Errata in Volume 12
Page 61: "*T. spinose*" should be "*T. spinosa*"
Page 62: "10º95'03.91"N, 123º45'48.02"E" should be "10°57'01.4"N, 123°27'17.3"E"
"10º95'04.51"N, 123º45'39.70"E" should be "10°57'01.6"N, 123°27'14.3"E"

Cover Photo

Water birds such as the Chinese Egret *Egretta eulophotes* (left), Great-billed Heron *Ardea sumatrana* (middle), and Striated Pond Heron *Butorides striata* (right) play vital roles in maintaining a balance in the species composition in the coastal habitats by feeding on a variety of other marine fauna (Photos courtesy of LJ Paguntalan were edited and merged by RG Dolorosa).

EDITORIAL

Research generates technology advancement and innovations that have made life a lot easier today than in the distant past. Our ancestors' unrelenting quest for new knowledge and the systematic means of passing it on to the next generations, have brought us into where we are today. Shared information helps us understand the past, appreciate the present, and make a plan for a better future.

Sharing of knowledge especially in the form of publication is essential in problem solving and shaping our lives. We should be thankful to those authors who without a second thought, shared what they found in their quest for truth. The great philosophers and scientists like Socrates, Plato, Charles Darwin, Carolus Linnaeus and Isaac Newton, to mention a few, had established solid educational foundations and were immortalized by their theories, inventions and published works. They will forever be remembered generations after generations for their great contributions to the body of knowledge.

The onset of advanced digital technology at the early part of the 21st century has made the sharing of information reaches a broader audience. It becomes accessible and is almost at everybody's fingertips. While we recognize that many information remained unshared, the Western Philippines University (WPU) supports and encourages the sharing of information and technology through publication in its internationally recognized, peer-reviewed multi-disciplinary research journal, The Palawan Scientist.

The whole world continues to struggle in overcoming the challenges brought by the COVID-19 pandemic which cause severe social and economic repercussions. One of the 10 articles in this 13th volume provided spread estimates of the said virus with or without measures, which can aid our policy makers in making sound decisions. The other nine equally interesting original papers are filling in essential information gaps in the fields of education, engineering, environment, biodiversity, and aquatic sciences. All these 10 articles are authored by 38 researchers coming from 18 organizations and institutions. Five authors are associated with institutions outside the Philippines. These authors form a pillar of their respective organizations. They help build a body of knowledge in their respective fields.

WPU has a strong drive for quality education, research and innovations, and will continue to provide researchers with a stable and dependable platform for the global accessibility of peer reviewed publications. As the current WPU President and as a Technical Adviser of the Palawan Scientist Journal, I assure our readers and contributors of our strong commitment and continued quest for excellence.

Mabuhay!

Julie Hope Timotea P. Evina
President, Western Philippines University

Bioethanol extraction from Coconut (*Cocos nucifera* Linnaeus) embryo using *Saccharomyces cerevisiae*

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ABSTRACT

The world oil crisis is looming as supply levels are under threat. This study is the first attempt to extract bioethanol from Coconut (*Cocos nucifera* Linnaeus) embryo using *Saccharomyces cerevisiae*. Samples of coconut embryos were collected, ground, and subjected to acid hydrolysis. These were then filtered, and the residues collected were treated with two different amounts of buffer solution. Cultured strains of *S. cerevisiae* were inoculated into the prepared Yeast Extract-Peptone-Dextrose (YPD) broth. Buffer-treated samples were then inoculated with 5 ml of the yeast solution and allowed to ferment at various times. After different fermentation times, samples were filtered, and the obtained filtrates were subjected to the distillation process for bioethanol concentration determination. Results showed that samples allowed to ferment at 72 h and 96 h yielded 7.11% and 12.22% bioethanol, respectively. The samples treated with 50 ml and 100 ml of buffer solution produced 9.02% and 10.31% bioethanol, respectively. The main effect of fermentation time on bioethanol concentration was statistically substantial such that samples allowed to ferment in 96 h yielded higher bioethanol concentration than samples permitted to ferment in 72 h. Based on the results, bioethanol could be extracted from a novel, cheap, and readily available coconut embryo using *S. cerevisiae*.

INTRODUCTION

Due to the continuous annual oil consumption, the reserves are quickly being depleted, with scientists predicting that at the current rate of use, in just 40 years, the entire fossil fuel supply will run entirely out (Lazkano et al. 2017). While oil has numerous uses in the global community, burning it increases the trace gas concentration in the atmosphere and causes environmental problems. The global annual energy demand of over 12 GT of oil results in the emission of 39.5 GT of carbon dioxide, and the yearly emission of this gas would increase up to 75 GT when future energy demand will rise to 24–25 GT of oil (Abas et al. 2015). The produced carbon dioxide gas, a principal constituent of greenhouse gases, is accountable for global warming and other harmful effects to the ecosystem, such as the melting of ice caps and glaciers, reduction of dissolved oxygen in oceans, death of coral reefs and drought (Shakun et al. 2012).

The world community supported the grand energy transition from fossil fuels to renewable and more economically viable alternative fuel sources to decelerate climate change and develop sustainable energy resources for domestic and industrial uses. Previous research found out that hydroelectric power, fuel cells, solar energy wind power, and bioethanol were feasible as renewable and alternative energy sources (Bhatia 2014; Zou et al. 2016; Islam et al. 2018).

Bioethanol, a clear, colorless, and biodegradable liquid known to be a potential alternative to gasoline, is the best alternative fuel to replace the current fossil fuel. It is most commonly formulated with liquid gas in concentrations of 10% bioethanol to 90% gasoline, known as E10, and nicknamed gasohol. When used, it burns up to 75% cleaner than fossil fuels. The fermentation process produces this energy source from the crops that are rich in carbohydrates. Reports available suggest that previous natural substrates for bioethanol production have included wheat straw, corn, and sugarcane bagasse (Schwietzke et al. 2009; Talebnia et al. 2010; De Souza et al. 2014). However, these substrates yielded smaller amounts of bioethanol, and the processes of extraction were too expensive to sustain.

The Food and Agriculture Organization of the United Nations (FAO 2017) reported that the Philippines is the world's largest producer of coconuts, producing 14,049,131 T . However, there are lots of unused excess parts of it, notably the embryo, which is called "Buwa" in Philippine vernacular. These are wastes and sometimes, used as animal feed, and may contribute to the country's garbage problem. Furthermore, the country is experiencing an issue in waste management. According to Remo (2017), about 35,000 tons of municipal solid waste is generated by the Philippines daily. These wastes would accumulate, taking up valuable real estate and become a source of land

pollution. As a solution to this problem, researchers came up with a study about the bioconversion of these waste products.

When a coconut fruit falls from the bush, the water inside after some time converts into a tissue-sponge. This tissue nourishes and helps in the germination of a new plant that will become another coconut tree. This sponge is called a coconut embryo. Coconut fruit, along with coconut embryo, composed of 60% carbohydrates (Decker 2018), making it a viable substrate for bioethanol.

Previous reports explored the bioethanol yield from coconut husk fiber (Goncalves et al. 2015; Cabral et al. 2016) and produce a comparable concentration. The potency of coconut waste water was also explored and estimated to produce ethanol at a rate of 50-60 kg day^{-1}; however, the study found that the material has higher potential for producing alcoholic beverage for profitability. Based on the review, there appears to be no published study that has assessed the potential of using coconut embryo as substrate for bioethanol production. For this reason, the coconut embryo, an unexploited material of coconut, is worthwhile to investigate.

Bioethanol production from carbohydrate feedstocks such as coconut embryo, requires fermentation process. This process is carried out by various microorganisms such as fungi, yeasts, and bacteria. The yeast *S. cerevisiae* is the most widely used and studied organism for bioethanol production at both household and industry levels (Tesfaw and Assefa 2014). It is superior to fungi, bacteria, and other yeasts because of its ability to hasten the fermentation process (Goncalves et al. 2015; Azhar et al. 2017). In addition, it tolerates a wide range of temperature and pH, two most essential variables that affect yeast growth and bioethanol production (Benjaphokee et al. 2012). *Saccharomyces cerevisiae* is generally regarded as safe for human consumption which improves its advantageous application more than other yeasts and microorganisms. Several studies found that the use of *S. cerevisiae* in the fermentation of coconut products such as husk fiber and water, produced the greatest bioethanol concentration compared to other microorganisms (Goncalves et al. 2015; Azhar et al. 2017).

The present study aimed to analyze the potential of Coconut (*C. nucifera* L.) embryo extract as an alternative source of bioethanol using *S. cerevisiae*. It also sought to examine the effect of fermentation time and the amount of buffer on bioethanol production. In doing so, it also attempted to come up with an alternative bioethanol source that is cheap and readily available.

METHODS

Collection and Acid Hydrolysis of Sample

Coconut embryos (Figure 1) were collected from an authorized local coconut shop at Davao City, Philippines. The shop grows non-genetically modified coconuts in an organic method. Before collecting the embryos, all coconut fruits were submitted to a Botanist for taxonomic identification and verification of botanical specimen (Certificate #2019-00124). After verification, the samples were washed with 5% potassium permanganate solution and distilled water to disinfect and remove any debris (Ma et al. 2015). These were then ground into pulp using a house blender and placed in a 1,000 ml glass beaker. The ground sample was then subjected to acid hydrolysis.

Figure 1. Coconut (*Cocos nucifera* Linnaeus) embryo.

A weight of 800 g of the ground sample was added to 1,000 ml of 5% sulfuric acid. The utilization of 5% sulfuric acid solution was based on the study of Kuhad et al. (2010). The sample was then filtered using Whatman 11 µm-filter paper. The residue was then set aside at room temperature while the filtrate was discarded.

A weight of 50 g of the residues was equally transferred to eight 1,000 ml Erlenmeyer flasks. The flasks were then grouped into two; the first group, labeled as A, contained 50 ml of the prepared 2% sodium hydroxide buffer with a pH of 9.25 while the second group, labeled as B, contained 100 ml of the same buffer.

Preparation of the Culture and Inoculation Procedure

The preparation of the Yeast Extract-Peptone-Dextrose (YPD) broth followed the procedures of Ho et al. (2006). The medium was prepared in a flask by mixing 50 g of YPD agar to 1,000 ml of distilled water. The medium was brought to boil for one minute using the hot plate and stirred

continuously. The solution was allowed to cool, and the mouth of the flask was covered tightly with a cotton plug wrapped with aluminum foil, and finally sealed with indicator tape. The container was stored away from light at 2-8°C to avoid loss of moisture.

The inoculation procedure followed the steps of Guevara (2005). Cultured strains of *S. cerevisiae* or Baker's yeast were inoculated into the prepared YPD broth. This mixture was then shaken for 10 minutes before inoculation into the fermentation medium.

Fermentation

All of the eight flasks containing 50 g of the sample and different amounts of 2% sodium hydroxide buffer (50 ml and 100 ml) were inoculated with 5 ml suspension of *S. cerevisiae*. The containers that were previously divided into two were further divided into two subgroups, forming two replicates at each buffer-fermentation time combination. These were labeled depending on the amount of buffer used and fermentation time (Table 1). The fermentation times, 72 h and 96 h, are standard bioethanol production parameters used to determine the minimum perceptible effect of fermentation time on bioethanol concentration; hence, these values were previously used in several studies (Srimachai et al. 2015; Hossain and Jalil 2017).

Bioethanol evaporation was intercepted, and aerobic conditions were kept by placing plugs on all flasks (Figure 2). After their fermentation times, the fermented sample was filtered using cheesecloth, and the filtrate of each flask was subsequently submitted for chemical analysis.

Table 1. Preparation of sample under different fermentation parameters.

Flask Code	Amount of Buffer (ml)	Fermentation Time (h)
XA1	50	72
YA1	50	72
XA2	50	96
YA2	50	96
XB1	100	72
YB1	100	72
XB2	100	96
YB2	100	96

Bioethanol Determination by Distillation

The filtrates contained in the flasks of the two groups were sent to Science Resource Center–University of the Immaculate Conception, Davao City for bioethanol determination using the distillation method. Samples of each liquid filtrate in each of the flasks were loaded to the distillation equipment for chemical analysis, and the results of the test were recorded and analyzed.

Figure 2. Flasks containing samples for fermentation.

Statistical Analysis

The experiment was conducted in three repeated trials to increase the validity of the results. The three trials (T1, T2 and T3) were conducted between 07 January and 02 February 2019, and each trial lasted 4 days. Mean ± standard deviation (SD) was used to express the average concentration of bioethanol produced per trial for three trials and the variability of the said concentrations. A two-way analysis of variance was employed to determine if there is a significant difference in the concentration of bioethanol produced when fermentation times and amounts of the buffer are varied. Furthermore, this was used to determine if there is a significant interaction between the varied fermentation times and the amounts of the buffer used. To confirm where the differences occurred between groups, pairwise comparisons using Bonferroni correction was employed. A P-value <0.05 was considered as statistically significant. The data were analyzed using the trial SPSS version 23.0 software package.

RESULTS

The samples that were treated with 100 ml buffer solution and allowed to ferment in 96 h yielded the highest bioethanol concentration at 16.05±0.01% compared to others (Table 2). On the other hand, the samples that were treated with 100 ml buffer solution and allowed to ferment at 72 h produced the lowest bioethanol concentration at 4.57±0.01%.

Table 2. Concentration (% weight by volume) of bioethanol produced after 72 h and 96 h fermentation and using 50 ml and 100 ml of buffer solution in three trials (% w/v means % weight by volume).

Flask Code	Amount of Buffer (ml)	Fermentation Time (h)	Bioethanol Concentration (% w/v)						
			T1	Mean ± SD of T1	T2	Mean ± SD of T2	T3	Mean ± SD of T3	Overall Mean ± SD
XA1	50	72	9.68	9.65 ± 0.05	9.68	9.65 ± 0.05	9.68	9.66 ± 0.04	9.65 ± 0.01
YA1	50	72	9.61		9.61		9.63		
XA2	50	96	8.39	8.39 ± 0.01	8.42	8.39 ± 0.04	8.42	8.41 ± 0.02	8.39 ± 0.01
YA2	50	96	8.38		8.36		8.39		
XB1	100	72	4.60	4.57 ± 0.05	4.61	4.58 ± 0.05	4.60	4.56 ± 0.06	4.57 ± 0.01
YB1	100	72	4.53		4.54		4.52		
XB2	100	96	16.1	16.04 ± 0.08	16.07	16.04 ± 0.05	16.07	16.06 ± 0.01	16.05 ± 0.01
YB2	100	96	15.98		16.00		16.05		

There was a statistically significant interaction between the effects of fermentation time and amount of buffer on bioethanol concentration, F=89.54, $P<0.01$ (Table 3). The table also presented the value of adjusted R squared which tells that 95.5% of the variance in bioethanol concentration is attributed to fermentation time and amount of buffer.

Table 3. Two-way ANOVA in the interaction effect of fermentation time and amount of buffer. *$P<0.05$. **$P<0.01$.

Source	F-statistic
Fermentation time	57.73*
Amount of buffer	3.67
Fermentation time * Amount of Buffer	89.54**
R Squared = 0.974 (Adjusted R Squared = 0.955)	

At 72 h, the samples treated with 50 ml buffer solution yielded a statistically higher bioethanol concentration compared to those treated with 100 ml buffer solution ($P<0.01$) (Table 4). At 96 h, the samples treated with 100 ml buffer solution yielded a statistically higher bioethanol concentration compared to those treated with 100 ml buffer solution ($P<0.01$).

Table 4. Pairwise comparisons of bioethanol concentration by amount of buffer using Bonferroni correction. **$P<0.01$.

Fermentation Time (h)	Amount of Buffer (ml)	Bioethanol Concentration (% w/v)	Mean Difference
72	50	9.65	-5.08**
	100	4.57	
96	50	8.39	7.66**
	100	16.05	

Using 50 ml buffer solution, the samples fermented at 72 h yielded a comparable bioethanol concentration compared to those fermented at 96 h ($P>0.05$) (Table 5). Using 100 ml buffer solution, the samples fermented at 96 h produced a statistically higher bioethanol concentration compared to those fermented at 72 h ($P<0.01$).

Table 5. Pairwise comparisons of bioethanol concentration (% weight by volume) by fermentation time using Bonferroni correction. **$P<0.01$.

Amount of Buffer (ml)	Fermentation Time (h)	Bioethanol Concentration (% w/v)	Mean Difference
50	72	9.65	-1.26
	96	8.39	
100	72	4.57	11.48**
	96	16.05	

DISCUSSION

In this study, bioethanol was extracted from coconut embryos using *S. cerevisiae* and the interaction effect of fermentation time and amount of buffer on bioethanol yield was analyzed. The study produced bioethanol at 7.11-12.11% w/v which is higher compared to that of pineapple waste at 0.09% w/v, sweet potato waste at 0.079% w/v, Indian water chestnut waste at 0.045% w/v, and jackfruit waste at 0.045% w/v (Gosavi et al. 2017). The bioethanol yield was also higher compared to that of pretreated seagrass at 0.047% w/v (Ravikumar et al. 2011). Meanwhile, the standard deviations of bioethanol concentration across all samples ranged from 0.01-0.08. This is highly indicative that the measurements conducted in two replicates for three repeated trials were homogenous and means across the samples did not vary, thereby, increasing the validity of the study results (Hopkins 2017).

The amount of sugars, such as sucrose, fructose, and glucose, present in a material determines the bioethanol produced during fermentation. In the biochemical process, the sugar is converted into ethanol and carbon dioxide. Hence, the materials with higher amount of sugar would yield higher bioethanol compared to those with lower amount of sugar. In this study, the total sugar content of coconut embryos was not examined; however, the sample used may have higher sugar content compared to the samples used in the previous studies based on the previous theoretical assumption. To date, there is no existing study which analyzed the sugar content of coconut embryos; hence, preliminary test of total sugar estimation may be conducted in the future.

Simple main effect analyses were conducted using Bonferroni correction. The fermentation time of 96 h produced higher bioethanol concentrations than 72 h fermentation time. This finding is similar to previous reports of Fahrizal et al. (2013) and Sheikh et al. (2016). Based on their experiments, bioethanol yield increases from 24 h to 96 h fermentation time. However, bioethanol concentration decreases after 96 h. The decrease

of bioethanol concentration after 96 h may be attributed to the decline in the total sugar content of the sample as most of its sugar were already converted to ethanol in the previous hours of fermentation (Fahrizal et al. 2013). Fermentation times beyond 96 h may be noteworthy to investigate in the future. While previous studies corroborate the findings of the present study, several scholarly works revealed that decreasing fermentation time results to improved bioethanol yield. El-Mekkawi et al. (2019) reported that bioethanol yield increases to 94% as the fermentation time is decreased from 72 h to 48 h. In their study, Gutierrez et al. (2015) demonstrated that the bioethanol yield decreases due to the formation of acetic acid, pyruvic acids, and lactic acids. These acids increase linearly with time and could significantly decrease the pH of the fermented sample and the production of ATP, which is critical to the survival of *S. cerevisiae*.

The bioethanol concentration did not significantly differ in samples treated with varied amounts of buffer. This finding is contradictory to the study of Kundiyana et al. (2011). Their report showed that samples treated without morpholinoethanesulfonic (MES) acid produced higher ethanol concentration. Future studies may be conducted to test for the effect of different types of buffer on bioethanol concentration.

This study successfully extracted bioethanol from coconut embryos; however, several limitations may be looked in the future. The distillation method may underestimate the ethanol content of the sample (Togarepi et al. 2012); hence, an accurate ethanol determination method such as gas chromatography may be used in the future. Other parameters such as pH may be considered to optimize the bioethanol yield. Although the present study did not extract pure ethanol for application in vehicles, this study is the first to successfully determine the ethanol content of processed coconut embryos. Nevertheless, the study came up with a novel bioethanol source that is cheap and readily available.

ACKNOWLEDGMENTS

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eS²MART Teaching and learning material in chemistry: Enhancing spatial skills thru augmented reality technology

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ABSTRACT

This study developed a teaching and learning material (TLM) in chemistry entitled eS²MART TLM with integrated augmented reality (AR) technology and assessed its effect on students' learning gains in terms of spatial skills and students' learning experience on the use of augmented reality as a tool in understanding atomic theory, chemical bonding and molecular structure. The present study utilized the design-based research paradigm in the development of AR-enabled teaching and learning material while the assessment of the effect of using the developed material on learners' spatial skills employed the pre-experimental single group design. To provide the AR component of the TLM, this study also developed a database of intuitive virtual 3D objects and animations that can be manipulated by tactile controls, a dedicated mobile application software called eS²MART TLM designed to retrieve, display, and control the virtual 3D objects, and unique trackers for each virtual 3D object and animation that were printed in eS²MART TLM. A pretest and posttest using standardized spatial skills test composed of seven Purdue Spatial Visualization Test (PSVT) items and 13 content-specific items were administered to the participants before and after using eS²MART TLM. Using Hake factor test, the study found out that student participants obtained a normalized gain value of 0.50 on the PSVT spatial visualization test which signifies medium learning gain and a normalized gain value of 0.76 on the Content Specific Spatial Skills Test which indicates high learning gain. In terms of learning experience, there is an overall very positive learning experience on the use of augmented reality in eS²MART TLM as implied by the composite mean value of 3.54.

Keywords: educational technology, virtual molecules, mobile learning, chemical education, STEM

INTRODUCTION

Augmented Reality (AR), an emergent technology with great possibilities for its use is slowly being adapted as an effective tool in education which results to enhanced learning achievement and positive attitudes toward learning activities (Akçayir and Akçayir 2017). Augmented Reality is defined as "a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual" (Klopfer and Squire 2008) and combines digital and physical information in real time through different technological formats such as tablets or smartphones to create this new reality (Fombona et al. 2018). When compared with other technological pedagogical resources like multimedia resources and traditional teaching tools, there is higher learning gains when AR is used (Garzon and Acevedo 2019).

Augmented Reality is a cost-effective technology for providing students with more attractive contents than paper alone and that learners are comfortable in using AR for practical and theoretical content (Martín-Gutiérrez et al. 2015b). According to Cabero-Almenara et al. (2019), future research should focus on the creation of instructional materials with AR technology and should investigate how AR objects should be utilized and developed for their use. Furthermore, Garzon and Acevedo (2019) suggested that there should be an assessment of knowledge or skill that could specifically be attributed to AR.

Spatial skills are one of the student attributes that has long been identified as an essential skill in the science, technology, engineering and mathematics (STEM) disciplines. (Stieff 2007; Sorby 2009; Davidowitz and Rollnick 2011). In the field of chemistry, spatial skills is important in visualizing abstract concepts like atomic and molecular structure, Valence Shell Electron Pair Repulsion theory and hybridization of molecular orbitals, to name a few. It is an important skill that must be developed among students in introductory chemistry course because of its application in advanced chemistry courses like organic chemistry, biochemistry and physical chemistry. However, studies have shown that only a few percentage of students have the spatial skills necessary to succeed in early STEM coursework (Wai et al. 2009; Uttal and Cohen 2012), making the teaching of spatial skills important in chemistry education and STEM disciplines in general.

Based on the premises discussed above, the researcher considers the need to develop a teaching and learning material that incorporates the use of augmented reality. Furthermore, the researcher also believes that augmented reality can be used to enhance the students' spatial skills, an important student attribute in the STEM discipline, because of its capability to rescale virtual images and provide real-time visualization of molecules, atoms and other chemical species through tactile manipulations of their virtual 3D images.

Hence, this study intended to measure the effect of using Augmented Reality in eS²MART Teaching and Learning Material on the students' spatial skills and assess the students' learning experience in the use of eS²MART Teaching and Learning Material.

METHODS

Study Site

This study was conducted at Batangas State University (BatStateU) Integrated School–Senior High School Department, Main Campus I, located at Rizal Avenue, Batangas City. Batangas State University only offers STEM discipline in its Senior High School curriculum to prepare students for the STEM programs in the university.

Research Design

The development of the eS²MART teaching and learning material utilized the design-based research paradigm while the assessment of the impact of the developed material on learners' spatial skills used the pre-experimental single group design utilizing one intact class.

The goal of the design-based research is to "offer the relationship between theory-design-implementation through embodying the principles about teaching and learning" (Cengizhan 2007) "to address complex problems in educational settings" (Sari and Lim 2012) while "supporting design and development of prototypical products to solve complex authentic context-specific problem" (Lai et al. 2009). The prototypical product in this study refers to eS²MART TLM.

Participants of the Study

The participants of the study were composed of Grade 11 STEM students who were taking up General Chemistry 1. The result of Kolmogorov-Smirnov (K-S) statistical test on their spatial skills pretest revealed that the data set is well modeled by a normal distribution as evidenced by the P-values which were greater than the alpha value of 0.05.

Research Instrument

To determine the level of spatial skills among the participants, the researcher adapted the Spatial Reasoning Test developed by Carlisle (2012). This test was designed to measure spatial skills in chemistry and was measured to have Cronbach's alpha of 0.65, signifying an acceptable internal

consistency and reliability. The first part of the test consists of seven items that were lifted from Purdue Spatial Visualization Test (PSVT) - a standardized test that was usually administered to measure cognitive spatial skills (Bodner and Guay 1997; Brownlow et al. 2003; Morgil et al. 2005). A sample of this test question is presented in Figure 1A.
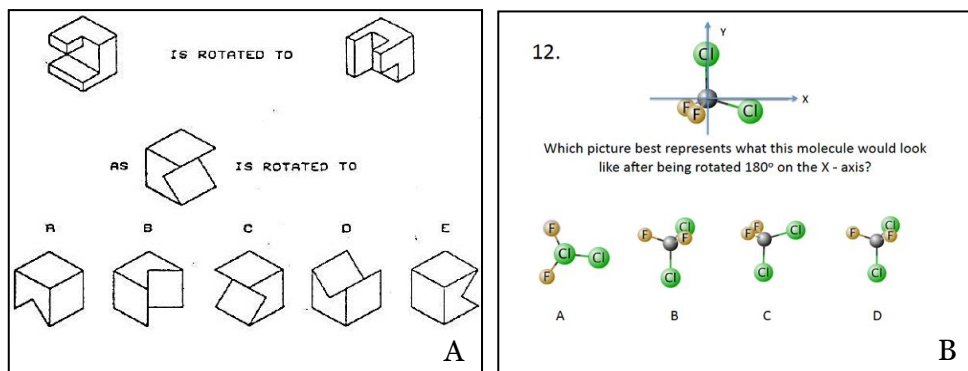
Figure 1. Example of Purdue Spatial Visualization Test (PSVT) item in the Spatial Skills Test (A); and example of content-specific item in the Spatial Skills Test (B).

The second part consists of thirteen content-specific questions on chemistry that were related to spatial skills (Figure 1B). The questions on the content-specific test of spatial skills covered the topics of chemical bonding and VSEPR theory. These contents were selected because of their relevance to spatial skills in chemistry, like mental rotations of three-dimensional molecular structures, and visualization of molecular structures from different perspectives that requires spatial orientation and spatial relations.

Research Procedure

The present study was conducted in five successive phases. The first phase was the analysis of the instructional problem which involved a review of literature in order to understand the problem and setting of research objective.

The second phase was designing the features of eS²MART TLM which incorporated the instructional approach of using innovative technology through AR. This phase also involved reviewing the Department of Education's (DepEd) K to 12 chemistry curriculum for senior high school. From this, the topics that will be included in eS²MART TLM were selected and an outline was made.

The third phase was the development of eS²MART TLM which implemented the design features crafted in the second phase. Concurrent with the development of the printed teaching and learning material was the design and development of original AR database of virtual 3D objects and a dedicated mobile application software called eS²MART TLM for the retrieval, display and manipulation of intuitive 3D objects and animations. The augmented reality component of the teaching and learning material was designed and specified by the researcher based on the need and suitability of the lesson.

However, its development was consigned to a computer programmer who built the prototype needed in this study. Each of the AR virtual object and animation has a unique tracker that was strategically placed in the accompanying teaching and learning material. The mobile application software called eS²MART TLM was used to retrieve and display the AR objects and animations in the teaching and learning material.

