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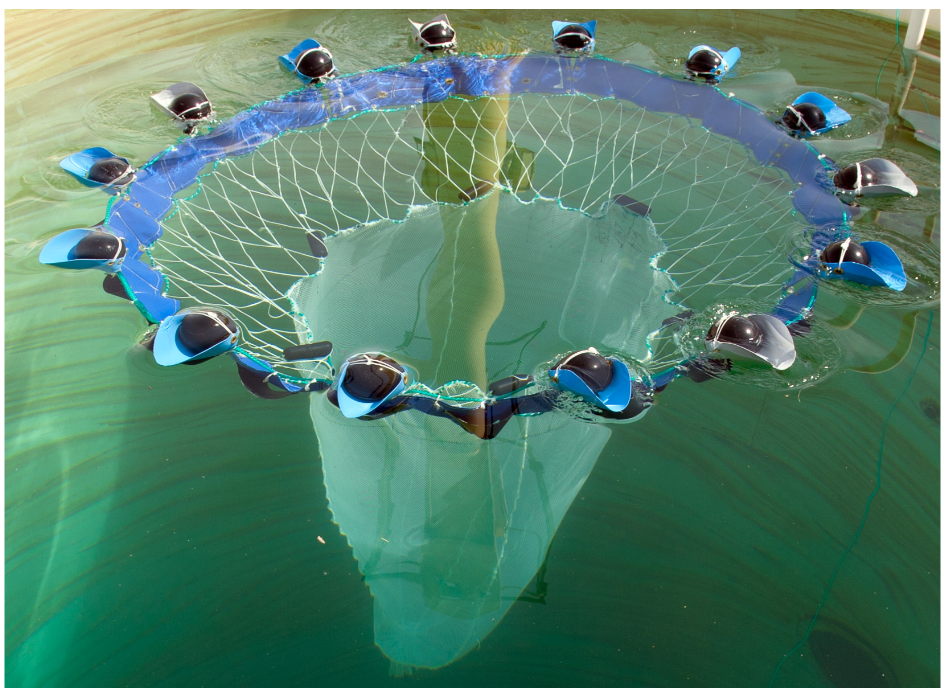
# A Hydrodynamic Mouth Rope Spreading System for an Autonomous Sampling Trawl

July 2011



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# A Hydrodynamic Mouth Rope Spreading System

# for an Autonomous Sampling Trawl

by
Barney Baker

Alaska Fisheries Science Center
Resource Assessment and Conservation Engineering Division
7600 Sand Point Way NE
Seattle WA 98115

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## Abstract

The free vehicle trawl, also referred to as the pop-up trawl, is an autonomous sampling instrument that fishes vertically as it ascends through the water column. I constructed and tested several mouth rope opening devices for prototype free vehicle trawls using various hydrofoil configurations. On one prototype, vanes (fins) were attached to trawl floats to provide directed lift and aid horizontal spreading. Hydrofoil kites were attached around the circumference of the mouth which worked in conjunction with the finned floats to spread the mouth rope and maintain a consistent mouth area as the trawl ascends to the surface. This two component hydrofoil system consistently formed and maintained a fully open circular mouth area in all field trials. I progressively constructed larger prototypes, and found that the time it took the mouth rope to open increased with the size of the trawl's mouth area

## Contents

## Introduction

To accurately quantify the volume of water a trawl has filtered, a consistent mouth area throughout the tow is essential. The mouth opening of a midwater otter trawl is formed and maintained by the hydrodynamic force exerted by its trawl doors and by the trawl web itself, as the net is towed through the water. The vertical opening is also aided by either the buoyancy of trawl floats, or by the hydrodynamic force of a kite made of fabric or small mesh web, which is attached to the headrope. Yonezawa et al. (1996) concluded that their fabric kite maintained a more consistent trawl mouth area than did trawl floats. Trawl door spread, however, may vary during a tow (Gunderson and Ellis 1986) due to a number of factors including variations in tow wire scope, towing speed, and wave height (Weinberg and Kotwicki 2008).

Many small midwater trawls have rigid mouth frames which keep their mouth area reliably consistent. When equipped with a flow meter to measure the distance a trawl has fished, researchers can calculate very accurate volumes of water filtered by rigid frame trawls, provided that a consistent mouth frame angle can be maintained at all towing speeds. Various frame trawls may be towed horizontally, obliquely or vertically, and are commonly used to sample ichthyoplankton and invertebrate zooplankton. Rigid mouth frame trawls may not be as well suited to the sampling of larger organisms, however, as some percentage of late larval and juvenile fish or invertebrates may avoid their mouth opening (Murphy and Clutter 1972, Clarke 2005). Their escape may be facilitated by the water pushed ahead of the net (Clarke 2005) or tow bridles may partially obstruct the mouth opening (UNESCO 1968, Watanabe and Kawaguchi 1999, Itaya et al. 2007). To alleviate this (mouth obstruction) problem, frame nets have been developed with mouth openings that are mostly unobstructed by tow lines or bridles. Some examples are the bongo net, the Isaacs-Kidd midwater trawl (Devereux and Winsett 1953), the cantilevered bridle net (Filion et al. 1993) and the Methot trawl (Methot 1986). But the factors that cause net avoidance may be of less consequence in trawls with larger mouth openings. In their study of catch efficiency in framed trawls, Itaya et al. (2007) found the catch per unit effort (CPUE) for their 16.0 $m^2$ and 12.3 $m^2$ (mouth area) nets was greater, for all species, than the CPUE for their 4.0 $m^2$ net. Itaya et al. (2007) also found that net mouth area had a greater effect on catch efficiency than did towing speed. On otter trawls, tow bridles tend to increase a net's efficiency by herding fish into the mouth area, especially on bottom trawls (Gunderson and Ellis 1986). To ensure that a discrete volume of water is being filtered, an ideal sampling trawl would have a mouth opening that is neither obstructed nor enhanced by tow bridles.

