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DEVELOPMENT OF A LOW-COST, PORTABLE, AND NONINVASIVE OYSTER HEARTBEAT MONITOR

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ABSTRACT

Aquaculture is an essential component of Prince Edward Island's economy. One portion of it is dedicated to oyster farming, which is greatly influenced by environmental conditions, such as seasonal temperatures and water salinity. These conditions affect the wellbeing of oysters and, consequently, reflect on the quality and taste of the produce. One method to characterize oysters' wellbeing is through the measurement of their heartbeats. Therefore, this paper presents the design of a noninvasive oyster heartbeat monitor that is built using off-the-shelf components to enable farmers to assess the quality of their product in real time. The paper also presents heartbeat measurements in deionized water and salt water.

INTRODUCTION

Oysters live abundantly in eastern North America, north from Canada and south to the Gulf of Mexico. The farming of oysters in Canada is of high importance. It is an industry that was worth about $240M US in ex-vessel price in 2015 [1], and the most harvested oyster is the American oyster, Crassostrea virginica [2]. In fact, Prince Edward Island (PEI) and New Brunswick produce 90% of Canada's Crassostrea virginica [2]. Oyster farming is affected by many environmental factors, such as nutrients, food content, temperature, and salinity [3].

One indicator of oyster health is the heart rate. However, measuring the heart rate is often challenged by the hard shell of an oyster and monitoring heart rate underwater when the oyster is in its natural habitat [4]. In general, oysters live on reefs or water bottoms in mixtures of fresh and salt water and the shape of their shells is influenced by the place they live in [5]. While oysters have different genders, they change their gender in a process called spawning, or protandric hermaphroditism, which is influenced by environmental conditions, mainly water temperature and physiological strength [5]. This is important to reproduce more oysters.

Oysters generally grow better if their food is of the right size and quality, like bacteria, algae, detritus, and microorganisms [6]. Their growth is also increased by relatively high water temperature and salinity [5] and influenced by the presence of contaminants [2, 7]. These factors affect oysters' metabolism and wellbeing [2, 4]. Therefore, monitoring their heartbeats could give an indication of their physiologic activities [4]. Also, if oyster heartbeats were correlated to optimum water temperature and salinity, aquaculture farmers could enhance the quality and quantity of their produce [4-5].

The general anatomy of an American oyster is shown in Figure 1. Oysters have hard, thick, and rough shells. They also have three hearts; two accessory hearts beat independently a couple of times per minute, while the main heart has three chambers in which two auricles receive blood from the gills and send it to a ventricle about every second [8]. The hearts of

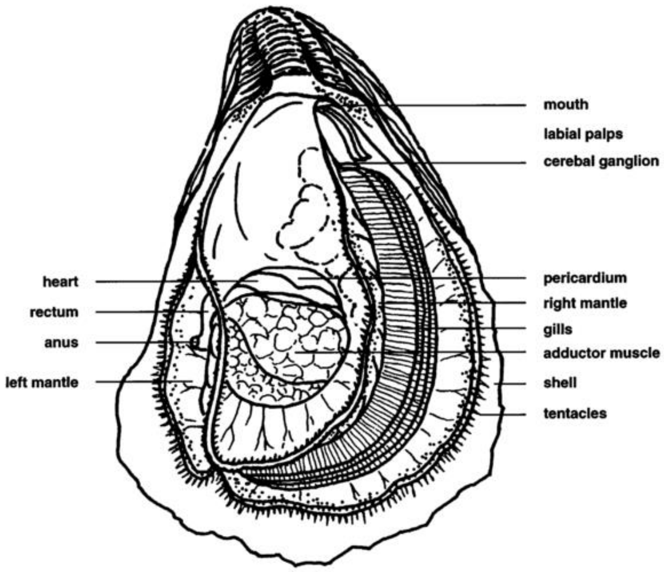

Figure 1: General anatomy of the American oyster [5].

oysters are one hundredth the size of a human heart and about two times slower [8].

There are multiple attempts towards oyster heartbeat measurement, some of them are successful [4, 9] and some are under research and development [10]. These sensors have required the investment of millions of dollars, but they are able to monitor multiple physiologic variables. The aim of this paper is to present a simple and low-cost sensor design that provides portable and noninvasive heartbeat measurement for oysters.

