Site selection for new green mussel culture area expansion in Buguey estuary, Cagayan, Philippines

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ABSTRACT

Currently, there is limited data on the suitability of estuaries in Cagayan province, Philippines for aquaculture. In this brief report, we discuss the overall assessment score of Buguey estuary in the municipality of Buguey, Cagayan as potential spot for the culture of green mussel (*Perna viridis*), locally known in the Philippines as "tahong". The score is mainly based on salinity and water temperature. We also present the condition of dissolved oxygen and pH levels in the estuary but these factors do not have major effect on mussel growth compared to salinity and water temperature. The reference ideal values for a suitable culture site are 27 to 35 psu for salinity; 27 to 30 degC for water temperature; >5 mg/L for dissolved oxygen; and 7.7 to 8.4 for pH. Based on this reference values, areas in Buguey estuary have acceptable possibility of success for green mussel culture, which is qualitatively equivalent to having "good" suitability. This translates to a production estimate of 81% to 90% of cultured mussels will have a marketable size. However, these ratings may vary due to competition with existing oyster farming, water depth of the chosen site (since several areas in Buguey estuary are shallow), and other factors.

Keywords
Green mussel, Philippines, Aquaculture, Salinity, Water temperature

INTRODUCTION

The green mussel (*Perna viridis*), locally known in the Philippines as "tahong", is one of the bivalve species with high potential for commercial aquaculture because it requires less production cost while having fast growth rate [1,2]. Mussel farming offers additional livelihood to many Filipinos living in the coastal areas all year round, with little capital investment needed [3]. It usually requires minimal maintenance and no additional feed. However, mussel production in Philippines has declined in the past years. In 2012, the average mussel production is around 25,700 metric tons (MT) and in 2014, it declined to 18, 800 MT [3]. One of the major reasons for this decline is the unpredictable supply and little demand [3]. The acceptable marketable size for green mussel is 50 to 100 mm, which can be harvested after 6 to 10 months [1,4].

One of the initiatives of the Philippine government is to expand the production areas of mussel farming. Buguey estuary in the municipality of Buguey located at Cagayan province in the Philippines is one of the selected areas for possible expansion. There is limited data on the suitability of Buguey estuary for green mussel aquaculture, although oyster farming is already present [5]. Here, we discuss the overall assessment score of Buguey estuary as potential spot for the culture of green mussel. The mussel transplanting framework in this study uses longline method [1]. The suitability of the estuary is assessed based on salinity, water temperature, dissolved oxygen and pH levels. The reference ideal values for a suitable green mussel culture site are 27 to 35 psu for salinity; 27 to 30 degC for water temperature; >5 mg/L for dissolved oxygen; and 7.7 to 8.4 for pH [1,2].

In this report, salinity, water temperature, dissolved oxygen and pH are considered. However, other factors such as chlorophyll-α, water current, typhoons, anthropogenic activities, and competition with other species can be considered in the future. Moreover, many areas in Buguey estuary are shallow, other forms of longline method can be designed (e.g., horizontal) [1]. Safety measures for human consumption is also important. Harmful algal blooms can cause parasitic shellfish poisoning, but no reports of this harmful algal blooms are reported in Cagayan [5].

RESULTS

There are 17 surveyed sites in Buguey estuary (refer to Figure S1 in the Appendix). The survey period for the water quality feasibility study is from March to October 2016. This feasibility study, using non-CTD equipment, is done before placing the green mussels for transplantation. The transplantation and culture of green mussels for this study are done from February to August 2017. Another water quality test for salinity is done using CTD deployment in January 2018. Salinity is considered the most important factor in green mussel culture.