Another net that fishes vertically through the water column is the free vehicle (autonomous) trawl, also referred to as the pop-up trawl. The free vehicle trawl concept originated with John Isaacs of Scripps Institution of Oceanography (T.W Pietsch, University of Washington, pers. comm., 2006). Over the past four decades, however, there have been only a few prototypes developed (Clarke 2005; T.W. Pietsch, pers. comm., 2006). This trawl does not have bridles or tow lines because it is towed directly by each of its floats, and requires no external energy source. The potential energy, transferred from the disposable weight to the floats while the net is descending, provides the power for its ascent. Once deployed, the free vehicle trawl descends to a pre-chosen depth, where a weight is jettisoned giving it positive buoyancy. A free vehicle trawl with a rigid mouth frame begins fishing immediately upon ascent, and requires no opening time. Clarke (2005) developed pop-up ring nets to capture larger (post larval) oceanic squid that may have been avoiding bridled ring nets. But ring nets, like all rigid mouth frame trawls, have size limitations such as storage availability aboard ship (UNESCO 1968). A flexible mouth frame (e.g., fiber rope) is a feature that allows a researcher to increase a trawl's mouth area without creating a storage problem at sea, as it can be packed away along with the bundled net. An ideal spreading system opens the flexible mouth frame as the trawl begins to rise, and maintains its fully open circular shape all the way to the surface. To accomplish this, I developed a two component hydrofoil system in which concave fins are attached to trawl floats and work together with fabric kites to spread the mouth rope and maintain its shape during ascent.

## Methods

### Net Construction

I constructed several prototype free vehicle trawls with various mouth rope opening systems and field tested them in Puget Sound, Washington. On an early prototype, I attached kites consisting of fabric bands with three convex hydrofoils sewn on one side around the circumference of the mouth rope (Fig. 1) and used (un-finned) trawl floats for buoyancy. Burlap bags filled with gravel and tied shut with biodegradable twine were used for ballast. The ballast bags were released at the target depth by means of a tethered pelican hook (for sets <15 m of water depth). This early prototype opened fully on 6 of 10 trial sets. On a later prototype, hydrofoil fins were added to the trawl floats to provide horizontal force, which causes them to travel obliquely as the mouth rope is opening (Figs. 2, 3 and 4). Once the mouth is fully open, the finned floats travel vertically, but continue to exert horizontal force on the mouth rope. This horizontal force assists the kites in maintaining the mouth opening.

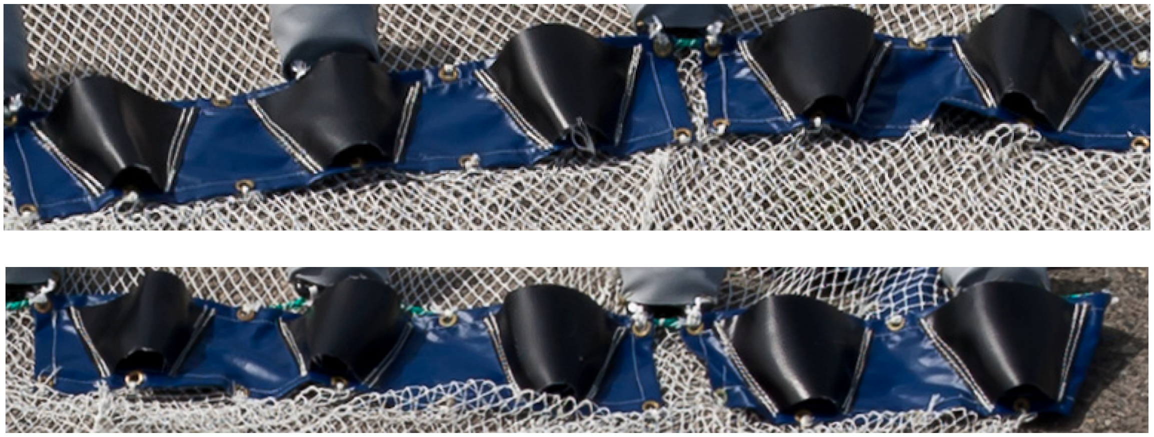


Figure 1.-- Hydrofoil kites.

