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March 2022

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# Construction of a Remotely Operated Catamaran with Acoustic System for Observations of Fish Response to Bottom Trawls

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# Dedication

We dedicate this report to the memory of the late captain of the FV *Vesteraalen* and co-author of this paper, Tim Cosgrove, our colleague and project collaborator, in thanks for his support of this project from its inception. It would not have been possible to finish, or as a matter of fact, to start this project without Tim. His ideas were essential in the planning stages and preparation of the project and he was critically involved in preliminary trials conducted in the Bering Sea. Completion of these trials led to the origination of the idea to develop the Remotely Operated Catamaran. Tim's advice on the topics of steering, deployment, and operations of the catamaran were key to the success of the project. We will always remember Tim as a friend and collaborator from the fishing industry who promoted a mutual understanding and exchange of knowledge between fisheries researchers and the fishing community.

# Abstract

A remotely operated catamaran (ROC) was constructed with the goal of accessing the area behind a trawling vessel, but in front of the trawl net, to observe fish behavior in this unique and otherwise difficult to access area. This report focuses on the technical components used to construct the ROC. Once constructed, the ROC was towed behind a trawling vessel and remotely steered in order to acoustically image all locations between the vessel and the front of the trawl net. The data gathered by the ROC and equivalent vessel-mounted acoustic systems were used to compare fish vertical distribution and density directly under the survey vessel and in front of the bottom trawl. Results of the research conducted using the ROC are presented elsewhere (Kotwicki et al. 2019).

# Contents

## Introduction

Semi-pelagic fishes are often dominant components of marine ecosystems (FAO 2010). As such, they serve important roles in those ecosystems and are often commercially important as well. Their dominant role in marine ecosystems and their commercial importance underscores the necessity of accurate and precise population assessments. However, these assessments are often uncertain because scientists are unable to completely survey semi-pelagic fish populations with a single-survey method. The vertical distribution of these fishes, as well as their utilization of both near-bottom and pelagic habitats, necessitates the use of separate bottom trawl (BT) surveys and acoustic trawl (AT) surveys to estimate their total abundance in the water column and their spatial distribution (Karp and Walters 1994). Combining BT and AT data results in abundance estimates that are more accurate and precise than those provided by either survey alone (Kotwicki et al. 2018).

Combining population estimates from multiple surveys can be challenging since fish availability is often unknown to both survey methods due to spatial overlap of the sampling volumes and fish behavior in response to vessels and trawls (e.g., Godø 2003, Godø and Wespestad 1993, Hjellvik et al. 2007, Kotwicki 2014). The direct observation of fish in between the trawling vessel and the opening of the trawl has been recognized as helpful to the development of realistic models of fish behavior in this area. However, observations to date have been limited. For example, previous observations of the behavior of semipelagic fish in front of trawls have been conducted using stationary buoys (Ona and Godø 1990, Godø et al. 1999, Wilson and Demer 2001, Handegard et al. 2003, Handegard and Tjøstheim 2009). However, stationary buoys have several limitations, including that they can only capture observations from one stationary location.

Towable acoustic systems allow observations to be averaged over long periods of time, which should lead to higher precision in observing behaviors of interest and estimation of quantities of interest, such as effective fishing height (EFH). The acoustic data gathered by towable acoustic systems during trawl operations provide density estimates in front of the trawl. In addition, data are collected on fish behavioral response to both the vessel and the BT, such as herding, scattering, rising, and diving. The knowledge of fish behavior in front of the survey trawl can be useful for developing conceptual models of fish response to the survey vessel and the trawl. This knowledge can also help in estimating bottom trawl survey catchability and for obtaining combined estimates of abundance from acoustics and BT surveys. In turn, these estimates can be used to improve fisheries stock assessments.