Examples of AR objects that were included in the database are 3D images of molecules (Figure 2A). These AR objects are intuitively designed and can be rotated and zoomed through tactile manipulations on the screen of smartphones (Figure 2B). Because of this, students can view the molecule from any angle by just simple hand controls, strengthening the mind and hand coordination in learning. Likewise, the rotation of 3D molecules in real time gave the students a visual perspective of the actual orientation of molecules.
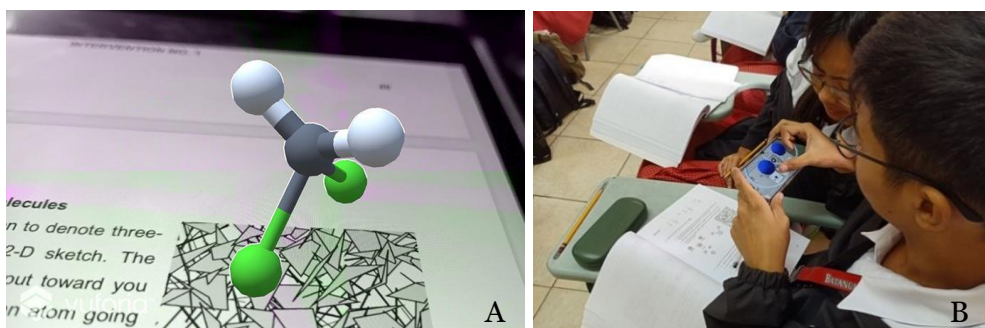
Figure 2. Augmented Reality virtual image of dichloromethane (CH_2Cl_2) molecule (A); and a student controlling the Augmented Reality virtual animation of covalent bonding through tactile manipulations on their smartphones (B).

To further maximize the augmented reality component of eS²MART TLM and provide exercises that can develop spatial skills, four intervention activities were also included in the developed material. The intervention activities include guided instructions that required observing and manipulating AR molecules from their mobile phones and then sketching and drawing these molecules from different angles. Prior to the utilization of

eS²MART TLM, five chemistry professors evaluated the material using DepEd's Learning Resources Management and Development System (LRMDS) Evaluation Rating Sheet for Print Resources. Results revealed a mean score of 27.4 in terms of content, 71.6 in terms of format, 19.4 in terms of presentation and organization, and 24 in terms of accuracy and up-to-datedness of information. A score of 21, 54, 15 and 24 are needed in order to pass the criteria for content, format, presentation and organization, and accuracy and up-to-datedness. Thus, eS²MART TLM passed the standard evaluation for print resources set by the Department of Education and was approved for use as a resource material for chemistry course.

The fourth phase was the utilization of eS²MART TLM in the teaching and learning of General Chemistry 1 course. Student participants were given free copies of eS²MART TLM and the accompanying mobile application software that they have downloaded and installed in their mobile phones.

To establish rapport between the researcher and the participants, and to make the students knowledgeable and confident on the use of augmented reality, the researcher handled the participants and used eS²MART TLM one month prior to the actual study. During this period, the students were immersed on the use of eS²MART TLM in the discussion of atomic theory and quantum numbers. These topics were outside the scope of the present study. The spatial skills pretest was administered during the first week of the study while the posttest was administered at the conclusion of the study.

The fifth phase was the evaluation of eS²MART TLM in terms of its effect on the spatial skills of students, its level of acceptability and the overall learning experience of the students. Results of the spatial skills pretest and posttest provided data for calculating the average normalized gain, g. This test was used to evaluate the effectiveness of using AR in eS²MART TLM on enhancing students' spatial skills. The following coefficient range for g was utilized: a value between 0.10–0.30 denotes low gain, 0.31–0.70 signifies medium gain and 0.71–1.0 equates to high gain.

To further investigate where the students showed the most improved skill area, the learning gains in the three attributes of spatial skills which are visualization (VZ), spatial orientation (SO) and spatial relations (SR) were also measured. The test items in the standardized test were categorized based on which skill area/s was/were used in answering the question. Ten items that include numbers 1–7, 11, 13, and 15 fall under Visualization Skills, five items that include numbers 9, 12, 14, 16, and 18 fall under Visualization and Spatial Orientation, and lastly, five items including numbers 8, 10, 17, 19, and 20 falls under visualization, spatial orientation, and spatial relations. Figure 3 shows a test item that requires all these three skill areas.
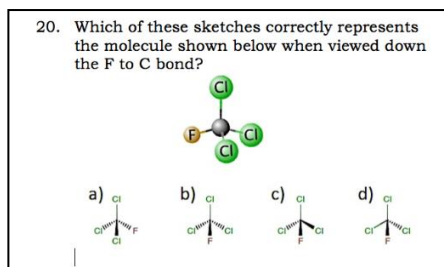
Figure 3. Test item that requires VZ-SO-SR skill area.

Finally, the mean and standard deviation (±SD) were the statistical tools utilized in assessing the students' learning experience on the use of eS²MART teaching and learning material.

RESULTS

Effect of AR Component of eS²MART TLM on Students' Spatial Skills

The spatial skills had medium gain in the Purdue Spatial Visualization Test (PSVT) and high gain in the Content-Specific Test Items. The medium gain in the PSVT component may be attributed to the high pretest scores of the students (Table 1).

Table 1. Average normalized gains (g) and standard deviation (±SD) for spatial skills of student participants.

Test Component	Pretest	Posttest	g	(±SD)	Interpretation
Purdue Spatial Visualization Test (PSVT)	0.84	0.92	0.50	(±0.26)	Medium Gain
Content-Specific Test	0.71	0.93	0.76	(±0.18)	High Gain

In terms of frequency distribution, majority (75%) of the students obtained medium learning gains under the PSVT component. On the other hand, 68% of the students obtained high gains under the content-specific spatial skills test (Table 2).

Table 2. Frequency distribution of Hake Factor interpretation of results in terms of test component. F-frequency.

Hake Interpretation	Test Component			
	Purdue Spatial Visualization Test (PSVT)		Content Specific Spatial Skills Test	
	F	%	F	%
High Gain	5	11.36	30	68.18
Medium Gain	33	75.00	1	2.27
Low Gain	6	13.64	13	29.55
Total	44	100.00	44	100.00

It can be deduced that the intervention activities designed to enhance spatial skills are effective in terms of content specific spatial skills as evidenced by the percentage of students that obtained high gains in this particular test.

All of the students recorded medium gains in all three spatial skill areas (Table 3). From the pretest scores, test items that require visualization skills (VZ) only, obtained the highest average scores while test items that require an interplay of all three spatial skill areas of visualization (VZ), spatial orientation (SO) and spatial relations (SR) obtained the lowest scores. Visualization skills require an ability to imagine molecules from different perspectives by mentally changing their point of view or reference. It is understandable that without exposure to any learning intervention, students can demonstrate higher spatial skills that require only one skill area than one that requires two or more skill areas.

Table 3. Average normalized gains (g) and standard deviation (±SD) for spatial skills of student participants. VZ-visualization; SO-spation orientation; SR–spatial relations.

Skill	Pretest	Posttest	g	(±SD)	Interpretation
VZ	0.76	0.88	0.50	(±0.19)	Medium Gain
VZ-SO	0.73	0.83	0.37	(±0.15)	Medium Gain
VZ-SO-SR	0.64	0.85	0.58	(±0.39)	Medium Gain

However, after using augmented reality technology in depicting virtual molecular models in the intervention exercises, test items that require all spatial skills area (VZ-SO-SR) registered the highest normalized gain value of 0.58 (±0.39). It was followed by test items that require visualization (VZ) skills and lastly, those that require visualization and spatial orientation (VZ-

SO) skills. This only shows that AR is an effective tool in improving all of the spatial skill areas (Table 3).

Majority of the students obtained low learning gain in the test items that require visualization skills only. This is not to say that they performed poorly, but rather the low gain was attributed to the high pretest scores in these type of test items, which mostly consists of the PSVT items. The effectiveness of using AR in the developed material could be seen in the VZ-SO skill area where majority of the students fall under medium learning gain and most especially in the VZ-SO-SR skill area where the students registered medium and high learning gains. This further corroborates the result in Table 3 which shows that the highest average normalized gain value among the three spatial skill areas belong to VZ-SO-SR category (Table 4).

Table 4. Frequency distribution of Hake Factor interpretation of results in terms of spatial skills area. VZ-visualization; SO-spatial orientation; SR-spatial relation; F-frequency

| Hake Interpretation | Spatial Skills Area | | | | | |
| | VZ | | VZ-SO | | VZ-SO-SR | |
	F	%	F	%	F	%
High Gain	6	13.64	0	0.00	15	34.09
Medium Gain	5	11.36	35	79.55	22	50.00
Low Gain	33	75.00	9	20.45	7	15.90
Total	44	100.00	44	100.00	44	100.00

When students were asked if they feel it's important to be able to imagine or visualize molecules in 3D, all of them provided affirmative answers as they reason that it is critical to understand the structure of molecules. It can be deduced that students have an understanding of the importance of spatial skills in understanding and making mental visualizations of molecules in chemistry. Figure 4 shows a student's actual response to the question.
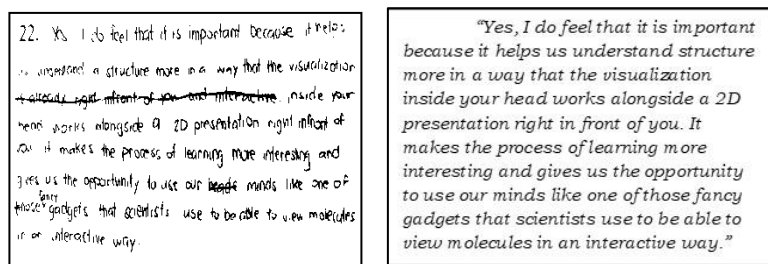
Figure 4. A sample of a Student's actual response about visualization of molecules.

Likewise, when students were asked whether the use and manipulation of AR molecular models helped them enhance their spatial skills, all of them again gave a positive response. Majority of them stated that they have a better understanding of the 3D shape of molecules because AR made it a lot easier and faster to visualize the structure (Figure 5). One specific response of a student is presented in Figure 5.
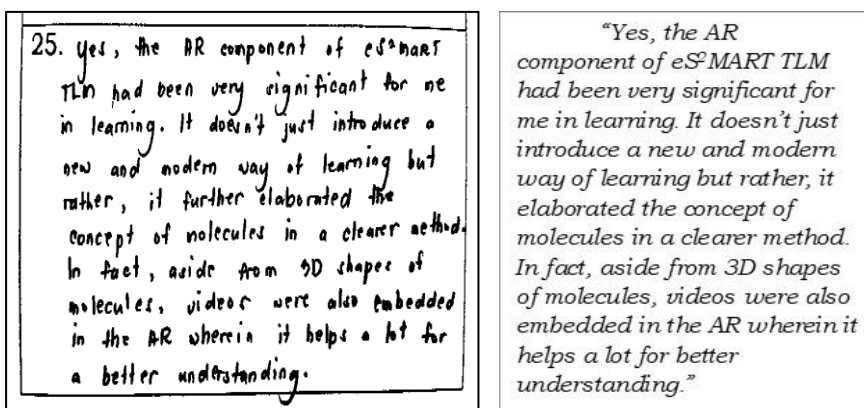
Figure 5. A sample of a student's actual response on the effect of AR.

Another student shared that they can "feel or view the molecules from their preferred perspective, and with the ability to rotate, zoom and view from different angles, better learning is already ensured when studying using AR". The student further elaborated that they felt like they're chemists or scientists that can manipulate a certain molecule.

Students' Learning Experience on the Use of eS²MART TLM

There is an overall very positive learning experience on the use of eS²MART TLM in terms of augmented reality component as implied by the composite mean value of 3.54 (±0.57) (Table 5). Eight out of ten experiences obtained mean values that were interpreted as very positive and only two have mean values that correspond to a positive experience. Among the very positive experiences, the statement "The AR objects and animations of eS²MART TLM made me visualize molecules and other chemical concepts more clearly than mere pictures in textbooks" got the highest mean value of 3.73 (±0.54). Figure 6 shows samples of students' actual statements when asked about their learning experience.

Table 5. Students' learning experience on the use of eS²MART TLM.

Statements	Mean	±SD	Adjectival Rating	Interpretation
1. I enjoyed learning chemistry using augmented reality-enabled eS²MART TLM.	3.39	0.54	Strongly Agree	Very Positive
2. The AR animations and actual manipulations of AR objects in eS²MART TLM helped me understand the concepts faster.	3.52	0.55	Strongly Agree	Very Positive
3. The AR objects and animations in eS²MART TLM made learning chemistry more interesting.	3.68	0.56	Strongly Agree	Very Positive
4. The AR objects and animations of eS²MART TLM made me visualize molecules and other chemical concepts more clearly than mere pictures in textbooks.	3.73	0.54	Strongly Agree	Very Positive
5. The intervention activities using AR objects in eS²MART TLM enabled me to visualize and make mental rotations of molecules.	3.66	0.57	Strongly Agree	Very Positive
6. I became more engaged in class because of the AR component of eS²MART TLM.	3.00	0.68	Agree	Positive
7. It is easy for me to operate the dedicated mobile app needed to manipulate the AR objects embedded in eS²MART TLM.	3.36	0.57	Strongly Agree	Very Positive
8. I find AR as a useful tool in learning chemistry.	3.57	0.59	Strongly Agree	Very Positive
9. I prefer to use learning materials/textbooks with AR component than traditional learning materials/textbooks.	3.25	0.54	Agree	Very Positive
10. I want to continue using teaching and learning materials with AR component.	3.32	0.56	Strongly Agree	Very Positive
Composite Mean	**3.45**	**0.57**	**Strongly Agree**	**Very Positive**

It is to be noted that the question here is in general whether AR helped them understand the lesson or not, and not specifically asking for comparison between eS²MART TLM and regular textbooks. As a response, some of the students compared their experience on AR-enabled eS²MART TLM with that of ordinary books and recognize the role of AR in seeing and understanding how molecules really look like as opposed to ordinary pictures or descriptions in regular textbooks.

"Yes, because with the learning material, I can visualize the atoms' structure using the AR. I've understood how they bond and get a picture of what I am really learning. It's an experience that we've got to experience how they actually look and not just based from descriptions of books."

"Yes, books cannot provide the 3D aspects of molecules that only eS²MART TLM can give. Being able to manipulate molecules on a 3D level gives better learning experience."

Figure 6. Sample of actual statements of students on Augmented Reality (AR) Learning experience.

The next experience with the second highest mean value of 3.68±0.56 relates to how AR objects and animations in eS²MART TLM made learning chemistry more interesting. Moreover, during the pilot meeting when the researcher oriented the class about the study and demonstrated the mobile application software and its use in scanning the trackers in eS²MART TLM to reveal the intuitive AR objects, the class erupted into loud applause and cheers. They were really amazed by the features of eS²MART TLM and they were all eager to download the mobile application software in their individual smartphones and experience AR technology.

The third highest mean value equivalent to 3.66±0.57 interpreted as very positive pertains to their experience on the intervention activities that uses AR objects designed to enhance their spatial skills.

On the other end of the spectrum, the learning experiences that obtained the lowest mean scores of 3.25±0.54 and 3.00±0.68 pertains to the statements "I prefer to use learning materials/textbooks with AR component

than traditional learning materials/textbooks" and "I became more engaged in class because of the AR component of eS²MART TLM". Nevertheless, these experiences were still identified as positive learning experiences based on the adjectival rating and interpretation.

DISCUSSION

Effect of AR on Students' Spatial Skills

The study revealed that the students acquired medium learning gains in the PSVT component of spatial skills test and high learning gains in the content-specific test items. The medium gain in PSVT which requires visualization skills, was due to the fact that students already got high scores in the pretest in the PSVT component as compared to content-specific spatial skills pretest. This is similar to the results obtained by Carlisle (2012) in her study about development of spatial skills where 80 to 90 percent of STEM students correctly answered the PSVT component of spatial skills pretest. Since the participants in the study are STEM students, they may already have good visualization skills.

However, the normalized high learning gains in content specific test items that require visualization, spatial orientation and spatial relations signify that using augmented reality as a component in teaching and learning material can enhance spatial skills of students, a trait that is very important for academic success in chemistry and in STEM discipline in general. Furthermore, the normalized high learning gain in the content-specific test items may be the effect of the four intervention activities in eS²MART TLM where students were directed to view the molecules from different perspectives or views, have a grasp of identifying planes of symmetry and learned how to illustrate 3D objects in two-dimensional surface in their paper through the wedge and dash notation of Lewis structures. This result is consistent with the result obtained by Martín-Gutiérrez et al. (2015a) in their study which concludes that students improved their spatial skills after using an AR application that has been created to improve spatial skills using didactic content of graphics. Likewise, the results of this study further prove the conclusion of Hornbuckle et al. (2014) that spatial skills improvement does not occur by chance alone, but by instructional interventions like the ones utilized in this study. The instructional interventions helped the students develop domain-specific spatial skills which are important in chemistry because they are critical in connecting particulate representations of molecules to conceptual and symbolic knowledge.

The recorded normalized high gains for spatial skills in the content specific test items further corroborates the research findings of Terlecki et al.

(2008) that spatial skills can be enhanced by continuous usage of models regardless of students' initial spatial experience and appeared to be long lasting. In the present study, the molecular models that were used were AR virtual objects that can be manipulated by tactile controls, instead of the regular handheld models. As conveyed by a student participant, the AR component helped them visualize clearly the molecular structure and gave them a better learning experience. Furthermore, this is also similar to the findings of Kurniawan et al. (2018) which articulates that human anatomy learning system with interactive AR helped students visualize and learn human anatomy more easily. As such, it can be said that this technology is proving to be a game changer on how lessons that require 3D modelling can be presented innovatively to the class in order to enhance specific student attributes like spatial skills.

Using interactive AR images as a tool in presenting abstract concepts in chemistry provided experiential learning which enhanced the spatial skill of students. Spatial skills are learned and developed through life experiences (Harle and Towns 2011). Student manipulation of intuitive AR virtual images in the developed instructional material in this study resulted to deeper and broader understanding of concepts by concretizing their experience through conclusions and applications.

Likewise, because the instructional material used an innovative approach of presenting images other than 2D pictures, the multimedia learning theory gives potential explanation on how the AR component resulted to improved spatial skills, especially on items that required all skill areas. The interactive 3D virtual images gave the students an opportunity to construct pictorial mental models and to build connections between them.

Students' learning experience on the use of eS²MART Teaching and Learning Material

With regard to the use of e²SMART TLM, the students have a very positive learning experience of using augmented reality-enabled teaching and learning material. The students conveyed that the experience they got cannot be obtained in traditional books alone, that the AR component helped them understand the lesson better. This result agrees with the findings of Akçayir and Akçayir (2017) which reveals that AR technology in education leads to adoption of positive attitude toward AR enhanced learning activities. The novelty of the technology makes learning chemistry more interesting and fun. The ability of AR to rescale virtual objects and enable the manipulation of the properties and relationships of objects that would either be too small or too large to examine in real life (Johnson et al. 2010) has been capitalized in this study to develop a new hybrid of teaching and learning material with AR.

The findings of this study prove that the developed augmented reality-enabled teaching and learning material is a useful and effective tool resulting to enhanced spatial skills and positive learning experience in chemistry among the student participants. Moreover, the combination of printed text and augmented reality with the use of mobile software application ushers a new type of teaching and learning material that is adaptive to the learning styles of 21st century learners and is a well-needed educational resource that will enhance spatial skills, an important attribute for students to become successful in the disciplines of science, technology, engineering and mathematics. Finally, because of the students' positive learning experience on the use of augmented reality, curriculum experts in the country should consider updating our regular textbooks and incorporate this innovative technology to enhance student engagement.

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Pulverized blue swimming crab shell utilized as partial replacement for sand in concrete mixture

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ABSTRACT

Problems in the construction today include the overexploitation of natural aggregates as well as corrosion of steel reinforcement. Studies are needed to explore alternative materials that can be used in lieu of natural aggregates. This study investigates the use of pulverized crab shell (PCS) for partial replacement of sand in concrete mixture. The properties of conventional concrete mix are compared with concrete mix with its sand replaced with 10% and 15% PCS. Properties evaluated include compressive strength and splitting tensile strength. The sodium chloride penetration in concrete with PCS is also evaluated. Analysis of variance (ANOVA) was also used to determine if there is any statistical difference among the means of samples compared. The results show that the conventional concrete mix obtained the highest compressive strength and splitting tensile strength, while showing the lowest sodium chloride penetration resistance. The concrete mix with 15% of sand replaced by PCS showed the highest chloride penetration resistance. Although the incorporation of PCS in concrete reduced the compressive strength and split tensile strength in concrete mix, this has potential for use in plastering structures near coastal areas. This is to increase resistance to penetration of chloride in concrete structures which may accelerate deterioration of steel reinforcements that has always been a problem in coastal areas. For further tests, it is recommended that before using PCS in concrete, it should be oven dried or treated and prepared for better fineness and quality. In addition, investigating the potential of heating powdered PCS for cement replacement can be a subject for future research.

Keywords: concrete, pulverized crab shell, compressive strength, sand replacement, splitting tensile strength, sodium chloride penetration

INTRODUCTION

Economic growth in any developing country depends on infrastructures available. As a country progresses, infrastructure development grows along with the demand for more material such as concrete. Concrete is the most used material in construction industry, and it undergoes various types of deterioration due to environmental effect. Concrete is made up of

three major components, namely water, aggregates, and cement. The cement mixed with water acts as a binding agent. Fine and coarse aggregates occupy about 60 to 80 percent of the volume of concrete. Large volumes of fine aggregates used in concrete are from the rivers. These are used up, causing negative impacts to the environment (Chetan and Aravindan 2020). Hence, there is a need to find alternatives for aggregates, particularly the fine ones.

On another side, the amount of waste materials produced daily also increases. These are produced mainly from agriculture, industries, and bio-waste. Wastes can be used as an admixture to make green concrete structures (Liew et al. 2017). Agricultural wastes such as rice husks, bagasse, oil palm waste, corn husks, among others, have also been found as potential for aggregates and cement partial replacements (e.g. Kunchariyakun et al. 2018; Mo et al. 2020; Zawawi et al. 2020). Material wastes from shells such as from crustaceans can be used considering their availability and properties. Crab, shrimp, and lobster shell waste generation is around 6 to 8 million tons annually (Nistico 2017). Crustaceans contain high degree of mineralization, commonly calcium carbonate, that can yield mechanical rigidity (Chen et al. 2008). Shells contain three primary chemicals that can be used in the industry such as protein, chitin, and carbon carbonate (Yan and Chen 2015). Only a small amount seafood processed are used, and the surplus like the exoskeletons is frequently trashed and discarded (Mehta and Monteiro 2001). These shells consist of 20-40% protein, 20-50% calcium carbonate and 15-40% chitin (Yan and Chen 2015).

On the main goal to make use of wastes while looking for alternatives to strengthen concrete performance, studies have been done making use of marine wastes. Marine waste such as oyster shell can be crushed and sieved to optimum size to replace aggregates (Vishwakarma and Ramachandran 2017). Using crushed oyster shell leads to increase in compressive strength but reduces workability with increasing substitution rate (Yang et al. 2005). Researchers have specifically studied the effects of shells such as oyster shells for partial aggregate replacement (e.g. Yang et al. 2005; Yang et al. 2010; Ramirez et al. 2015). Mussel shells were also used as replacement for fine and coarse aggregates (Martinez-Garcia et al. 2017). Seashells, in general was also used as partial replacement for aggregates (e.g. Richardson and Fuller 2013). Binag (2016) and Lertwattanaruk et al. (2012) also investigated the use of various powdered shell wastes, mixed with cement in masonry cement mortar which showed enhanced effect. In addition, oyster shell when used as aggregate in concrete added further with metakoalin and marble powder have indicated good strength properties similar to cement produced with sand (Aye et al. 2019). Moreover, Ammari et al. (2017) investigated the compressive and flexural strengths of concrete with crushed seashells. Using 29% of seashells, results revealed slight decrease in the compressive strength comparing to the control, while the flexural strength slightly increased. Despite the reduction in

strength as observed in study results in a review conducted by Mo et al. (2018), seashell wastes can be used as replacement of not more than 20% of the aggregate. This is to keep the level of strength required for non-structural purposes.

The arthropod exoskeleton, a multifunctional for use in concrete mix (Chen et al. 2008) has not been fully explored. Minerals in crabs are deposits of calcite or amorphous calcium carbonate within the chitin-protein matrix. Crabs belong to the subphylum crustaceans, part of the arthropods, the largest phylum in the animal kingdom (Ahmed et al. 2017). Moreover, crab shell is the world's second most common natural composite material as well as most useful (Gadgey and Bahekar 2017). They have become more abundant and their disposal is becoming a problem, especially in coastal zones. Blue swimming crabs (*Portunus pelagicus*), are native in South East Asia and are widely seen in the coastal waters of the Philippines. Locally known as "kasag" (in Hiligaynon), "alimasag" (in Tagalog), and "lambay" (in Bisaya) in the Philippines, this is a tropical species that belong to the Portunidae family. Young crabs can be found in algal beds, seagrass, and seaweeds. While mature crabs are in deeper waters up to 20 m. Mature female crabs grow up to 10.56 cm, while mature males could reach 9.64 cm. Based on the 2009 Bureau of Fisheries and Aquatic Resources (BFAR) Statistics in the Philippines on highest commodities in the fishery sector, the *P. pelagicus* fishing industry ranked at 20th place. In terms of the value of processed crabmeat and fat, this type of crabs is the 4th most important fishery export of the country. This amounted to Php 1,852,785. Also, in the year 2011, the volume of exported and processed crabmeat and fat was about 5.80% of the total product exports (BFAR 2011). The *P. pelagicus* harvested at the municipal fishery sector level, was 27,920.67 MT. This accounts to 95.38% of the total harvest. The rest are from the commercial fishery contribution of only 1,353.53 MT (4.62%). The volume of harvest was accounted to 1.34% of the year's production in the fishery sector. Currently, one example of fishery is the REL Seafoods where they gathered about 15,700 kg (during "amihan" or northeast monsoon period) to 22,400 kg (during "habagat" or southwest monsoon period) per month. This produces 9,000 to 12,880 kg of crab shells per month. Considering the other bigger fisheries, combining all the generated waste will accumulate to a great volume. With this number of wastes produced in a span of time, clearly it can be a big problem if not dealt with.

These circumstances led to this study for the improvement of concrete while lessening production cost by partially replacing sand with PCS. This study aims to compare the properties of conventional concrete mixture to that of the mixture with PCS partially replacing its sand. Specifically, this study seeks to evaluate the compressive strength, splitting tensile strength, and sodium chloride penetration of concrete with PCS. Mix proportions were taken into consideration to determine the mixture with the highest

workability. This study can be helpful to the innovation of cement concrete, if the compressive strength, splitting tensile strength and sodium chloride penetration depth of concrete with PCS can be close or equal to that of the conventional Portland cement concrete. The mixture can be nature-friendly since it provides solutions in the disposal problems of seafood wastes, particularly crab shell wastes.

METHODS

Materials and Sample Preparation

Materials used in this study were prepared and are discussed here. Materials include sand, coarse aggregates, cement, water, PCS and paraphernalias such as molds, and tamping rods. The sand, cement, and gravel used here are locally available materials brought from New Sankim Construction Supply, in Muntinlupa, Metro Manila. These conforms with the standards set by the Department of Public Works and Highways (DPWH). The sand that was used are fine aggregates of maximum size of 4.75 mm with specific gravity of 2.58. The coarse aggregates used has maximum size of 20 mm. The specific gravity and absorption ratio of the coarse aggregates were 2.75 and 0.56%, respectively. The aggregates were washed before mixing it with other materials to form the concrete mixture. On the other hand, type I ordinary Portland cement was utilized in this study. For the hydration of cement, a water-cement ratio of 0.4 was used so that for every unit weight of cement there should be 0.4-unit weight of water. For the PCS, the blue swimming crab shells were used. The shells were obtained from REL Seafoods, Pena, Cawayan Masbate. The crab shells were pulverized using a grinder mill after placing under the sunlight for 24 hours to remove its water content (Figure 1). The coarse and fine crushed shells were separated by grading. Grading showed that more than 94% of the PCS are between 150-600 μm. All the materials were prepared based on the Department of Public Works and Highways (DPWH) standards that also conform to American Society for Testing and Materials (ASTM) specifications and standards. The experimental design for mixtures used for preparing the samples are detailed in Table 1.