Figure 2. -- Finned ½ liter trawl float.

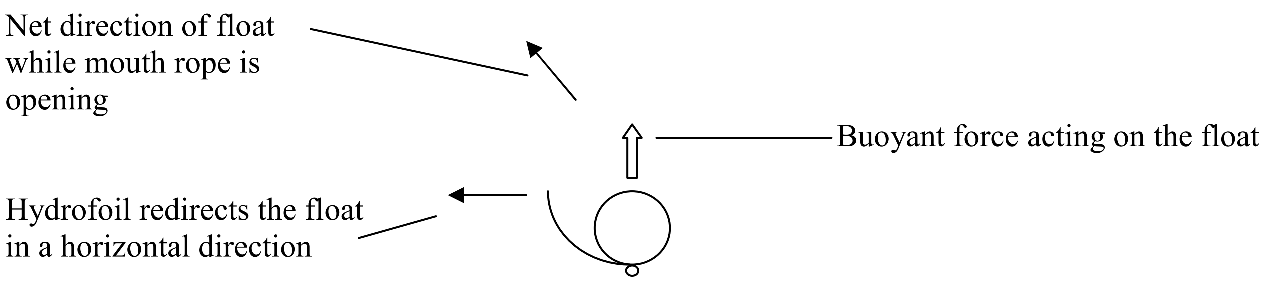



Figure 3. -- Cross section of finned trawl float.

Figure 4. -- Finned trawl floats and hydrofoil kites on mouth rope.

A corroding link weight release device was used to release ballast on sets deeper than 15 m. This device consists of a 20 cm PVC pipe, 2.5 cm in diameter. The upper end of the pipe was attached to the closed codend. The other end of the pipe is notched to accommodate an Alka Seltzer tablet and a loop of no.120 cotton twine (Fig. 5). The cotton twine was secured to a burlap bag filled with gravel. Once the net was deployed, the Alka Seltzer tablet began to dissolve. The time elapsed between deployment and release varied from approximately 2 to 6 minutes.

Figure 5.-- Corroding link weight release device.

A free vehicle trawl with a mouth area of 8.4 m² (Fig. 6) was field tested in Lake Washington in Washington State, at depths between 40 m and 45 m. This trawl is buoyed by 24 finned 0.5 liter trawl floats attached to the mouth rope, for a total of 12 kg of directed lift. Also attached to the mouth rope and to the web just below it are 12 hydrofoil kites. I used 3.8 cm mesh web (stretched measured), 100 meshes deep, and 490 meshes on the mouth rope (Fig. 7).

Figure 6. -- Free vehicle trawl with 8.4 m² mouth area.