For the Bering Sea stock of walleye pollock, in particular, direct observations of fish behavior in response to the fishing vessel and the BT are important because they help to validate previously obtained model-based estimates of the EFH and density-dependent trawl efficiency, and provide model estimates of vertical overlap between AT and BT methods. To date, acoustic and BT data have been combined using complex modelling techniques requiring multiple untested assumptions (Kotwicki et al. 2018). To validate the inferences drawn from these models, direct observations of fish in front of the BT are necessary. Such observations would allow direct estimation of the EFH of the BT, as well as efficiency of the BT relative to the acoustic measurements.

Here, we describe a novel instrumentation platform -- the remotely operated catamaran (ROC) -- that can be towed behind a trawling vessel to acoustically sample all locations between the vessel and the bottom trawl (BT). For the first time, the ROC enabled direct acoustic observations of fish in front of a bottom trawl, which can be used to validate previously developed models combining the BT and acoustic data from surveys in the eastern Bering Sea (EBS; Kotwicki et al. 2013). The ROC was deployed in 2017 and 2018 throughout the Bering Sea to observe walleye pollock (*Gadus chalcogrammus)* movements in the pelagic area between the bottom trawl survey vessel and the opening of the bottom trawl net (grey-shaded area, Figure 1). The objective of this report is to outline detailed methods of construction for the ROC. Our goal is to disseminate these ideas and to aid other investigators who are interested in observing the behavior of semipelagic fish species relative to research and commercial trawl nets.

## ROC Construction

The ROC is built upon the hull of a small recreational catamaran-style sailboat which could be towed behind a commercial or survey trawl vessel. The ROC is operated from the vessel and has the ability to reach any location between the vessel and the trawl net opening. The ROC design and deployment methods were collaboratively developed by Alaska fishermen and the National Oceanic and Atmospheric Administration's (NOAA) Alaska Fisheries Science Center (AFSC). The ROC consists of several major components, including a catamaran hull, power supply, towing and steering system, computer system with an echosounder transceiver, Global Positioning System (GPS), tow body with acoustic transducer, and communication equipment (Fig. 2).

### *Catamaran Base*

The remotely operated catamaran unit was built on a 2016 Hobie Wave 4 m catamaran hull (Fig. 3), which has a carrying capacity of 363 kg. In place of the fabric "trampoline" that normally provides hull stability for the Hobie Wave, a set of tensioned 0.64 cm steel guy-wires were positioned crosswise connecting the inner intersections of the catamaran pontoons and the crossbars. Aluminum rails were affixed to the crossbars to provide support for a mounting platform for the electronics. A cage was also constructed over the rails to provide more stability and protect the electronics from incidental contact with the vessel.

### *Power Supply*

The power source is located at the front of the ROC mounting platform (Fig. 2). The power supply consists of two 13.2V NiMH batteries wired in parallel to supply enough power for the system during long deployments. Each 13.2V battery is equipped with a 30-amp fuse. The batteries and fuses are mounted inside a waterproof box (Fig. 4A), which is connected to the computer using a waterproof cable and connector.

### *Towing and Steering System*

The ROC was deployed and retrieved off the vessel using a compact, single-speed, electric commercial tuna fishing winch (Tuna Brute II: Electra-Tra-Mate ELC-0036) with a 10 cm spool containing 400 m of 1/3 cm AmSteel spectra line. While the vessel was in motion, the catamaran was deployed over the trawl by releasing tension on the spool clutch mechanism and letting the drag on the ROC pay out the line from the spool. To retrieve the unit, the clutch mechanism was tightened and the electric motor engaged, which brought the ROC back to the vessel. The winch was powered using a 120V AC to 24V DC transformer connected to vessel-generated power (120V AC).

ROC steering was achieved by adjusting the horizontal position of the towing point relative to the catamaran platform (Fig. 5). This approach required several customized motion and control components. A small electric anchor winch (Trac Outdoor Inc. Model T10110) mounted on the ROC and housed in a separate enclosure provided high-torque, low-speed, and non-slip line position control. A short length of line was attached from the anchor winch through cheek blocks and bullseye fairleads to the bow of the boat to attach to the tow point rigging. The anchor winch action was controlled using a motor controller located in the computer housing. A rotary encoder was installed on the winch to provide feedback on line travel to the computer on the vessel.