Figure 1. Crab shells before and after grinding. a) Sun dried crab shells, and b) Pulverized crab shells.

Table 1. Experimental design showing the different tests on concrete mixtures with different percentages of pulverized crab shell (PCS).

Test	Concrete Mix (% PCS)	Number of Specimens	Volume of Materials Used (kg m^{-3})				
			Cement	Sand	Gravel	PCS	Water
Compressive strength	0/Control	3	470	490	981	0	188
	10	3	470	441	981	49	188
	15	3	470	417	988	73	188
Split tensile strength	0/Control	3	474	494	988	0	190
	10	3	474	444	988	49	190
	15	3	474	420	988	74	190
Sodium chloride penetration test	0/Control	3	474	494	988	0	190
	10	3	474	444	988	49	190
	15	3	474	420	988	74	190

Before preparing the concrete samples for testing, slump test based on ASTM (2020b) was performed. This is to assess the consistency of freshly mixed concrete. The measured slump of freshly mixed concrete was at 75±25 mm while the air content volume was at 5.0±1%. Freshly mixed concrete was placed into the mold in three layers, each tamped 25 times. The cylindrical molds used for preparing samples for the compressive strength test have dimensions of 150 mm for its diameter and 300 mm for its height. While the cylindrical molds used for preparing samples for the splitting tensile strength and sodium chloride penetration tests have dimensions of 100 mm for its diameter and 200 mm for its height. Specimens were removed from the molds after 24 hours and were cured in water at 23±2°C until the testing date. A total of 27 samples including the mixtures with 0%, 10% and 15% PCS were made for the tests conducted in this study as detailed in Table 1. The samples were cured for 28 days. The three samples each with 10% and 15% PCS prepared for sodium chloride penetration test, were ponded in sodium chloride solution for another 28 days. The concentration of the solution is 35 grams of sodium chloride per liter of water.

Testing Process

After preparation of samples as discussed above, these were subjected to the three tests including compressive strength test, splitting tensile strength test, and the sodium chloride penetration test. The compressive and splitting tensile strength test were done to investigate long-term mechanical properties of the concrete mix. While the sodium chloride penetration test was conducted

to evaluate the ability of the concrete with the PCS to minimize penetration for concrete steel reinforcement protection. All tests were conducted at the DPWH Bureau of Research and Standards located in Quezon City, Metro Manila, Philippines.

The testing for compressive strength follows the standards according to Test Method for Compressive Strength of Cylindrical Concrete Specimens (ASTMC 2020a). The compressive strength test was performed after grinding the loading surface of the samples for smooth finish. The loads were applied using the universal testing machine (UTM) with a capacity of 2000 kN. The load was applied at the rate of 140 kg cm^{-2} per minute until the sample fails. Compressive strength was calculated using equation 1, where $f'c$ is the compressive strength in megapascals (MPa), P_{max} is the maximum applied load in Newtons (N), and A is the cross-sectional area in mm^2.

$$f'_c = \frac{P_{max}}{A} \qquad \text{Eq. 1}$$

The splitting tensile strength of concrete is one of the basic and important properties which greatly affect the extent and size of cracking in structures. The splitting tensile test procedure followed the standards for testing of cylindrical concrete based on Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens (ASTM 2020c). This test is used to evaluate the shear resistance of concrete. The test samples are set on the UTM so that the two ends of the specimen were lying on the same axial place. The UTM is then set, and load is continuously applied on the specimen without shock at a rate within the range 0.7 to 1.4 MPa per minute. The breaking load is then recorded. Then, the splitting tensile strength was calculated using equation 2, where T, is the splitting tensile strength in MPa, P is the maximum applied load in N, l is the length in mm, and d is the diameter in mm.

$$T = \frac{2P}{\pi l d} \qquad \text{Eq. 2}$$

The penetration depth of sodium chloride was done using the application of 0.1 mol/liter of silver nitrate (AgNO$_3$) solution into the exposed sides of concrete samples after it was split in half (He et al. 2012). The molarity of AgNO$_3$ were measured using an online molarity calculator (Merck 2020). The AgNO$_3$ solution was sprayed onto the exposed sides. Then, sections with white and brown color appeared with clear color change boundary. Eight points were identified, and depth penetration were measured (Figure 2). The depth of the white color zone was measured and recorded as the chloride penetration depth. The zone with the brown color zone resembles the area without chloride penetration.
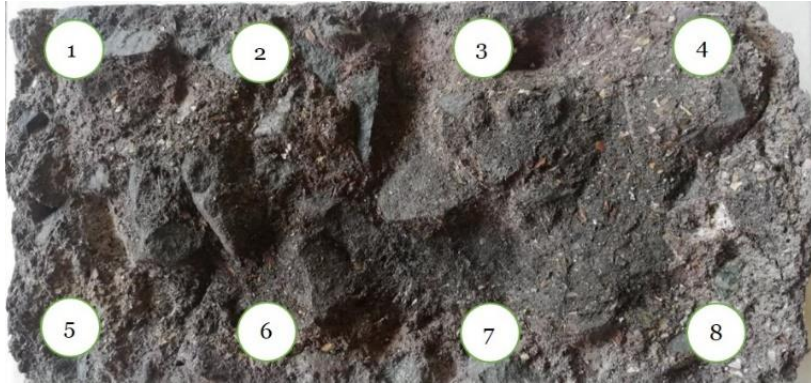
Figure 2. Sections in the fractured concrete where penetration depth of sodium chloride was measured.

Statistical Analysis

One-way analysis of variance (ANOVA) was used to determine if there is a significant difference among the means of the samples tested at the level of significance of 0.05. This shows statistical differences between the properties of the conventional concrete mix and concrete with 10% and 15% PCS, in terms of their compressive strength, splitting tensile strength, and sodium chloride penetration depth. QI Macros (2019) for Microsoft Excel was used to run the single factor ANOVA.

RESULTS

Compressive Strength Test

The results showed that control concrete samples have the highest compressive strength, followed by the samples with 10% and 15% PCS, and are significantly different ($P<0.05$). The compressive strength of samples containing 10% and 15% PCS which are 12.79 and 9.37 MPa respectively, were comparatively lower than that of the control which is 23.80 MPa (Figure 3). A decrease from 23.80 MPa to 12.79 MPa, with 46.26% can be observed between control samples and 10% PCS samples while a decrease from 23.80 MPa to 9.37 MPa, with 60.63% can be observed between control samples and 15% PCS samples.
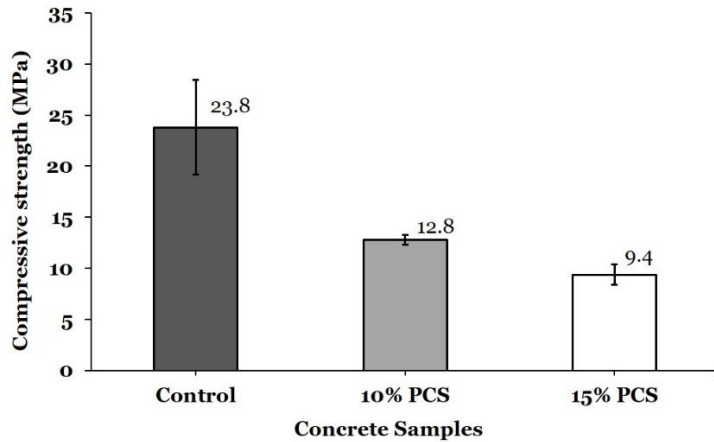
Figure 3. Average (±SD) compressive strength of concrete added with different percentages of pulverized crab shell cured for 28 days.

Splitting Tensile Strength Test

The result show that splitting tensile strength of samples containing 10% and 15% PCS with 3.62 and 3.65 MPa respectively was comparatively lower than that of the control with 7.36 MPa (Figure 4). Anova test further showed that these are significalty different ($P<0.05$). It is observed that control samples have the highest splitting tensile strength. The strength from 7.36 MPa to 3.62 MPa, shows a 50.82% decrease between control samples and 10% PCS samples. A decrease 50.41% from 7.36 MPa to 3.65 MPa is evident between control samples and those with 15% PCS.
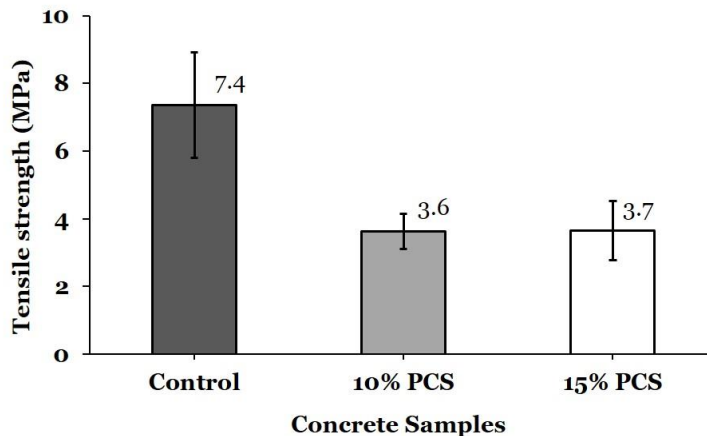

Figure 4. Average (±SD) of splitting tensile strength of concrete mixture added with different percentages of pulverized crab shell after curing for 28 days.

Sodium Chloride Penetration Test

As mentioned earlier, penetration depth of chloride was determined after spraying 0.1 mol L^{-1} of $AgNO_3$ solution onto the fractured concrete samples. The results in Figure 5 shows that the control mixture had the highest average value of penetration depth. The penetration depth of samples containing 10% and 15% PCS with 1.43 and 1.14 cm is comparatively lower than that of the control with 2.10 cm. Comparing the means of the sodium chloride penetration test results of the samples, the calculated P-value of 0.001 is less than the significance level of 0.05.
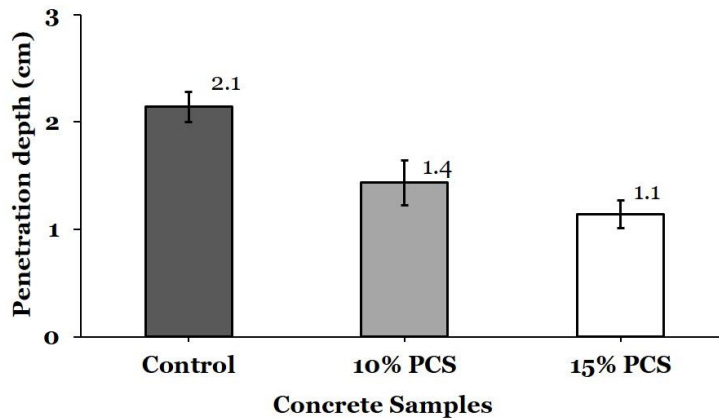
Figure 5. Average (±SD) sodium chloride penetration depth on concrete samples added with different percentage of pulverized crab shell (PCS).

DISCUSSION

Effects of the addition of PCS were evaluated against conventional concrete samples. The properties that were evaluated include compressive strength, splitting tensile strength, and resistance to sodium chloride penetration. Findings in terms of compressive strength revealed that control samples with 23.8 MPa compressive strength, has the highest compressive strength compared to that of samples with 10% and 15% PCS with 12.79 and 9.37 MPa, respectively. This indicates that addition of PCS to the concrete reduces the compressive strength of concrete. This was confirmed using single factor ANOVA results. The addition of PCS to concrete mix as partial replacement of sand, is consistent with the findings in past studies where seashells were used for partial replacement of aggregates (e.g. Richardson and Fuller 2013; Ramirez et al. 2015; Ammari et al. 2017; Martinez-Garcia et al. 2017). However, results in this current study are contrary to findings in some

studies where 10% oyster shells were used as replacement of sand (Yang et al. 2005) and 30% oyster shells were used to replace aggregates (Aye et al. 2019).

For the splitting tensile strength test, results show that the 10% and 15% PCS with 3.62 and 3.65 MPa, respectively, indicate lower strength than the control samples. Statistical analysis result shows that there is a significant difference between the means of the control mix and the mix with 10% and 15% PCS. This indicates that the addition of PCS significantly decreased the splitting tensile strength of the concrete. The findings here is consistent with the results found in the study of Martinez-Garcia et al. (2017) where mussel shells were used to replace sand in concrete mixture. Further, results from this current study is contrary to the results in Ramirez et al. (2015) where sample tensile strength values were near those of the control when replacing 10% of sand with oyster shells.

In terms of sodium chloride penetration, the 10% PCS with 1.43 cm gives a lower value of chloride penetration compared to the control mix. Hence, showing that the addition of PCS has the potential of reducing the permeability of chloride in concrete. This was also supported through the statistical analysis results. This result is like the study of Javier et al. (2017) where the potential of using admixture in improving the permeability of concrete mixture against sodium penetration using 10% rice husk, was conducted.

The above discussions show that the addition of PCS to concrete mix resulted to decreased compressive and splitting tensile strength. While results here are not consistent with some of the results in past studies, most of the studies that used sea shells for aggregate replacement showed similar results. The preparation of crab shells, without heating in the current study may have added to the reduction in the strength of concrete with PCS. It is therefore recommended that before grinding and adding PCS to concrete, it should be heated for 24 hours in an oven to remove the excess water content. It is necessary to treat and prepare the PCS for better fineness and quality.

In addition, this current study shows that addition of PCS helps prevent the penetration of salt into the concrete mixture. With this, it is recommended that addition of PCS for application of plaster in mortar can be helpful for protection against salt penetration. This especially will be helpful to structures in coastal areas where sodium penetration has always been a problem. Before using, PCS should also be oven dried and crushed to finer sizes, for better results. In addition, heating powdered PCS to bring about properties similar to cement and use it for cement replacement can also be studied in the future.

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Bacteriological assessment of the recreational water of Bacuit Bay, El Nido, Palawan, Philippines

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ABSTRACT

In early 2018, the recreational water of Bacuit Bay in El Nido, Palawan, Philippines was declared by the Department of Environment and Natural Resources (DENR) to be contaminated with a coliform count of 1,139 MPN 100 ml^{-1} sample water. Although water quality assessment was done in the area, no study was conducted on the associated clinically important bacterial pathogens. This study was conducted to assess the microbial contamination and presence of some pathogens, and to compare microbial contamination between 2018 and 2019 in Bacuit Bay. Surface water samples were collected from 11 stations in Bacuit Bay in June 2018 and June 2019. The multiple tube fermentation technique was done to assess the coliform contamination. Selective and differential microbial culture media were used to isolate some clinically important pathogens. Results showed that in 2018, all stations were positive with coliform where nine out of 11 stations exceeded the acceptable level of coliform count for recreational waters. Also, there were eight clinically important putative bacterial pathogens isolated, the *Escherichia coli, Proteus mirabilis, Klebsiella pneumoniae, Pseudomonas aeruginosa, Shigella* sp.*, Salmonella* sp., *Vibrio parahaemolyticus* and *Vibrio cholerae*. In 2019, the coliform count and the associated bacterial pathogens decreased in number with only two out of 11 stations exceeded the acceptable level and two of eight bacterial pathogens were detected. These could be attributed to the activities that were conducted by the local government unit of El Nido to mitigate the pollution in the coastal environment.

Keywords: beach, coliform, bacterial pathogens, water quality

INTRODUCTION

Recreation is one of the most important components in life of people inhabiting coastal areas (Saba and Tekpor 2015). Recreational waters are coastal waters used for recreational activities such as bathing, sailing, boating, surfing and diving (MFE 2002). The use of marine waters for recreation has been increasing in many countries. It is estimated that foreign and local tourists together spend around two billion days annually at coastal recreational resorts (Shuval 2003). According to Fogarty et al. (2003), recreational waters are susceptible to a variety of sources of microbiological pollution. However, little information exists when it comes to the quality of water for recreation (van Heerden et al. 2005).

In coastal environments, the contamination of waters raises a major concern due to public health issues (Griffin et al. 2001). Among the leading sources of chemical and biological contamination of recreational waters are the uncontrolled releases of human waste in water, which is one of the problematic consequences of increasing population (Jackson et al. 2001; Howarth et al. 2002; Dwight et al. 2004). The release of untreated sewage is the number one contributor of waste into the oceans and is a major source of nutrient input, environmental damage and eutrophication (Shahidul-Islam and Tanaka 2004). Sewage release can also increase mortality of marine organisms (Hernández et al. 1998) when infected with pathogens (Bossart et al. 1990). The quality of recreational waters is not only critical to environmental health, but also to human health (Fleming et al. 2006).

The presence of fecal indicator bacteria (e.g. *Escherichia coli, Klebsiella* sp. and *Enterobacter* sp.) in recreational waters measures the quality of water and indicates the presence of some clinically important bacterial pathogen (Korajkic et al. 2018). Recreational exposures to pathogens in the water environment may result in disease (Pond and WHO 2005). Although recreational waters do not serve as potable water to many individuals across the globe, its quality must meet that of drinking water since many swimmers accidentally drink it during swimming and there is high risk of microbial contamination from the environment which poses serious health threat to humans (Saba and Tekpor 2015).

El Nido, Palawan is known to be one of the prime tourist destinations in the Philippines because of its diverse ecosystem and beautiful, white sand beaches (WWF-Philippines 2005). It also hosts unique bird species and is frequented by large marine wildlife like the sea or marine turtles, sea cow or dugong, dolphins, sharks and rays (Maguya 2018). Tourism industry of El Nido increased significantly in the number of tourist arrivals starting in 2010 with a number of 37,383 and further increased to 64,896 in 2013 (Aguila et al. 2015) and reaching ~200,000 in 2016 (Maguya 2018). Bacuit Bay is the area

in El Nido where business establishments are located nearshore and also serves as the entrance and exit area for tourists who do island hopping. However, in February 2018, the microbial contamination of El Nido coastal water in Bacuit Bay was reported in. According to the Department of Environment and Natural Resources (DENR) in MIMAROPA region, water tests in Bacuit Bay showed that the coliform count has reached 1,139 most probable number (MPN) 100 ml^{-1} water samples (Bajo 2018). This count is a lot higher compared to the level of coliform count acceptable for swimming which is 100 MPN 100 ml^{-1} (DAO 2016) and 200 colony forming units (cfu) 100 ml^{-1} water sample (US EPA 1976).

Though there were studies conducted in El Nido on the assessment of water quality (DENR 2019; Maguya 2019), none of it assessed the presence of clinically important pathogenic bacteria and looked into the effects of rehabilitation projects. Thus, this study was conducted to assess the microbial contamination and presence of some pathogens, and to compare microbial contamination between 2018 and 2019 in the recreational water of Bacuit Bay, El Nido, Palawan.

METHODS

Locale of the Study

This study was conducted in Bacuit Bay, El Nido, Palawan, Philippines (Figure 1). The study site is located near residential and business areas (11.181744°N, 119.3913803°W). There are many tourist activities going on in the area because El Nido is a major tourist destination of the Philippines. There are also business establishments like hotels and restaurants built on the 3-meter coastal easement zone. Some establishments were found to have discharged wastewater that greatly exceeded the allowable DENR effluent standards which is a violation of Republic Act 9275 or the Philippine Clean Water Act of 2004. The wastewater of these hotels drains to Bacuit Bay through the Barangays Masagana, Buena Suerte, Maligaya and Corong-corong outfalls, which were likewise recorded with soaring fecal coliform count (Maguya 2019). There were 11 stations identified in Bacuit Bay for surface water sampling (Figure 1).
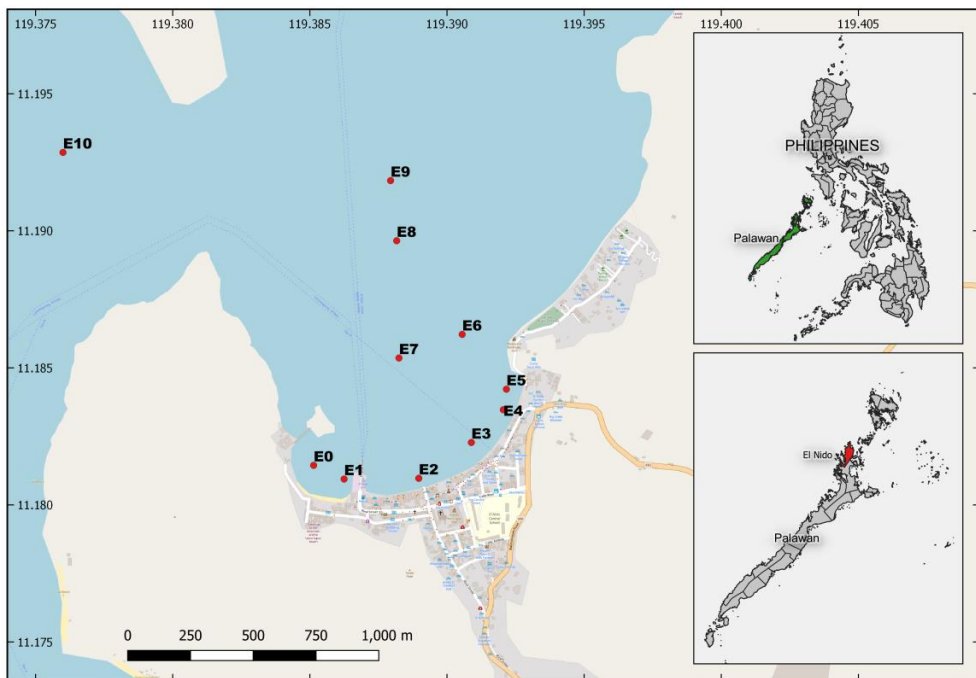
Figure 1. Map of the Bacuit Bay, El Nido, Palawan, Philippines showing the 11 sampling stations; E0 (11.18144444°N, 119.3851389°W), E1 (11.18094444°N, 119.38625°W), E2 (11.18097222°N, 119.3889722°W), E3 (11.18227778°N, 119.3908889°W), E4 (11.18347222°N, 119.3920556°W), E5 (11.18422222°N, 119.3921667°W), E6 (11.18622222°N, 119.3905556°W), E7 (11.18536111°N, 119.38825°W), E8 (11.18963889°N, 119.3881667°W), E9 (11.19183333°N, 119.3879444°W), E10 (11.19286111°N, 119.376°W).

Collection of Water Samples

Water samples were collected using sterile polyethylene plastic bottle in surface waters approximately up to 10 cm depth. Three samples were collected from each station and homogenized in a sterile container. Collection was done within the distance ranges from 100 m to >1,000 m away from the seashore. Seawater was collected using sterile polyethylene plastic bottle. The samples were stored in 100 ml sterile vials at 6°C and were then transported to the Western Philippines University-Puerto Princesa Campus, Microbiology Laboratory for the analysis within six hours. The first sampling was conducted on 20 June 2018, four months after the news on water contamination broke out and

on 13 June 2019, approximately one year after the first sampling and the start of rehabilitation project of the recreational area. This is to find out if the rehabilitation project conducted by the Local Government Unit was successful.

Coliform Detection

Coliform load in the samples was determined using the conventional three-tube MPN (most probable number) method (Rompre et al. 2002). Ten milliliter of water sample was added in test tube containing 10 ml of double strength lactose broth (DSLB). One milliliter and 0.1 ml of each water samples were added separately in test tube containing 10 ml of single strength lactose broth (SSLB). The total sets were incubated at 35°C for 24 hours and examined for the presence of growth accompanied by gas production. Those cultures positive for gas formation were inoculated into Eosin Methylene Blue (EMB) agar and were incubated at 35°C for 24 hours. After incubation, EMB Agar plates were examined for differential colony-forming units. *Escherichia coli* colonies grow with a metallic sheen and a nucleated center, *Aerobacter aerogenes* colonies have a brown center, and nonlactose-fermenting Gram-negative bacteria appear pink. A loopful of sample from positive EMB agar were inoculated in DSLB tubes and incubated for 24 hours at 35°C. Quantification was determined using the standard MPN table and coliform was reported as MPN 100 ml^{-1} water sample.

Isolation of Putative Pathogenic Bacteria

Isolation of putative pathogenic bacteria was done using selective and differential culture media following the manufacturers standards. One milliliter of each water sample from 11 stations were poured in thiosulfate citrate bile sucrose salt agar (TCBS) for the isolation of *Vibrio* species, xylose lysine deoxycholate agar (XLD) for *Salmonella-Shigella* species and McConkey agar for *E. coli*. All plates were incubated at 35°C for 24 hrs. After incubation, the plates were examined for the growth of putative pathogenic bacteria. The colonies of bacteria were identified based on the description of Zimbro et al. (2009). Isolates were chosen based on different characteristics of the colony forming units. These were transferred into sterile agar slants for pure culture, incubated for 24-48 hours and Gram stained to check for purity.

RESULTS

Coliform

The data showed that all water samples collected from all sampling stations in Bacuit Bay in June 2018 (first sampling) were positive for total coliform, with counts ranging from 93 to 1,100 MPN 100 ml^{-1} (Table 1). According to the DENR water standard, the stations are categorized in a range from Class SB (recreational water class I for bathing, swimming, skin diving, etc.) to class SC (recreational water class II for fishing and boating, etc.)

Out of 11 stations tested in 2018, nine stations exceeded the recommended fecal coliform bacteria, which is 100 MPN 100 ml^{-1} (DENR 2016) 200 CFU (colony-forming units) 100 ml^{-1} (US EPA 1976). These are stations E0, E1, E2, E3, E4, E5, E6, E9 and E10 (Table 1). Results also showed that contamination was higher in sampling sites that are close to the coast and other islands like E0, E1, E3 and E10. The category wise distribution of coliform count showed that six stations (E0, E1, E3, E5, E9 and E10) were unfit even for bathing and swimming having a water grade of poor.

Table 1. Coliform count and category wise distribution (categories: I-drinking, II-bathing and swimming, III-bathing and swimming, IV-Unfit) of eleven stations in El Nido Bay in June 2018 and June 2019 (Pandey and Sharma 1999; Saleem et al. 2013).

Sampling stations	June 2018		June 2019	
	MPN Index per 100 ml	Category (grade)	MPN Index per 100 ml	Category (grade)
E0	1,100	IV (poor)	21	II (good)
E1	1,100	IV (poor)	240	III (fair)
E2	240	III (fair)	7	II (good)
E3	1,100	IV (poor)	7	II (good)
E4	240	III (fair)	240	III (fair)
E5	460	IV (poor)	23	II (good)
E6	240	III (fair)	4	II (good)
E7	150	III (fair)	9	II (good)
E8	93	III (fair)	0	I (excellent)
E9	460	IV (poor)	0	I (excellent)
E10	1,100	IV (poor)	0	I (excellent)

On the other hand, coliform count in June 2019 (second sampling) decreased in number as compared to 2018 (Figure 2). Table 2 shows that out of 11 stations, only two stations (E1 and E4) exceeded the recommended fecal coliform, and all other stations were acceptable for bathing and swimming with water grade ranging from fair to excellent.
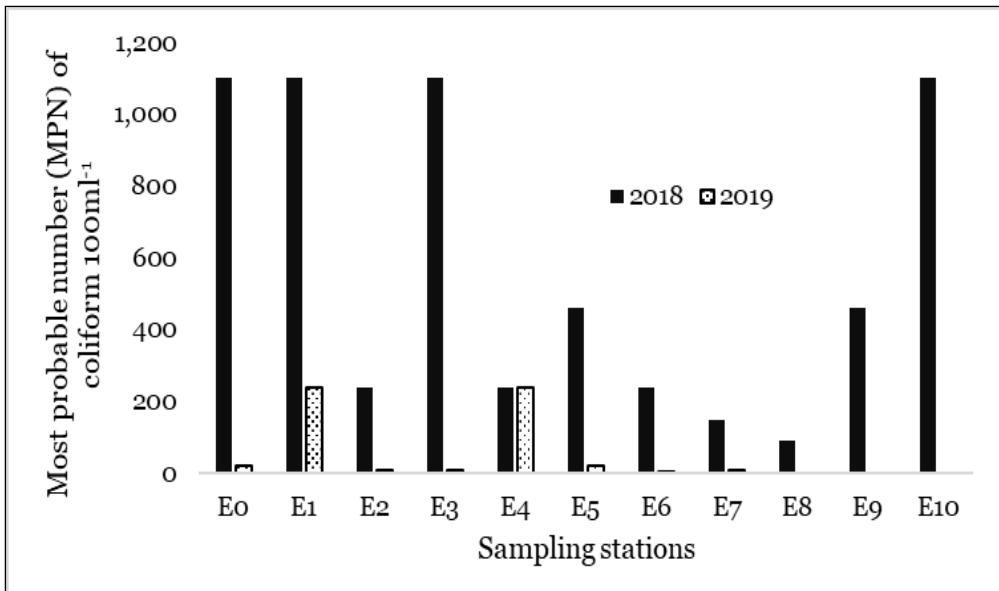
Figure 2. Comparison of coliform count 100 ml^{-1} water sample at 11 stations in June 2018 and June 2019.

