing gear causes some alteration of the seabed, although the significance and duration of this alteration continues to be debated. In the absence of clear scientific evidence, qualitative rankings of relative impacts of different fishing gears have been made based on observations and experience. Scallop dredges are generally felt to have a large impact compared to other gears.

The Atlantic sea scallop *Placopecten magellanicus* industry contributes significantly to the economy of New England. The Northeastern United States sea scallop fishery landed over 60 million pounds of scallop in the 2005-2006 season. This stock now produces a value of over $300 million annually. In 2005, the overall biomass of scallops exceeded BMSY and was therefore no longer overfished.

Scallop dredges used in New England are constructed of heavy steel bar welded into a triangular-shaped frame, with a bag hung from the back made of steel rings (Figures 1 & 2). Current regulations require a 4" ring for scallop size selectivity and a 10" twine mesh on the upper side to reduce finfish bycatch. The dredge rides along the sea floor on shoes welded to the dredge at the corners of the triangle where the bag is attached. A pressure plate is mounted along the top rear of the triangular frame to provide some downward hydrodynamic pressure, however, the weight of the frame and chain bag is the predominant downward force assuring bottom contact. A cutting bar (Figure 2) provides structural support to the dredge and plays a much debated role in scallop capture. From underwater video, it is known that the cutting bar can remove the tops of bottom features such as small sand dunes.

The underside of the chain bag is supported by a chain sweep that hangs in a catenary from either side of the frame. As shown in the photo, it is also common to have tickler chains preceding this sweep chain, presumably in order to lift scallops from the bottom in anticipation of the approaching chain bag. Also shown are rock chains intended to prevent rocks and boulders from entering the bag and damaging the gear and the catch.

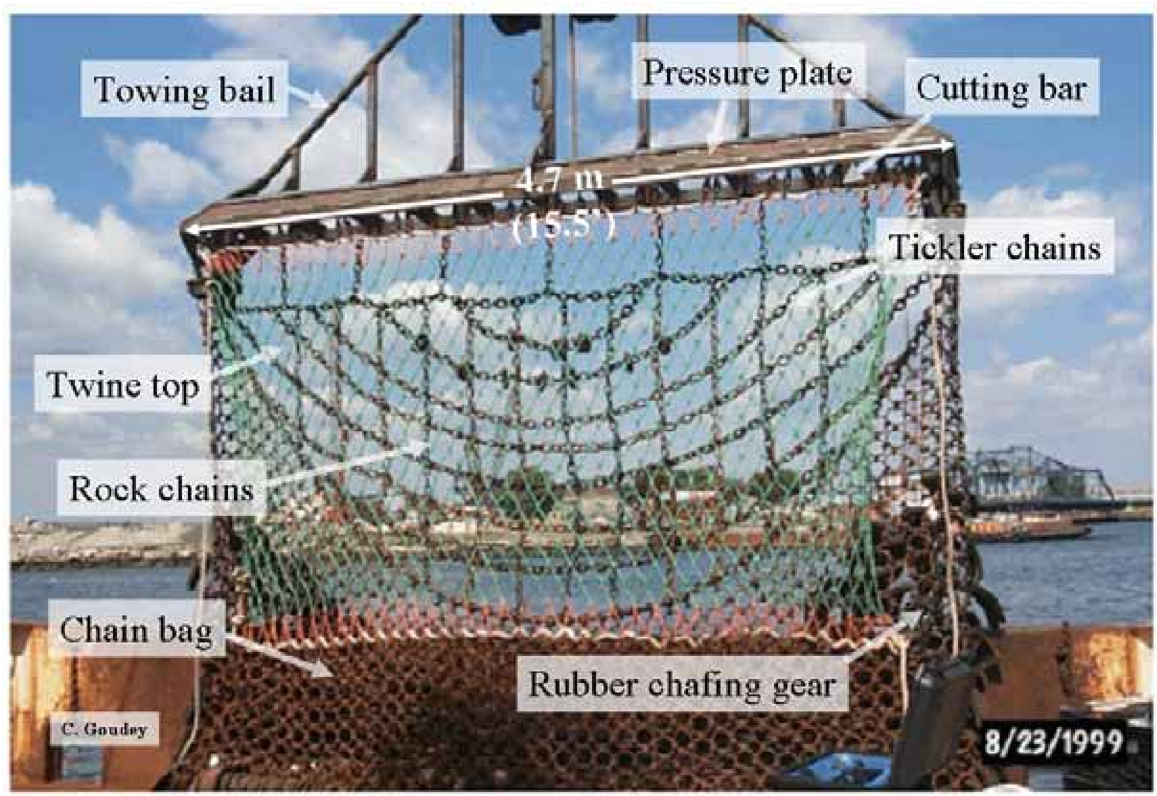


Figure 1. A typical New Bedford scallop dredge (1).