MATERIALS AND METHODS

Since heartbeats induce vibration in the oyster's shells, a piezo disk vibration sensor is chosen for noninvasive heartbeat measurement (Pulse Sensor, SparkFun, CO, USA). Measured data are processed and graphically displayed via an 8-bit microcontroller (4Duino, 4D Systems, CO, USA) which has a 2.4" resistive LCD touchscreen for ease of handling and an ESP8266 Wi-Fi module for data transmission off-site. The microcontroller is powered by two AA battery packs. All components are contained in a three dimensional (3D) printed case made from acrylonitrile butadiene styrene (ABS) plastic that is tightly assembled to ensure a waterproof design. The assembled sensor is shown in Figure 2.

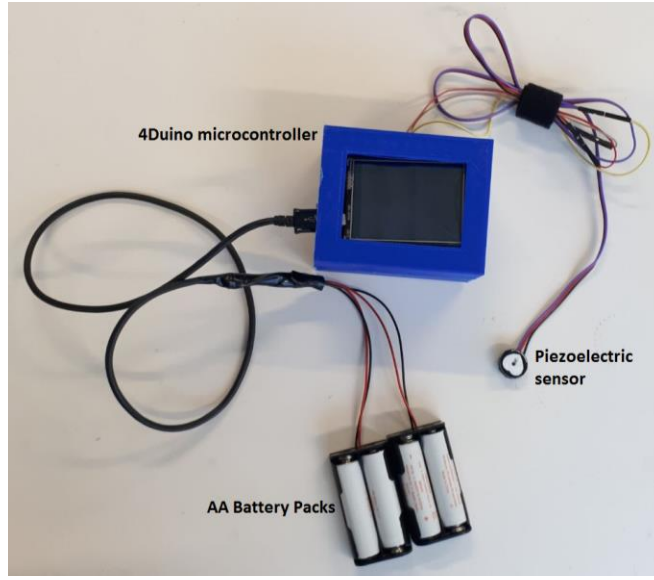

Figure 2: The oyster heartbeat monitor.

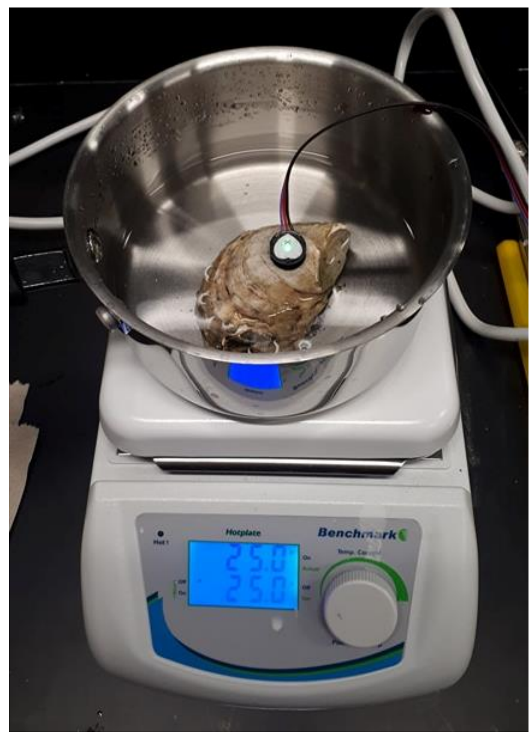

Figure 3: Experimental setup of the oyster heartbeat sensor.

For testing the sensor, an oyster is immersed in a bath of deionized water to observe its heartbeat response to different water temperatures (21 ºC, 25 ºC, 27 ºC, and 30 ºC). The bath can be seen in Figure 3. Also, oyster heartbeat response to different saltwater concentrations is measured by immersing the oyster in a saltwater bath at 21 ºC. To prepare a 1% saltwater bath, 1 g of table salt is dissolved in 100 mL of deionized water. Salt concentrations of 1%, 3%, and 5% were tested. The testing conditions were chosen because Crassostrea virginica oysters typically live in 0.5% to 3% saline habitats with temperatures ranging between 0 ºC and 32 ºC [11].