Clinically Important Putative Pathogenic Bacteria

There were eight different putative pathogenic bacteria isolated from Bacuit Bay, El Nido, Palawan during the first sampling in June 2018. These are the *E. coli, Proteus mirabilis, Klebsiella pneumoniae, Pseudomonas aeruginosa, Shigella* sp.*, Salmonella* sp., *Vibrio parahaemolyticus* and *V. cholera* (Table 2 and Figure 3). On the other hand, only two bacterial species, *E. coli* and *Salmonella* sp., were detected and isolated in the second sampling in June 2019. Results also showed that sampling sites with high coliform count also have high number of pathogenic bacteria (Table 2).

Table 2. Clinically important putative pathogenic bacteria from 11 stations (presence is indicated by √) in Bacuit Bay, El Nido, Palawan in June 2018 and June 2019.

Year	Putative Pathogenic bacteria	Sampling Stations										
		E0	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
2018	*Escherichia coli*	√	√	√	√	√	√	√	√	√	√	√
	Proteus mirabilis	√	√									
	Klebsiella pneumoniae	√	√	√	√	√						
	Pseudomonas aeruginosa	√	√	√		√						√
	Salmonella sp.	√	√	√	√	√	√	√	√		√	√
	Shigella sp.	√	√	√	√	√	√					√
	Vibrio cholerae	√	√	√	√	√						√
	Vibrio parahaemolyticus	√	√	√	√	√	√					√
2019	*Escherichia coli*	√	√			√						
	Salmonella sp.		√									

Figure 3. Isolated clinically important putative (further characterization is needed) bacterial pathogens from Bacuit Bay, El Nido, Palawan growing on selective culture media.

DISCUSSION

In this study, the multiple fermentation (MTF) technique revealed that the water samples collected from 11 stations of Bacuit Bay, El Nido in June 2018 sampling were all contaminated with coliform specifically, *E. coli*. Nine out of eleven stations exceeded the acceptable level of coliform count in recreational waters (US EPA 1976). The water grade ranged from fair to poor where most areas were unfit even for swimming and bathing. Among the coliform bacteria, *E. coli* is the most abundant and can be found in the gastrointestinal tracts of humans, birds and animals, but rarely found in water or soil that has not been subjected to fecal pollution. The use of contaminated or polluted marine water for recreational purposes poses a number of health risks which depend on factors such as the nature of the hazard, the characteristic of the water body and the immune status of the user (Pond and WHO 2005). According to Dwight et al. (2004), one of the main reasons of the degradation of the recreational waters is the increasing number of population and uncontrolled release of human waste. The release of human, animal and industrial sewage is the number one contributor of waste into the oceans and is a major source of nutrient input, leading to environmental damage and eutrophication (Shahidul-Islam and Tanaka 2004). Sewage release can also increase mortality of marine organisms (Herńandez et al. 1998) and infect these animals with pathogens (Bossart et al. 1990). On the other hand, in June 2019 sampling, results showed that coliform count decreased in number and the water grade ranged from fair to excellent. Recreational waters can now be used for bathing and swimming.

The quality of recreational waters is not only critical to environmental health but is also closely tied to human health (Fleming et al. 2006). In this study, there were eight clinically important pathogenic bacteria isolated from El Nido Bay, Palawan. These are the *Escherichia coli, Proteus mirabilis, Klebsiella pneumoniae, Pseudomonas aeruginosa, Shigella* sp*., Salmonella* sp*., Vibrio parahaemolyticus* and *V. cholerae*. Presence of these bacteria in recreational water is alarming because these are waterborne pathogens that can cause illness with severe outcomes even in an average population (WHO 2003). Although not always severe, infection by these pathogens can result in hospitalization, surgery and death (Pond and WHO 2005).

Escherichia coli is the common cause of non-bloody diarrhea, which can progress to bloody diarrhea and haemolytic uraemic syndrome (McLellan et al. 2001). Most strains of *E. coli* are not regarded as pathogens, but they can be opportunistic that can cause infections in immune-compromised hosts. Presence of *E. coli* indicates presence of other pathogens like *Klebsiella, Vibrio* and other clinically important bacterial pathogens (WHO 2001). After *E. coli*, *P. mirabilis* is one of the most frequent etiological agents associated with urinary tract infections (UTIs). The most widely occurring species of

Klebsiella are *K. pneumoniae* and *K. oxytoca*. They are found in nature associated with vegetable matter and surface waters, including surface waters used for recreational purposes. *Klebsiella* strains have low pathogenicity for human but can cause serious human infections only when the resistance of the host is impaired. However, some literatures state that *Klebsiella* is a serious pathogen (Brown and Seidler 1973; Knittel 1975; Seidler et al. 1975; Bagley and Seidler 1977; Caplenas et al. 1981) and should not be taken for granted. It has been suggested that this organism causes a significant number of cases of community pneumonia which have a high mortality rate (Caplenas et al. 1981) and that it is an important cause of urinary tract infections and various other infections in the community (Knittel 1975; Bagley and Seidler 1977). *Pseudomonas aeruginosa* is an opportunistic pathogen capable of infecting immunocompromised individual and causing severe pulmonary disease (Alhazmi 2015). *Salmonella* and *Shigella* species are normally found in water polluted with human excrement (Saha et al. 2009). Most common illness associated with these bacteria is diarrhea. *Vibrio parahaemolyticus* is recognized throughout the world as the leading causal agent of human gastroenteritis resulting from ingestion of contaminated water or consumption of raw seafood (Iida et al. 2006). On the other hand, *V. cholerae* causes cholera with symptoms of acute watery diarrhea. It has been a common disease reported since the 19th century in the United States (Sack et al. 2004) and remains an internationally widespread though neglected disease (Ryan 2011).

Monitoring the number of indicator microorganisms such as fecal coliform and *E. coli* is a common approach to quantifying pathogenic microorganisms present in the surface waters (Pandey et al. 2014). However, there is still much debate concerning the ability of the indicator microorganisms to represent the potential pathogens present in sampled water. One noteworthy result of this study is the relationship of the coliform load and the number of pathogenic bacterial species found in the recreational waters of El Nido. It was shown that as the coliform load increases, the number of pathogenic bacteria also increases.

From June 2018 to June 2019, both coliform load and the number of clinically pathogenic bacteria in Bacuit Bay decreased. These can be due to the rehabilitation activities that were conducted by the local government unit (LGU) of El Nido. To address the contamination reported in 2018 and the pressure from the national government, the local government of El Nido planned and executed actions on addressing the sewage problem in the area. Business establishments directing their sewerage pipes towards the sea were closed temporarily. The Department of Environment and Natural Resources (DENR) issued cease-and-desist orders (CDO) for establishments polluting Bacuit Bay, especially those found to have discharged wastewater that greatly exceeded the allowable DENR effluent standards, in violation of Republic Act

9275 or the Philippine Clean Water Act of 2004 (Maguya 2019). The DENR also created a task force El Nido for establishments violating the 3-meter easement zone, as provided for urban areas under the Water Code of the Philippines (Maguya 2018). Tourist establishments with 30 or more rooms are required to build their own dislodging plants before the sewage is piped into the sewage treatment plant. Those who would not comply would face a Php 500,000 fines (Cimatu 2019).

The LGU also passed the no-plastic ordinance that requires all those going to the islands to surrender their single use plastic bottles, plastic bags and other disposable plastic materials before boarding their boats; tourists are to take portable jugs and reusable water containers only (Cimatu 2019). Restaurants, bars and other tourist establishments ceased selling bottled water and other drinks using polyethylene terephthalate (PET) and other plastics under the supervision of the Department of Health. In addition to that, the Protected Area Management Board (PAMB) of El Nido-Taytay Protected Area passed a resolution that limits tourist entry and activities in three of the most visited places in El Nido. In the Big Lagoon, one of the major attractions in the area, only 60 guests are allowed at any one time or a maximum of 720 guests per day. In the Small Lagoon, a maximum of 30 guests are allowed at any one time or a total of 360 persons per day. For the Secret Beach, only 12 visitors are allowed at any one time or a total of 144 a day. Limits on the number of conveyances have also been set – maximum of five boats in the anchorage area and 30 kayaks inside the Big Lagoon, 15 kayaks inside the Small Lagoon, and two boats in the anchorage area of Secret Beach (DENR 2019).

The rehabilitation conducted in the study area to address the water contamination remarkably decreased the coliform load as well as the associated pathogens within a year. The mitigation of coastal water contamination, which includes proper wastewater disposal and municipal wastewater treatment, is an effective measure to improve the water quality in El Nido. It is recommended that a regular monitoring of the presence of pathogenic bacteria must be conducted not just in El Nido but in other tourist attractions in the Province of Palawan, such as Coron, Ulugan Bay, Port Barton, and Puerto Princesa Bay. The results of this study can be used as basis for the formulation of management strategies for coastal tourist sites in Palawan and the Philippines to ensure safety, healthy and aesthetically pleasing coastal environment.

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Implementing environmental plans and laws at rural grassroots, Palawan, Philippines: status, factors, and moving forward

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ABSTRACT

In the Philippines, the coastal and marine areas in its numerous small islands provide food, minerals, raw materials, and others contribute significantly to the country's GDP. However, its environmental governance at the grassroots level is poorly studied. Hence, this study aims to: monitor and evaluate the implementation of the Area Specific Activity Plan (ASAP) of the identified barangays/municipalities; assess the enforcement of environmental laws, namely: a) solid waste management, b) fishery and c) forestry at the barangays of Palawan; and identify the factors which influence the implementation of environmental plans and laws at the barangay level. This study gathered data among 194 respondents from six municipalities and 59 barangays across Palawan. The result shows that the implementation of the environmental plan of activities of municipalities and barangays ranged from "most of the proposed activities are implemented" to "all of the activities are implemented", indicating a high implementation rate of plans and laws across the barangays of Palawan. There are 15 issues and concerns in the implementation of the ASAP, categorize into five factors: funding, capability, legislative, political will, and IEC. The most common factors are funding, capability, legislative, followed by IEC and political will. Gender equity must be factored-in in plans and strategies.

Keywords: local governance, environmental management, performance evaluation

INTRODUCTION

Good governance is a critical tool for advancing sustainable development (Kardos 2012). The Good Governance in Sustainable Development aims to enhance local implementation actions of the Rio

Resolutions and Agenda 21 for real progress towards sustainable development through 1) empowering the public to enable them to participate in decision making for public interest effectively and to undertake local initiatives; 2) developing and strengthening good governance at the local level; 3) developing the capacity of the public and the government at the local level to cooperate in increasing the welfare of the people (UN 2020). Dewitt (2006) suggested three regulations: "top-down" used by the Federal Government, which has been the backbone of environmental governance in the United States since 1970, however, "bottom-top" grassroots governance and "middle-out" civic environmentalism approaches are also necessary to sustain the environmental protection of the country. Furthermore, Gera (2016) emphasized the institutionalization of public participation in environmental governance in the Philippines, analyzing the shifting demarcations of public engagement and how these define the interplay of institutional-legal structures with the country's political economy constraints.

The main challenges of good governance are lack of participation and engagement, lack of accountability, low transparency, lack of awareness of active citizens, the weak role of civil society, and gender inequality (PIN 2017), while the quality of decision making, accountability processes, directed towards continuous improvement, is also of equal importance (Taylor 2016). Furthermore, to improve efforts, require a grassroots approach by factoring in local attitudes and behaviors in the policies (Cameron 2016).

The grassroots are where direct interactions between people and people, people and the environment, and people and government openly happen. This makes the grassroots a critical functional unit of the society, wherein the effectiveness of the framework and processes of its local governance is imperative for the sustainable development of the country and well-being of the communities. However, the different types of law implementations at grass root levels may cause public policies to fluctuate due to the low level of applicability of policies in the local contexts and changes in pressure from above create social conflicts and governance problems (Chen and Zhang 2016). Currently, the interactions between the people and the environment create growing environmental insecurities, which means not having enough food, water, and natural resources to live in, and can fuel increases in wildlife crime. Thus, understanding the local perception of policies can help predict buy-in for current and future risk-management strategies (Cameron 2016). On the other hand, environmental planning and the implementation of local plans and laws are equally important to support governance in particular and sustainable development in general.

In the Philippines, the coastal and marine areas in its multiple small islands provide food, minerals, raw materials, and others, contributing significantly to the country's GDP (Adan 2010). However, in the past, the

Philippine Local Government Units (LGUs) are largely unaware of their roles in managing municipal waters, as much as they are uninformed about the roles of government institutions task to assist them, while in general, resource management receives low LGU prioritization (Pestaño-Smith et al. 1999).

Consequently, as anthropogenic activities took tolls on once pristine environments of the country, such approaches as the Coastal Resource Management (CRM) in the Philippines have grown (Hansen et al. 2007). Realizing this, the Philippine Government enacted legislation that empowers the LGU with full jurisdiction over the management of their natural resources, known as the Local Government Code of 1991 or Republuc Act 7160. This law transfers control and responsibility of delivering basic services to the hands of LGUs. It aims to enhance the provision of services at the grassroots level and sought to widen the decision-making space by encouraging the participation of stakeholders, especially at the local level (Republic of the Philippines 1991). The Philippine government hopes to mitigate and regulate further degradation of its natural environment and promote sustainable development through a bottom-up approach. Hence, it is likewise worth to get information on the performance of RA 7160 at the grassroots level.

One of the goals of the Environmental Justice Reform Program thru the Institute of Environmental Governance (IEG) project funded by the International Technical Assistance Program US Department of the Interior-International Narcotics and Law Enforcement (USDOI-INL) of the US Department of State is to capacitate the Philippine barangay, municipal, and provincial officials on environmental management and law enforcement for them to be able to carry out their mandated responsibilities under RA 7160: which is to safeguard, conserve and protect the resources from the smallest unit of the government, which is the Barangay LGU, to the Municipal LGU, and at the Provincial LGU.

Within the above program, the NGO Tanggol Kalikasan (TK) partnered with the Western Philippines University (WPU), to create the IEG office to assist in the monitoring of the implementation of the Area Specific Activity Plans (ASAPs) on the ground. Hence, this study generally answers on how the barangays implement the environmental plan and laws and identify the factors influencing the implementation of local plan and law. Thus, this study monitored and evaluated the implementation of ASAP of the identified barangays/municipalities; assessed the enforcement of such environmental laws as a) solid waste management, b) fishery laws, and c) forestry laws at the barangays of Palawan; and identified the factors which influence the implementation of environmental plans and laws at the barangay level.

METHODS

The barangay and municipal officials were trained on Disaster Risk Reduction Management (DRRM), Climate Change, Fisheries Management, and Biodiversity, in June 2018, followed by the formulation of their respective ASAPs, through the auspices of the TK. Copies of plans, proposed projects and activities, and contact directories of lead persons of every barangay/municipalities were obtained from the TK and used as the reference of field contact persons. Survey forms were designed and provided by TK.

Data was gathered through purposive personal interviews, using a Likert Scale (implemented, sometimes implemented, and not implemented) to rate the performance of barangays. The respondents are the municipal and barangay officials, barangay constituents, and members of relevant organizations affiliated with barangays. Activities and projects found in ASAP were visited, photographed on-site, and activity updates were evaluated against the original plans that the municipality/barangay has formulated during workshops, including the time frame of the project. Respondents were interviewed on the implementation of ASAP first, followed by questions on the enforcement of environmental laws and factors that might have affected the implementation of the plans and laws. Free and prior informed consent was solicited from the respondents. They were informed that they might not answer the questions if they so choose not to. Responses were processed and analyzed using descriptive statistics.

Data was gathered in the following municipalities: Busuanga from 12 to 19 January; Magsaysay between 20 and 26 January 2019; Araceli from 28 January to 02 February 2019; from 21 to 24 January 2019 in Brooke's Point; from 25 to 29 January in Sofronio Española; and from 30 January to 01 February 2019, in Narra. This study gathered data among 194 respondents from six municipalities and covered 59 barangays across the province of Palawan.

Interviews were conducted in the following municipalities and barangays: 1) Araceli with 10 Barangays: Dagman, Tinintinan, Osmeña, Taloto, Poblacion, Mauringuen, Madoldolon, Santo Niño, Lumacad, and San Jose De Oro; 2) Busuanga with 12 barangays: Sto. Nino, Concepcion, Sagrada, Bogtong, Salvacion, Old Busuanga, San Rafael, New Busuanga, Buluang, New Quezon, Panlaitan, and Maglalambay; 3) Magsaysay with 7 barangays: Lucbuan, Balaguen, Danawan, Igabas, Lacaren, Los Angeles, and Rizal; 4) Narra with 10 barangays: Antipuluan, Aramaywan, Batang-batang, Caguisan, Calategas, Malatgao, Panacan, Panacan 2, Tacras, and Teresa; 5) Sofronio Española with 7 barangays: Abo-abo, Isumbo, Pulot Shore, Labug, Iraray, Panitian, and Punang; and 6) Brooke's Point with 13 barangays: Aribungos, Amas, District

2 - Poblacion, Imulnod, Ipilan, Mainit, Malis, Mambalot, Oring-oring, Pangobilian, Salogon, Samariniana, and Tub-Tub.

RESULTS

Municipality of Araceli

Area Specific Activity Plan. The barangays mostly implement the activities indicated in the ASAP. The community officials wanted to implement the action plan, but the dry season adversely affected the water source of the island. The strong wave actions of the monsoons also affected the recently planted young mangrove trees. Furthermore, there is no mangrove nursery to provide seedlings for planting.

Environmental Laws Implementation. On solid waste management, the construction of Material Recovery Facilities (MRF), and the enactment of the Solid Waste Management (SWM) ordinance, as well as monitoring, are implemented, but the segregated waste is not collected. The barangays always do the composting, but don't implement the SWM Board. The barangays sometimes implement the Information, Education, and Communication (IEC) for SWM.

Regarding the fishery laws implementation, the mangrove planting is always implemented, while mangrove nursery is not implemented. All the barangays have no mangrove nursery. The barangays did not create the bantay-dagat (Baywatch) and did not apprehend the illegal fishers. Respondents claim that these are responsibilities of the municipality. However, they sometimes implement the IEC regarding fishery laws. The creation of the ordinance, as well as monitoring, are always implemented.

On the forestry laws, the barangays always implement the tree planting activities, but they did not implement the tree nursery projects. They did not create the bantay-gubat (Forest-watch) and did not apprehend the illegal loggers. The community believes that these are the responsibilities of the municipal government. There are no agroforestry and advocacy programs.

Municipality of Busuanga

Area Specific Activity Plan. In terms of environmental protection, the activities in the barangays are mainly under SWM: construction of MRFs, composting of biodegradable wastes, and house-to-house collection of segregated waste. Other initiatives are mangrove and tree planting, as well as the enactment of barangay ordinances.

All barangays implement all the SWM activities indicated in their action plans. The three-wheeled vehicle collects the waste, and is also used for other activities of the barangay. Furthermore, the NGOs assist in the implementation of the environmental plans of LGU.

Planning is conducted just before the election of officials. Implementing the plan becomes a challenge to the newly elected officials. The grass fire is a threat to the tree planting, while the prevailing wind surges and livestock are threats to newly planted mangroves.

Environmental Laws Implementation. Regarding the waste management laws, the waste segregation and collection, construction of MRFs, creation of the SWM Board, the passing of SWM ordinance, and monitoring are always implemented, while composting is sometimes implemented. The respondents argue that it is the responsibility of the households to make their composting pits.

Almost all of the activities related to fishery laws are implemented, except for the mangrove nursery. The IEC related to fishery laws is sometimes implemented.

On forestry laws, tree planting activities are always implemented but need tree nurseries. The barangays create the bantay-gubat and always apprehend illegal loggers, while sometimes implement the agroforestry and advocacy programs.

Municipality of Magsaysay

Area Specific Activity Plan. The communities have implemented most or all the activities included in their ASAP. The newly elected barangay officials started their services in July 2018, who were challenged by the limited time to formulate the budget for the activities for the year 2019.

The barangays have submitted SWM Plans to the municipality and created their respective SWM Barangay ordinances. All barangays constructed the Material Recovery Facilities, but due to lack of garbage transport, the barangays don't collect segregated waste materials from households, except MRFs.

The municipality requires barangays to formulate a ten-year SWM plan. The barangays do not collect the waste materials from households, though the municipal LGU already informed them MRFs availability. Hence, barangays don't usually bring recyclable materials to MRFs, including single-use plastics. On the other hand, since there are negative reactions by some fishers to the establishment of MPAs, there is a need for IEC.

Environmental Laws Implementation. For solid waste management, the barangays always implement the waste segregation, construction of MRFs, creation of SWM Board, IEC regarding SWM, the creation of ordinance, and monitoring. However, the waste materials are not composted. The communities insist that the collection of segregated waste and composting are obligations of the municipal government.

In fishery laws, the barangays always implement the mangrove planting, create fishery law ordinance, and do monitoring, but do not implement mangrove nursery. Moreover, they always implement the bantay-dagat and apprehend illegal fishers. Others felt that this is the responsibility of the municipality rather than the barangay. The barangays sometime implement the IEC regarding fishery laws, which is being discussed only during the barangay assembly and no activity proposed.

In the forestry laws, tree planting activities are sometimes implemented, while tree nursery is not implemented. Furthermore, the bantay-gubat and apprehension of illegal loggers are thought by the majority as the responsibility of the municipal government and not the barangay. The barangays do not implement agroforestry and forestry advocacy programs.

Municipality of Narra

Area Specific Activity Plan. In general, the barangays implement the SWM activities indicated in their ASAP. The barangays allocated funds for the construction of MRF. They also strengthened their IEC among the constituents.

There is strict compliance in terms of the implementation of fishery and forestry laws. Problems that hindered the implementation of the ASAP of the barangays are the limited source of funds, and the bad timing of planning *vis a vis* election and budget hearing.

Most of the areas in the barangay strictly implemented the SWM Act of 2001. They constructed MRFs and conducted IEC to inform their constituents on proper waste segregation.

Mangrove reforestation is done in areas where there is illegal cutting, one to two times annually. The barangays conduct tree planting and coastal clean-up. Some barangays anchor their environmental protection programs to the municipal and national laws.

Environmental Laws Implementation. Waste segregation is one of the highlights in the barangays of Narra. The segregated wastes are collected, but no service vehicle is available to transport the waste materials,

hence waste collection is not implemented. The barangays implement composting, but some members have no composting area. The construction of MRF, the creation of the SWM board, IEC for SWM, SWM ordinance, and monitoring are always implemented.

Regarding fishery laws, more than half of the respondents perceive that the barangays implement the mangrove planting while they do not implement the nursery for mangroves. The barangay bantay-dagat is not created, the illegal fishers are not apprehended because the communities believed that these are the responsibilities of the municipality. Meanwhile, they sometimes implement the IEC regarding fishery laws. The creation of the ordinance, as well as monitoring, are always implemented.

On forestry laws, tree planting activities are conducted, but a tree nursery is missing. They do not create the bantay-gubat and don't apprehend illegal loggers, thinking that these are the responsibilities of the municipal government. There is no program regarding agroforestry or reforestation.

Municipality of Sofronio Española

Area Specific Activity Plan. In general, all SWM activities indicated in their ASAP are implemented. The barangays allocate funds for the construction of the MRFs and strengthen the conduct of IEC among the constituents and strictly comply with the fishery and forestry laws.

Problems that hindered the implementation of the barangay ASAP are the limited funds to implement activities and the timing of planning and implementation of the project.

The municipality conducts mangrove and tree planting in its three identified barangays. Community members and barangay staff planted assorted fruit trees as a potential source of income. Some of the environmental protection programs of the barangays are anchored to municipal and national laws.

Environmental Laws Implementation. The SWM laws range from sometimes or not implemented among the barangays of Sofronio Española. They did not implement the waste segregation. The creation of the SWM Board is sometimes implemented. There is no transportation to collect waste materials. Some respondents have no composting area.

The barangays always construct MRF, while IEC for SWM, the creation of SWM ordinance, and monitoring are always implemented.

The mangrove planting is implemented, however the nursery is not implemented. The bantay-dagat is not created, therefore the illegal fishers are not apprehended. Respondents believe that these are the responsibilities of the municipality. Meanwhile, IEC on fishery laws is sometimes implemented. Ordinances are created, while monitoring is always implemented.

Tree planting activities are always implemented, but a tree nursery is missing. The creation of the bantay-gubat and apprehension of illegal loggers are sometimes implemented. Respondents believe that these are the responsibilities of the municipal government. There are no agroforestry and reforestation programs implemented.

Municipality of Brooke's Point

Area Specific Activity Plan. In general, the barangays of Brooke's Point properly plan and implement their environmental projects strictly in accordance with the Republic Act 9003.

Forest rehabilitation activities coordinate with the Department of Environment and Natural Resources through their "Enhanced National Greening Program," which produced not only timbers but also fruit trees with financial returns. The locals and volunteers actively implement forest conservation activities. The implementation of their plan is efficient. The enhanced version of IEC brought awareness to various aspects of SWM, forest protection, and sustained water source to barangays.

The barangays strictly implement the Republic Act 9003. They also conduct tree planting activities in the upland areas of various barangays. Some of the environmental protection programs of the barangay are anchored to municipal and national laws. Mangrove reforestation is conducted twice a year. They also conduct information and education on the proper waste segregation and composting to produce organic fertilizers.

Environmental Laws Implementation. Waste segregation is always implemented in the barangays, but there is no transport vehicle to collect the segregated wastes. They also implement composting, but some respondents have no composting areas. The MRFs are always implemented. They enacted SWM ordinances and always implement the SWM board, SWM monitoring, and IEC for SWM.

The mangrove planting is always implemented, however there is no nursery. The bantay-dagat is not created, and illegal fishers are not apprehended. The community felt that these are the responsibilities of the municipality. Meanwhile, IEC on fishery laws is sometimes implemented. The enactment of ordinances and monitoring are always implemented.

Tree planting activities are always implemented, but there is no nursery. Further, there is no bantay-gubat, therefore illegal loggers are not apprehended. Respondents thought that these are the responsibilities of the municipality. There are no agroforestry programs as well.

Summary of the perception of the implementation of the environmental laws across 59 barangays of Palawan.

The respondents' profile across barangays of Palawan is 56.70% barangay officials and 43.30% barangay constituents, 82.99% of whom are females (Table 1). Eighty-two point ninety-nine percent (82.99%) of the respondents are married. Graduates of secondary school comprised 41.75% of the respondents, while 35.05% have finished college education. Below is the assessment of ASAP and environmental laws implementation in barangays across Palawan.

Table 1. Distribution of the respondents according to socio-demographic data.

Socio-Demographic	Frequency (n=194)	Percentage (%)
Social Status		
Barangay Official	100	56.70
NGO/PO/Association	0	0.00
Ordinary Citizen	84	43.30
Gender		
Male	75	61.34
Female	119	82.99
Civil Status		
Married	161	82.99
Widow	10	5.10
Separated	4	2.06
Single	19	9.79
Education		
Elementary	30	15.46
Secondary	81	41.75
Vocational	15	7.73
College	68	35.05

Waste segregation is always implemented (86.60%) (Table 2). The collection of segregated wastes is sometimes implemented. Composting (52.58%), MRF (87.11%), SWM Board (59.79%), waste management monitoring (89.18%) IEC of SWM, and SWM ordinances are always implemented across barangays of Palawan.