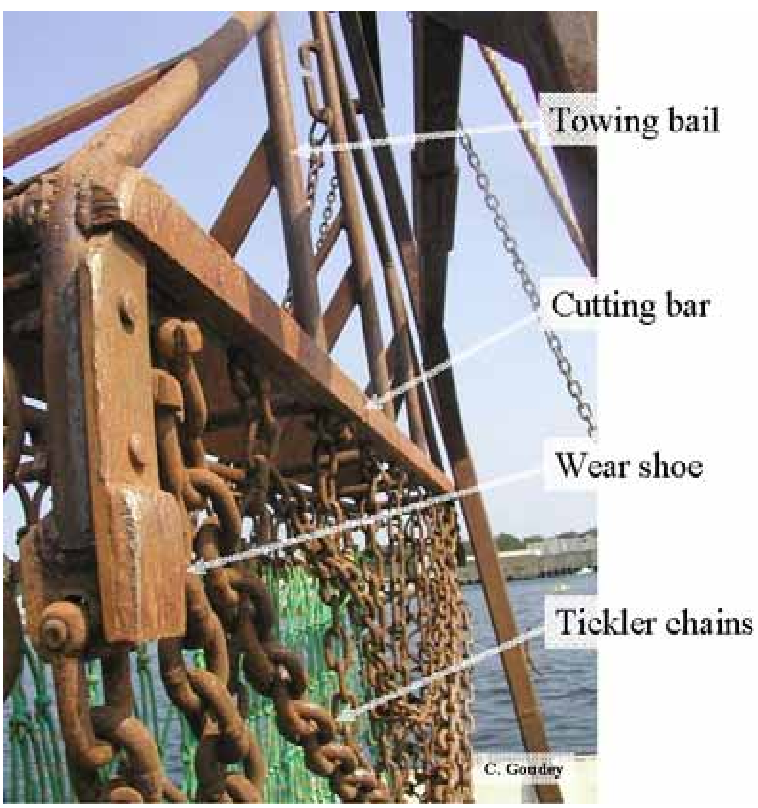


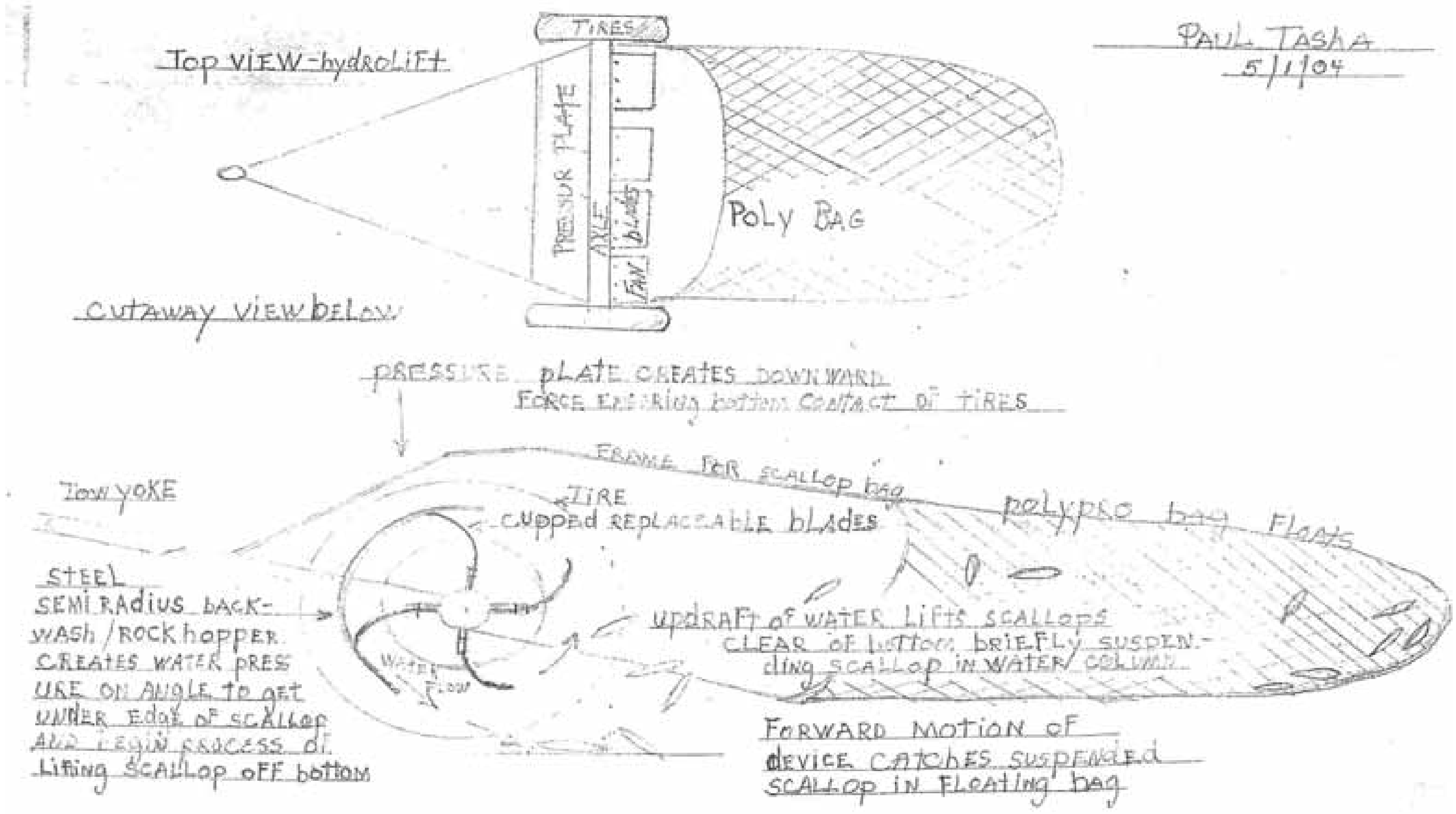
Figure 2: Side view of scallop dredge

The combined weight and amount of hardware in contact with the seabed explains why this type of gear is singled out as uniquely damaging to ocean habitat. Yet, the economic significance of the east coast sea scallop fishery and the traditional use of this gear make the adoption of alternate gear challenging. In spite of this challenge, a clear mandate exists for developing a habitat-friendly and economically viable method of catching scallops.

Project description:

Commercial fisherman and diver Paul Tasha approached Michael Pol at the Massachusetts Division of Marine Fisheries (DMF) and Olivia Free at the Massachusetts Fishermen's Partnership (MFP), and then Cliff Goudey at Center for Fisheries Engineering Research (CFER), MIT Sea Grant College Program, with some ideas for a novel approach to harvesting scallops aimed at reducing habitat impacts associated with current scallop dredging methods. Mr. Tasha's ideas were based on underwater in situ experiments he conducted on what moves and lifts sea scallops off of the sea bottom. He found that the passage of a diver's hand or a circular disk over a scallop created lift. Specifically, a rotational movement of a diver's hand can lift a 6" scallop 6-12" off of the sea floor. Further experiments in shallow water with a 10" round piece of plastic lifted 4-5" scallops 12-18" off of the bottom.

What Mr. Tasha observed is important in meeting the recognized need for better methods of harvesting scallops. His discovery may explain why past experiments in trying to produce more "lift" from a dredge's depressor plate have proven ineffective. Therefore, in 2005 a Northeast Consortium collaborative development project was begun to examine the potential of using hydrodynamics to raise scallops sufficiently off the bottom to render them vulnerable to capture without physically scraping the seabed. The project started from a drawing of a prototype from Mr. Tasha (Figures 3 a and b). This design employed the concept of hydrodynamic lift and reduced bottom contact. To continue development of the concept, full-scale experiments using the Ocean Engineering Towing Tank at MIT were conducted. This test facility allowed us to experiment in a controlled way to build an understanding of how hydrodynamic shapes can be positioned and towed over the bottom to produce the desired effect. Rugo, Tasha and Pol participated with Goudey in tow tank trials and informed the development of the shapes and angles required to raise scallops off of the bottom.