The ROC's narrow catamaran hulls are optimized to maintain a straight course even when being forced laterally, as when sailing with a beam wind or true wind that is at a right angle to the sailing craft. This tracking capacity was leveraged to allow lateral offsetting of the ROC course relative to the vessel's course. The mechanism of using the anchor winch to shorten and lengthen the line attached to one side of the towing bridle is demonstrated in Figure 5.

In addition to position feedback of the anchor winch spool, a live-feed camera mounted on the ROC frame also monitored the state of the towpoint actuation (HIK VISION Model: DS-2CD2132F-I). The camera allowed scientists on the vessel to see the real-time view from the ROC; monitor the towing point; monitor other system components for problems; monitor the

ROC's position in relation to the vessel, if fog was prohibiting a direct view of the ROC from the trawl vessel; and monitor the performance of the ROC during rough weather conditions.

### *Computer System*

The computer system (located on the ROC mounting platform; Fig. 2) was assembled in-house and composed of the following components (Fig. 4B): 1) Cincoze Rugged Intel Bay Trail Compact Fanless Computer with a 256 GB solid state HDD, an Intel Wireless AC and Bluetooth card, a wireless dual band antenna, and a 12V DC power adapter; 2) Garmin GPS (Model 19 N); 3) EK60 GPT connected to acoustic transducer; 4) FreeWave wireless data transceiver (Model HTP-900RE) attached to an external omnidirectional antenna; and 5) Sparkfin Redboard microcontroller for controlling the towpoint winch and a programmable output 160 W DC-DC converter (Mini-box DCDC-USB-200) for regulating power to the components. All of the components were mounted inside a Polycase waterproof housing (Polycase Part # YH-161407-07), with all the connections to and from the enclosure made using SubConn underwater bulkhead connectors.

The GPS in the ROC computer housing was used to determine the ROC's position relative to the vessel and to provide the necessary GPS inputs for geolocation of the acoustic data. The computer locally stored all of the acoustic and location data during each deployment, and the data transceiver and antennae allowed scientists on the vessel to remotely access the ROC computer and see the acoustic feed in near-live time. In addition to the GPS built into the computer, a Garmin Astro 430/T5 GPS/GLONASS Dog Tracking System was also attached to the ROC cage to provide an independent, isolated real-time distance and bearing between the vessel and the ROC that was not connected to the ROC power supply.

### *Tow Body*

The tow body used for this study was designed and manufactured by BellaMare Subsea Engineered Systems (Fig. 4C) and can operate 2-3 m under the surface of the water, which provides a level platform for instruments under tow. A Simrad 120KHz EK60 acoustic transducer

(S/N 821) was mounted on the tow body and connected to the computer on the ROC via a 15 m 8-conductor transducer cable. This acoustic transducer is similar to the hull-mounted transducers currently used on fishing and survey vessels, allowing for direct comparisons of fish vertical distribution and density under the fishing vessel and under the ROC.

To monitor the tow body platform stability and orientation during data collection, a HOBO Pendant G Data Logger was used to record the tilt and roll angles of the tow body. The tilt sensor was mounted on the tow body using a custom 3-D printed housing (Fig. 4D).

### *Communication*

FreeWave radio data transceivers (FWR, MODEL HTP-900RE) were used for real-time communication between the vessel and the ROC (Fig. 4E). A directional antenna pointing sternward was affixed to the vessel and an omnidirectional antenna housed inside a waterproof PVC housing was affixed to the ROC. A laptop was connected to the shipboard FWR, which allowed direct access to the ROC computer by using remote computer-control and desktop-viewing software (TightVNC Inc.). Once connected to the computer on the ROC, data acquisition, ROC position (steering) controlled using a custom interface for moving the towpoint winch, and viewing of the winch position could commence. The towpoint winch control interface also provided an estimate of the ROC battery voltage, which was critical for operating the system. Real-time feedback was available by remotely viewing the EK60 echogram display running on the ROC computer. Similarly, the live-feed camera was viewed indirectly though the remote desktop.