Table 2. Distribution of the respondents according to their perception of solid waste management implementation.

Activities	Frequency (n=194)	Percentage
Waste Segregation		
Not Implemented	7	3.61
Sometimes Implemented	713	6.70
Always Implemented	168	86.60
Segregated Waste Collection		
Not Implemented	71	37.63
Sometimes Implemented	13	6.70
Always Implemented	89	45.88
Decided not to answer	21	10.82
Composting		
Not Implemented	35	18.04
Sometimes Implemented	54	27.84
Always Implemented	102	52.58
Decided not to answer	3	1.55
MRF		
Not Implemented	19	9.79
Sometimes Implemented	6	3.09
Always Implemented	169	87.11
SWMB		
Not Implemented	37	19.07
Sometimes Implemented	0	0.00
Always Implemented	116	59.79
Decided not to answer	41	21.13
Environmental IEC		
Not Implemented	14	7.22
Sometimes Implemented	47	24.23
Always Implemented	130	67.01
Decided not to answer	3	1.55
SWM Ordinance		
Not Implemented	7	3.61
Sometimes Implemented	0	0.00
Always Implemented	174	89.69
Decided not to answer	13	6.70
Monitoring		
Not Implemented	11	5.67
Sometimes Implemented	7	3.61
Always Implemented	173	89.18
Decided not to answer	3	1.55

As for fishery laws (Table 3), mangrove planting projects are always implemented, but mangrove nursery is not implemented. In bantay-dagat and illegal fishing apprehensions, the majority of the respondents decided not to answer. However, 36.60% of bantay-dagat and 32.47% of apprehension answered always implemented. Hence, bantay-dagat and illegal fishing apprehension are sometimes implemented. Fishery law IEC, ordinances, and monitoring are always implemented.

Table 3. Distribution of the respondents according to their perception of fishery laws implementation.

Activities	Frequency (n=194)	Percentage
Mangrove Planting		
Not Implemented	28	14.95
Sometimes Implemented	3	2.06
Always Implemented	121	66.49
Decided not to answer	38	20.10
Mangrove nursery		
Not Implemented	129	66.49
Sometimes Implemented	7	3.61
Always Implemented	8	4.12
Decided not to answer	50	25.77
Bantay dagat		
Not Implemented	45	23.20
Sometimes Implemented	5	2.58
Always Implemented	71	36.60
Decided not to answer	73	37.63
Illegal fishing apprehension		
Not Implemented	36	18.56
Sometimes Implemented	1	.52
Always Implemented	63	32.47
Decided not to answer	94	48.45
Fishery Law IEC		
Not Implemented	7	3.61
Sometimes Implemented	59	30.41
Always Implemented	76	39.17
Decided not to answer	52	26.80
Fishery Law Ordinance		
Not Implemented	26	13.40
Sometimes Implemented	0	0.00
Always Implemented	100	51.55
Decided not to answer	68	35.05
Fishery Law Monitoring		
Not Implemented	15	7.73
Sometimes Implemented	7	3.61
Always Implemented	123	63.40
Decided not to answer	49	25.26

Regarding forestry laws, tree planting projects are always implemented, but tree nursery projects are not implemented. Bantay-gubat, illegal loggers' apprehension and agroforestry projects are not implemented, while advocacy program is sometimes implemented (Table 4).

Table 4. Distribution of the respondents according to their perception of forestry laws implementation.

Activities	Frequency (n=194)	Percentage
Tree Planting		
Not Implemented	38	19.59
Sometimes Implemented	6	9.09
Always Implemented	148	77.27
Decided not to answer	2	1.03
Tree Nursery		
Not Implemented	129	23.20
Sometimes Implemented	6	3.09
Always Implemented	50	25.77
Decided not to answer	9	4.64
Bantay Gubat		
Not Implemented	45	62.12
Sometimes Implemented	5	2.58
Always Implemented	53	27.32
Decided not to answer	91	46.91
The apprehension of Illegal Loggers		
Not Implemented	63	32.47
Sometimes Implemented	14	7.22
Always Implemented	57	29.38
Decided not to answer	60	30.93
Agroforestry Program		
Not Implemented	91	46.91
Sometimes Implemented	22	11.34
Always Implemented	76	39.18
Decided not to answer	5	2.58
Advocacy Program		
Not Implemented	72	37.11
Sometimes Implemented	24	12.37
Always Implemented	91	46.91
Decided not to answer	7	3.61

The plan of activities of municipalities and barangays ranges from "most of the proposed activities are implemented" to "all of the activities are implemented". There are fifteen issues and concerns in the implementation of the ASAP (Table 5), categorized into five factors, funding, capability, legislative, political will, and IEC. The most

common factors are funding, capability, legislative, followed by IEC and political will.

Table 5. Issues encountered in the implementation of ASAP with their corresponding influencing factors and percent number of issues per factor.

Factors	Identified Issues	Total Number of Issues	%
Funding	1. The dependency of barangay funds and logistics on municipal LGUs. 2. No salary for tanods and fish wardens. 3. Lack of logistics to apprehend illegal fishers and collection of waste.	4	26.7
Capability	1. Insufficient technical knowhow on livestock-related livelihoods (piglets dying, mother pig cannot reproduce). 2. Marine turtles invade seaweed farms. 3. Lack of knowledge on timing for the planting of mangrove seedlings. 4. Occurrences of grass fires.	4	26.7
Legislative	1. Absence of ordinances in some barangays (e.g., mitigate slash and burn). 2. Legal issues in some land boundaries for tree planting. 3. Sudden changes in barangay officials affect the timing of planning. 4. Grazing of goats and cows on mangrove reforestation.	4	26.7
Political Will	1. The council does not prioritize some proposed activities in the plan.	1	6.7
EIEC	1. The communities believe that the collection of segregated waste and composting are the mandates of the municipality. 2. Insufficient IEC interventions for MPAs.	2	13.3
Total		15	100

DISCUSSION

The participants/LGUs utilized the knowledge that they learned from the workshops. There is a high rate of implementation of environmental plans and laws across the barangays of Palawan. The implementation of the plan of activities of municipalities and barangays ranged from "most of the proposed activities are implemented" to "all of the activities are implemented",

indicating a high implementation rate of plans and environmental laws across the barangays of Palawan.

The barangays always implement the waste segregation and composting, but sometimes collect the waste materials. The barangays always construct the MRFs, create the SWM Boards, enforce ordinances, conduct IEC, and do monitoring. Communities believed that the collection of segregated waste and composting are responsibilities of the municipal government. The bantay-dagat and apprehension of illegal fishers are sometimes implemented. Fishery ordinances, IEC on fishery laws, and monitoring on enforcement of fishery laws are always implemented. Tree/mangrove planting is always implemented, but nursery projects are not implemented. Bantay-gubat and apprehension of illegal loggers are sometimes implemented, along with agroforestry and advocacy programs.

Successful implementation of environmental protection at the ground level are affected by lack of participation and engagement, lack of accountability, low transparency, lack of awareness of active citizen, weak role of civil society, and gender inequality (PIN 2017). Moreover, Taylor (2016) emphasizes that quality of decision making, accountability processes also influence the protection of the environment. Additionally, local attitudes and behaviors (Cameron 2016), and political will, legislation, stakeholder's participation, and priority of outsourced funds (Gonzales 2011) must be considered as critical factors in the protection of the environment.

On the other hand, crucial strategies to mainstream environmental concerns to government units must include: the use of innovative IEC that will install long term effect to stakeholders; set issues into the main agenda of the government; enact legal frameworks and policies; pursue development plans at all levels with the budget for the execution of the plans; execute the plan; set monitoring and evaluation regimes to the program (Gonzales 2012).

Gender equity did not appear as a factor in the implementation of plans and laws, which may mean that Palawan barangays are not sensitive to gender issues. Hence, more efforts should focus on gender and development (GAD) in the surveyed barangays and or other barangays.

Although there are legislative issues (Table 5), the Palawan municipal LGUs, in general, display a common vision of successfully conducting and sustaining Coastal Resource Management programs accompanied by more than just supportive legislation as the Local Government Code of the Philippines (Hansen et al. 2007). However, barangays must also exhibit the necessary technical competence and financial capability as suggested by Riggs (2003), which can resolve the capability issues at the local level (Table 5),

along with political will, which also plays a major role in successful CRM programs (Hansen et al. 2007).

Barangays and municipalities in Palawan have effectively carried out their respective ASAP, which is in contrast to the past observation that LGUs across the country develop their coastal management plans, but are not always used. It seldom forms part of the LGU's development plan, though some LGUs welcome the use of the plan making it an integral part of their development plans with budget allocations (Gonzales 2011). With this premise, there is a need to evaluate the implementation in barangays outside Palawan to discern whether the Philippine grassroots LGU has improved the enforcement of their environmental laws and plans through time. Additionally, monitoring and evaluation should be practiced and institutionalized at the barangay level.

The plans are not immediately integrated or interfaced with the existing development or investment plans of the municipality or city, thus, no budget is allocated (Gonzales 2011). Therefore, ASAP should find means to be included in the Annual Investment Plan (AIP) of the municipality to be funded. Although various funds for projects come from the 20% Development Fund in the AIP of the Internal Revenue Allotment (IRA), other sources of the budget for environmental plans may also come from outside sources. However, funding from external sources may have structured objectives and directions that are inconsistent with, may not suit, or directly respond to the real needs of the beneficiary community (Gonzales 2011).

Another factor in implementing barangay environmental plans and laws is IEC. In the past, the Philippine LGUs are largely unaware of their roles in managing municipal waters, as much as they are uninformed about the roles of government institutions that have been tasked to assist them, while in general, resource management receives low LGU prioritization (Pestaño-Smith et al. 1999). This is also reflected in this study where the communities are unaware of who is responsible for the waste management, the creation of bantay-dagat/bantay-gubat and apprehension of violators. Moreover, many residents don't necessarily see wildlife trafficking as a crime, thus communication and outreach directed specifically to changing locals' attitudes could be one possible tool in solving this disconnect, rather than focusing on the socio-environment dimensions such as access to land to grow food or having a reliable source of clean drinking water (Cameron 2016). Hence, strategic IEC should become one of the enablers for sustainable development at the grassroots level, emphasizing the changing of local attitudes and behavior.

The Local Government Code of the Philippines has enabled the LGU to gain control of the management of their respective natural resources. Still, this study and the findings of Hansen et al. (2007) showed problems

encountered in implementing the Code at the grassroots level. Besides, although the existence of a causal link from governance/institutions to growth performance is widely accepted, this does not suggest that one can systematically rely upon improved ordinance to generate growth over the time horizon that policymakers can care about (a decade or two). Improved governance in a particular dimension would be effecting in generating growth when poor governance in that dimension is among the binding development constraints in the country (Rodrik 2008). Moreover, there should be a strong equity in the national policy and legislation to provide clear guidance on food security and nutrition at grassroots levels. Ground works should also be laid out for good governance, including empowerment and capacitation of grassroots levels (Immink 2011).

The above results and discussion show five factors that influence the implementation of environmental plans and laws at the barangays of Palawan, namely: funding, capability, legislative, political will, and IEC. The most common factors are funding, capability, legislative, followed by IEC, and political will. Gender equity did not appear as a factor; hence, it should be factored-in in the future barangay plans and strategies as recommended by PIN (2017).

The above arguments also emphasize that the national government putting in place the legislative support for environmental protection/CRM through RA 7160 must also provide follow-up laws and programs to augment and support the implementation of environmental protection and management at the grassroots, including but not limited to the above-mentioned implementing factors.

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Use of Facebook as a medium for asynchronous learning: perceptions among undergraduate industrial technology students at a public higher education institution in the Philippines

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ABSTRACT

The online social networking, Facebook has gained much popularity among the public primarily for interactions and for the exchange of information. However, the extent of the benefits of this social networking platform in facilitating students' learning needs to be assessed. A quantitative descriptive study was conducted to determine the perceptions of undergraduate industrial technology students in a public university of using this social networking platform as one of the tools for asynchronous learning. Seventy (70) randomly selected respondents were asked to answer some questions related to their perceptions of using Facebook in their learning activities. The respondents, as a whole group, had a "Favorable" perception towards using Facebook as a learning tool for asynchronous learning. There were no significant differences in the perception of using Facebook when the respondents were grouped according to sex, length of membership and the time spent on using the social network. Respondents who had low scholastic standing had a "Strongly Favorable" perception towards Facebook as a learning tool and their level of perception was significantly different from both groups with average and high scholastic status. There was a weak correlation between the level of perception towards the use of Facebook and the different independent variables and the degree of relationship was not significant. Nevertheless, Facebook can still be used as a platform to create awareness among students about their lessons in school and can be used as one of the avenues to help students who are weak academically through online tutorials and correspondence.

Keywords: academic performance, e-learning, network, online learning, social media

INTRODUCTION

Social network allows individuals to construct a personal profile within a bounded system and connect with common users within that system (Boyd and Ellison 2008). Over the years, the use of social networks has considerably expanded, and these include websites that are related to work (e.g., LinkedIn.com) or those that are used solely for recreation (e.g., MySpace). These social media sites do have a common purpose, and that is to connect people digitally.

Social network sites (SNSs), including MySpace and Facebook are popular among young people (Silius et al. 2010) because these can be used in education to enhance student learning and encourage them to network and share resources with one another (Alexander 2006; Boulos and Wheeler 2007; Chen et al. 2009). In these social networking sites, a user has direct interaction with another participant; thus, creating different kinds of groups that cater to different needs.

Facebook, one of the popular social network sites, has become a powerful communication medium. In fact, Facebook is described as "one of the new titans of the Internet" as it facilitates interconnectivity among users through personal relationships and recommendations with the inclusion of features including *like* and *comment* (Schwartz 2011). On a global scale, slightly more males than females use Facebook and the largest Facebook users are those in the age group between 26-34 years of age followed by 18-25 years old and then 13-17 years old (Hilton and Plummer 2012).

The use of Facebook also allows the possibility of creating closed groups that allow asynchronous and synchronous interactions among its members (Meishar-Tal et al. 2012). This facilitates sharing of information, such as links to websites, text documents, pictures, and many other features. The Facebook group contains at least two of the three components of the learning management systems: the digital content component and the interaction component. Hence, it raises the possibility of utilizing Facebook as an alternative learning management system in both synchronous and asynchronous teaching platforms.

There are few research studies that demonstrate the educational potential of Facebook in higher education (Boyd and Ellison 2008; Junco 2012). Selwyn (2009) stressed that the conversational, collaborative and communal dimensions of Facebook are what its users' value. Moreover, much

of the learning that takes place on Facebook is similar to the type of learning that happens outside of the classroom. It is evident that Facebook provides an environment for informal learning that encompasses a range of essential skills including teamwork and organizational competencies, which are relevant for future employment (Madge et al. 2009). Likewise, Vivian (2011) recommended further research into the relationship between the use of social network services and informal learning so that teachers can be informed about how to effectively incorporate this technology into the teaching and learning process. The perceived benefits of Facebook on the facilitation of informal learning among students provided the impetus for this study as there is scarcity of available data along this line of research in the Philippines. Using a small cohort size of undergraduate students of Industrial Technology in a public higher education institution, the students' perception towards using Facebook in asynchronous learning was assessed and the relationships of the different variables such as sex, scholastic status, length of membership to Facebook and the time spent of using Facebook to these perceptions were also determined.

METHODS

Respondents

The study was conducted at the Iloilo Science and Technology University **(**Main Campus), a public institution of higher education located in Central Philippines. The subjects were the students enrolled in the Bachelor of Industrial Technology (B.I.T.) during the First Semester 2017-2018. A total of 70 respondents were included in the study determined by random sampling.

Data-Gathering Procedures

The instrument used to gather data was a modified version of the validated questionnaires of Hilton and Plummer (2012) and of Barczyk and Duncan (2013) on Perception on the use of Facebook for asynchronous learning. These items were modified from the validated instrument on Classroom Community Scale that measures students' responses in relation to their attitudes towards the use of the internet for distance education (Rovai 2002). The standardized instrument had a Cronbach's coefficient of 0.93 and the equal-length split-half coefficient was 0.91, indicating excellent reliability.

The questionnaire was composed of two parts: Part 1 was about the respondent's personal details such as sex, grade point average in the preceding semester, length of membership to Facebook and the duration spent on browsing Facebook per day, and Part 2 which consisted of 10 questions, pertaining the use of Facebook in the various areas of their learning activities

which they rated based on a scale of 0-100. The approval to conduct the study was granted by the head of the institution and the respondents who took part in the study gave consent to have their responses used anonymously in the study.

Data Analyses

The respondents were categorized into the different variables including sex (male or female), academic status (High: GPA of 1.75-1.0; Average: GPA of 2.5–1.76; and Low: GPA of <2.5), length of membership to Facebook (less than 1 year, 1-3 years and more than 3 years) and the amount of time spent browsing Facebook per day (less than 1 hr, 1-3 hours, and more than 3 hours). The students' perception on the utilization of Facebook as one of the tools to assist them in learning was expressed in percentage based from the mean values that the student has rated in the 10 questions. The mean values were classified either as: strongly unfavorable (0-20), unfavorable (21-40), neutral (41-60), favorable (61-80) and strongly favorable (81-100).

Descriptive profile of the respondents and the degree of their perception on the use of Facebook for asynchronous learning were determined by obtaining the means, standard error of the mean, frequency counts and percentage. Significant differences among variables tested using two tailed t-test (sex) and Analysis of Variance (ANOVA) (for scholastic status, length of membership to Facebook and time spent for using Facebook) were determined. Correlation analysis was used to establish the relationship between the different variables of the study and the degree of perception on the use of Facebook for learning activities. Statistical tests were all done at 0.05 level of significance.

RESULTS

In terms of personal details (Table 1) majority of the respondents were males (88.6%), had average scholastic status (GPA of 2.5–1.76; 78.6%), been a member of Facebook for more than 3 years (62.9%) and spent browsing or using Facebook on the average less than 1 hr per day (50.0%). Although majority (54.3%) (Table 2) of the respondents had a "Strongly Favorable" perception towards the use of Facebook in asynchronous learning, the average perception of the group was 78.9%$\pm$ 6.1, which was "Favorable".

When grouped according to sex, majority of the males (75.0%) and females (51.6%) had a "Strongly Favorable" perception towards the use of Facebook in asynchronous learning (Table 3A) and no significant differences (P>0.05) in the levels of their perceptions were noted (Figure 1A). In terms of scholastic status, all in the low academic status and majority (51.0%) of those

in the average scholastic status had a "Strongly Favorable" perception on the use of Facebook for asynchronous learning (Table 3B). Further analysis revealed that the perception on the use of Facebook in asynchronous learning among students who were low in their scholastic status was significantly different ($P<0.05$) from the groups who had either Average or High scholastic status (Figure 1B).

Table 1. Profile of the respondents in the study (n=70).

Variable	Frequency	Percentage (%)
1. Sex		
Male	62	88.6
Female	8	11.4
2. Scholastic status		
Low	8	11.4
Average	55	78.6
High	7	10
3. Length of Membership		
Less than 1 year	8	11.4
1 - 3 years	18	25.7
More than 3 years	44	62.9
4. Time spent on Facebook		
Less than 1 hr per day	35	50
1 - 3 hrs per days	24	34.3
More than 3 hrs per day	11	15.3

Table 2. Perceptions of the students on the use of Facebook in asynchronous learning (n=70).

Perception	f	%
Strongly Unfavorable	2	2.9
Unfavorable	1	1.4
Neutral	7	10.0
Favorable	22	31.4
Strongly Favorable	38	54.3
TOTAL	70	100

Table 3. Distribution of the students' perceptions towards the use of Facebook in asynchronous learning activities according to (A) sex, (B) scholastic status, (C) length of membership to Facebook and (D) amount of time spent on Facebook per day (n=70).

A. Sex	Strongly Unfavorable (0 - 20)	Unfavorable (21 - 40)	Neutral (41 - 60)	Favorable (61 - 80)	Strongly Favorable (81 - 100)	Total (n/%)
Female (f/%)	0 (0)	0 (0)	2 (25.0)	0 (0)	6 (75.0)	8
Male (f/%)	2 (3.2)	1 (1.6)	5 (8.1)	22 (35.5)	32 (51.6)	62

B. Scholastic Standing	Strongly Unfavorable (0 - 20)	Unfavorable (21 - 40)	Neutral (41 - 60)	Favorable (61 - 80)	Strongly Favorable (81 - 100)	Total (n/%)
Low Scholastic Achievement (f/%)	0	0	0	0	8 (100)	8
Average Scholastic Achievement (f/%)	1 (1.8)	1 (1.8)	6 (10.9)	19 (34.5)	28 (51.0)	55
High Scholastic Achievement (f/%)	0	0	1 (14.2)	3 (42.9)	3 (42.9)	7

C. Length of Membership to Facebook	Strongly Unfavorable (0 - 20)	Unfavorable (21 - 40)	Neutral (41 - 60)	Favorable (61 - 80)	Strongly Favorable (81 - 100)	Total (n/%)
Less than a year (f/%)	0 (0)	0 (0)	2 (25.0)	3 (37.5)	3 (37.5)	8 (100)
1 to 3 years (f/%)	1 (5.6)	1 (5.6)	0 (0)	6 (33.3)	10 (55.5)	18 (100)
More than 3 years (f/%)	0 (0)	0 (0)	5 (11.4)	13 (29.5)	26 (59.1)	44 (100)

D. Duration of Facebook Use per day	Strongly Unfavorable (0 - 20)	Unfavorable (21 - 40)	Neutral (41 - 60)	Favorable (61 - 80)	Strongly Favorable (81 - 100)	Total (n/%)
Less than one hour/day (f/%)	0 (0)	1 (2.9)	3 (8.6)	15 (42.8)	16 (45.7)	35 (100)
1 to 3 hours/day (f/%)	2 (8.3)	0 (0)	3 (12.5)	3 (12.5)	16 (66.7)	24 (100)
More than 3 hours/day (f/%)	0 (0)	0 (0)	1 (9.1)	4 (36.4)	6 (54.5)	11 (100)

When the respondents were grouped according to the length of membership to Facebook, majority (55.5% and 59.1%) of those who have been a member for at least 1 year had a "Strongly Favorable" perception towards the use of Facebook in asynchronous learning, while those who have been a member of Facebook for less than year perceived the use of this social media platform as either "Favorable" to "Strongly Favorable" (Table 3C). However, no significant differences ($P>0.05$) in the levels of perception were observed among the groups (Figure 1C). In terms of the daily use of Facebook, majority of those who spend at least 1 hour in Facebook had a "Strongly Favorable" perception on the use of the social media platform in asynchronous learning

(Table 1D), and the levels of perception among the groups were not significantly different ($P>0.05$; Figure 1D).
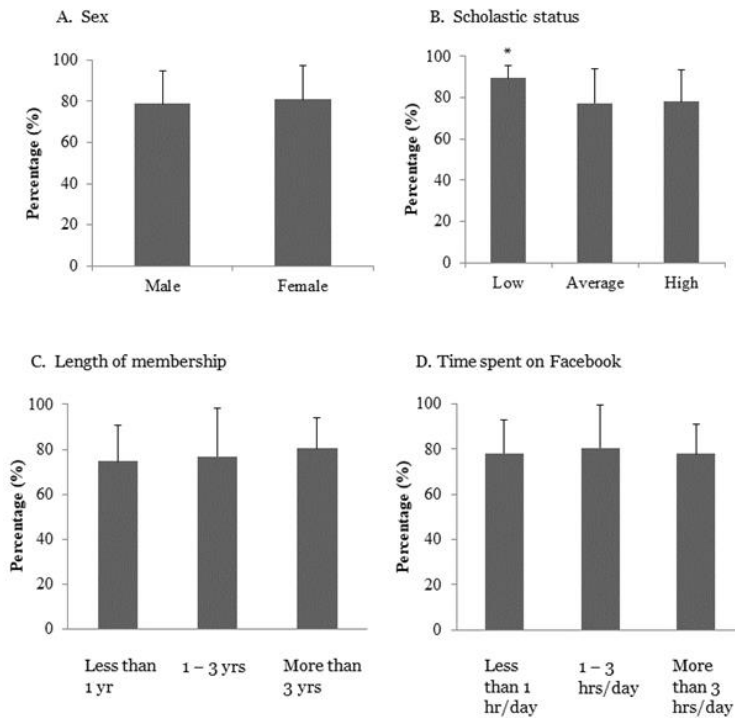

Figure 1. Perception (expressed as percentage) of the students towards the use of Facebook in their learning activities. A total of 70 respondents were involved in this study. An asterisk above column bars indicates significantly different ($P<0.05$).

Correlation analysis revealed a weak but no significant relationship ($P>0.05$) between the different variables and the levels of perception towards using Facebook in the learning activities of the respondents (Table 4).

Table 4. Correlation of the different variables with perception towards using Facebook in the students' learning activities (n=70).

Variable	Coefficient of Correlation (r)	Significance
Sex	0.042	Not significant
Scholastic status	0.174	Not significant
Years of membership	0.13	Not significant
Time spent on FB	0.023	Not significant

DISCUSSION

The present study clearly demonstrated that Industrial Technology is still a male-dominated degree program, with more males taking this course than females. Not only this scenario is prevalent in the Philippines but in other countries as well, where Industrial Technology has one of the lowest numbers of female students, faculty members and even those involved in the executive department (Kulatunga et al. 1999; Kassi and Dugger 2000; Weber and Custer 2005). In order to attract more women to enrol in this degree, there should be intensive campaigns in re-directing the public perception that this course could also be suitable for women and there are job prospects along this field that women can enter. Schools that offer degree programs in industrial technology are encouraged to redesign the curriculum and break sex-role stereotypes in the choices of degrees by providing more opportunities for women participation in traditionally male-dominated degree programs. For example, Weber and Custer (2005) suggested that more women can be recruited to take up technology courses if curriculum developers in technology education are able to design and implement teaching and learning methods that can comprehend "women's ways of knowing". Moreover, Shroyer et al. (1995) stressed that the inclusion of environmental and social technologies into industrial technology curriculum could also be appealing to female students.

It is evident that students had a generally favorable perception towards using Facebook as one of the means to help them in their learning particularly when they are not inside the classroom. The favorable perception towards Facebook is manifested on the widespread use of this social media platform in the daily lives of the students. For example, Cain (2008) estimated that 80-90% of the college students in the United States use Facebook. Among secondary school students in Ontario, Canada, more than 70% agreed that Facebook is a useful a tool in learning (Fewkes and McCabe 2012). A survey done from 126 universities in the US and one Canadian university revealed that 90% of the students used social networking services, and 97% of them used Facebook (Junco 2012). Similarly, about 95% of the British undergraduate students regularly used social networking services (Madge et al. 2009). Aside from its widespread popularity and use, Facebook is also an important method of communication, particularly for students in their late teens to twenties (Hilton and Plummer 2012). Learning institutions can take advantage of this positive perception of students towards Facebook so that teachers can prepare teaching and learning materials that can be uploaded to a Facebook page, which the students can access when they are not in school. Facebook could help convey the teacher's messages (Madge et al. 2009; Roblyer et al. 2010) and thus can reinforce learning among students.

Four independent variables were used to find out if these had correlation with the level of perception of the students regarding the use of Facebook as a platform for asynchronous learning. No significant correlations were found, yet, students had a favorable perception towards Facebook as a tool in asynchronous learning. This indicates that there are other factors that need to be explored, which might have an effect on how students perceive the use of Facebook in their learning of a particular subject. Kabilan et al. (2010) in their studies involving college students in Malaysia obtained similar results on the use of Facebook in the learning of English. In general, the students favorable views toward Facebook as means of facilitating the leaning of a particular subject might be explained by the fact that online platforms, to which Facebook belongs, offer genuine interactions among students in an informal setting. If students experience positive interactions among themselves, they develop increased self-confidence and a deeper sense of connectedness with one another, which are important factors in a learning environment (Wang and Chen 2007; Kabilan et al. 2010). Moreover, Lave and Wenger (1991) opined that students will have a positive view towards learning if it is viewed as a form of social participation brought about by authentic and relevant interactions. Teaching-learning situations including asynchronous learning that are carried out in social online communities, such as Facebook should therefore allow and facilitate the necessary interactions among students that result in the enhancement of learning (Wenger et al. 2002). As such in this study, the students viewed the use of Facebook as a positive experience for them and they could use that favorable experience when they study a new subject. This positive reinforcement will help them understand and learn better the various concepts and lessons that are given to them.