The suitability scores are computed using interpolation and measure of distance from the reference ideal values [1,2]. The possibilities of success are computed by combining the information gathered through the calculated scores. The qualitative interpretations of the scores and possibilities of success are based on existing literature and knowledge [1,2]. The possibility of success (say *X*%) may be translated to "*X*% of the transplanted green mussels are expected to be marketable". Marketable weight of a mussel is around 10g. For example, if there are 100 transplanted mussels and possibility of success is 80%, then 80 of the cultured mussels are expected to be marketable, which amount to 800g. If we need 1 MT of marketable mussels, we need to culture 125,000 mussels (refer to Equation S1 in the Appendix for the formula).

Results based on salinity

Salinity is one of the major factors to be considered in selecting sites for green mussel culture. A salinity value of 27 to 35 psu is ideal for mussel growth and survival [1,2]. Salinity

values in Buguey estuary, especially at 3m or deeper water levels are stable (Figure 1), as implied by small standard deviation. During other survey months, the salinity values are still stable (Figure 2). Consequently, salinity levels in Buguey estuary can support mussel culture all year round.

The Buguey estuary has sufficient and stable level of salinity that offers opportunity for mussel culture. Based on the data analysis, it is predicted that the overall salinity-based maximum possibility of success for green mussel culture around the surveyed sites is 90% (Table 1). Even at 1m depth, most of the surveyed sites have salinity values that are still acceptable. Salinity levels in all surveyed sites with 2m and 3m water depth are within the range suitable for mussel culture. Recommended water depth for longline method is at >2m (around 3m).

Results based on water temperature

Water temperature within the range of 27 to 30 degC is considered optimal for mussel growth and survival [1]. The range 24 to 34 degC is also considered "good" [2]. The water temperature in Buguey estuary is spatially constant with average of 28.57±0.32 degC given the January 2018 CTD data. Water temperature is also approximately temporally constant as shown in Figure 3. With these values, the possibility of success all year round based on water temperature is nearly 100% ("good").

Results based on dissolved oxygen

Range of dissolved oxygen values for optimal green mussel growth and survival is >5 mg/L. Figure 4 shows that dissolved oxygen levels in Buguey estuary fall short of the desired levels. With these values, the possibility of success based on dissolved oxygen is 57% ("medium" suitability).

Results based on pH

Range of pH values for optimal green mussel growth and survival is 7.7 to 8.4. Figure 5 shows that pH in Buguey estuary is at a risky level. The possibility of success based on pH is 50% ("poor"). However, pH has lower weight of effect compared to salinity, temperature and dissolved oxygen [2].

Results based on combined effect of factors

Based on the formulated model and data gathered, it is predicted that the possibility of success for green mussel culture in Buguey estuary is 81% to 90% ("good" suitability), considering salinity, water temperature, dissolved oxygen and pH (Table 2). Further studies need to be done to test how pH and dissolved oxygen affect mussel growth at the extreme, but their effect on mussel growth at the current condition is lesser compared to salinity and water temperature.

Mussel growth curve model

We model the growth of the average length of the bivalve using the following formula. Let X be the average length of the green mussel (in mm). The growth is described by

$$\frac{dX}{dt} = r_X X^{\beta_X}\left(1 - \frac{X}{100}\right)$$

which is characterized by combining power law and logistic models. Fitting the model to the gathered data (Figure 6), results in the following parameters:

$$r_X = 42.6876$$
$$\beta_X = -0.390873$$

given the starting length size of the transplanted bivalve, $X(0) = 1.5$ mm. Refer to the Appendix for the definition of the parameters.

We also model the average length and average width of the bivalve, combined. Let Y be the $length \times width$ of the green mussel (in sq.mm). The growth is described by

$$\frac{dY}{dt} = r_Y Y^{\beta_Y}\left(1 - \frac{Y}{K}\right).$$

Fitting the model to the gathered data (Figure 7), results in the following parameters:

$$r_Y = 39.5498$$
$$\beta_Y = 0.367204$$
$$K = 1{,}818.75$$

given starting $length \times width$ value of the transplanted green mussel, $Y(0) = 1.33812$ sq.mm.