## ROC Development, Assembly, and Testing

The initial concept of using a catamaran with towing point situation was tested using a scale model. The project benefited from the ability of purchasing only the catamaran components needed for the ROC, without the need of acquiring the entire Hobie Wave sports craft. The ROC platform was then assembled without the electronics and tested using a small towing vessel on Lake Washington in Seattle, Washington. Finally, the full operational system was tested on two occasions in Lake Washington. During this time, the tow body was trimmed by adding weights and adjusting the tow-body bridle attachments to ensure it was level during data collection. The ROC was designed to allow rapid removal of the electronics by mounting the waterproof housings on individual plastic (nylon) bases that could be easily attached to and removed from the ROC frame. This concept was necessary for protecting the equipment in the field and allowing for the removal of all electronic components from the catamaran during regular survey operations. The computer housing was mounted to its plastic base using shock absorbing isolators (Isolation Dynamics Corp. SS Cable Isolators Model # SB6A-213-05-A) to prevent vibration and shock damage to the GPT and other electronic components. An external "roll bar" style aluminum protective cage was designed to go over the electronic housings to provide protection from any external impacts during use. A lifting harness consisting of four heavy-duty nylon straps was connected to the crossbars and used to lift the unit in and out of the water off the side of the vessel. Large soft bumpers were attached to the front and one side of the ROC pontoons to prevent damage to the craft from collision with the survey vessel during deployment and retrieval.

### *Deployment*

The ROC was deployed in the field during AFSC bottom trawl surveys in the eastern Bering Sea in the summers of 2017 and 2018. To deploy the ROC, all the components were first mounted to the mounting platform and the ROC was lifted to a staging area near the side of the vessel deck. Next, the system was powered on, which started the computer and GPT by using a Wake-on-LAN protocol. Once all electronics on the ROC were confirmed to be functioning, and communication with the vessel operator was operational, the crane was used to lift the ROC into the water alongside the vessel with the tow line held forward to maintain its position. The craft was then released from the crane and held next to the vessel, and the tow body was lowered by hand into the water at the stern of the ROC.

Once the tow body was fully in the water, the ROC was released and the tow line allowed to pay out while the vessel was maneuvered to ensure that the tow body was clear of the propeller. The vessel would then move away. When the ROC and tow body were located approximately 120 m behind the vessel, the ROC tow winch was arrested and the trawl net was then deployed in accordance with standard survey protocols (Stauffer 2004). During experiments, the codend of the trawl was left open to allow for long observation times without concern of managing catch.

### *Calibration*

Both the vessel and the ROC's echosounder systems were calibrated following the standard sphere method (Demer et al. 2015) using a 38.1 mm tungsten-carbide sphere. Gains were determined using the on-axis method, and the beam angles and offsets were determined using the 'Lobes' software provided with the EK60.

## Data Collection

The primary ROC data collected were acoustic backscatter. These data were recorded locally on the ROC computer, along with GPS feed, camera video, and additional data such as tow-point winch state and system voltage. No data were recorded on the survey vessel laptop used to interact with ROC via FWR. Upon retrieval, the data were downloaded from the ROC computer using a network cable, while the orientation and accelerometer data from the tow-body sensor were independently downloaded (Fig. 6).

## Remarks

The ROC has many potential uses that could be beneficial to both scientific surveys and commercial fisheries. Scientific surveys could not only utilize the ROC for direct observation of fish behavioral response to trawl vessels, but also to improve survey parameter estimates, such as EFH. Furthermore, ROC is a great platform to collect data to learn more about trawl catchability by providing information about BT efficiency and vertical availability to the bottom and pelagic trawls. The fishing industry could also use the ROC to observe fish behavior in front of trawls or other fishing gear, in addition to monitoring and improving both catch efficiency and desired selectivity of the gear.

