

# **LiEFi (Light-Energy Fish): Using Simple Mechanical Models to Simulate Climatic Changes in Fish Communities**

Maddy Wilson

2311 E. Alder St, Seattle, WA

[mnwilson003@gmail.com](mailto:mnwilson003@gmail.com)

April 14, 2019

University of Washington

1400 NE Campus Parkway, Seattle, WA

## I. Project Summary

There are many different ways to model climatic changes: through computer modeling, idealized simulations, or real-life mechanical models. This project will use a simple fish-like ROV model with an idealized “fish-eye” ,a rear thruster, and a three dimensional accelerometer to simulate the sight ability, energy use, and stability in flow of a pelagic fish in an estuarine environment. This fish, LiEFi, or Light-Energy Fish, will measure the ideal speed and orientation for stability at different flow speeds, as well as direct measurements of spectral reflectance in the red, blue, and green wavelengths at different depths, and ideal fin shape. Information gathered during the design / build / and testing procedure will address key ocean science and technology questions regarding using biomechanical modeling techniques; what worked, what did not, and how to design a process that allows for practical approaches to modeling solutions. The data collected will show the effectiveness of the research vessel in measuring stability, power, and light levels. These data are informative about the energy requirement and efficiency of organisms in any given habitat and how the effects of climate change in estuarine environments affect their behavior. This project exists as a way to show that even simple, innovative modeling techniques based on straightforward means are capable of producing compelling results and providing information on possible future impacts that can be used to manage these environments.

## II. Introduction

Questions based on modeling biological systems and behavioral patterns for specific organisms or ecosystems can be difficult to answer, and every design-based approach may take on a different form. The question addressed here is can an ROV research vessel designed as a biomechanical simulation for fish movement be used to assess the energy requirements to sustain position in an optimum habitat? Marine habitats are expected to experience dramatic changes due to long term climate changes-can organisms adapt to those energy requirements? Numerical models and simulations cannot always give the breadth and depth of information needed to make conclusions about smaller ecosystems and individual communities. Using LiEFi, which operates as a simple mechanical robot to collect data in a complicated environment, information will be gathered and analyzed to determine the effects of turbidity and increased river flow to both the eyesight and the energetic output of fish modeled by the turbine power. On top of this, an accelerometer and two pectoral-like fins will help determine the stability of the ROV, as it is focused on staying in one place in a swift current. Our prediction is, in a higher flow, LiEFi will encounter more turbulent conditions, and less stability, as well as more trouble with murkiness and a higher energy output to stay in one place. In terms of environmental testing and conditions, this model will work well in areas designated to be important for fish, where environment can change often and flow conditions can differ. For example, information collected from numerical modeling estimates and simulations show that with climate change, Puget Sound rivers will experience increased storm surges and greater flooding, which when combined with rising sea levels, can create engorged river conditions on an average year (Hamman 2012). The increased peak flow will be caused by a higher snow line and greater precipitation, especially in winter, creating a greater river output and the likelihood of greater turbidity at the Skagit River mouth, especially at the surface ( Hamman 2012). Pelagic fish who hunt and avoid predators in this area expend certain amounts of energy, more than

those that inhabit open water, in order to prevail and enjoy the readily available resources in this estuarine environment (Hamman 2012). River outflow from these areas brings sediments and sustenance into the open ocean, in the form of decaying material and living organisms. With greater flow comes a greater amount of material, which can cloud the water and create conditions where fish are not able to hunt effectively or even watch for predators and protect themselves appropriately. Fish will be forced to move where the water is clearer and will prefer areas where flow is dispersed to slower speeds and less energy will be expended and conditions will enable greater visibility (Phamduoy 2015). An environment such as this would be ideal for this ROV model to be tested. It can be difficult to determine how certain environmental parameters will affect biotic communities, and this design-build will attempt to build a simple, easy to replicate model that allows the user to correct for specific parameters that are pertinent to the question being asked. LiEFi is a straightforward, easy to recreate ROV that maintains a practical approach, consisting of only several parts. As a whole, LiEFi will manage to streamline the process used to find answers to scientific questions about how fish behavior will change when encountering complex problems, like climate change or changes in habitat and environment. LiEFi will illustrate a plan for a rudimentary ROV that stays stable in a heavy current, and measures ambient light and energy output.