These two models present how we can predict the growth of the green mussels in the future. In Buguey estuary, green mussels can grow 50 mm in length, which is within the standard marketable target for the period of 6 to 10 months [4].

CONCLUSION

The 81% to 90% possibility of success of Buguey estuary for green mussel farming means that 81% (medium estimate) to 90% (optimistic estimate) of the transplanted mussels will have a marketable size. In Buguey estuary, green mussels can grow 50 mm in length in 6 months. The standard growth target is 50-60 mm (length) in 6 to 10 months [4].

The calculated ratings may vary due to competition with existing oyster farming, water depth of the chosen site (since several areas in Buguey estuary are shallow), and other factors (e.g., heavy rainfall). However, we are optimistic that our conclusion will not change in the next 5 to 10 years since the environmental conditions and water quality in Buguey estuary are expected to be stable. To be able to improve the production of green mussel, technology and best practices in other locations can be adopted [6,7].

ACKNOWLEDGEMENT

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The authors declare no competing interests.

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TABLES

Table 1: Computed Salinity Scores and Possibility of Success

Minimum Salinity Score*	Maximum Salinity Score*	Possibility of Success based on salinity**
0.85	0.94	0.90

*Salinity score ≥ 1 (unitless) is ideal based on reference salinity level of 27 psu

**Possibility of success measures suitability for green mussel farming (perfect score = 1)

Table 2: Possibility of Success based on equal combined effect of factors

Possibility of Success based on salinity	0.90
Possibility of Success based on water temperature	1.00
Possibility of Success based on dissolved oxygen	0.57
Possibility of Success based on pH	0.50
Possibility of Success based on combined effect (medium estimate)	**0.81**
Possibility of Success based on combined effect (optimistic estimate)	**0.90**