Due to the ROC’s system complexities, as well as the proximity of the catamaran to the survey vessel during operations, the ROC has some shortcomings, including lengthy setup, deployment, and retrieval time. The large number of complex components and systems required to run all the various parts made the ROC into a very specialized piece of equipment that required a large time commitment for deployments. We found it was beneficial to ensure all systems were functioning properly before deployment off the side of the vessel because deployment and retrieval was a time consuming procedure. Additionally, the physical distance between the ROC and the survey vessel made troubleshooting difficult and time consuming because it often required complete retrieval and redeployment.

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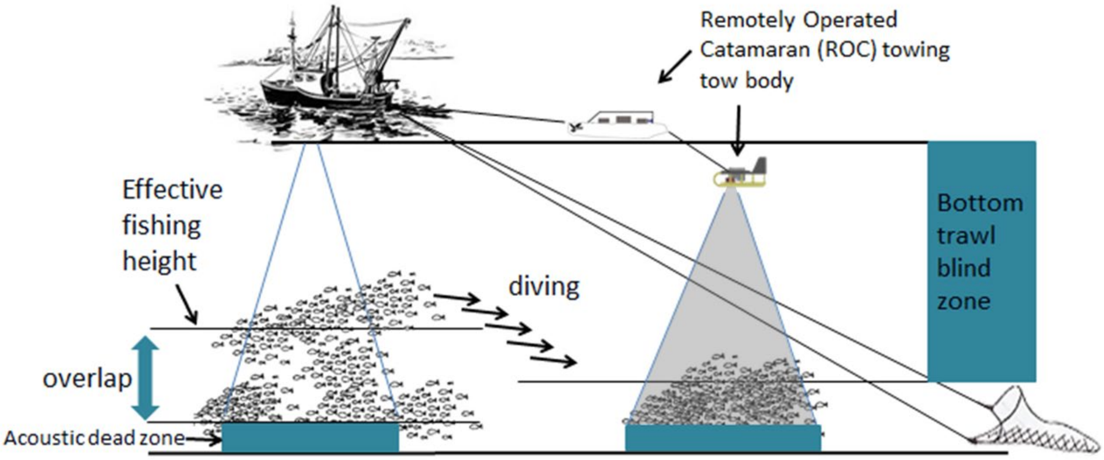

Figure 1. -- Illustration of acoustic sampling by vessel and Remotely Operated Catamaran (ROC) in front of a trawl. Comparable acoustic data are collected directly under the survey vessel and under the tow body attached to the ROC (area under tow body is shaded in grey) to assess fish behavior and allow for a better estimate of the true effective fishing height.