Taken together, the results of the study showed that the undergraduate students of Industrial Technology had a positive and favorable perception towards the use of Faceboook as a means of facilitating learning outside the classroom. This social networking platform can be used by teachers and perhaps included in the course syllabi as an additional way of connecting with students. It should provide encouragement to educational institutions in considering the use of Facebook to move forward in their efforts to recruit and interact with students in order for them to attain their institutional objectives. Facebook is not a "silver bullet" for educational or any other kind of organizations' efforts to recruit and communicate with students, rather it should be added to the toolbox of those reaching out to young adults. Although there is so much to learn about social media in general, and Facebook in particular, it is evident that this is one of the tools in asynchronous learning that cannot be overlooked in terms of its potential. Future research should also focus on methods that can assess the ability of Facebook towards the development of competencies among students when online platforms are integrated in the subject. Moreover, a comparison between traditional learning management approaches and the use of Facebook in the teaching-

learning process should be done in order to determine the most efficient educational platform for student engagement and learning.

Overall, the authors believe that educational institutions should explore Facebook as a means of not only to communicate with students but also to facilitate self-directed learning. There is still much to learn on how Facebook or any other social media can aid students' learning, nevertheless, it offers potential benefits in the teaching-learning process that should not be overlooked.

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Sargassum, Padina and Turbinaria as bioindicators of cadmium in Bais Bay, Negros Oriental

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ABSTRACT

Marine pollution is becoming one of the global environmental problems around the world. Heavy metal concentrations in the environment is 100-1,000 folds higher than those in the Earth's crust due to anthropogenic sources. The use of algae as bioindicators of metal pollution and the effective removal of toxic metal ions has received increasing attention. Brown algae is thought to be excellent in the sequestration of metal. In this study, cadmium (Cd) concentration in the thalli of *Sargassum* sp*., Padina* sp. and *Turbinaria* sp. from North Bais Bay, Negros Oriental was determined using Atomic Absorption Spectrophotometer (AAS). The concentration of cadmium in the sediment of North Bais Bay was also determined because environmental pollutants could also accumulate in the sediment. Results of this study showed the cadmium contamination in Bais Bay, wherein *Sargassum* sp., *Padina* sp., and *Turbinaria* sp. absorbed these cadmium ions. *Sargassum* sp. had the highest concentration of cadmium which ranged from 2.14 to 4.45 mg kg^{-1}. The concentration of cadmium in *Padina* sp. and *Turbinaria* sp. ranged from 2.2 to 3.4 mg kg^{-1} and 2.36 to 2.76 mg kg^{-1}, respectively. The concentration of cadmium in the sediment ranged from 3.72 to 5.53 mg kg^{-1} dry weight. This indicates that these brown algal species could be utilized as bioindicators of cadmium contamination in marine waters and possible phytoremediation of cadmium in wastewater.

Keywords: brown algae, phytoremediation, pollution, biomonitoring, cadmium

INTRODUCTION

In recent years, heavy metal pollution has become a persistent problem in coastal and estuarine ecosystems around the world (Khan et al. 2017). Accumulation of heavy metals in the aquatic environment has been

METHODS

Description of the Study Area

This study was conducted in North Bais Bay (9°39'4.4208"N, 123°8'41.2908"E) located on the eastern side of Negros Island (Figure 1). There were human settlements areas, industrial plants, resorts and two rivers draining water into the bay.
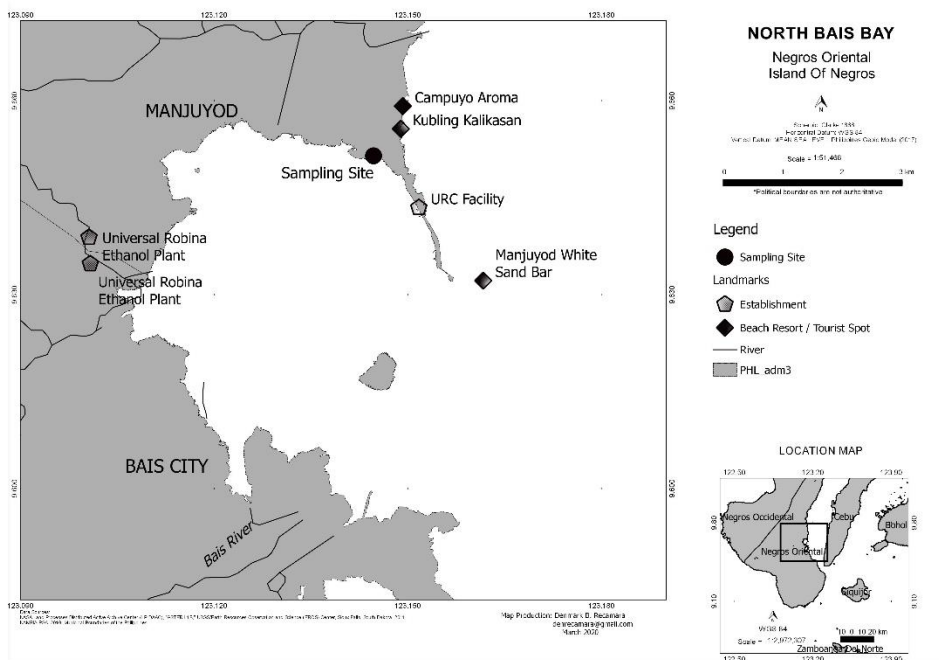
Figure 1. Map of North Bais Bay showing the sampling site (black circle), industries, resorts and Bais River.

Collection and Treatment of Samples

From August to October 2018, six sampling events were conducted to collect samples of algae belonging to the following genera: *Sargassum, Padina,* and *Turbinaria*. These months are within the southwest monsoon (Habagat) which may bring frequent heavy rains and surface runoff. The samples were then washed with filtered seawater and brought to NORSU Biology Laboratory in a polyethylene bags with ice. Upon arrival at the laboratory, the algal samples were thoroughly cleaned from epiphytes and sediment using distilled water and air dried on an absorbent paper for at least 1 week. After which, the dried samples were oven dried at 100°C for 1.5 h to

remove the remaining moisture in the samples. The samples were then pulverized in an electric grinder for more efficient digestion and brought to University of San Carlos Water Laboratory, Cebu City for heavy metal analysis.

Since bioaccumulative substances are also incorporated into the sediment (Ansari et al. 2004), concentration of cadmium in the sediment of North Bais Bay was also determined. Two hundred grams (200 g) of sediment samples were collected from the same sites where the algal samples were collected three times a month from August to October 2018 using a polyethylene core borer (5 cm diameter x 50 cm length) at a depth of 5 cm. The collected sediment was then placed inside a plastic bag and brought to NORSU Biology Laboratory for air drying. The dried sediment samples were then submitted to University of San Carlos Water Laboratory, Cebu City for heavy metal analysis.

Analytical Method for Heavy Metal Determination in Brown Algae and Sediment

To determine the heavy metal in *Sargassum, Padina* and *Turbinaria* species, 1 g each of dried sample (dry weight) was digested with 20 ml of nitric acid (HNO_3) and 5 ml of hydrogen peroxide (H_2O_2). The samples were stirred gently to homogenize with the acids. The solution was then heated to 95°C and concentrated for analysis.

Heavy metal in the sediment samples was determined using the method from US EPA (1996). The sediment samples were mixed thoroughly to achieve homogeneity and filtered using a USS #10. After homogenization, 1 g of dry sample was digested in a digestion vessel using 10 ml of HNO_3. It was then heated to 95°C and refluxed for 10 to 15 min without boiling. Five (5) ml of concentrated HNO_3 was added and refluxed for 30 min until production of brown fume has ceased. The solution was allowed to evaporate to approximately 5 ml using a ribbed watch glass or vapor recovery system. If the sample has cooled, 2 ml of water and 3 ml of 30% H_2O_2 was added. Acid-peroxide digestate was again heated until the volume has been reduced to approximately 5 ml. Acid-peroxide digestate was allowed to cool then diluted to 100 ml with water. Particulates in the digestate should then be removed by filtration, by centrifugation, or by allowing the sample to settle. The sample is now ready for analysis.

The concentration of cadmium in brown algae and sediment was analyzed using Shimadzu Atomic Absorption Spectrophotometer (AAS) at the Water Laboratory of University of San Carlos, Cebu City following AAS Flame technique. All analyses were carried out in triplicate. For each run,

three "blanks" were analyzed to check the purity of reagents and any possible contamination.

Statistical Analysis

The data represent the mean and standard deviation (mean±SD) of triplicate samples. Monthly cadmium concentration in the sediment of Bais Bay were compared using Kruskal Wallis test, while two-way ANOVA was used for the three brown algal species among sampling months at 95% confidence interval.

RESULTS

Among the three species, *Sargassum* sp. had the highest concentration of cadmium which ranged from 2.14 to 4.45 mg kg^{-1} dry weight. The concentration of cadmium in *Turbinaria* sp. ranged from 2.36 to 2.76 mg kg^{-1} dry weight while *Padina* sp. had cadmium concentration which ranged from 2.23 to 3.4 mg kg^{-1} dry weight. The highest concentration of cadmium across the three species was observed in September (Figure 2). However, there is no significant difference between algal species across sampling months (P=0.3; CI=95%). The concentration of cadmium in the sediment ranged from 3.72 to 5.53 mg kg^{-1} dry weight. Highest cadmium concentration was recorded in October while lowest in August (Figure 3) but the difference was not statistically significant (P=0.4; CI=95%).
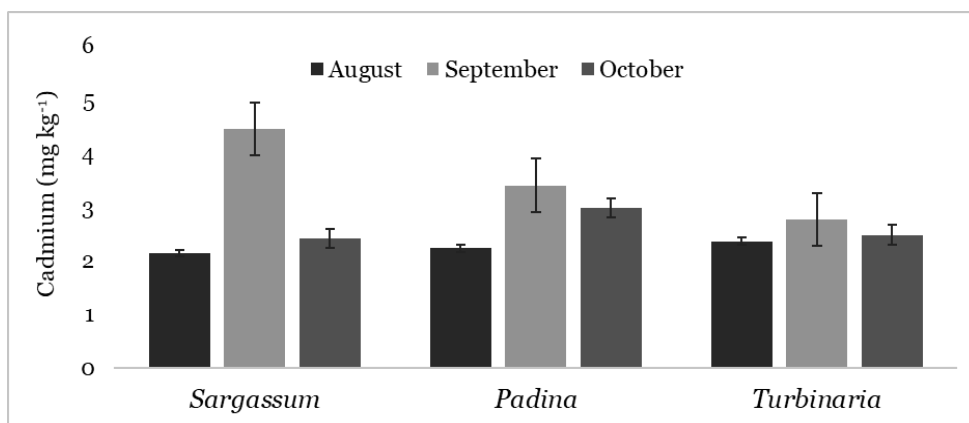

Figure 2. Concentration of cadmium (Cd) in 3 species of brown algae from August to October 2018. (P>0.05; error bar=±SD).
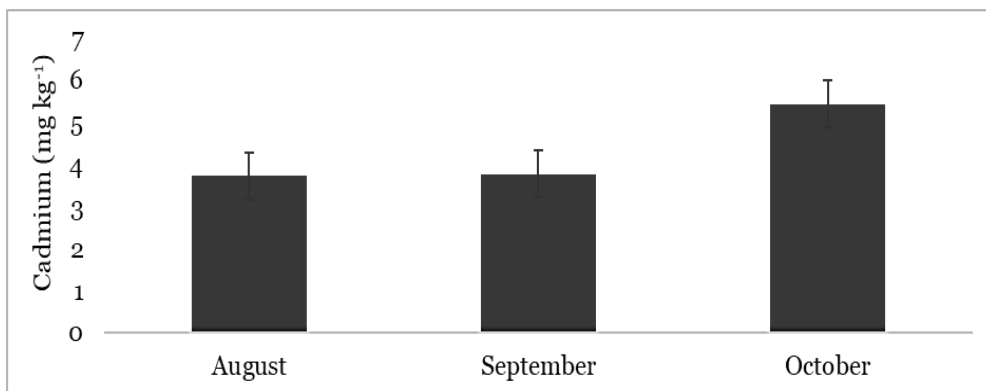
Figure 3. Concentration of Cadmium (Cd) in the sediment from August to October 2018. (P>0.05; error bar=±SD).

DISCUSSION

Cadmium concentration in *Sargassum* sp., *Padina* sp. and *Turbinaria* sp. provided an estimate on the bioavailability of cadmium in Bais Bay. Comparison of Cd concentration in the algal samples collected from Bais Bay were higher than other areas in the Philippines such as the coastal waters of Batangas, Philippines with 0.50 mg kg^{-1} (Borja et al. 2015). Likewise, cadmium level in Bais Bay during this study was higher by several orders of magnitude than the natural range from 0.15 to 0.20 mg kg^{-1} of concentration for this element (Kabata-Pendias and Pendias 1979). This implies input of cadmium in Bais Bay from various sources within the bay.

Electroplating, smelting, paint pigments, batteries, fertilizers, mining and alloy industries are considered as the major anthropogenic sources of cadmium in the environment (Iqbal and Edyvean 2005). In Bais, agricultural, domestic and industrial wastes are the most important sources of pollution. In 2001, waste generation of the domestic, commercial and institutional sectors in Bais City was estimated at 7,300 tons yr^{-1} but will most likely increase to at least 10,000 tons yr^{-1} in 2020. The domestic sector generated an average waste of 0.20 kg capita^{-1} day^{-1} while the two sugar mills generated approximately 85,000 tons of mudpress, lime-mud and ash every year as main process residues. Widespread and regular application of chemical fertilizer and pesticides on more than 19,000 ha for agricultural production every year and using the river system for scattered waste disposal provided further waste sources (Paul 2002). In 2015, release of industrial untreated wastewater into the bay was reported (Matus 2015). Though the chemical composition of untreated industrial effluents and urban runoff has not been characterized, accumulation of environmental pollutants may occur in Bais

Bay due to its enclosed condition with limited water exchange as observed in the Gulf of Thailand (Wattankorn 2006).

The presence of cadmium in the thalli of *Sargassum*, *Padina* and *Turbinaria* showed that these species absorbed cadmium from Bais Bay. Thus, these species could be most effective for biomonitoring and phytoremediation of toxic heavy metals because their thalli directly interact with the water column. It has been observed that *Sargassum* and *Padina* had the highest potential as biosorbents for the removal of heavy metals such as Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+}, and Ni^{2+} from aqueous solutions. The general affinity sequence for *Sargassum* was Pb>Zn>Cd>Cu>Ni while that of *Padina* was Pb>Cu>Cd>Zn>Ni (Sheng et al. 2004). Due to abundance of alginate in the cell wall of brown algae especially order Fucales and Laminariales, metal ions such as Pb^{2+}, Cu^{2+}, Cd^{2+}, Zn^{2+}, Ca^{2+} are sequestered from the aqueous solution through the formation of network junctions by the cations of homopolymeric guluronic acid blocks in alginic acid (Davis et al. 2003). When guluronic acid content increased, affinity of alginates for divalent cations also increased (Haug 1961). The higher specificity of polyguluronic acid residues for divalent metals is explained by its "zigzag" structure which can accommodate the Ca^{2+} (and other divalent cations) ion more easily (Haug et al. 1967). The alginates are thought to adopt an ordered solution network, through inter-chain dimerization of the polyguluronic sequences in the presence of calcium or other divalent cations of similar size (Rees 1981). Fourier-transformed infrared (FTIR) spectral analyses have shown that cadmium biosorption to *Sargassum* arises from bridging or bidentate complex formation with the carboxylate groups of the alginate (Fourest and Volesky 1996). It has been also shown that ion-exchange takes place between metals when binding to alginate (Myklestad 1968). Untreated biomass generally contains light metal ions such as K^+, Na^+, Ca^{2+}, and Mg^{2+}. These are originally bound to the acid functional groups of the alga. During exposure of macroalgae to heavy metal solutions, metal ions replace for some of the cations such as K^+, Na^+, Ca^{2+}, and Mg^{2+} that were initially bound to the acid functional groups and make stronger cross-linking (Saravanan et al. 2011). Aside from alginate, sulphonate groups of fucoidan also contribute to heavy metal biosorption. But its role could become prominent if the binding of the metal occurs at a low pH (Fourest and Volesky 1996).

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Significant records of birds on Puerco Island, Roxas, Palawan, Philippines

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ABSTRACT

We documented a total of 53 species of birds on Puerco Island from May 2016 to December 2019 using a combination of modified area search method and photo-documentation. The number of birds increased from only 15 species in 2014 to 53 in December 2019. Records included two endangered species, 18 migratory and 28 native birds. Monthly monitoring of Barred Rail *Hypotaenidia torquata*, Olive-backed Sunbird *Cinnyris jugularis* and Collared Kingfisher *Todiramphus chloris* showed varying levels of abundance. Nest monitoring of the Near-threatened Philippine Scrubfowl *Megapodius cumingii cumingii,* locally called "tabon", using close circuit television cameras, showed a significant increase from only three nests reported in 2012 to 154 in September 2019. The changes in the species composition and the increase in the breeding population of Philippine Scrubfowl are attributed to the integration of conservation management strategies on Puerco Island.

Keywords: Endangered, Megapodius, Tabon

INTRODUCTION

The Philippines is an archipelago made up of 7,641 islands with 722 known birds of which 254 are endemic to the country (Allen 2020). The list of species is likely to increase to more than 722 as new records are added (Allen 2020). The revisions in taxonomy elevated a number of subspecies to species level thereby contributing to the increase in the number of endemic birds to 254 (Campbell et al. 2016; Cai et al. 2019; Allen 2020; McClure et al. 2020). Majority of the endemic species are restricted to one or a few groups of islands.

Most bird studies in the country focus on the endemic and resident birds on major islands with very few information available on smaller islands (Alcala and Sanguila 1969; Jakosalem et al. 2002; King et al. 2003; Paguntalan

et al. 2004). Small islands play an important role in the conservation of coastal and small island bird specialists including the Philippine Scrubfowl *Megapodius cumingii cumingii* and the Near-threatened Mantanani Scops Owl *Otus mantananensis mantananensis*. The Mantanani Scops owl is distributed mainly in a chain of small islands from southern Philippines that include Palawan, Mindoro up to Romblon (Kennedy et al. 2000). It is a poorly understood species with few studies conducted in the Philippines (Kennedy et al. 2000; Sloan 2017). The Philippine Scrubfowl, on the other hand, used to be common in coastal beach areas up to montane forests until it has been extirpated in most of its distribution range (Kennedy et al. 2000; del Hoyo et al. 2014; Bashari et al. 2017). Unlike the Mantanani Scops Owl, there were documentations on breeding ecology of the Philippine Scrubfowl (Kennedy et al. 2000; Aala 2001; King et al. 2003) with studies of Torres and Mendoza (2000) and Tabayag and Cruz (2013) focusing on a number of small islands in Palawan including Puerco Island.

Small islands with coastal mudflats are also important sites for migratory shorebirds including threatened species. There are currently seven threatened migratory shorebirds (IUCN 2020) that regularly visit coastal mudflats namely: Christmas Frigatebird *Fregata andrewsi* (Critically Endangered), Far Eastern Curlew *Numenius madagascariensis* (Endangered)*,* Great Knot *Calidris tenuirostris* (Endangered), Chinese Egret *Egretta eulophotes* (Vulnerable)*,* and Malay Plover *Charadrius peronii* (Near-threatened).

Birds dependent on coastal beaches and small islands are vulnerable to urban and tourism development (Kennedy et al. 2000; Ma et al. 2019; Zhang and Ouyang 2019). The Philippine Scrubfowl was identified as one of the species affected by loss of habitat due to coastal and beach development (Kennedy et al. 2000; del Hoyo et al. 2014; Bashari et al. 2017). In the course of monitoring bird populations on Puerco Island, it became apparent that information on birds on small islands in the Philippines is scanty. A full profile of the bird species on Puerco Island documenting the changes in the species composition from 2016 to 2019 provides pertinent information needed for future small island management.

METHODS

Study Site

The Island of Puerco (also called Banwa Private Island) falls within the political jurisdiction of the Municipality of Roxas, Palawan (Figure 1). The conservation program of the 6.2 ha island is privately managed by Aquos Foundation Inc. Prior to 2006, much of the vegetation on the island was

dominated by coconuts. There were few species of wildlife seen in the area including the Mantanani scops owl and a small breeding colony of Philippine Scrubfowl. It is because of the presence of a breeding population of Philippine Scrubfowl that a 200 square meter area was set aside as a Tabon Breeding Sanctuary by Aquos Foundation Inc. In the course of the development of the island, native species of beach forest trees and associated plants were replanted.

Figure 1. Aerial view of Puerco Island (Banwa Private Island), Roxas, Palawan.

Synchronized Bird Count

A modified version of the Area Search method (Dunn et al. 2006) used in monitoring bird populations in small geographic areas was adopted in this study. Researchers divided the island into eight units and observers were assigned to a pre-identified count station, separated at least 100 m apart to record birds for three minutes within 0800-0900 h, using 10x42 roof-type binoculars and 20-60x60 spotting scope. Information gathered include location, date, habitat type, species (sex and age if possible), distance from the observer and the number of individuals. Bird observations were conducted simultaneously every 19th day of each month. Areas were repeatedly searched, and location of territorial birds was plotted on a detailed map. The Field Guide

to the Birds of ASEAN (Lee et al. 2018) and A Guide to the Birds of the Philippines (Kennedy et al. 2000) were used as references. Photos were taken to verify species identification.

Four land birds e.g. Philippine Scrubfowl, Olive-backed Sunbird, Collared Kingfisher and the Barred Rail) were used as indicators in monitoring population trends on the island. The Philippine Scrubfowl was chosen as it was the flagship bird of the Aquos Foundation Inc.; the Barred Rail was included since it was one of the predators of the Philippine Scrubfowl eggs and chicks; and the Collard Kingfisher and Olive-backed Sunbird were added as both were common breeding residents on the island. Bird observations were primarily conducted by the Philippines Biodiversity Conservation Foundation Inc. and the trained staff of Aquos Foundation Inc. from May 2016 to December 2019. The monthly population counts were grouped to calculate mean number of individuals using the formula $\mu = \Sigma x/N$, where μ (mean number of individuals in a species) is the sum (Σ) of individuals in a species (x) divided by the number of individuals (N). The conservation status of birds was based on IUCN (2020) and DAO (2019).

Philippine Scrubfowl Monitoring

Monitoring of Philippine Scrubfowl breeding population on Puerco Island was conducted using three Close Circuit Television (CCTV) high-definition cameras strategically located to allow observations without creating disturbance. A total of 4,008 observation hours (1,344 h in 2017, 672 h in 2018 and 1,992 h in 2019) were spent covering 09-16 March, 08-17 April, 26 May to 03 June 2017; January, April, September–October 2018; and 06 September–30 December 2019.

Training on Bird Monitoring

Prior to the conduct of regular bird monitoring, a total of 14 island staff, two representatives from Community Environment and Natural Resources Office (CENRO) and the Municipal Environment and Natural Resources Office (MENRO) of Roxas participated in the wildlife identification and monitoring training conducted last 24-25 June 2017. The training involved classroom-type lectures, field activities and identification of species. Trained personnel initially joined the count as observers before officially joining the monthly synchronized bird counts.

RESULTS

Abundance

A total of 53 species of birds were recorded on the island (Figure 2) of which three were threatened, 22 were migratory and the rest were native to the Philippines. The threatened birds include the Far Eastern Curlew *N. madagascariensis,* Great Knot *C. tenuirostris*, and the Chinese Egret *E. eulophotes*. The Near-threatened species include the Eurasian Curlew *Numenius arcuata,* Japanese Paradise Flycatcher *Terpsiphone atrocaudata periophthalmica,* and the Mantanani Scops Owl *O. m. mantananensis* (Figure 2; Table 1).
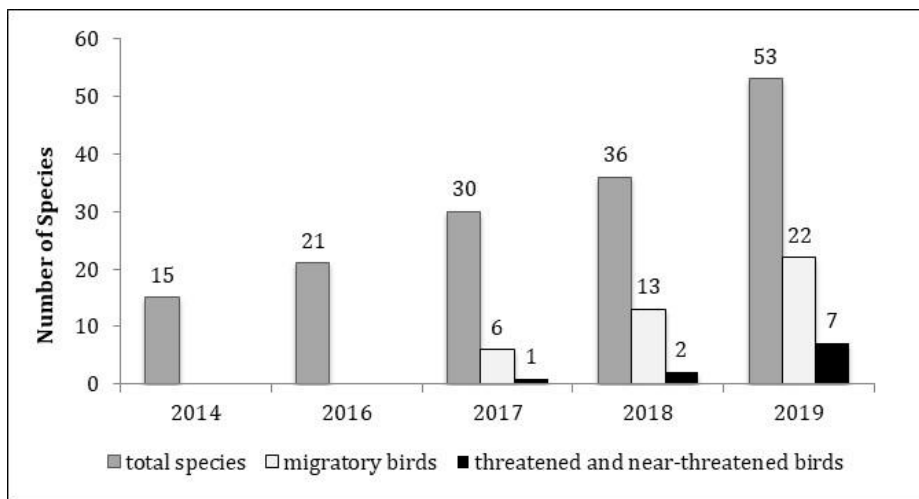
Figure 2. Yearly comparison of the number of species of birds recorded in the island.

Bird surveys from 2014–2016 recorded mostly breeding species as visits were conducted off migratory season. The addition of the migratory waterbirds significantly increased the number of species from 2017-2018 (Figure 2). In 2018 we recorded for the first time the Western Koel *Eudynamys scolopacea* and Northern Boobok *Ninox japonica*. The Northern Boobok was photographed feeding on the Philippine Scrubfowl chick while the Western Koel was observed searching for insects and worms on leaves of trees. Both were observed again in 2019.

The highest number of species of birds was seen in 2019 where a total of 17 birds were documented for the first time (Figure 2). Among the new records were the migratory Japanese Paradise Flycatcher and a number of species of doves e.g. Pink-necked Green Pigeon *Treron vernans*, Grey-capped Emerald Dove *Chalcophaps indica* and Pied Imperial Pigeon *Ducula bicolor*.

Table 1. List of bird species recorded in Puerco island from 2014-2018. Note that * stand for Threatened and Near-threatened birds (IUCN 2020).