Top VIEW-hydroLIFT
TIRES
PRESSUR PLATE
AXLE
FAN BLADES
POLY BAG
PAUL TASHA
5/1/04
CUTAWAY VIEW BELOW
PRESSURE PLATE CREATES DOWNWARD FORCE ENSURING BOTTOM CONTACT OF TIRES
FRAME FOR SCALLOP BAG
TOW YOKE
TIRE
CUPPED REPLACEABLE BLADES
POLYPRO BAG FLOATS
STEEL SEMI RADIUS BACK-WASH / ROCK HOPPER CREATES WATER PRESSURE ON ANGLE TO GET UNDER EDGE OF SCALLOP AND BEGIN PROCESS OF LIFTING SCALLOP OFF BOTTOM
WATER FLOW
UPDRAFT OF WATER LIFTS SCALLOPS CLEAR OF BOTTOM BRIEFLY SUSPENDING SCALLOP IN WATER COLUMN
FORWARD MOTION OF DEVICE CATCHES SUSPENDED SCALLOP IN FLOATING BAG

Figure 3a

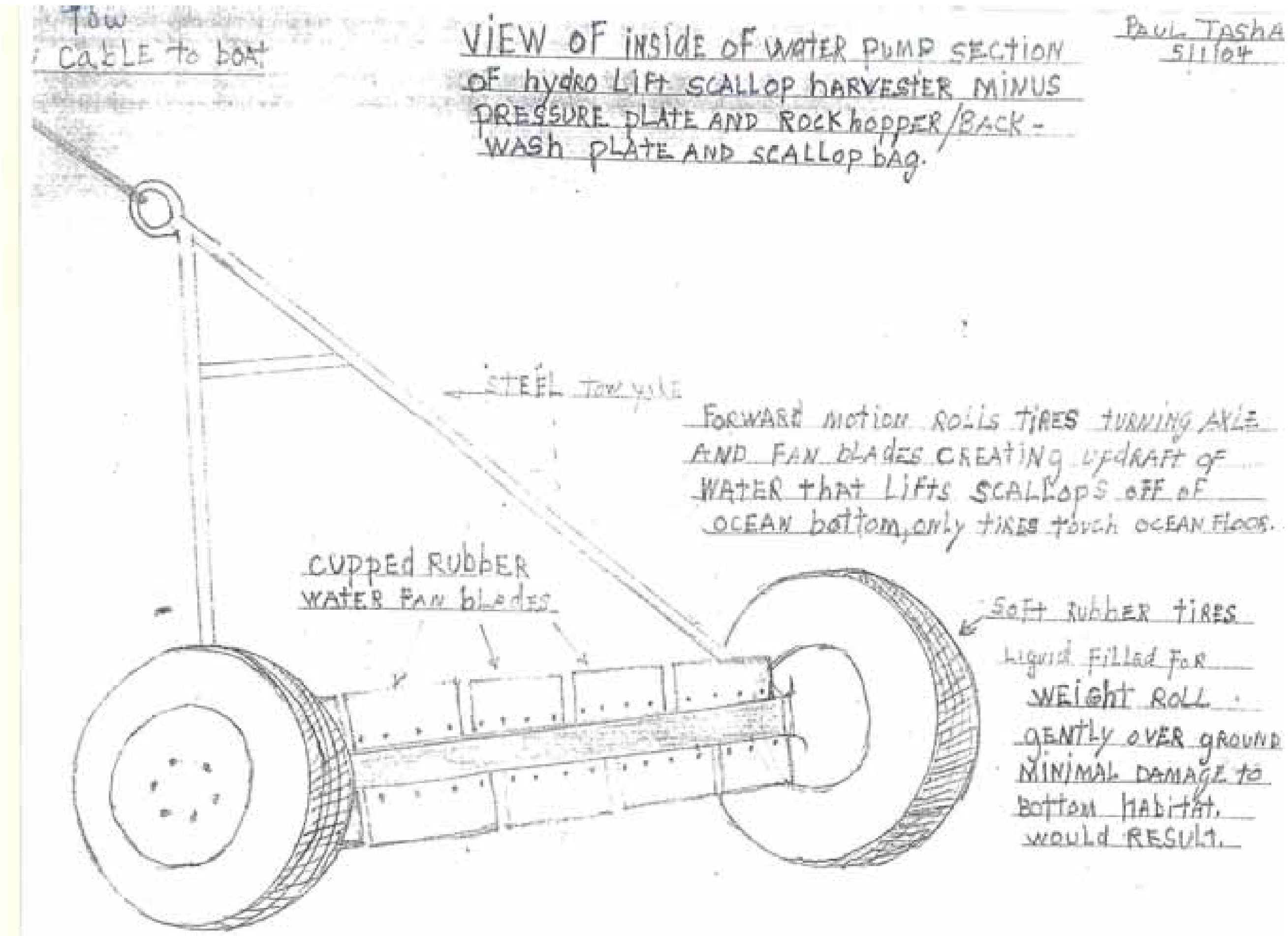


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Figure 3b