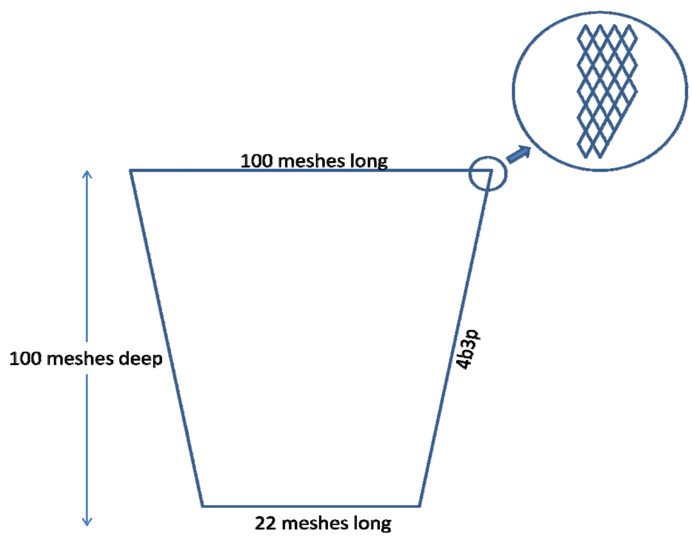


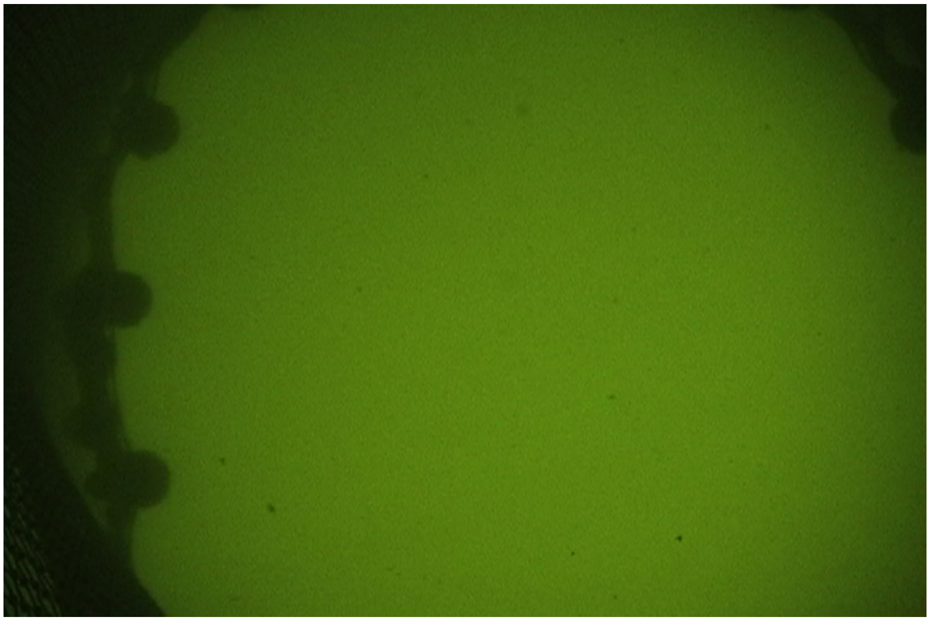

Figure 7. -- Cut plan for one of five tapered panels (3.8 cm mesh, 8 m² mouth area trawl). Note: 4b3p refers to the taper that is cut in the panel (i.e., 4 bars and 3 points).

## Field Tests

Several shallow test sets (10 m to 15 m) were made in Puget Sound, Washington, using a tethered pelican weight release. Trawls equipped with the two component hydrofoil system invariably broke the water's surface in a fully open circle. A corroding link weight release device was added later, which facilitated deeper sets. We made several sets with the 8.4 $m^2$ (mouth area) net in 40 m to 45 m in Lake Washington. Video was taken on two of these sets from a camera mounted in the bottom (codend) of the trawl looking upward.

## Results and Discussion

The video from the Lake Washington field trials show that the two component hydrofoil system kept a consistent mouth area throughout the trawl's ascent. Figure 8a through 8c presents a series of stills taken from the video shot by the camera mounted in the codend (looking upward). Figures 9a through 9h demonstrate the spreading of the mouth rope on a small free vehicle trawl during its ascent. This demonstration was conducted in NOAA dive program's training tank, Seattle, Washington. This tank is approximately 9 m deep and 4.5 m wide. The float line of this net began its ascent at about 7 m of depth.



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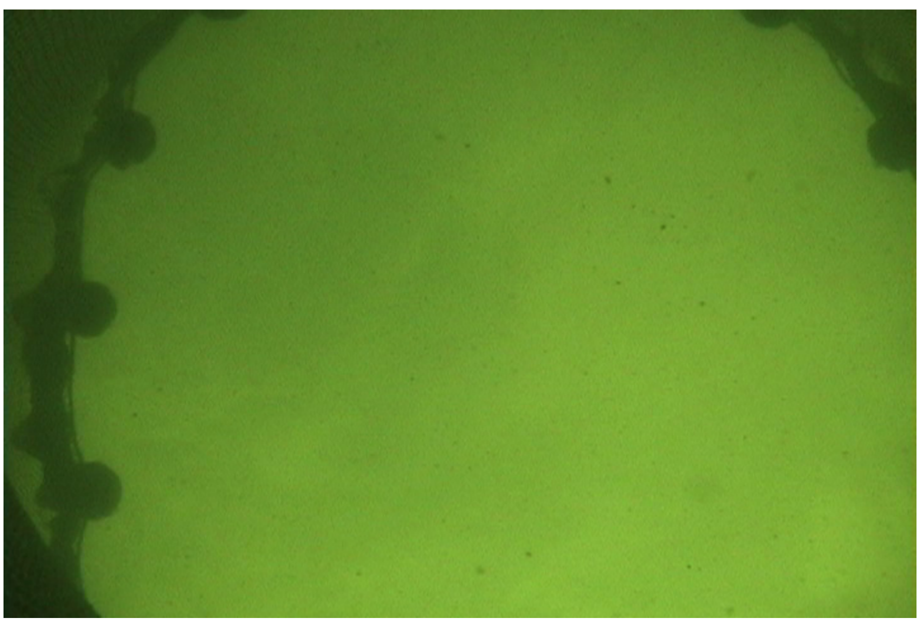