Species Name	2014	2016	2017	2018	2019
Lesser Frigatebird *Fregata ariel*	X	X	X		X
Brown Booby *Sula leucogaster*	X				
Barred Rail *Hypotaenidia torquata*	X	X	X	X	X
*Philippine Scrubfowl *Megapodius cumingii cumingii*	X	X	X	X	X
Pacific Reef Egret (dark phase) *Egretta sacra*	X	X	X	X	X
Little Egret *Egretta garzetta*	X	X	X	X	X
*Chinese Egret *Egretta eulophotes*		X	X	X	X
Intermediate Egret *Egretta intermedia*			X	X	X
Great-billed Heron *Ardea sumatrana*			X	X	
Striated Pond Heron *Butorides striatus*	X	X	X	X	X
Black-crowned Night Heron *Nycticorax nycticorax*	X	X	X	X	X
Cattle Egret *Bubulcus ibis*					X
Black-winged Stilt *Himantopus himantopus*					X
Osprey *Pandion haliaetus*	X	X	X	X	
Malay Plover *Charadrius peronii*			X		
Lesser Sand Plover *Charadrius mongolus*				X	X
Greater Sand Plover *Charadrius leschenaultii*			X	X	X
Whimbrel *Numenius phaeopus*				X	X
*Eurasian Curlew *Numenius arcuata*			X	X	X
*Far Eastern Curlew *Numenius madagascariensis*				X	X
Ruddy Turnstone *Arenaria interpres*			X	X	X
*Great Knot *Calidris tennuirostris*			X	X	X
Common Sandpiper *Actitis hypoleucos*			X	X	X
*Grey-tailed Tattler *Tringa brevipes*				X	X
Common Greenshank *Tringa nebularia*				X	X
Common Redshank *Tringa totanus*				X	X
Black-naped Tern *Sterna sumatrana*				X	X
Whiskered Tern *Chlidonias hybridus*		X		X	X
Greater Crested Tern *Sterna bergii*					X
Grey-capped Emerald Dove *Chalcophaps indica*					X
Pied Imperial Pigeon *Ducula bicolor*					X
Pink-necked Green Pigeon *Treron vernans*					X
Western Koel *Eudynamys scolopaceus*			X		
Himalayan Cuckoo *Cuculus saturatus*				X	
Northern Boobok *Ninox japonica*			X		X
*Mantanani Scops Owl *Otus mantananensis mantananensis*	X	X	X	X	X
Savanna Nightjar *Caprimulgus affinis*		X	X	X	X
Glossy Swiftlet *Collocalia esculenta*	X	X	X	X	X
Collared Kingfisher *Halcyon chloris*	X	X	X	X	X
Common Kingfisher *Alcedo atthis*				X	X
Barn Swallow *Hirundo rustica*		X	X	X	X
Golden-bellied Gerygone *Gerygone sulphurea*		X			X
Glossy Starling *Aplonis panayensis*	X	X	X	X	X
Brown Shrike *Lanius cristatus*			X	X	X
Rufous-crowned Bee Eater *Merops americanus*					X
*Japanese Paradise Flycatcher *Tersiphone atrocaudata periophthalmica*					X
Artic Warbler *Phylloscopus borealis*					X
White-Breasted Wood Swallow *Artamus leucorynchus*					X
Grey Wagtail *Motacilla cinerea*					X
Olive-backed Sunbird *Cinnyris jugularis*	X	X	X	X	X
Eurasian Tree Sparrow *Passer montanus*	X	X	X	X	X
Chestnut Munia *Lonchura atricapilla*		X	X	X	X
Scaly-breasted Munia *Lonchura nisoria*		X	X	X	
Total species	**15**	**21**	**30**	**36**	**46**
Total migratory birds*	**1**	**2**	**20**	**17**	**21**
Total threatened and near-threatened birds**	**2**	**3**	**5**	**7**	**8**

Bird Population Monitoring

The mean population count of Olive-backed Sunbird was five with a range of 2-9 individuals. Monthly population fluctuations remain relatively the same except for the month of October where 2–3 sunbirds were observed. Most records were of eight individuals (n=29) and only two instances where nine individuals were observed. The highest number of individuals of Collared Kingfisher was six (month of September) with a mean weekly average of three individuals (n=29). Each individual or pair was observed to maintain a territory within the island (Figure 3).
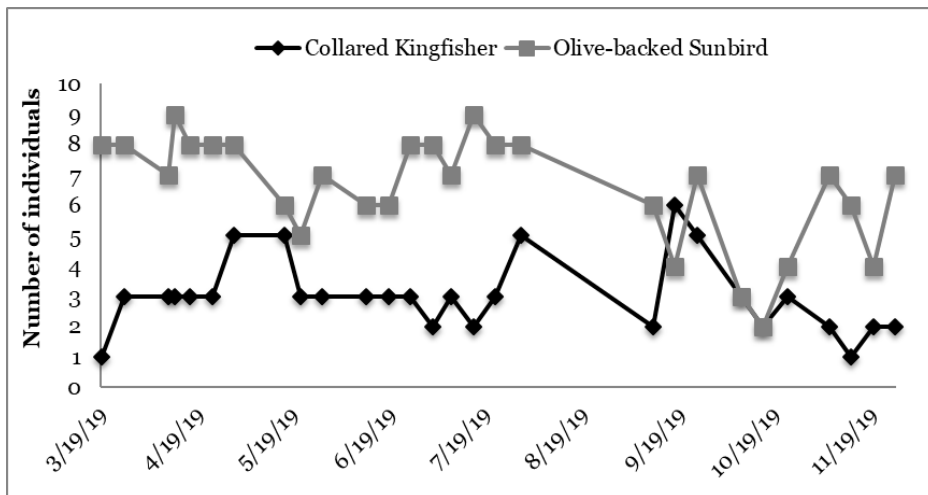

Figure 3. Weekly comparison of number of individuals of Olive-backed Sunbird and Collared Kingfisher in Puerco Island from 19 March 2019 to 19 November 2019.

Barred Rail population fluctuates from eight to 19 individuals with a mean monthly average of 13 (n=29). Highest population was recorded in the months of March and May. The Reef Egrets were frequently observed in mudflats and coastal areas. The synchronized counts on land often excluded the birds in the mudflats. Individuals reported here only include breeding birds actively making and tending nests (June–July) and birds roosting on top of trees or coconut during high tide. This had introduced a bias and we limit discussion on the number of breeding pairs (Figure 4).
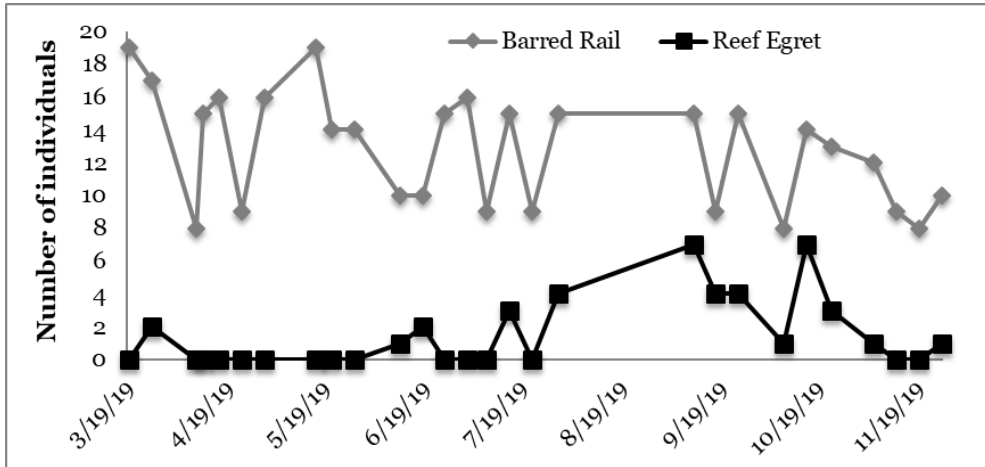
Figure 4. Weekly comparison of population counts of Reef Egret and Barred Rail in Puerco Island from 19 March 2019 to 19 November 2019.

Population monitoring of the Philippine Scrubfowl showed a significant increase in the number of active nest burrows from 2017 to 2019. The highest number of individuals tending nest burrows was consistently observed in the month of September (Figure 5). We recorded a total of 285 nests in at least seven clusters from March 2016 to November 2019. The highest count of active nest was 154 in September 2019 including nests in three more locations not covered by CCTV. No nesting activities were observed in late November until December since 2016.
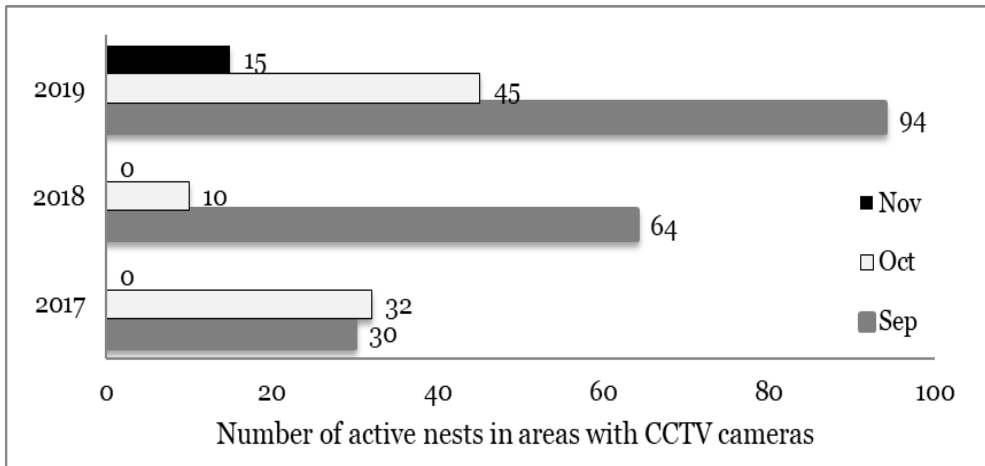

Figure 5. Annual comparison of the number of active nests counted from three nest mounds from September 2017 to 2019 in Puerco Island, Roxas, Palawan.

Species Accounts

Chinese Egret *E. eulophotes* Swinhoe, 1860 (IUCN Vulnerable; DAO Vulnerable) – Solitary birds were observed feeding on exposed seagrass beds and mudflats. At least six individuals were counted at low tide last October 2019. The bird was a frequent visitor of Puerco Island arriving as early as September and staying until early March.

Far Eastern Curlew *N. madagascariensis* Linnaeus, 1766 (IUCN Endangered; DAO Endangered) – At least three individuals were observed on separate occasions feeding on exposed mudflats. Individuals were seen roosting with other shorebirds on exposed sand bars during peak high tide.

Great Knot *C. tenuirostris* Horsfield, 1821 (IUCN Endangered; DAO Endangered) – A single individual was also observed on the exposed seagrass bed in March 2018. Several birds were observed in nearby sandbars and in Johnson Island.

Malay Plover *C. peronii* Schiegel, 1865 (IUCN Near-threatened; DAO Vulnerable) – On 14 May 2018, one female individual was seen and photographed along the shoreline during low tide on Puerco Island.

Philippine Scrubfowl *M. c. cumingii* Dillwyn, 1853 (IUCN Near-threatened; DAO Endangered) - A nest field with at least six colonies were closely monitored from 2016 to 2019. The nesting fields were occupied with breeding adult birds from January to early November on the island. On the months of November to late December of each year, no adult bird was observed on the island. In addition to this, we also identified four predators of *M. c. cumingii* chicks from the CCTV footages. Five Barred Rails were seen working in groups exposing eggs and harrasing the adult tending the nest. The Reef Egret *Egretta sacra*, Striated heron *Butorides striatus* and Northern Boobok *Ninox japonica* were also captured on camera preying on chicks emerging from the nest.

Mantanani Scops Owl *O. m. mantananensis* Sharpe, 1892 (IUCN Near-threatened; DAO Other Threatened Wildlife) – A breeding pair was found in Puerco Island that had successfully bred since 2014. An active nest was found lodged in between base of coconut fronds in June 2017. At least one or two immature owls were observed in the months of June 2017 and May 2018. Immature individuals were seen with their parents up to about four months and from November to June, only two mature individuals were recorded. Birds actively vocalized from 1800 h to around 2000 h and again at 0430 h just before daybreak. A pair was observed perched on a wire above the golf course last 03 October 2019. One of the pairs was seen perched

inconspicuously on a branch of *Delonix regia* about five meters from the trail on 04 October 2019. No immature bird was observed.

Pied Imperial Pigeon *D. bicolor* Scopoli, 1786 (IUCN Least Concern; DAO Other Threatened Wildlife) – The bird was first seen one morning on January 2018 and was since regularly sighted in 2019. One individual was observed roosting on a branch of a tree inside the 200 m² Tabon sanctuary last 24 May 2019 and two individuals on 03 October 2019.

Japanese Paradise Flycatcher *T. a. periophthalmica* Ogilvie-Grant, 1895 (IUCN Near-threatened; DAO Other Threatened Wildlife) – a female was photographed searching for insects among trees in the beach forest section last 23 September 2019.

Black-winged Stilt *H. himantopus* Linnaeus, 1758 (IUCN Least Concern; DAO Other Threatened Wildlife) – an immature individual was observed along the shoreline late evening last 27 August 2019. The bird may have temporarily stopped and rested on the island before flying to a different location. It was somewhat weak when it arrived and was no longer seen the following day.

Savanna Nightjar *C. affinis* Horsfield, 1821 (IUCN Least Concern; DAO Other Wildlife Species) – Only one mature individual was regularly heard calling early in the evening and just before daybreak. The bird was photographed camouflaged among the dried leaves close to the Tabon Wildlife Sanctuary on the island.

DISCUSSION

The number of species recorded on Puerco was still increasing as new records are added to the island every year. Among the smaller islands in the Philippines, Puerco has a relatively higher number of species compared to smaller islands off the coast of Cebu (Paguntalan et al. 2004), Danjugan Island in Negros (King et al. 2003) and in Palawan (Matillano et al. 2008; Tabayag and Cruz 2013). Danjugan Island is at least five times larger than Puerco with only 39 species (King et al. 2003) while the 173-ha island of Carnaza has 34 species of birds (Paguntalan et al. 2004). While larger islands are expected to have more species (Ricklefs 1999; Paguntalan et al. 2004; Hortal et al. 2009; Gonzalez et al. 2010; Bucol et al. 2011), increased field observations and continuous monitoring would result to more bird records even in remote islands (Mittermeier et al. 2013; Reeve et al. 2015).

We also see an increasing trend of number of species added to the island after the conduct of bird identification and monitoring training. Nine

birds were added from 2017 to 2018 and 11 birds were recorded for 2019 alone. It appears that improved capacity of citizen scientists in identification and skills in searching for birds largely contributed to the new records. In similar activities, citizen science when done properly was proven to provide adequate information in monitoring birds (Dunn et al. 2006; Kamp et al. 2016).

The improvement of the quality of the beach forest and vegetation on the island influenced the species composition and diversity. As more native trees were added in Puerco, it created new habitats for birds. The Western Koel, Northern Boobok and Japanese Paradise Flycatcher stayed for a week while the Pink-necked Green Pigeon visited the island to feed on ripe fruits. As more trees have matured, doves like the Pied Imperial Pigeon appeared. It was first recorded in January 2018 and was regularly observed to roost in Puerco since May 2019. Doves are known to roost and nest in small islands with tall trees (Kennedy et al. 2000), while migrants like the Japanese Paradise Flycatcher would look for beach and lowland forests (Spath et al. 2018). Their presence provided information on bird movement and the seasonal changes in the species composition on small islands.

The number of breeding birds had also increased. Currently there were 13 breeding species namely: Philippine Scrubfowl (*M. c. cumingii*), Mantanani Scops Owl (*O. m. mantananensis*), Savannah Nightjar (*C. affinis*), Pacific Reef Egret (*Egretta sacra*), Black-crowned Night Heron *(Nycticorax nycticorax)*, Barred Rail (*H. torquata*), Collared Kingfisher (*T. chloris*), Glossy Swiftlet (*Collocalia esculenta*), Barn Swallow (*Hirundo rustica*), Glossy starling (*Aplonis panayensis),* Olive-backed Sunbird (*C. jugularis*), Eurasian Tree Sparrow (*Passer montanus*) and Chestnut Munia (*Lonchura atricapilla*). There was only one breeding pair of Mantanani Scops Owl (*O. m. mantananensis*) and Savannah Nightjar (*C. affinis*).

The low abundance of the Mantanani Scops Owl, Savannah Nightjar, Olive-backed Sunbird and Collared Kingfisher was partly attributed to the size of the island and available habitat. This pattern was also similar to Polillo Islands (Gonzalez et al. 2010) and the 36 islands in the Andaman archipelago where bird abundance decreases with island size (Thiollay 1997). Rails, Collared Kingfisher and Olive-backed Sunbird are considered generalist and survive even in highly modified habitats (Steadman and Freifeld 1998; Kennedy et al. 2000; Jakosalem et al. 2019). Rails are also known for their ability to disperse and survive even on remote small islands (Kennedy et al. 2000). The presence of at least three threatened migratory birds, breeding populations of the Near-threatened Philippine Scrubfowl and a resident breeding pair of a small-island specialist (e.g. Mantanani Scops owl) highlights the key role and global importance of smaller islands like Puerco Island.

The significant increase in the Philippine Scrubfowl breeding population was largely attributed to the protection of the nesting habitat and the absence of hunting. There were only six individuals (three breeding pairs) reported on Puerco Island in November 2012 (Tabayag and Cruz 2013). At that time, vegetation was mostly made up of coconuts (*Cocos nucifera*) and a few exotic trees e.g. *Delonix regia*. Hunting and egg poaching was also reported by locals. In 2016, the Banwa Private Island allocated breeding areas for Philippine Scrubfowl and prohibited hunting in the area. The creation of the Aquos Foundation Inc. in 2018 was a positive move towards the integration of the biodiversity conservation program in the management of the island. The baseline information has already been laid down and the program structure had been created. The regular wildlife monitoring activities did not just update the list of species on the island, it also generated population counts of breeding residents in small islands.

There were 10 more islands close to Puerco within the Green Island Bay in Palawan. We suspect that a number of birds moved from one island to another to search for food and establish breeding territories including the Mantanani Scops Owl. The Philippine Scrubfowl was also observed to leave Puerco Island starting late October to December. It was highly possible that some individuals disperse to the other islands after breeding season. It is imperative that surveys will also be conducted in the nearby islands especially during breeding and migration season.

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Estimation, control and forecast of COVID-19 disease spread in Central Visayas, Philippines

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ABSTRACT

The current trend of infections from COVID-19 outbreak in Central Visayas (CV) is posing higher risk of continued spreading. When uncontrolled, swarming of infected individuals to hospitals puts a greater challenge to the health care systems in the region and may breakdown. It is imperative in this situation that data-driven decisions and policies are required the most. In response, this study provided estimates of the epidemiologically important parameters namely, reproduction metric (R_o) and infection (α), recovery (β) and mortality (γ) rates, by using a modified Susceptible-Infected-Recovered-Dead (SIRD) model. This modified model incorporated control parameters, σ and ω, associated with enhanced community quarantine (ECQ) implementation and observance of social distancing (SD), respectively. For the covered months from 27 March 2020–10 May 2020, results of the simulation estimated these parameters at: R_o=3.12, α=0.18, β= 0.029, and γ=0.029 with 90% confidence. Moreover, the reproduction metric can be effectively reduced with the combined effect of the control parameters at $\sigma, \omega \geq 0.5$ resulting to an effective R_o below unity. Similarly, this lowered the peak value of infection to 23% (or 7% of the total number of susceptible population) compared to when these measures are not observed and moved the peak time farther as well. While these estimates reflected the timely implementation of ECQ keeping its current level comparable with the country's estimates and the world, reducing the reproduction metric effectively requires strict observance to both ECQ and SD control measures. Lastly, the temporal dynamics of this metric may not be necessarily true in any given area, and hence geographically induced.

Keywords: Central Visayas, ECQ, social distancing, SIRD model, reproduction metric

INTRODUCTION

The Philippines is among the hard-hit country in the ASEAN region from the COVID-19 outbreak which originated in Hubei, China. Approximately 12,400 cases have been recorded in the country as of 16 May 2020. This is 10% compared to the overall cases recorded in the ASEAN region and 0.3% compared to the world data during this time. It also recorded 2,561 recoveries and 817 deaths, hence there are 8,927 active cases in the entire country.

In the local setting, Central Visayas (CV) region has been considered a high-risk area in the country with 1,876 active cases 53 recoveries and 28 deaths or 1,957 recorded positive cases. With the increased turn out of active cases, the region has been recently placed in ECQ status quo and is constantly monitored by the regional interagency task force (RIATF). Putting the region at this quarantine level signals the inevitable increase of infections particularly in highly congested areas. The effects are, as Anderson et al. (2020) puts it, increased deaths and economic downturn are generally impacted with the viral spread. While measures of quarantine were put up as above, it is imperative in this situation that data–driven policies and decisions are needed in translating them into practical actions beneficial to people and the government. However, the challenge in the imposition of these measures may require stringent quarantine guidelines, such as social distancing measures and early implementation of quarantine, just as the Chinese government did when the COVID-19 outbroke in Wuhan City (Anderson et al. 2020; World Health Organization 2020).

Relative to these measures, it is vital that by using epidemiological models, decisions have better lensing of approaches in the control and forecast of disease spread (Dimitrov and Meyers 2010; Heesterbeek et al. 2015; Lutz et al. 2019; Morgan 2019; Skrip and Townsend 2019). Thus, we provide estimates on epidemiologically important parameters and forecasts on the infection dynamics in the region using the widely-used Susceptible (S) – Infected (I) – Recovered (R) – Dead (D) (SIRD) model for Central Visayas (CV), Philippines. The bias of using the SIRD model, while it is classic, is that it is commonly employed by most studies of COVID-19 disease spread tackling the different aspects of control and forecast (Ahumada et al. 2020; Anastassopoulou et al. 2020; Canto and Avila-Vales 2020; Fanelli and Piazza 2020; Shinde et al. 2020). In fact, Carletti et al. (2020) highlighted that COVID-19 outbreak belongs to the class of simple SIR model and its extensions while that of Canto and Avila-Vales (2020) showed that SIRD model have better predictive power over time. We have followed the method provided in Anastassopoulou et al. (2020) that provided reasonable picture of the disease dynamics at earlier stage. It is also reasonable to use the discretize SIRD model particularly when the element of time is on daily basis or equally

saying that most statistical data were obtained in discrete time (Hattaf et al. 2015). In fact, there are several applications for the analysis of COVID-19 spread using a discrete SIRD model and their variants including that of Bertozzi et al. (2020), Carcione et al. (2020), Giordano et al. (2020), Marinov and Marinova (2020), and ud Din et al. (2020), among others.

We have adopted the method provided in Anastassopoulou et al. (2020), we determine (i.e. estimate) these essential epidemiological parameters with emphasis on the reproduction metric and the decay pattern of infections. Besides the availability of literatures to anchor on, simplicity and ease of algorithm, the choice of the method described therein fitted the scenario in Central Visayas. The urgency of putting up data-driven measures to control the viral spread necessitated to use the simplest algorithm from which the method can provide. On the same note, their method provided a coarse estimate of the reproduction metric without the need to compute other parameters, i.e. infection (α), recovery (β) and mortality (γ) rates, however, valid only at the beginning of the disease spread. The latter justified the use of the model since the outbreak in Central Visayas was in its earlier stage during this time.

For policy directions, we introduced control parameters associated to the implementation of enhanced community quarantine and observance to social distancing measures were introduced providing a variety of perspective to effectively combat and reduce the COVID-19 disease spread (Lewnard and Lo 2020; Sen-Crowe et al. 2020). To note, these vital information are important in making sound decisions as the ongoing public health crisis has severe social and economic repercussions. These estimates and the forecasts provided herein can be used as guides to local executives in planning non-pharmaceutical interventions to control widespread disease spreading.

METHODS

In this paper, we start by employing the coupled system of equations of the discrete SIRD model which reads

$$S(t) = S(t-1) - \frac{\alpha}{N} S(t-1)I(t-1), \qquad \text{Eq. 1}$$
$$I(t) = I(t-1) + \frac{\alpha}{N} S(t-1)I(t-1) - \beta I(t-1) - \gamma I(t-1), \quad \text{Eq. 2}$$
$$R(t) = R(t-1) + \beta I(t-1), \qquad \text{Eq. 3}$$
$$D(t) = D(t-1) + \gamma I(t-1), \qquad \text{Eq. 4}$$

where the number of susceptible, S(t), infected, I(t), recovered, R(t), and dead, D(t) as functions of discrete time points, t = 1, 2, 3...; and N refers to the population size which is a constant through time.

For the data resource needed in this study, we utilize the 54 data points for CV with reported cases of Infected (I), Recovered (R), Dead (D) from 27 March 2020 up to 10 May 2020. For Susceptible (S) data, we used an approximate value of **S_{CV} = 5M** susceptible in CV. This is approximately equivalent to the population in Cebu Province, hence this is also a reasonable estimate since almost all cases recorded in CV are in Cebu Province.

To determine whether the COVID-19 outbreak in the country and in CV can spread into the population or die out, we exploited the discrete method provided in Anastassopoulou et al. (2020) to estimate the essential epidemiological parameters, R_0, α, β, and γ given by the relation

$$R_0 = \frac{\alpha}{\beta + \gamma},$$ Eq. 5

where R_0 (i.e. reproduction number) represents the average number of secondary cases resulting in the introduction of a single infections in a totally susceptible population; the parameters α, β, and γ are the corresponding rate constants associated to infected, I(t), recovered, R(t), dead, D(t) functions, respectively. Qualitatively, small values of R_0<1 translate to less turn out of secondary cases or equally saying that the spread dies out.

It is pointed, however, that one can encounter problems of estimations particularly in large-scale epidemics where the actual total number of infected, I(t), population often is unknown. Nonetheless, Anastassopoulou et al. (2020) provided a coarse estimation procedure of which the researcher had faithfully verified. The coarse estimation of these parameters is then solved by linear regression using least–square problem. The parameter estimation is a two-step process of which rate constants β and γ are obtained using linear regression while α is obtained from the SIRD simulator. Moreover, these parameters are obtained for t = {1, 2, ...} with a rolling window of 1 day using the available daily data of actual cases from 06 March 2020 to 10 May 2020. Estimates and time series plots of daily R_0 were rendered using Matlab R2019b.

Parameter Estimation from the Reported Confirmed Cases

We denote $\Delta I(t), \Delta R(t), \Delta (t)$ as the reported new cases of infected, recovered and deaths at time t respectively. The cumulative numbers of confirmed cases are then calculated as

$$C\Delta X(t) = \sum_{i=1}^{t} \Delta X(t)$$

where, $X = I, R, D$, and $\Delta X = X(t) - \Delta X(t-1)$.

We then denote $\mathbf{C\Delta X}(t)$ which is the $t \times 1$ column vector containing the cumulative numbers up to time t expressed as

$$\mathbf{C\Delta X}(t) = [C\Delta X(1), C\Delta X(2), \ldots, C\Delta X(t)]^T$$

From these definitions, we can provide a coarse estimation of R_0 by using equations 2, 3, 4, and 5. We then substitute the terms $\beta I(t-1)$ and $\gamma I(t-1)$ with $\Delta R = R(t) - R(t-1)$ and $\Delta D = D(t) - D(t-1)$ and then add Eqs. 4 and 5. After careful manipulation of the equations, we then arrive at

$$\frac{C\Delta I(t) + C\Delta R(t) + C\Delta D(t)}{C\Delta R(t) + C\Delta D(t)} = \frac{\alpha}{\beta + \gamma} = R_0.$$

Note that we can directly compute R_0 with the use of regression without the need first to compute the other parameters. Using this equation, we can extract a coarse estimation of R_0 by solving the linear regression using the least-squares problem as

$$\hat{R}_0 = ([\mathbf{C\Delta R}(t) + \mathbf{C\Delta D}(t)]^T [\mathbf{C\Delta R}(t) + \mathbf{C\Delta D}(t)])^{-1}$$
$$[\mathbf{C\Delta R}(t) + \mathbf{C\Delta D}(t)]^T [\mathbf{C\Delta I}(t) + \mathbf{C\Delta R}(t) + \mathbf{C\Delta D}(t)],$$

Also, the coarse estimation of the mortality and recovery rate can be calculated using linear regression problem for corresponding cumulative functions by least square given as follows

$$\hat{\gamma} = \left[\left(\mathbf{C\Delta I}(t) - \mathbf{C\Delta D}(t) - \mathbf{C\Delta R}(t)\right)^T \left(\mathbf{C\Delta I}(t) - \mathbf{C\Delta D}(t) - \mathbf{C\Delta R}(t)\right) \right]^{-1}$$
$$\left(\mathbf{C\Delta I}(t) - \mathbf{C\Delta D}(t) - \mathbf{C\Delta R}(t)\right)^T \mathbf{C\Delta D}(t),$$

$$\hat{\beta} = \left[\left(\mathbf{C\Delta I}(t) - \mathbf{C\Delta D}(t) - \mathbf{C\Delta R}(t)\right)^T \left(\mathbf{C\Delta I}(t) - \mathbf{C\Delta D}(t) - \mathbf{C\Delta R}(t)\right) \right]^{-1}$$
$$\left(\mathbf{C\Delta I}(t) - \mathbf{C\Delta D}(t) - \mathbf{C\Delta R}(t)\right)^T \mathbf{C\Delta R}(t).$$

Next is we estimate the infection rate, α, by running the SIRD simulator using $\hat{\beta}$ and $\hat{\gamma}$ as the initial conditions with one infected person from 27th of March until the last date available (10 May 2020). The value of α is then determined by wrapping around the SIRD simulator an optimization to solve the problem

$$\text{argmin}\left\{ \sum_{t=1}^{M} (w_1 f_t(\alpha; \hat{\beta}, \hat{\gamma})^2 + w_2 g_t(\alpha; \hat{\beta}, \hat{\gamma})^2 + w_3 h_t(\alpha; \hat{\beta}, \hat{\gamma})^2) \right\},$$

where

$$f_t = C\Delta I^{SIRD}(t) - C\Delta I(t)$$
$$g_t = C\Delta R^{SIRD}(t) - C\Delta R(t)$$
$$h_t = C\Delta D^{SIRD}(t) - C\Delta D(t)$$

and $C\Delta X^{SIRD}(t), (X = I, R, D)$ are the cumulative cases resulting from the SIRD simulator at time *t*. Whereas the constants w_1, w_2, and w_3 correspond to scalars serving in the general case as weights to the relevant functions. We can easily get the solution of the above problem by using the function "lsqnonlin" of matlab using the Levenberg-Marquard algorithm.