FIGURES

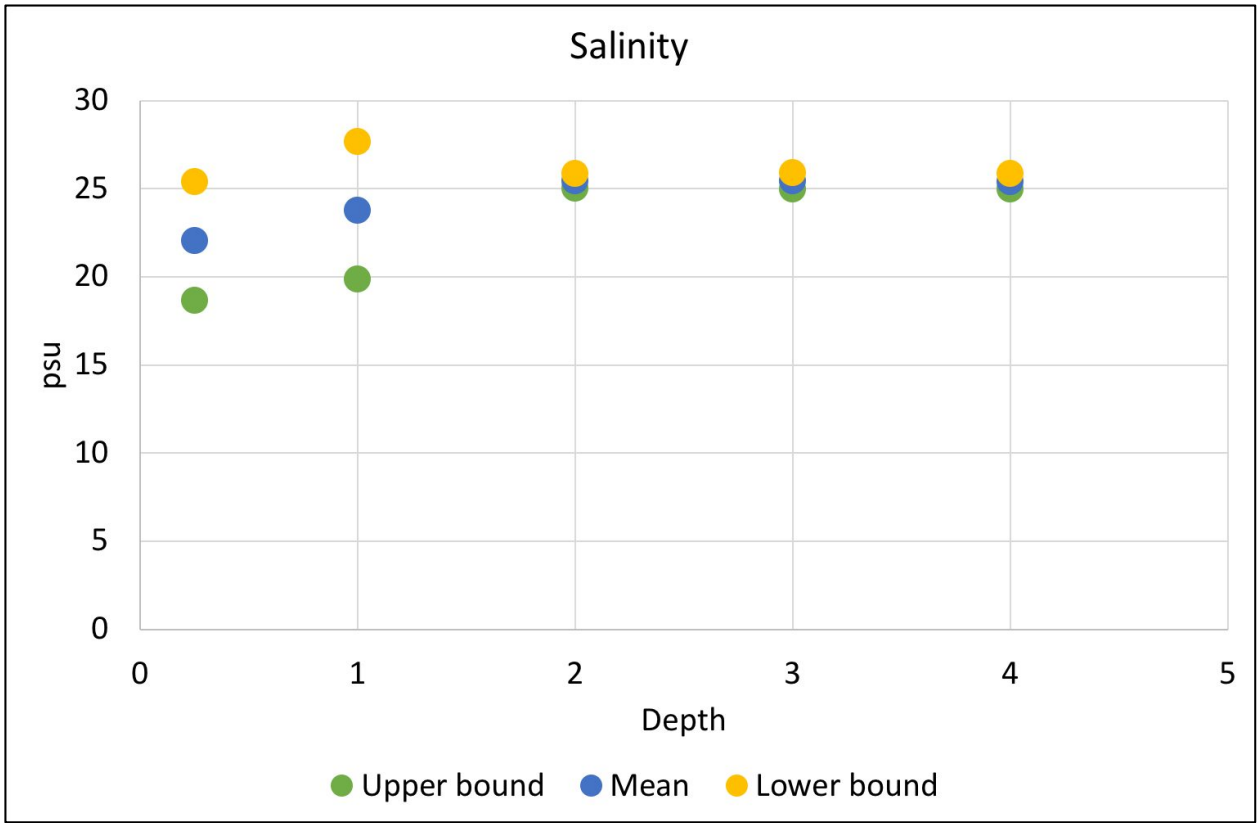

Figure 1. Average salinity levels ± standard deviation based on January 2018 CTD deployment.