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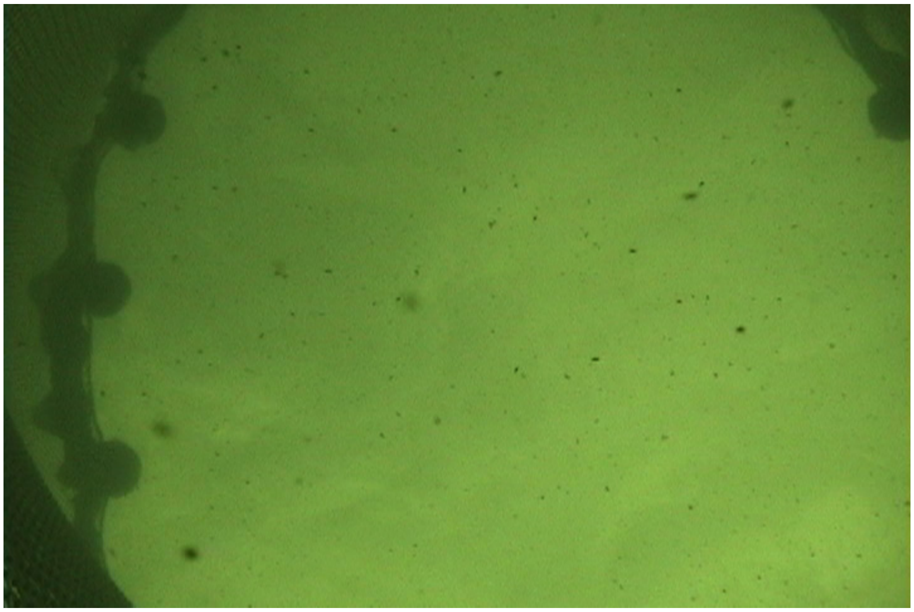
Figures 8a - 8c. -- Series of still shots from a video taken by a camera mounted in the codend looking up toward the surface (Lake Washington, Washington State, May 2010).



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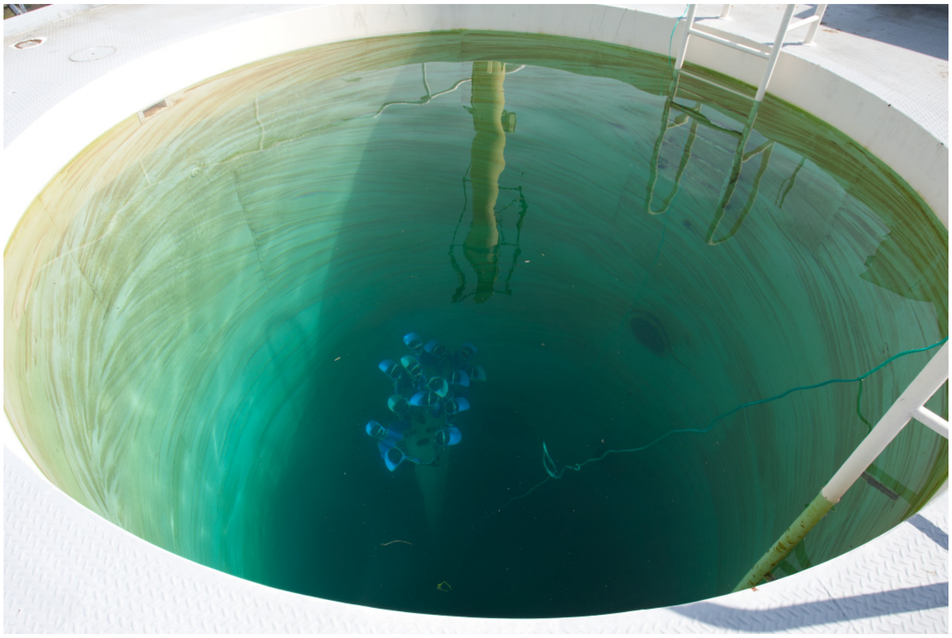
Figures 8a - 8c. -- Cont.



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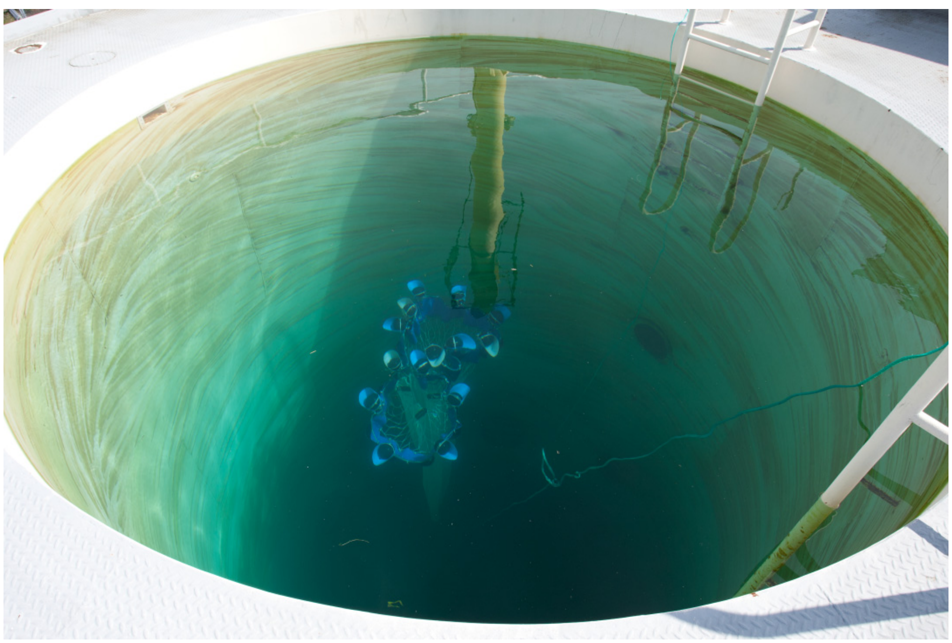