### III. Methods

The approach to this project began with a simple idea that manifested into a design phase, where drawings and sketches were created in line with the measurements of the robotics kit and plans and phases of the build were detailed and scheduled. The process was then carried out over two quarters, culminating in a technology build based on blueprints and then a testing phase-on bench and in both a freshwater and saltwater environment.

The project's purpose was to create and design a simple fish-like robot that would strategically

allow the testing of certain important parameters. These parameters were manifested in the robotic build by the sensors and attachments inside and outside of the plexiglass enclosure; the accelerometer, the light sensor, and the turbine. The goal was to create a design that would allow these three sensors to be used to highlight the energy use of the fish in flow, light visibility in different environmental conditions, and stability of the overall robotics build when deployed at depth, and in a current. The design had the accelerometer inside of the plexiglass enclosure, where it would measure the tilt, roll and orientation of the build once deployed. The light sensor was to be attached to the inside of the front plexiglass cover of the enclosure, for maximum exposure and to mimic the light conditions that a fish would see in the environment. Lastly, the turbine was moved several times during the design build, from the top, to the back, to the bottom as the build continued. Initially, four rails were sketched and planned to be attached to both the top and the bottom of the enclosure, where they would hang off of the back and allow the motor to be moved as so desired. A electronics shelf was bought from Blue Robotics and used to mount the Arduino microcontroller and the breadboard, using velcro, inside of the interior of the enclosure. The original deployment plan for LiEFi was to deploy using a rope that would encircle the enclosure at both ends and lower the robot straight down into the water, allowing for a sway back and forth in the current and when the thruster was deployed.

Once the build began, the accelerometer and light sensor were attached to an Arduino microcontroller through a breadboard, on two of the same pins, A5 and A6, as both were I2C sensors and could be combined as long as their names in the code were differentiated. The code was taken from the Arduino Library and combined to run on the same project. The sensors were tested independently on the bench, as well as the thruster, which used an Afro ESC PWM hardware input and plugged directly into the Arduino, as well as an external power supply. The

components were then attached to the electronics shelf and slid into the plexiglass enclosure, where a 3D printed shell was glued to the front of the enclosure with the light sensor within. The plexiglass enclosure was sealed with two lids, a front and a back, which were customized with three O-rings to allow for water tightness. The port holes in the back lid were customized with a USB cable for data that attached directly to the microcontroller inside of the case, as well as a cord for external power to the thruster via the ESC and the cord that connected the thruster directly to the microcontroller. The cord openings were sealed with epoxy and the entire enclosure tested for a vacuum seal. Finally, two stabilizing rings were attached to the outside of the enclosure, upon which one set of rails was fixed to the bottom of build, and the thruster mounted directly behind the robot on the rail. Two plastic fins made out of a flexible but rigid material were attached to both sides of the robot using the stabilizing rings, to allow the robot to remain stable and not roll to either side when deployed.

The fish was then placed in freshwater in the Ocean Tech basement and after observation, made neutrally buoyant by the addition of two pieces of ballast, a bronze plate and a screw, which were fixed to the underside of the enclosure onto the rail using zip ties. Finally, a thin woven plastic rope was attached in the direct center of the robot on either side through eyelets attached to the stabilizing rings, allowing LiEFi to be lowered directly into the water.

Several alternative designs were considered throughout the process-deployment was a major factor, and plans were made for the robot to be attached to a rope only from the front, from a hollow copper wire that would lower over the side of the boat, with the rope running through it, that would allow for a feeling of tension in a current, and would keep the robot stable and allow for slack once the turbine was deployed. However, the two attachment rope design was favored

as the design was less problematic and unwieldy, and ensure that the person deploying would have more control over the robot's center of mass once it was deployed.