A test apparatus (see Figure 4) was built that attached to the tow tank carriage and could position our experimental devices in close proximity to the tank bottom while held at various angles. The test rig had multiple mounting locations that allowed the evaluation of device combinations. The devices we tested are diagrammed in Figure 5 All were roughly the same size though we included geometries that were wider to represent the effect of a conventional cutting bar and a cambered depressor panel.

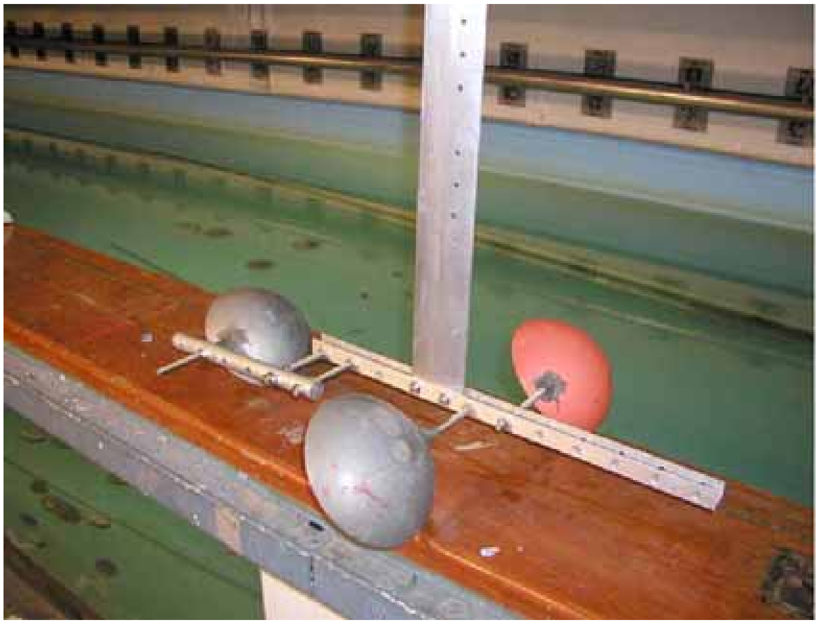

Figure 4. The test apparatus with three cupped devices attached.

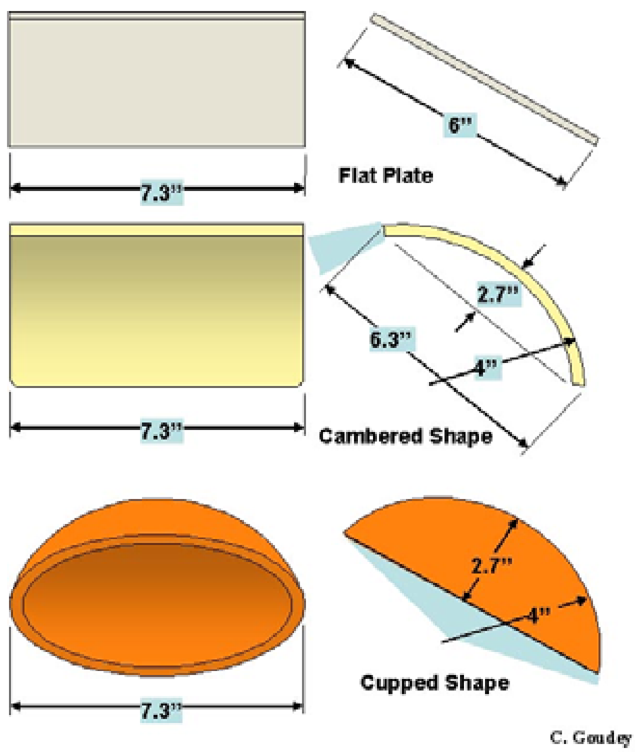

Figure 5. The 3-D shapes tested in the MIT tow tank.