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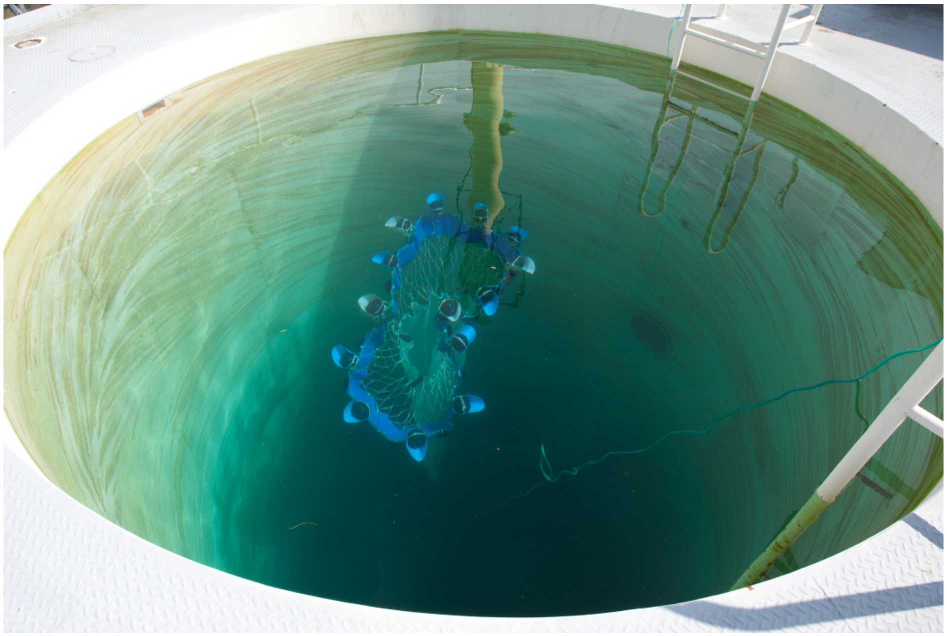
Figures 9a – 9h. -- A free vehicle trawl during a tank demonstration. The float line of this net ascended from about 7 m below the surface.



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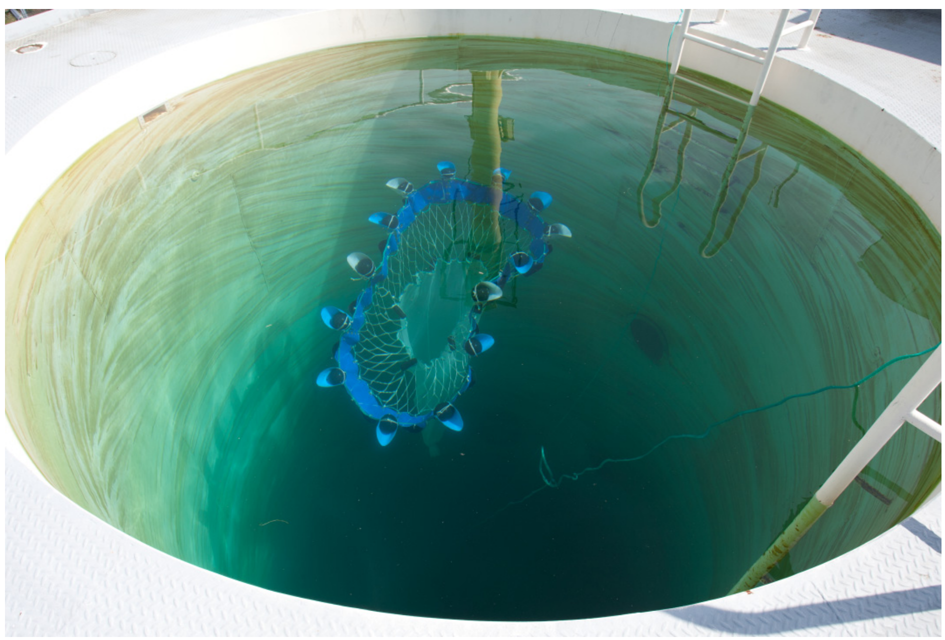