Phase I: Sketch and Create Design

Phase II: Create Rail Idea and Shop

Phase II: Order Clamps and Light Sensor and Accelerometer

Phase IV: Design Stabilizing Fins

Phase V: Create stand alone component wiring and coding for the light sensor, accelerometer, and IMU

Phase VI: Integrate all components and bench/water test

Phase VII: Test in flow tank and off dock

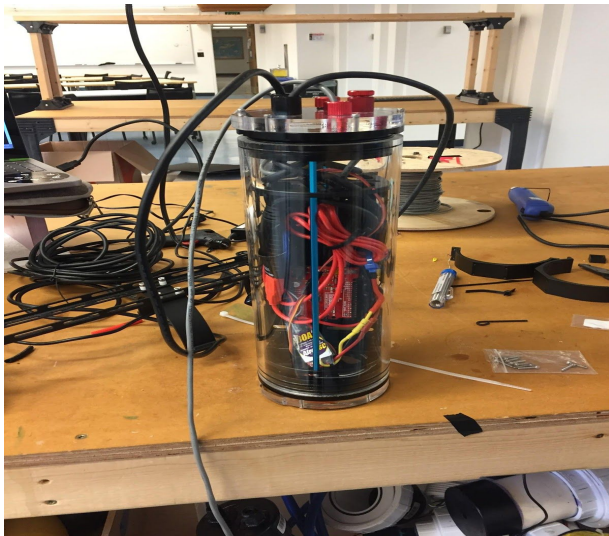


Figure 1: End of the Building Phase with all Components Inside

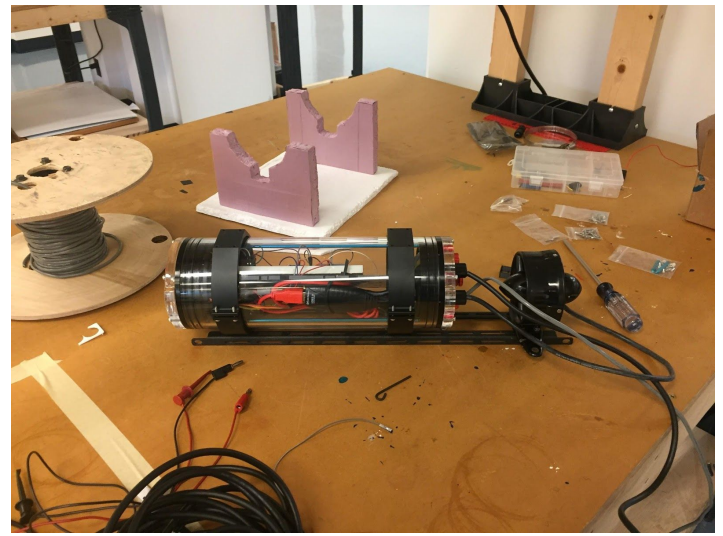


Figure 2: Plexiglass Enclosure with Instrument Tray

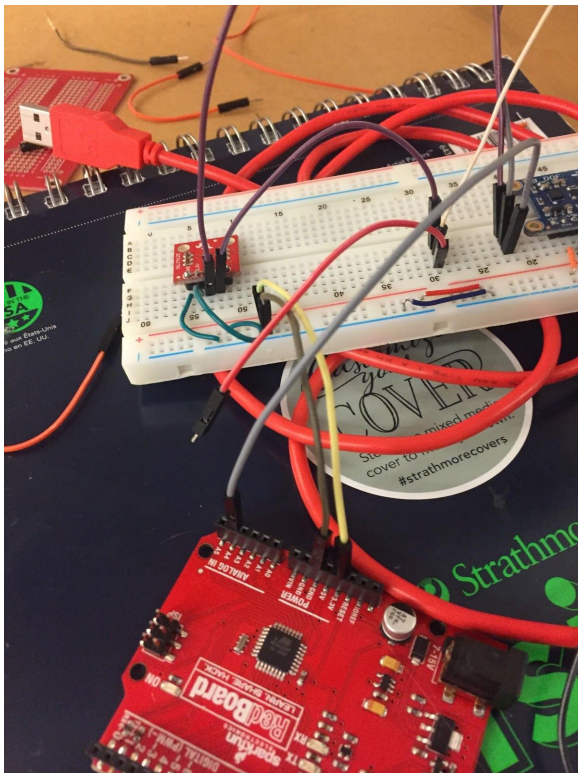


Figure 3: Accelerometer and Light Sensor attached to Arduino through breadboard

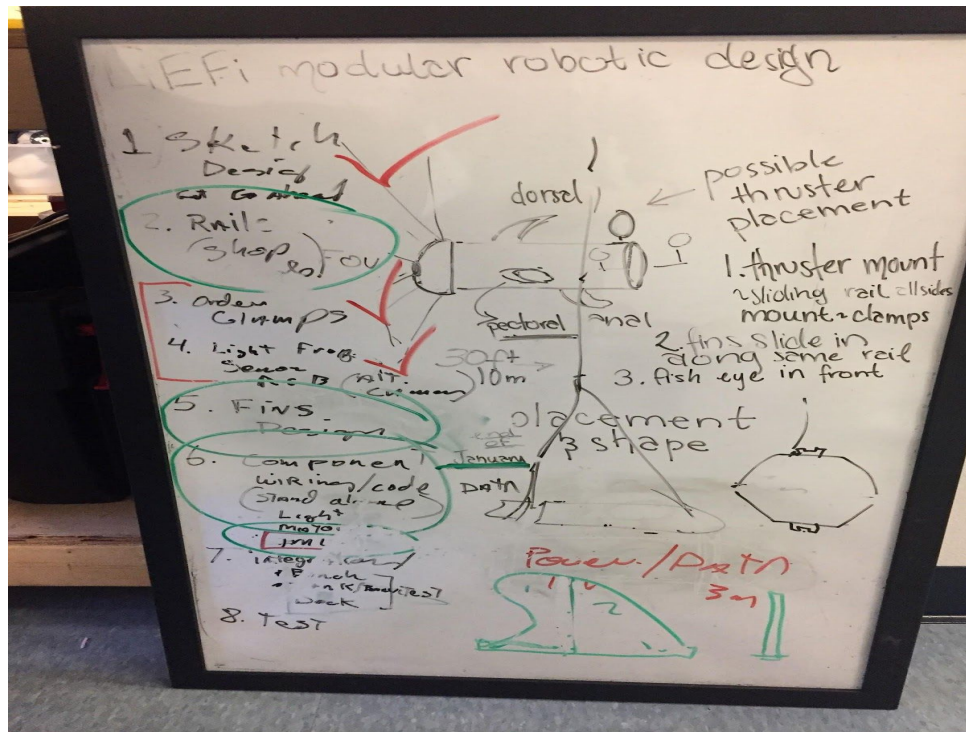