Paired empty scallop shells from both the inshore and offshore fisheries were obtained and glued together. They were only partially sealed around the edge to allow air to escape and to fill with water, simulating the underwater weight of a living scallop. An assortment of scallop sizes was placed in a regular pattern on the bottom of the tow tank. They were repositioned after each pass of the carriage. The effect of each test was observed and recorded on videotape.

Figure 6 depicts a test with a single cupped device oriented at –30˚ with 3" of clearance from the bottom and traveling at 3.2 knots. The effect is difficult to convey in a still image as the lifting effect trails the device considerably. Here the scallops to the right of the frame have been lifted off the bottom, while the ones to the left are only beginning to see the effects of the downwash.

Figure 6 Video of a cupped device at –30˚, 3" of clearance.

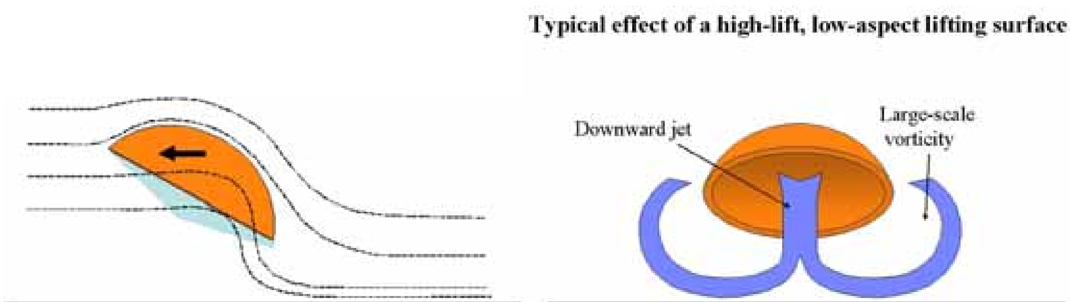

Figure 6: Schematic of fluid flow around a cup shape

Figure 7 describes our theorized description of the forces at work when the cups move through the water. Based on our tests, the cupped device oriented at angles between -30˚ and -40˚ were found to be particularly consistent in causing nearly nearby scallops to markedly lift from the bottom. Subsequent tests showed that the effect was equal or enhanced by side-by side placement of the devices separated by a distance of roughly their diameter.

Based on these results, a prototype dredge was designed and is pictured in Figures 5-8. It is sized to be a one-for-one replacement of the common 7' dredge used in the general category scallop fishery. The prototype dredge replaced the cutting bar with four of the successfully tested shapes mounted on springs; to reduce the impact of the shoes of the dredge, they were replaced, based on Mr. Tasha's design, with soft rubber wheels. Furthermore, a hydrodynamic wing shape was incorporated into the design to provide a downward force to maintain bottom contact. The prototype dredge did not replace the chain bag and sweep that are presumed to cause much of the seabed impact of the standard dredge. It was decided that this intial phase of development would concentrate on elimination of the cutting bag and shoes.

A day of preliminary tests of this dredge was done aboard the F/V Pretty Girl on Stellwagen Bank where its catch was compared to an 8' conventional dredge being towed nearby by another similarly sized vessel.

Figure 5. Prototype 8-foot hydrodynamic scallop dredge aboard the F/V Pretty Girl.

Figure 6: Front view of prototype dredge

Figure 7: Side view of prototype dredge

Figure 8: Detail of cup attachment to protoype dredge

These tests showed that scallops could be caught in those grounds in the absence of a cutting bar. Presumably the hydrodynamic flows generated by the four cups were sufficient to lift scallops up and over the sweep chain. However, the catch rates were approximately 50% of the conventional dredge. It was also noted that only the center of the sweep was seeing abrasion from the seabed. It is likely that catch rates could be improved by adjusting the height of the sweep tow points and adjusting the nearby links, shackles and rings to achieve better contact.

A second day of tests was done north of Cape Ann for the purpose of video observations. Using DMF's capabilities, a tethered video camera was mounted on the dredge while being towed on a sandy bottom. Underwater views revealed the flows around and between the cups were as predicted, and large-scale vorticity combined with the downward jets caused a useful pattern of flow.

It is clear from these preliminary trials that the concept of using hydrodynamic flow to lift scallops from the ocean floor with minimal disturbance is possible. Additionally, the replacement of the shoes of the dredge with wheels seemed to work well, although we did not conduct enough tests to determine their durability. Additional venues for further experimentation are clear.