RESULTS AND DISCUSSION

The oyster heartbeat monitor was tested to characterize the oyster's heartbeat response in varying water temperatures and salinity levels. A qualitative display of two heartbeats is shown in Figure 4. The graphical display of the data is clear and can be read by any oyster farmer. However, the display was sometimes distorted by external vibrations or very weak heartbeats. The results of the tests are shown in Figures 5 and 6. The general trend is an observed increase in oyster heartbeats as water temperature and/or salinity are increased. The drop observed between 25 ºC and 27 ºC could be due to experimental error by not allowing sufficient time for the oyster to acclimate in the new water temperature. It can also be due to unclear graphical signal(s) that might have been hard to read during the test. Overall, the observations indicate that alterations to these environmental conditions affect oysters' cardiac response. With further testing, the data collected would foster a better understanding of how these variables affect the health and meat quality of oysters.

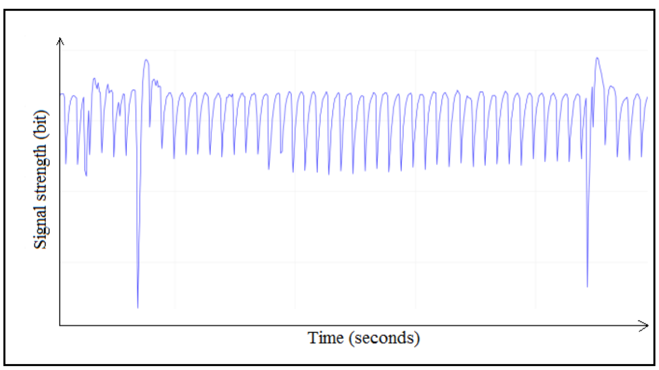

Figure 4: Qualitative display of oyster heartbeats.

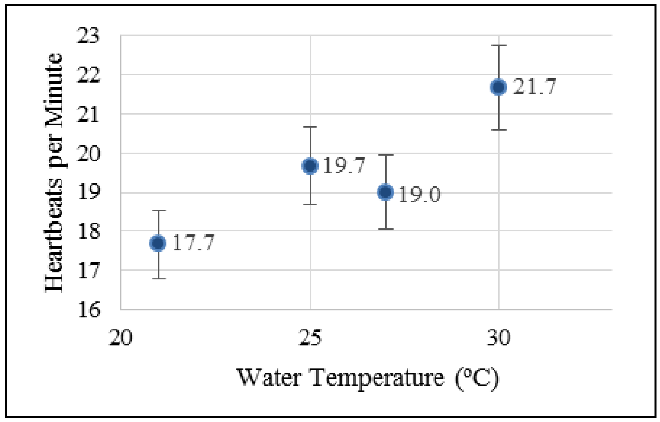

Figure 5: Oyster heartbeats at different water temperatures.

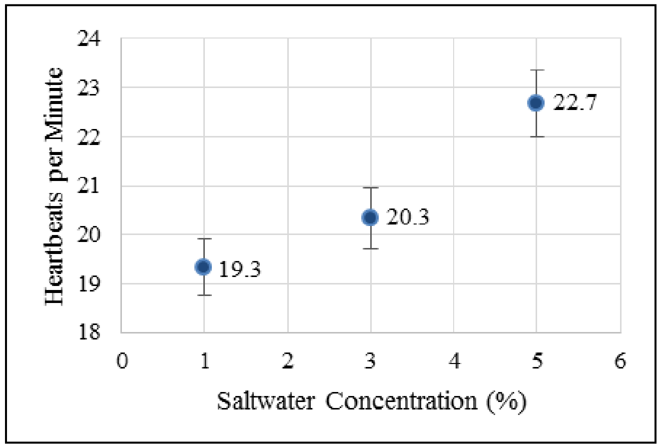

Figure 6: Oyster heartbeats at different saltwater concentrations.

CONCLUSION

The oyster heartbeat sensor provided reliable data that is easy to read by any user. It is also affordable, noninvasive, easy to build, and can be improved to be fully waterproof. The results of the tests show that more heartbeats are observed when water temperature and/or salinity are increased. The sensor could be further improved by adding a noise cancelling algorithm to display a clearer and/or amplified signal at times of distortion. It is also recommended to correlate oyster heartbeat data over a wide range of water temperatures and salinity levels to oyster metabolism and meat quality.

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