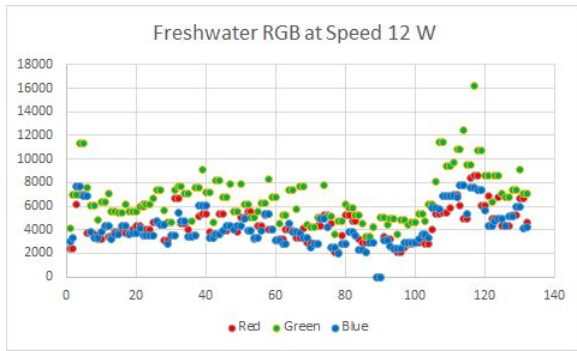
Figure 4: Step by Step Design Phases

Including Fin Design and Rope Placement

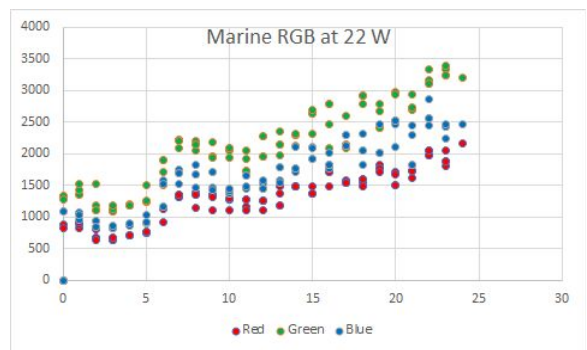
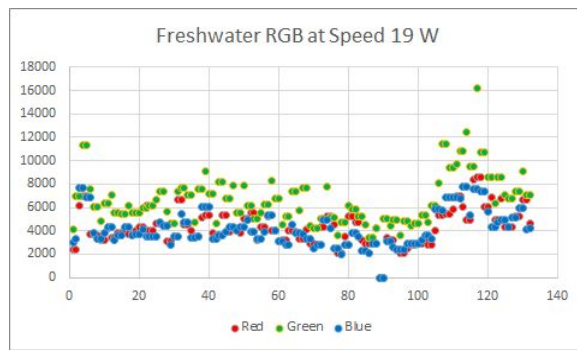
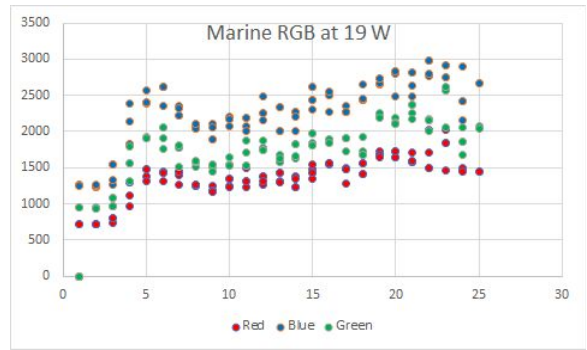
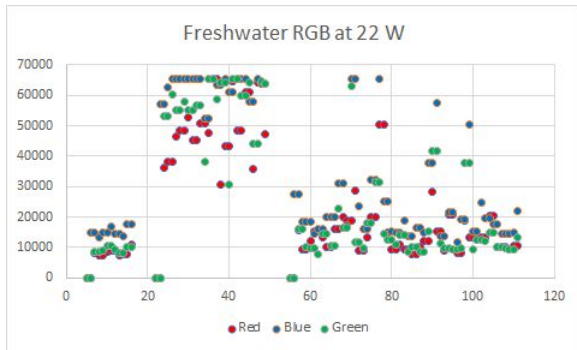
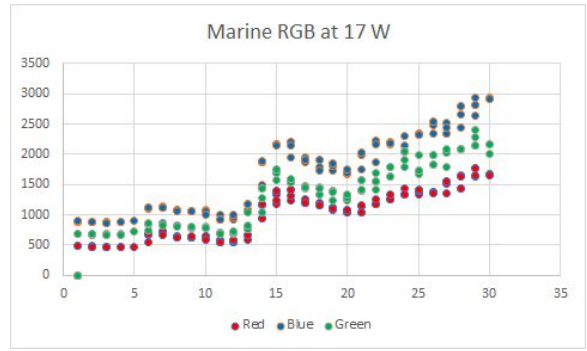
for Deployment