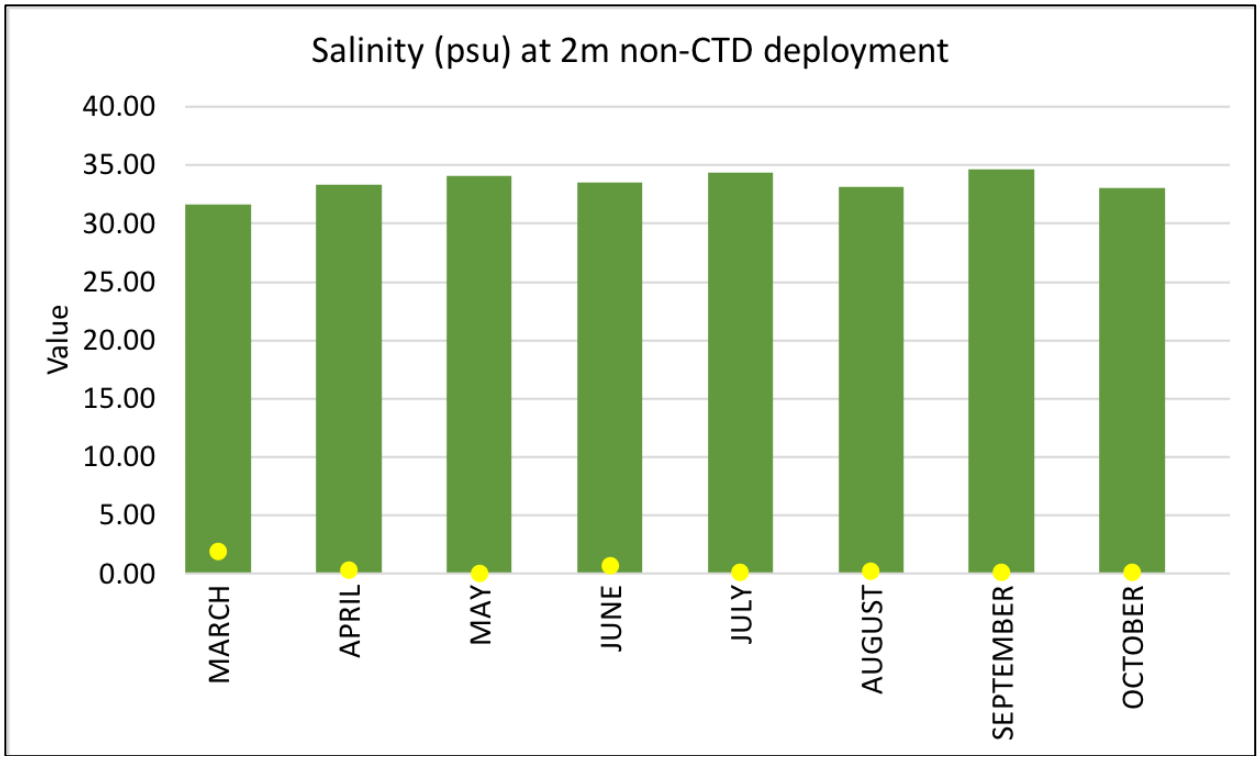

Figure 2. Average salinity levels (yellow dots are standard deviations) based on March to October 2016 data gathering.

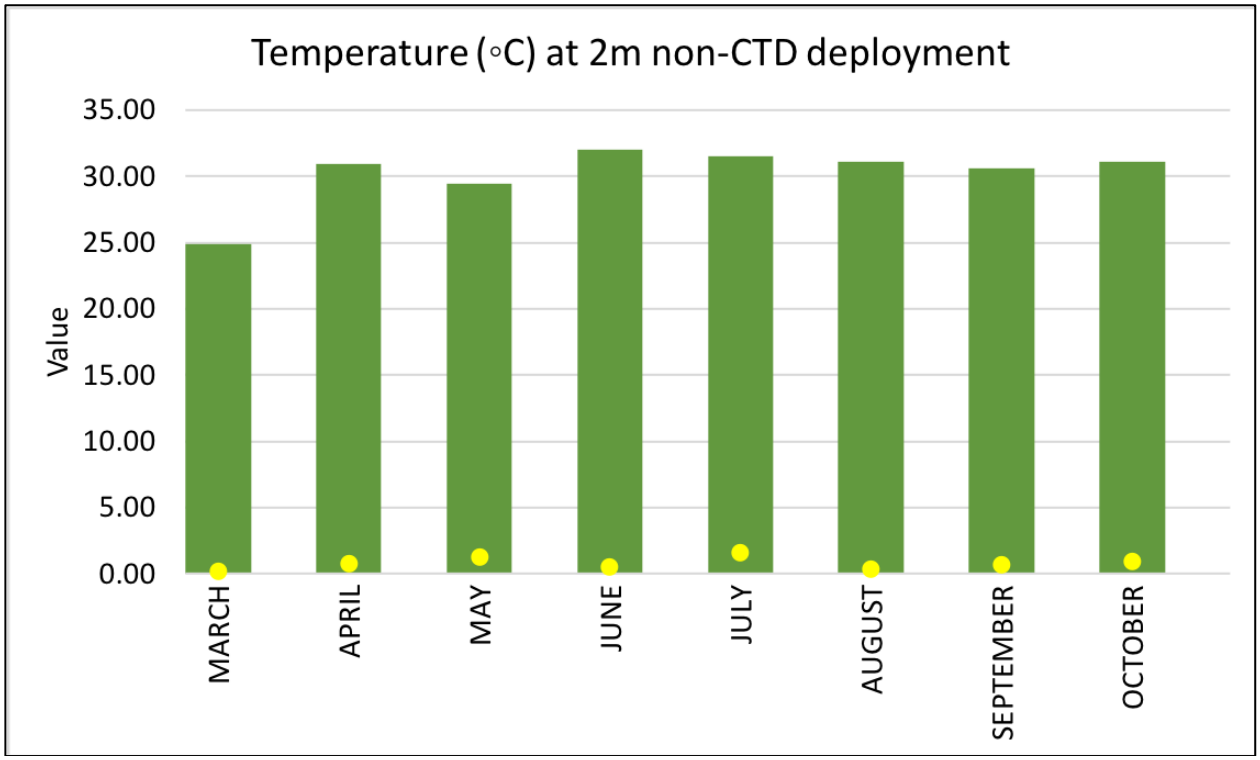

Figure 3. Average water temperature (yellow dots are standard deviations) based on March to October 2016 data gathering.