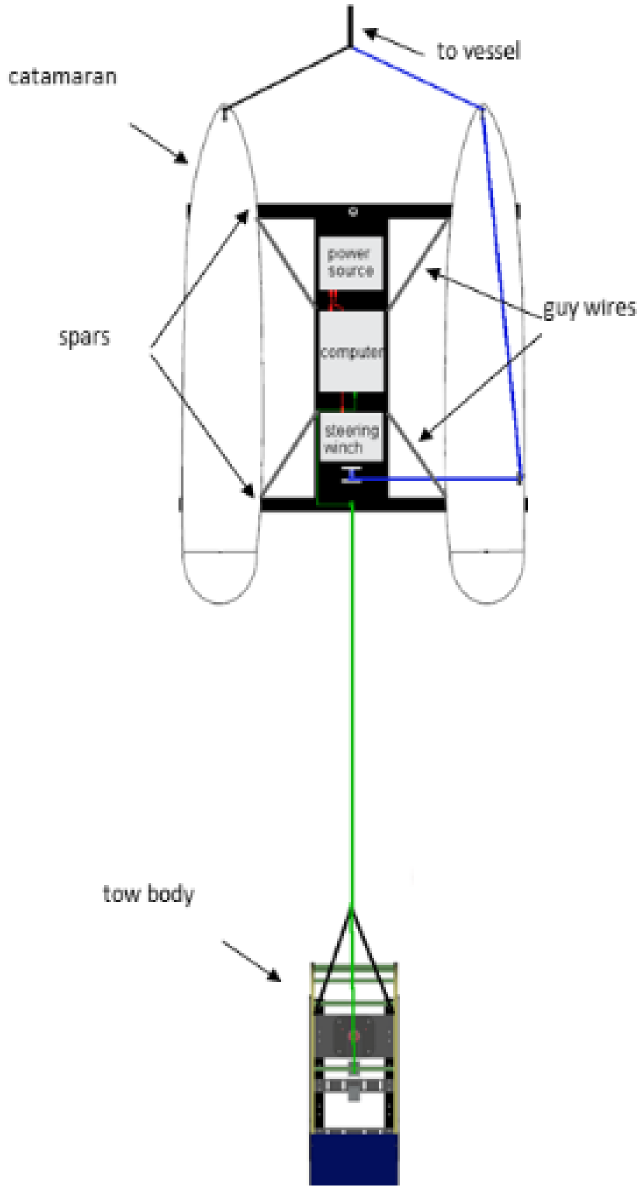

Figure 2. -- Diagram of Remotely Operated Catamaran (ROC) base and tow body. The tow body is equipped with an acoustic transducer connected to ROC computer by a cable. The computer sends data wirelessly to the survey vessel. The power source provides power for the computer, steering winch, and acoustic transducer. The steering winch is used to adjust the horizontal position of the towing point relative to the catamaran platform, which can steer the catamaran either left or right.

Figure 3. -- Photograph of Remotely Operated Catamaran (ROC) with electronic components installed, which include power source, computer, steering winch, camera, and omnidirectional antenna (in white, vertical PVC tube).