### III. Deliverables

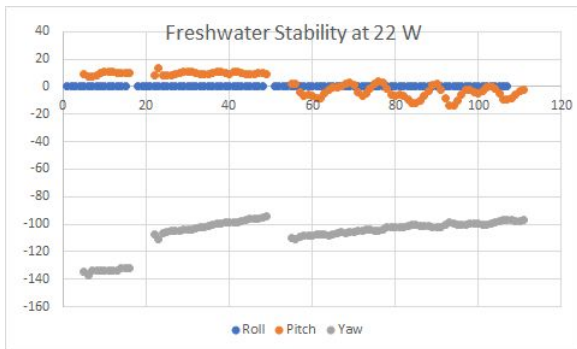
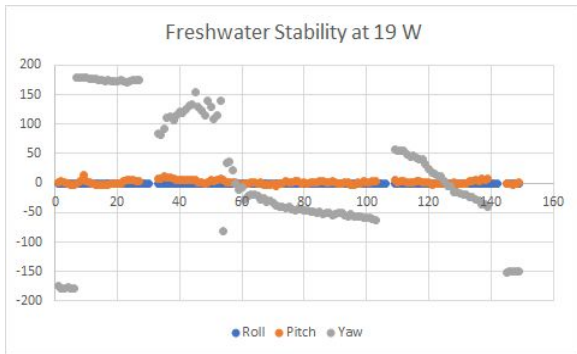
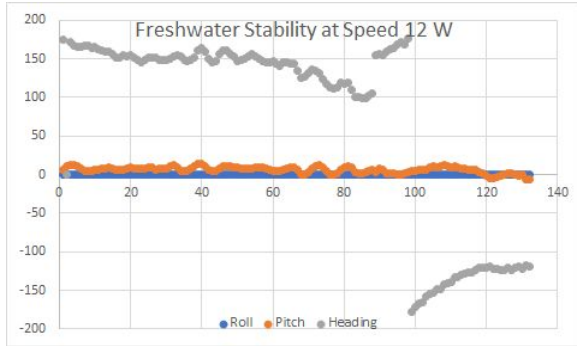
#### Freshwater RGB Levels



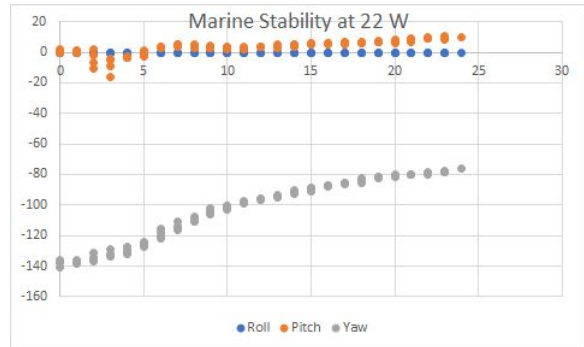
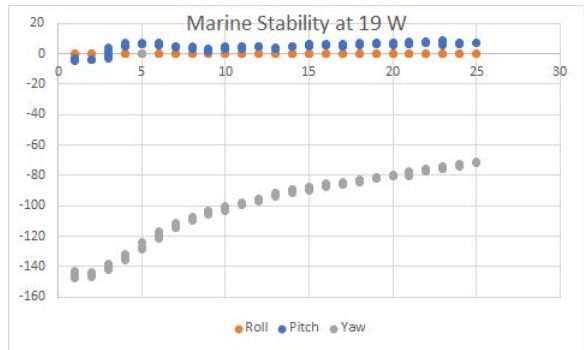
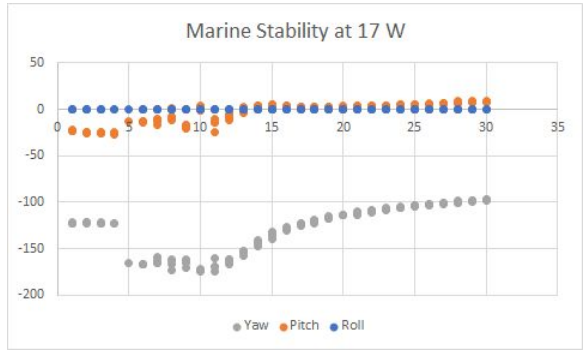
#### Marine RGB Levels



## Freshwater Stability Measurements



## Marine Stability Measurements



Test results were collected at the surface in two different environments-both marine and freshwater. For the red, blue and green results in the freshwater environment, the levels were higher as the day was much sunnier, and the test sight, in the Montlake Cut, was well-exposed to sunlight. At 12 and 19 W, there was not much difference in light levels, but at 22 W, there was a large difference from the other two, which faced another direction from the other two and moved more quickly towards the sun. The marine light levels were fairly similar, taken at the Shilshole Marina in Ballard under cloudy conditions. The lowest levels recorded were under the slowest speed. Stability in the freshwater conditions consisted of roll, pitch, and yaw acceleration, with pitch and roll remaining relatively stable and close to one another, and acceleration in the yaw direction showing a great deal of change in the X plane. The difference was also extreme at different speeds, compared to the very uniform results from the marine trial. Without a rudder, which this trial was conceived without, the acceleration and deceleration in the X plane deviates often for each speed trial. Each speed shows no large difference from the other, with perhaps the 22 W trial showing a difference in pitch along the Y plane in both marine and freshwater environments.