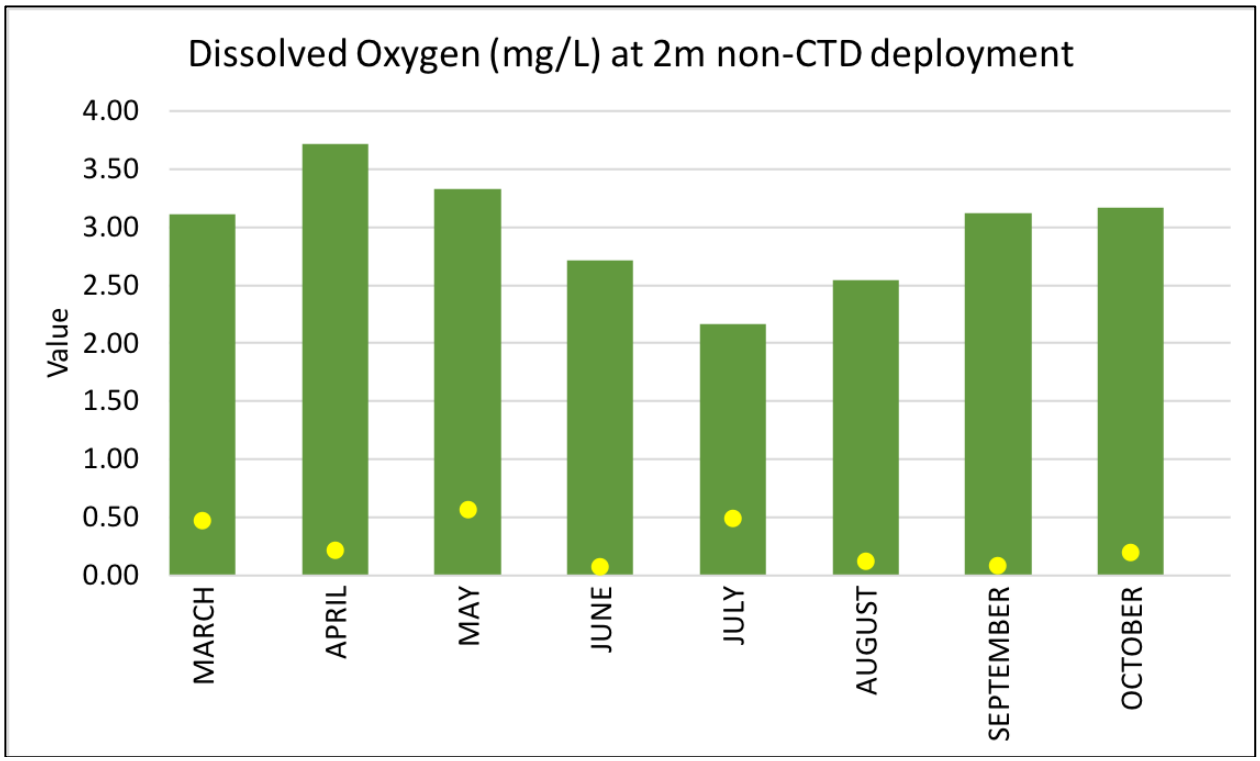

Figure 4. Average dissolved oxygen (yellow dots are standard deviations) based on March to October 2016 data gathering.