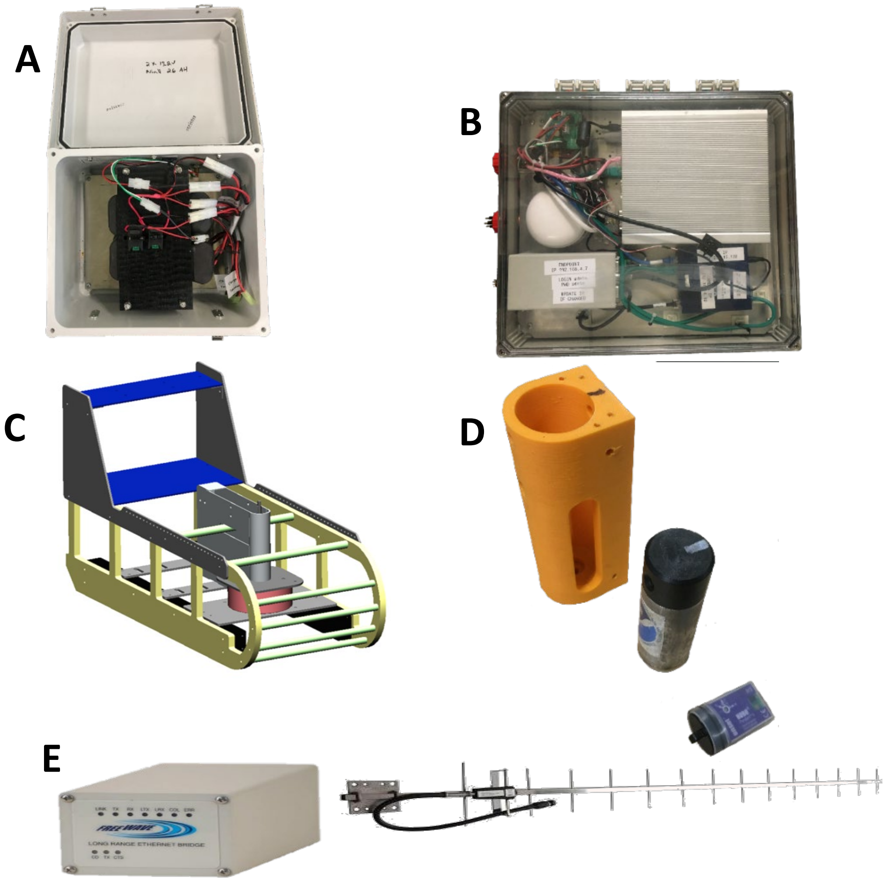

Figure 4. -- A) Remotely Operated Catamaran (ROC) power supply, B) ROC computer which includes Garmin GPS unit (white circle), Freewave Radio (small tan rectangle), GPT (not visible), and desktop computer unit (silver square), C) Diagram of tow body. The red disc within the tow body is the Simrad 120Hz EK60 acoustic transducer. The blue “spoiler” structure helps the tow body “fly” level and straight, while the green bars and yellow sides provide structure and protection. D) Diagram of tilt sensor housing and Hobo tilt sensor and data logger, orange housing was 3D printed, affixed to the tow body, and used to monitor tow body position while towing. Tow body needs to be towed horizontally to assure good quality of the collected acoustic data. E) Freewave radio and antennas used for communication between vessel and catamaran.

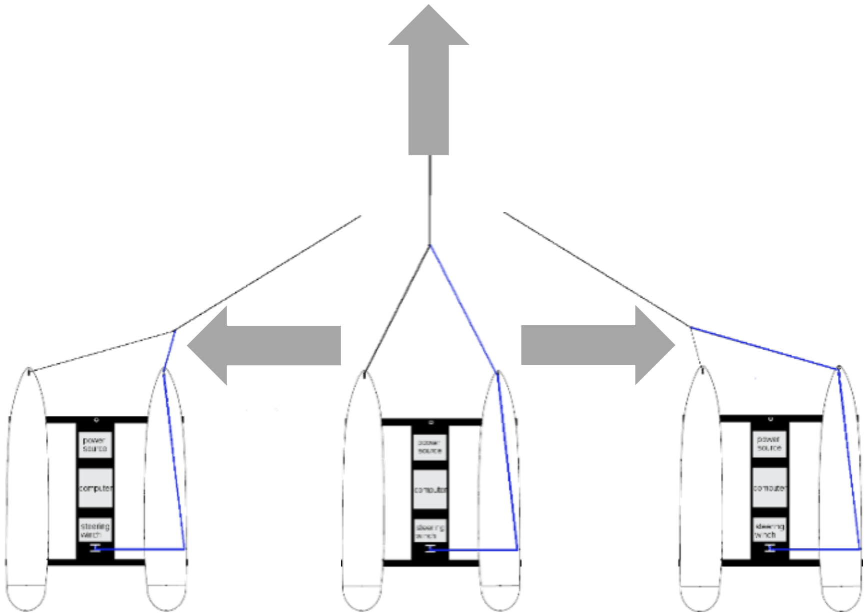

Figure 5. -- Illustration of the Remotely Operated Catamaran (ROC) steering mechanism. When ROC is towed from its center it is moving directly behind survey vessel. Paying out the blue line causes ROC to be towed from left side which results in ROC movement to the right. Bringing in blue line causes ROC to be towed from right side which results in ROC movement to the left. Side to side movements are important to observe pollock behavior at center and both sides of the trawl. Towing point was monitored in real time using a camera that was mounted on the ROC.

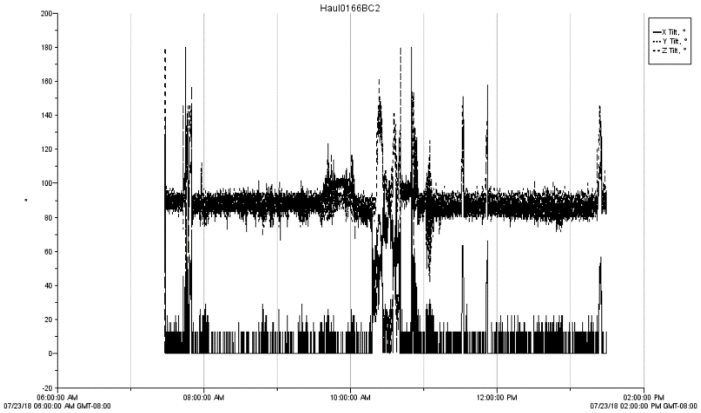

Figure 6. -- Example tilt data from Hobo G-Pendant accelerometer and tilt sensor.

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