#### IV. Conclusions

LiEFi was built in order to create a robotic research instrument that would measure light, power output and work required to stay in a flow, and a stable design that performed properly in flow conditions. We found that the addition of stable, flexible yet rigid fins allowed for extremely

stable swimming, even when running the thruster at higher speeds. The robot did not roll, but stayed neutrally buoyant according to whatever ballast was attached and would move without wavering. While the fins attached to both sides enabled the amount of roll and minimized the yaw, the robot can be hard to control at faster speeds in terms of pitch. If not put at a neutral speed in the current, the robot has the potential to move off in different directions.

If done again, LiEFi would benefit from a simple rudder used to steer until she reaches the speed at which she can continue in a straight line-for now, this capability has not been reached. At different depths, light readings were gathered and analyzed, and showed clear correlation with depth and turbidity. The power output at the flow current speed in the Montlake Cut was relatively low to stay in one place-however, once reached, the robot would remain in one place without flipping or moving too much from one side to the other.

To conclude, the design and build goals for this project were to build a field research instrument with several similar capabilities to a real fish, and to answer questions about stability, power output, and sight in a flow. The finished product accomplishes and answers each of these questions, manifested from a simple build that allows those particular inquiries to be focused upon. With minor adjustments, her design can be made to be customizable to answer many different research questions, with the addition of different sensors. Aspects such as temperature, sound, and more can all be easily integrated into the overall design. An addition of a simple rudder or even another turbine would streamline the design's ability to turn and become more dexterous as desired to collect more complex information.

## V. References

Hamman, J., & Hamlet, Alan F. (2012). Effects of projected twenty-first century sea level rise,

storm surge, and river flooding on water levels in Puget Sound floodplains and estuaries.  
University of Washington.

Cuo, L., Lettenmaier, D., Alberti, M., & Richey, J. (2009). Effects of a century of land cover and climate change on the hydrology of the Puget Sound basin. *Hydrological Processes*, 23(6), 907-933.

Landgraf, T. O., Akkad, R., Nguyen, H., Clément, R., Krause, J., & Rojas, R. (2012). A multi-agent platform for biomimetic fish. *Lecture Notes in Computer Science (including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7375, 365-366.

Savoca, M., & Skagit County . Public Works Department. (2009). Hydrogeologic framework, groundwater movement, and water budget in tributary subbasins and vicinity, lower Skagit River Basin, Skagit and Snohomish Counties, Washington (Scientific investigations report ; 2009-5270). Reston, Va.: U.S. Dept. of the Interior, U.S. Geological Survey.

Riedel, J., & Larrabee, M. (2016). Impact of Recent Glacial Recession on Summer Streamflow in the Skagit River. *Northwest Science*, 90(1), 5-22.

Khangaonkar, T. F., Long, W., Sackmann, B., Mohamedali, T., & Hamlet, A. (2016). Sensitivity of Circulation in the Skagit River Estuary to Sea Level Rise and Future Flows. *Northwest Science*, 90(1), 94-118.

Siebeck, & Marshall. (2001). Ocular media transmission of coral reef fish — can coral reef fish see ultraviolet light? *Vision Research*, 41(2), 133-149.

Phamduy, P., & Porfiri, M. (2015). Robotic fish. *Mechanical Engineering*, 137(3), 16-21.

Toft, J., Munsch, S., Cordell, J., Siitari, K., Hare, V., Holycross, B., . . . Hughes, B. (2018). Impact of multiple stressors on juvenile fish in estuaries of the northeast Pacific. *Global Change Biology*, 24(5), 2008-2020.