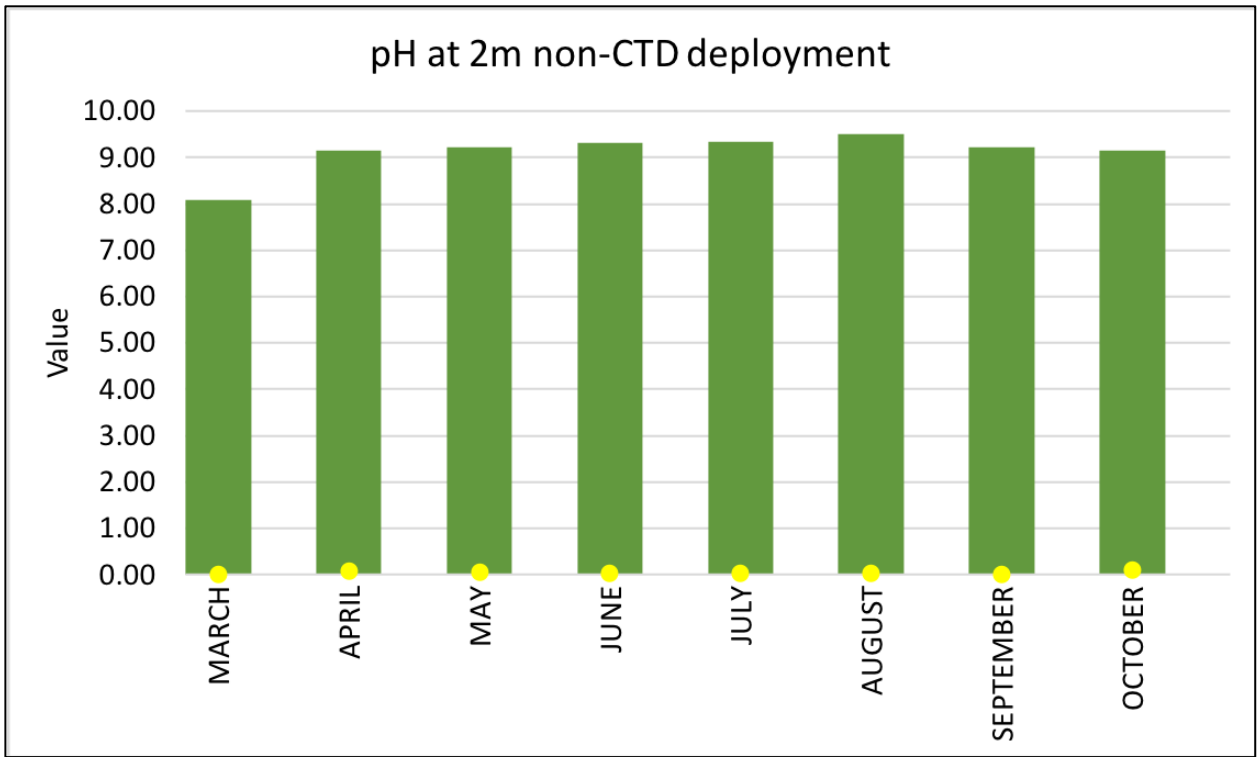

Figure 5. Average pH level (yellow dots are standard deviations) based on March to October 2016 data gathering.