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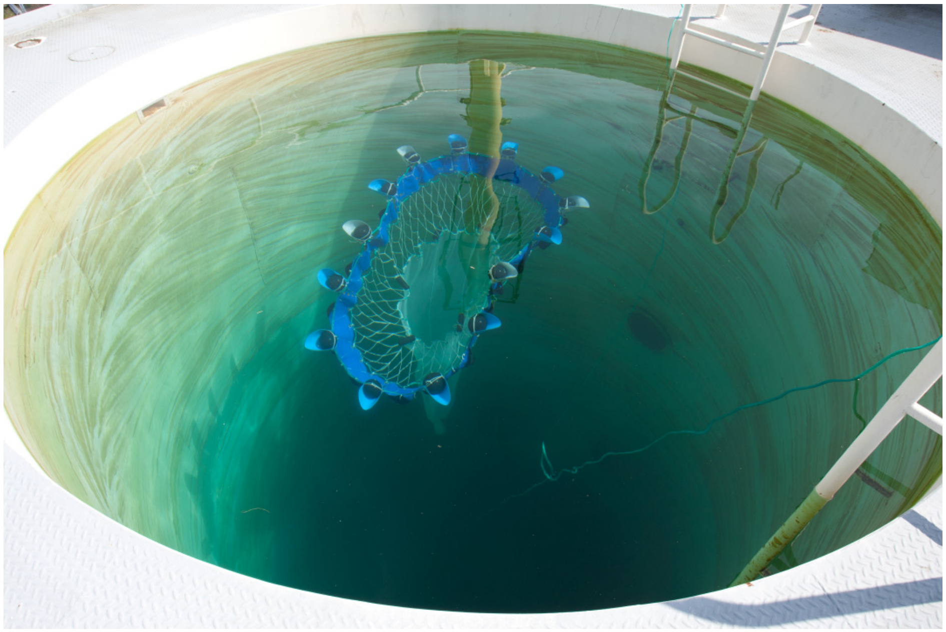
Figures 9a - 9h. -- Cont.



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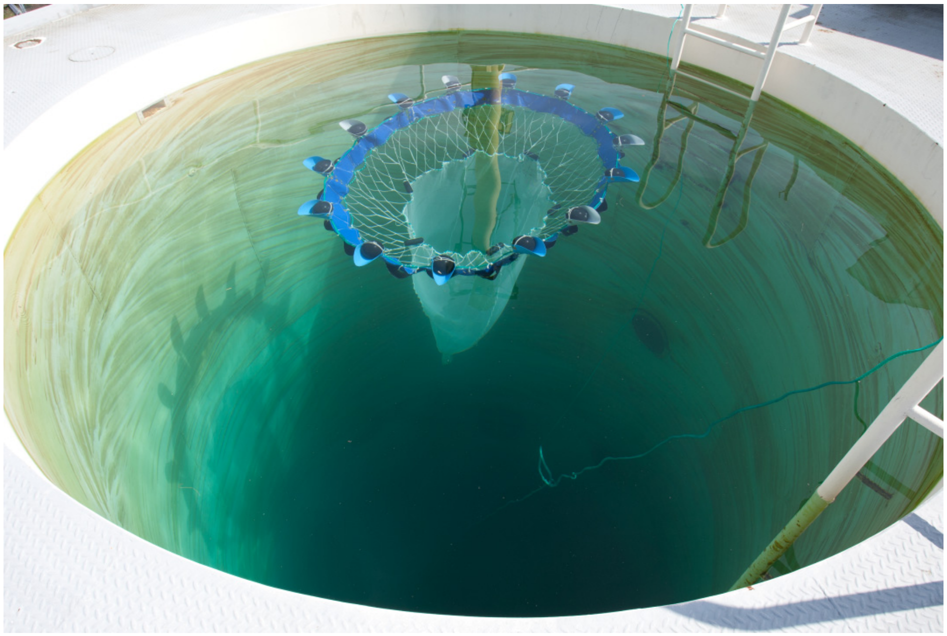

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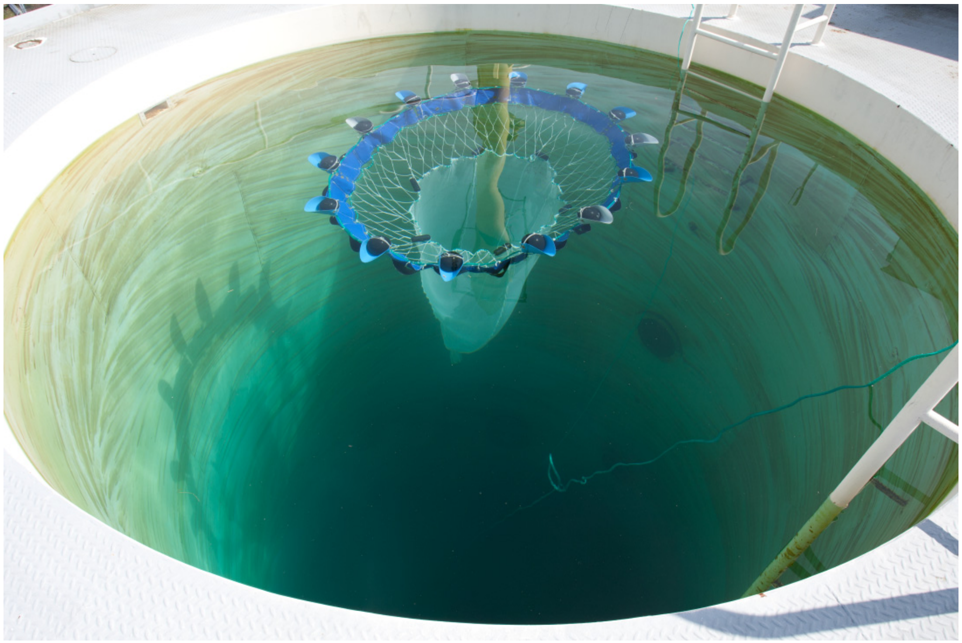
Figures 9a – 9h. -- Cont.