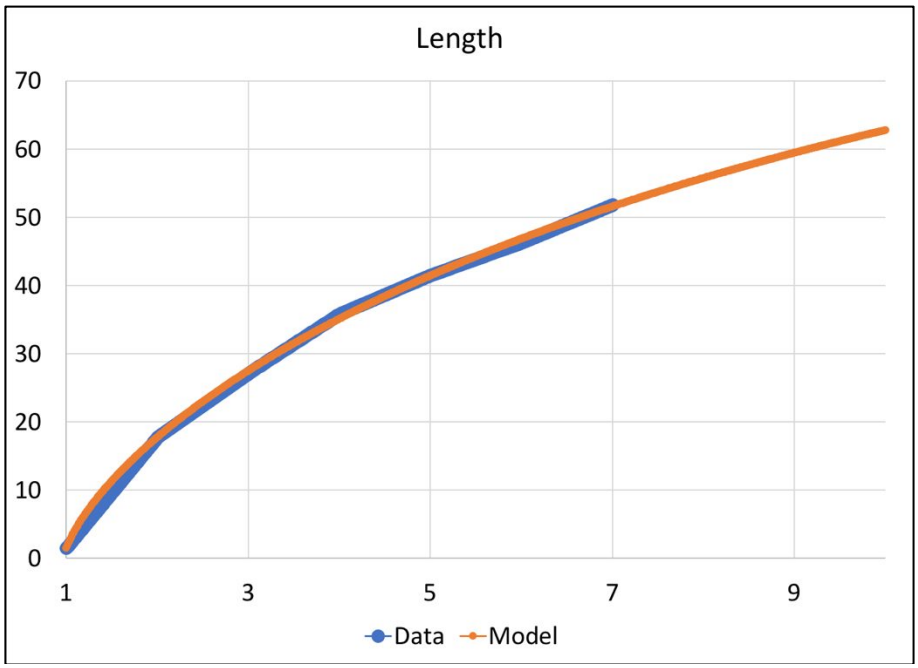

Figure 6. Green mussels in Buguey estuary attaining marketable size in 6 months. Average lengths of February-batch green mussel samples are shown in the figure. x-axis: month; y-axis: length.

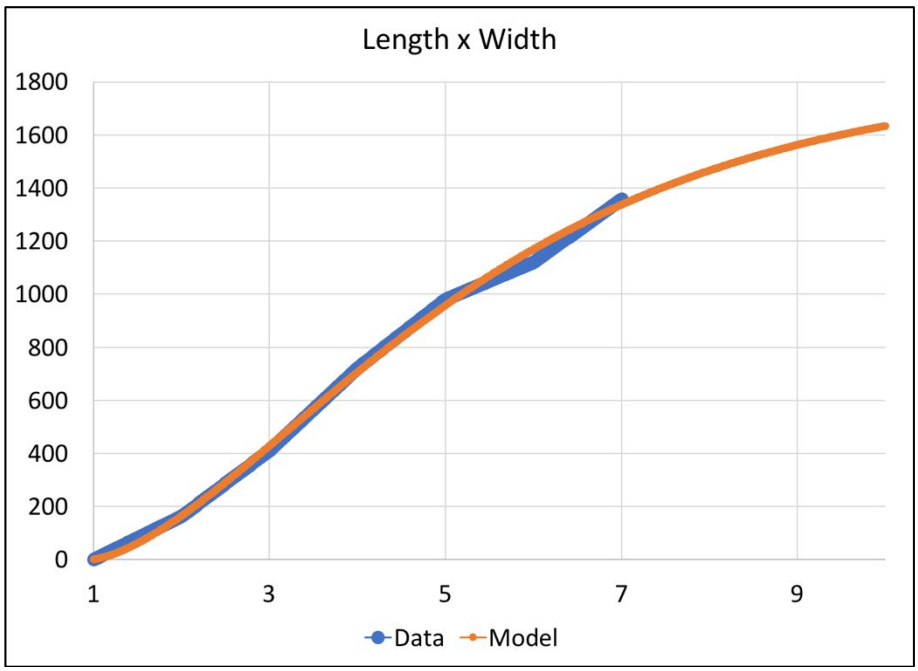

Figure 7. Length-by-width of February-batch green mussel samples vis-à-vis model. x-axis: month; y-axis: length.

APPENDIX

Figure S1. Location of Surveyed Sites. The mouth of the estuary has GPS location: Longitude 18°16.075'N, Latitude 121°54.318'E. Source: Google maps.

Equation S1: If 1 metric ton is needed, then $Number\ of\ mussels\ to\ be\ cultured = \frac{10^5}{X\%}$.

Definition of the parameters in the growth curve model:

- r is the logistic growth rate.
- β is the power law parameter (may influence the scale properties of the length and width).
- K is the maximum value of the variables.