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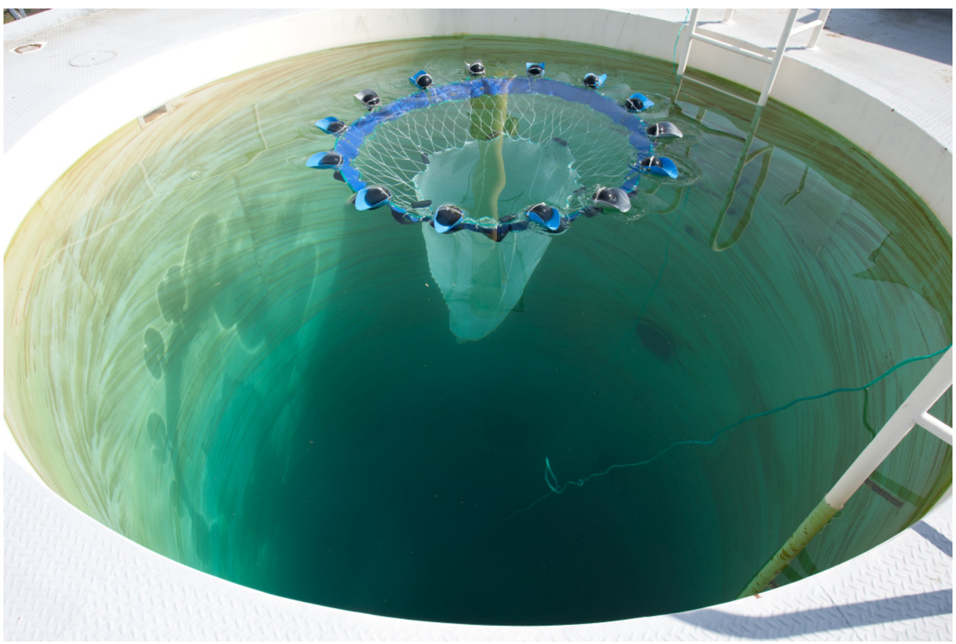

9h

Figures 9a – 9h. -- Cont.

I progressively increased the size of the mouth area with each new prototype. Not surprisingly, the time it took for a mouth rope to open fully increased with its size. In order to decrease the mouth rope's opening time on future sets, the net will be packed into a container with the finned floats secured in a circle at the top of the package and pointing outward like the petals of a flower. On tests before the time of this writing, the mouth rope was allowed to pack itself randomly as it descended through the water, leaving the finned floats pointing in random directions. To calculate the total volume of water sampled, a consistent opening time, and thus a consistently shaped cone on the bottom of the column that the trawl filters, is a must. Opening time for larger mouth ropes will be studied closely during upcoming field work.

The 8.4 $m^2$ trawl used in prior field work will be re-hung using 0.32 cm Delta knotless netting, in order to compare its performance to plankton samplers with similar mesh size. Larger nets with a mouth area of ~ 80 $m^2$ will be constructed to sample deep water fish and invertebrates. Because the free vehicle trawl has no depth limitation other than the depth rating of its floats, it could be an instrument that helps bridge the information gap on the subject of deep water biota, and its connection with life in upper pelagic waters (T.W. Pietsch, pers. comm., 2011). Free vehicle nets with mouth areas > 80 $m^2$ could be fitted with several (opening and closing) codends that sample discrete depths, in order to identify layers of smaller biological scatterers in the water column, when used in conjunction with hydroacoustic surveys.

Although fish could be seen in video taken, they were not clear enough to identify. But given the month (May), the location (Lake Washington, Washington State) and the fact that these fish were able to easily escape through the 3.8 cm mesh, it is possible that they were age 0 sockeye salmon, *Oncorhynchus nerka*. These fish did not appear to react to the approaching net until they were overtaken by it, and were in the narrowest section of the codend. It was a partly cloudy day with good light conditions. The web in the net was bright white. The reaction of fish and invertebrates to a bridleless net that approaches from underneath needs be investigated further. Cameras mounted to the mouth rope, some looking inward and some looking upward, would facilitate this study.

## Acknowledgments

Nicholas Baker and Karl Baker have helped with net construction and field work since the first prototype, and they have my deep appreciation. I thank Bill Gordon, with NOAA's Dive Program, for providing an inexpensive and reliable corroding link weight release device, and for help with dive tank demonstrations. I received a great deal of assistance from colleagues at the Alaska Fisheries Science Center, and want to thank Craig Rose and Scott McEntire for their help with cameras and Lake Washington field work; James Orr for his help with Lake Washington field work; Karna McKinney for her photography and graphics work; and Neal Williamson, Peter Munro, Craig Rose, and Matt Wilson for helpful comments on this manuscript. I am also grateful to Theodore Pietsch, University of Washington's School of Aquatic and Fishery Sciences, for inspiring my decision to take on the challenge of this net.

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