SIRD Implementation

At the onset of the spread, we set S(t=0)=N−I_o, I_o =1, R(t=0)=0, D(t=0) = 0. For the purpose of this study, we have used the percentage of the population instead. We implemented the model in five (5) different scenarios by changing the percentage of susceptible population, S(t=0), as well as introducing a control parameter, ω, which we have associated to social distancing. For example, S(t=0)=N, the entire population is considered susceptible. With the implementation of the community quarantine, we assume that there is a reduction of the susceptible population using the relation

$$n = (1 - \sigma) N, \qquad\qquad\qquad \text{Eq. 6}$$

where σ=[0,1] is a constant factor related to the implementation of community quarantine. Qualitatively, a σ=0 means absence of ECQ implementation, 0<σ<1 means relative implementation of ECQ, and σ =1 strict observance of ECQ.

The last implementation of the model proposes a control parameter, $\omega = [0,1]$, on the infection rate, α, similar to that implemented in Lin et al. (2010). Qualitatively, we associate this control parameter to the adherence of social distancing, that is an ω=1 means strict social distancing is observed, ω=0 means the other extreme – no observance of social distancing, and 0 < ω < 1 means relative observance of social distancing. In control theory, the parameter ω modulates the interaction rate of the susceptible and infected variables in the model, hence Eq. (2) becomes

$$i(t) = i(t-1) + (1-\omega)\alpha\, s(t-1)i(t-1) - \beta i(t-1) - \gamma i(t-1) \quad \text{Eq. 7}$$

In principle, this control parameter has also an effect on the susceptible function of Eq. (1), that is

$$s(t) = s(t-1) - (1-\omega)\alpha\, s(t-1)i(t-1) \qquad\qquad \text{Eq. 8}$$

with the scaled susceptible and infected function are defined as $s = S/n$ and $i = I/n$, respectively. This is also true for Eqs. (3) and (4). We, then, make plots of Eq. (7) using different values of ω. We note, further, that the fraction of susceptible (S) to the population, N, is used for the simulation. In reference to van den Driessche (2017), the reproduction metric in Eq. (5) becomes the effective reproduction number given as

$$\mathcal{R}_0 = \frac{(1-\sigma)(1-\omega)\alpha}{\beta+\gamma} \qquad\qquad \text{Eq. 9}$$

RESULTS

Cumulative COVID-19 Cases in Central Visayas

The Department of Health (DOH) updates the country of the status COVID-19 infections in the country. From these datasets, we used data from 27 March 2020 to 10 May 2020 for Central Visayas data (Figure 1). It is self-explanatory that there is an exponential increase in the turn-out of confirmed cases while a linear trend is observed for recoveries and deaths. It is observed that during the intervals between 09 April 2020 (e.g. 36 cases) to 23 April 2020 (e.g. 363 cases), there is a 10-fold increase in the total number of infections with an average of 47 daily recorded infections over a span of five days.
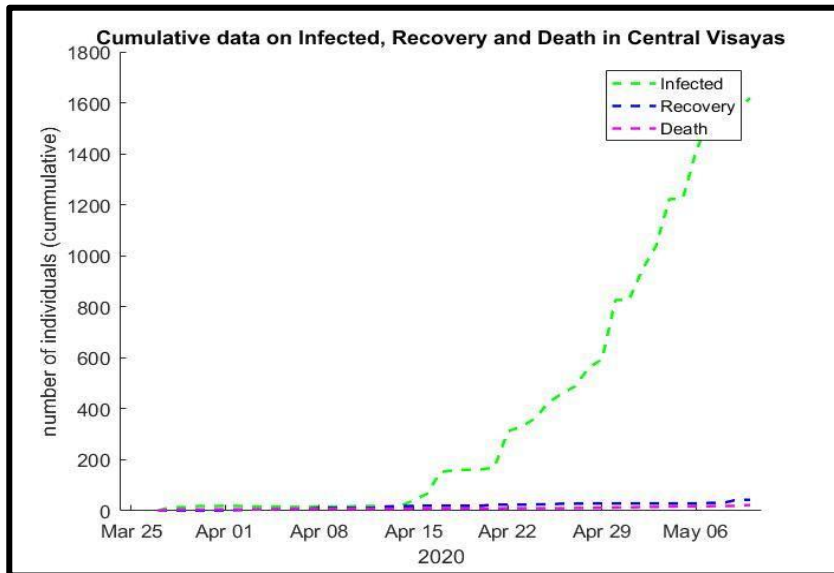

Figure 1. Time series data on recorded infection, recoveries, and death in Central Visayas, Philippines.

Essential Epidemiological Parameters

From the datasets, we determine the coarse estimates of the essential epidemiological parameters α, β, γ, and R_o. The time series of these estimates were plotted with a rolling window of 1 day and a 90% confidence interval. Using the values of these parameters, we obtain the effective reproduction number $\mathcal{R}_0$ from Eq. (9) as shown in Figure 2 below. The computed $\mathcal{R}_0$ from the actual data resulted to approximately $\mathcal{R}_0 \approx 3.1$. It is also worth noting that this metric is kept at this level and is relatively comparable to the global metric of $R_o = [2.0, 4.5]$. Nonetheless, this is above the threshold value of 1. For purposes of comparison, the trend of the reproduction metric for the entire country is relatively the same, however, showing a down trend as shown in Figure 2d.
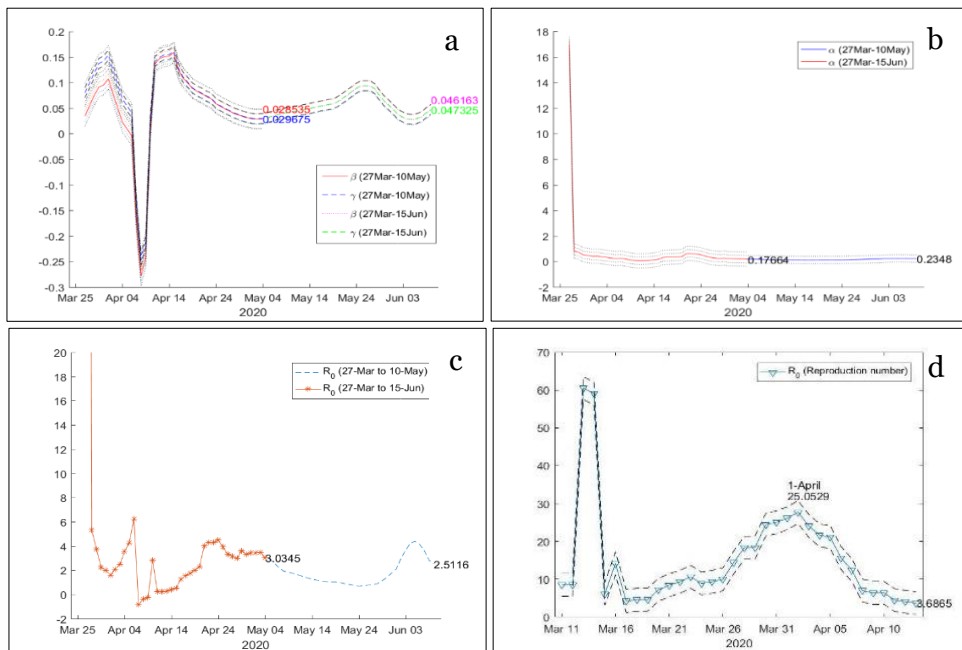
Figure 2. a) Estimated daily recovery and mortality rates (Central Visayas); b) estimated daily infection rate (Central Visayas); c) daily R_o values for Central Visayas with rolling window of 1 day from 27 March 2020 to 15 June 2020; and (d) daily R_o values for the Philippines (for comparison purposes) with a rolling window of 1 day from 11 March 2020 up to 17 April 2020. These estimates are obtained using linear regression at 90% confidence.

Modified SIRD Model for Central Visayas

The forecast on the percentage of susceptible (s), infected (i), recovered (r), and dead (d) individuals is shown in Figure 3. From the model, the critical

points we look into are peak values of these parameters and when it will occur when the control parameters, σ and ω, are implemented particularly the infection function, *i(t)*. We have implemented this in different scenarios depicting the control of susceptible population and the observance of social distancing as presented below.

It can be observed from the different scenarios in both peak values of infections and peak times when social distancing is introduced in the model. The peak values had reduced to around 23% from scenario III and V (Figure 3). These amounts to reducing the total infections to 7% (i.e. from 1.5M to around 105K infections) when social distancing is observed. We also point out that when both ECQ and SD are strictly observed, i.e. scenario I, infections are reduced to almost nil and peak value occurs in a much-delayed time. We point out, however, that the 1.5M infected individuals is a large number to reach by September 2020. This large value may be caused by the computational process, particularly, on the assumed initial number of susceptible individuals, which is 5M. It would be possible that only 10% or 1% of the total population is susceptible to the disease because the information on how to stop the spread of the coronavirus has been widely disseminated throughout the country. The latest report in our timeline, i.e. 30 June 2020, suggested that between 33.52% to 40.97% of the population were observed to be susceptible corresponding to the number of infections of 8,660 at 90% confidence interval.
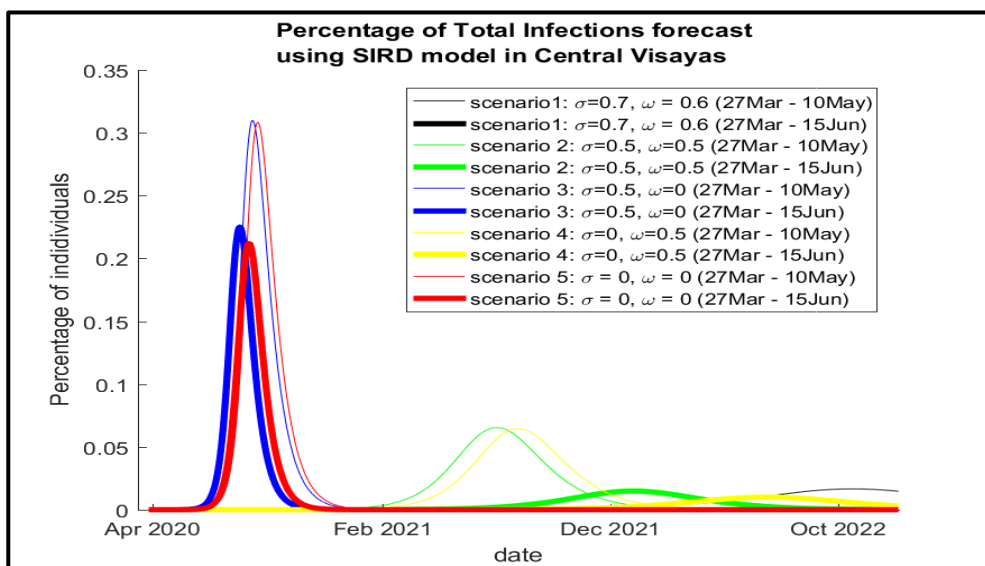

Figure 3. The infection curve simulated using modified SIRD model for Central Visayas in different scenarios. Thinner lines are infection curves of the earlier stages of the outbreak in Central Visayas. Thicker lines are infection curves with the inclusion of data until 15 June 2020.

Considering a totally susceptible population, i.e. s(t=0)=100%, i(t=0)=1/N, we obtained the effective reproduction metric from Eq. (9) for the different scenarios (Table 1). Clearly, when both ECQ and SD are observed, a flattened curve of infection is realized. Stricter implementations of these measures significantly reduce the number of infections as described by scenario I.

Table 1. Qualitative description in using control metrics.

Scenario	ECQ Metric	SD Metric	Effective Reproduction Metric ($\mathcal{R}_0$)	Description
			Sample metrics used in the Modified SIRD Model	
I	$\sigma = 0.7$	$\omega = 0.6$	$\mathcal{R}_0 = 0.37$	high ECQ and SD; flattened curve
II	$\sigma = 0.5$	$\omega = 0.5$	$\mathcal{R}_0 = 0.78$	moderately high ECQ and SD; flattened the curve
III	$\sigma = 0.5$	$\omega = 0.0$	$\mathcal{R}_0 = 1.55$	moderately high ECQ and absence of SD; approaching a flattened curve
IV	$\sigma = 0.0$	$\omega = 0.5$	$\mathcal{R}_0 = 1.55$	absence of ECQ and moderately high SD; approaching a flattened curve
V	$\sigma = 0.0$	$\omega = 0.0$	$\mathcal{R}_0 = 3.10$	absence of ECQ and SD; not flattened the curve

DISCUSSIONS

There are several reasons in the increasing trend of infections in CV, one of which is the increased turn out rate as caused by a) increased number of accredited testing centers, b) availability of testing kits, and c) the country-wide deployment of testing kits resulting to expanded testing activities. In perspective, these suggest that there could be more unrecorded and/or under reported positive cases in the country. In most pandemic studies, under-reporting seemed to be more likely as people experiencing mild symptoms often do not present themselves to health care as in the pandemic influenza (H1N1) (Mishra et al. 2010; Oberle et al. 2017) and TB epidemic (Zhou et al. 2019). Mathematically, it is non-normal to observe a sudden increase/spike in the number of cases. With COVID-19 infections, the actual number of cases may be two – or three – times more since infected persons are often asymptomatic. This increasing trend is, in fact, not unique to Central Visayas and the country as a whole, rather this is true worldwide. The severity of the spread reflects the imposed measures to curb the outbreak in the region. To note, the dynamics of the spread of any disease may not necessarily be the same in any given area. This reflects, further, the increasing trend of the reproduction metric in the region compared to the reproduction number in the entire country, although, the estimates are approximately the same (e.g. $R_{o,CV} = 3.1$ while $R_{o,PH} = 3.7$). This, further, showed that the implementation of ECQ region-wide is relatively effective keeping the reproduction metric at

$R_0 \sim 3.10$. While these values are relatively comparable worldwide and the earlier reported estimates in China between 2–7.1 (Lai et al. 2020a; Li et al. 2020; Mizumoto et al. 2020; Read et al. 2020; Zhang et al. 2020a; Zhou et al. 2020), an increasing trend suggests higher risk of continued spreading. Consequently, this may cause social and economic instability in the region as the possibility of swarming of infected persons may overwhelm its health care facilities (Sen-Crowe et al. 2020; UPC-19PRT 2020). Moreover, our results complimented that of Ridenhour et al. (2018) suggesting that reproduction metrics varies according to geographical location affected by changes in the environment, population structure, viral evolution and immunity, to include geopolitical influences (Katz et al. 2019; Kassem 2020; Peirlinck et al. 2020). When these geopolitical influences cater disagreement in the implementation of ECQ measures, such as the earlier transition to GCQ experienced in Central Visayas, resulted to sudden spike in the number of infections.

The uncertainties, however, of the actual number of infections (Lai et al. 2020a; Li et al. 2020; Zhang et al. 2020a) and of the nature and etiology of the virus (Andersen et al. 2020; Cascella et al. 2020; Zheng 2020) arrested the government and local government (LGU) leaders to implement drastic quarantine policies (i.e. home quarantine and social distancing) to contain the virus and control of the increasing loss of lives and of the continuing economic stress (Lim 2020). As reported in Pueyo (2020), these measures can isolate population to be exposed to the virus that slows down disease spreading. On preventing a wider spread of infection, we have shown here the effectiveness of how faithful adherence to the ECQ guidelines particularly on the number of exposed individuals as well as stricter observance to social distancing can reduce the reproduction metric below the threshold value. In Shim et al. (2020), they put prime on social distancing as measures to rapidly control the outbreak. This agreed well in our simulations of SD control parameter, ω, which significantly reduced the number of infections to 7% of the initially assumed total susceptible population. The same observations had been reported in many studies of historical pandemics such as in Caley et al. (2008). On the contrary, Reluga (2010) pointed out that social distancing is most beneficial to individuals when the reproduction metric is around two and larger values of metric requires a more efficient social distancing measures. These were implied in our simulation of SD parameters in scenarios I and II which the effective reproduction numbers were less than unity. More importantly, reducing the reproduction metric effectively requires strict observance to both ECQ and SD control measures and/or their combined effects.

We note that our predictions were proximate that of reported flattened curved for the number of infections in the country (Nepomuceno 2020; Parrocha 2020), the total number of predicted number of infections was relatively high given the initial number or susceptible individuals. This can be

justified since latest analyses suggested that it may be 10 to 40% lower where majority of cases were never confirmed (Annastassopoulou et al. 2020; Killeen and Kiware 2020; Mizumoto et al. 2020) and whose infectious carriers often exhibit mild to no symptoms during this time (Dong et al. 2020; Du et al. 2020; Lai et al. 2020b; Li et al. 2020; Tang et al. 2020; Zhang et al. 2020b; Zhou et al. 2020). In fact, as of the timeline of this study, the estimated susceptible population is between 33.52% to 40.97% corresponding to the total infections of 8660 at 90% confidence interval as of June 30, 2020. The latter percentage of susceptible population can then be used as initial input to s(t=0). Relative to all of these, sudden spikes in the number of infections during this time may be associated to contamination in densely populated or highly congested areas such as slum areas and/or jails (Dave et al 2020; ICRC 2020; Franco-Paredes et al. 2020; Simpson and Butler 2020; Wang et al 2020; WHO 2020). We point out, however, that most reported outbreaks in Central Visayas were associated to infected individuals showing mild to no symptoms at all. In result, granular lock down was imposed in the highly congested areas of Cebu City as well as several extensions of ECQ (UPCCEI 2020).

To further improve the predictive power of the model, it is worth noting that granular lock down was to further control the viral spread (Basu et al. 2020; Mandal et al. 2020; Mishra et al. 2020; Santamaria et al. 2020; Srivastava 2020), and hence can be a good parameter to understand the dynamics of COVID-19 spreading. Possible inclusion of other parameters such as that of density–driven dynamics (Cardoso and Goncalves 2020; Munshi et al. 2020), exposure–weighted dynamics (e.g. subdivision of the parameter I(t) into asymptomatic, mild, severe, or critical) (Adhikari et al. 2020; Allen et al. 2020; Weitz et al. 2020) and/or age-dependent dynamics (Allen et al. 2020; Zhang et al. 2020b) may be seen to be a plausible direction to better understand the COVID-19 disease spread dynamics in Central Visayas or the country as a whole.

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Protocol development for the improved hatchery propagation of Tiger grouper *Epinephelus fuscoguttatus* (Forsskål, 1775) **in Palawan, Philippines**

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ABSTRACT

The expanding grouper cage farming in Palawan, Philippines requires stable seed supplies from hatcheries to sustain the demands of fish cage operators. To improve the current hatchery practices for Tiger grouper *Epinephelus fuscoguttatus* (Forsskål, 1775), four experiments were undertaken. The first experiment (E1), involving three different temperatures ranges (T1: 24-26°C; T2: 27-29°C; and T3: 30-32°C) revealed significantly higher hatching rates at 27-32°C. The second experiment (E2) found that survival rates after 38 days from hatching were inversely proportional with density (T1: 3; T2: 5; and T3: 10 larvae L^{-1}). The third experiment (E3) found that the growth and survival of fry raised at three different stocking densities for three weeks (from 21 to 42 days after hatching) were not significantly different. The fourth experiment (E4) compared the growth and survival of fingerlings (from 70–91 days after hatching) fed with two brands of commercial feeds. After three weeks, both treatments had comparable total lengths. These desirable results are attributed to the weekly thinning or reduction in the density of juveniles in E3 and E4 and the use of small rearing containers.

Keywords: hatchery production, survival, growth, diet, stocking density

INTRODUCTION

In Southeast Asia, the main target reef species are groupers (subfamily *Epinephelinae*), which are mainly destined for international live reef-fish trade. The large demand and high price for groupers have led to severe overfishing. Even more worryingly, to obtain their catch alive, fishers often employ cyanide to temporarily immobilize their catch (Wilcox 2016). The use

of cyanide has a deleterious impact on the reef, including the health and productivity of other reef-dwelling organisms (Halim 2002).

To bring a halt to the overfishing and destruction of coral reefs across Southeast Asia, there is a need to provide alternative livelihoods to fishermen (Heeger et al. 2001). In addition, ensuring future food security and inclusive development in rural areas. The sustainable aquaculture of high-value marine finfish is often identified as a potential solution that meets these requirements (Haylor et al. 2003).

In Palawan, a local non-government organization (NGO) has been pioneering the hatchery production of different grouper species to support the livelihood of coastal inhabitants. To further refine its hatchery protocols, the organization teamed up with the Western Philippines University (WPU) to optimize the production and expand the volume and diversity of hatchery produced fingerlings.

One of the focal species for this joined research project was the Tiger grouper *Epinephelus fuscoguttatus* (Forsskål, 1775), locally known as "Lapulapu Baboy" or "Kugtong Baboy". This reef-dwelling species was selected because of its high demand in the local and international markets. This fish grows relatively fast reaching 500 g in nine to 10 months. However, this fast growth rate is accompanied by severe cannibalism, which can lower survival rates (SR). Therefore, improved hatchery and nursery protocols need to be established to support future grow-out culture in coastal areas. This paper included four studies which dealt with the following: 1) hatching rates (HR) at different temperatures, 2) larval SR at different stocking densities, 3) growth and survival of fry, and 4) growth and survival of fingerlings subjected to weekly reduction in densities.

METHODS

Egg Collection

Eggs were collected from 15 *E. fuscoguttatus* breeders (each weighing 15 to 20 kg) from floating sea cages (4 x 4 x 7 m) by the Bureau of Fisheries and Aquatic Resources (BFAR) – Inland Sea Ranching Station for over 5 years along the Sta. Lucia cove of Puerto Princesa Bay. The upper half of the inner circumference of the cage holding the breeders (~20 individuals) were lined with fine-meshed net to retain any floating eggs inside the cage. The breeders were monitored between 2300 and 0100 hours on the night of new moon and up to three consecutive nights thereafter. When spawning occurred, eggs were collected with a fine meshed net 10 minutes after the main spawning activity

to ensure proper fertilization. Eggs were then transported from the broodstock cage to the land-based hatchery using 10-L buckets with gentle aeration.

Egg Cleaning and Incubation

Newly collected eggs were first rinsed with fresh seawater to remove algae and other foreign materials. After this, the eggs were rinsed in water with an iodine solution for 1 min. Viable floating eggs were separated from the non-viable suspended eggs. Then the eggs were incubated in conical 50-L incubators with an upwelling flow-through system. Eggs typically hatched between 24 to 28 hours after spawning. Undeveloped eggs and other debris which sank at the bottom of the tanks were regularly removed by opening the bottom drain valve of the conical tank. The produced larvae were used in E2, E3 and E4, respectively.

Experiment 1 (E1): Hatching rates of *E. fuscoguttatus* Eggs at Different Temperature Regimes

In this experiment the HR at three temperature regimes (3 replications), T1: 24-26°C; T2: 27-29°C; and T3: 30-32°C were evaluated for a 24-hour period in nine 15-L capacity cylindrical plastic containers. For each treatment-replicate, 12,000 newly collected eggs were stocked in each cylindrical container (Table 1). Seawater ice (in double-layered plastic bags) and water heaters were used to maintain the desired temperature ranges. The temperature was monitored every five hours, and additional ice were added when necessary. After 24 hours, subsamples from each treatment-replicate were taken to determine the ratio between larvae and unhatched eggs.

Table 1. Density of tiger grouper *Epinephelus fuscoguttatus* eggs subjected to different temperature ranges for 24 h. T-treatment; R-replicate.

T	R	Temperature Range (°C)	Duration (h)	Egg Density/Container	Water Volume (L)
1		24-26			
2	3	27-29	24	12,000	15
3		30-32			

Experiment 2 (E2): Larval Rearing of *E. fuscoguttatus* at Different Stocking Densities

For this experiment the SR of newly hatched fry was monitored at three different stocking densities (individuals per liter or ind L^{-1}) or treatments (T1: 3 ind L^{-1}; T2: 5 ind L^{-1}; and T3: 10 ind L^{-1}) with three replications. This was carried out for 38 days (from the first day after hatching or DAH) in nine

5,000-L capacity concrete tanks (Table 2). The larvae were fed with a combination of rotifer, *Artemia* and imported commercial grouper feeds.

Table 2. Density of tiger grouper *Epinephelus fuscoguttatus* larvae at different stocking densities fed with a combination of rotifer, *Artemia* and commercial feed. T-treatment; R-replicate.

T	R	Feeding	Density (ind L $^{-1}$)	Density/ Tank	Duration (day)	Tank Volume (L)
1		rotifer,	3	15,000		
2	3	*Artemia,*	5	25,000	38	5,000
3		commercial feed	10	50,000		

The first feeding in E2 occurred on the 3rd DAH when the mouth of the larvae was large enough to consume rotifers (L type). The rotifer density in the larval rearing tanks was monitored twice a day (0700 and 1500 h) to maintain the desired number and size until the 25th DAH. On the 12th DAH, a pinch of artificial pellet was introduced every hour between 0600 and 1700. *Artemia* were added two times daily (0700 and 1500 h) between 12 DAH and 30 DAH, starting with newly hatched *Artemia*. As the grouper larvae increase in size, larger *Artemia* were fed. *Artemia* were enriched with vitamins for 4 h before feeding to the larvae. Water temperature, salinity, pH and ammonia were monitored in the morning (0800 h) and afternoon (1500 h).

Experiment 3 (E3): Growth and survival of *E. fuscoguttatus* Fry at Different Stocking Densities Fed with Commercial Feed

The experiment was carried out for three weeks in 15 plastic 25-L capacity blue basins to monitor growth and survival for 42-day old juveniles at different stocking densities. Three different stocking densities (treatments)

Table 3. Weekly density of tiger grouper *Epinephelus fuscoguttatus* juvenile at different treatments fed with commercial feed raised in small basin (25-L) for 21 days. T-treatments; R-replicates; W-week; DAH-days after hatching.

T	R	Feeding	Density (ind L^{-1})			Number per Basin			Starting Age (DAH)	Water Volume per Basin (L)
			W1	W2	W3	W1	W2	W3		
1		*ad libitum,* 3-	6	4	2	150	100	50		
2	5	5 min every hour	12	8	4	300	200	100	42	25
3		from 0700 - 1800	18	12	6	450	300	150		

were reduced each week for a period of three weeks by manually removing the largest and the smallest individuals (Table 3). Each treatment was replicated five times. The juveniles having the following initial average total length (TL): 2.66±0.34 cm (T1); 2.99±0.40 cm (T2); and 2.89±0.60 cm (T3) were fed *ad libitum* throughout the day using imported commercial grouper feed. Wastes that settled on the bottom of the basin were siphoned 2-3 times a day.

Experiment 4 (E4): Growth and Survival of *E. fuscoguttatus* Fingerlings Subjected to Weekly Reduction of Densities and Fed with Two Different Commercial Diets

This experiment monitored the growth and survival of fingerlings fed with two different commercial diets: an imported (T1) and a locally manufactured pelleted feed (T2). The experiment with nine replications was carried out in 18 plastic 25-L blue basins. To maintain uniform size and prevent the occurrence of cannibalism, the densities were manually reduced on a weekly basis (Table 4). The 70-day old fingerlings initially measured 6.07±0.70 cm (T1) and 6.17±0.70 cm (T2), respectively. The fingerlings were fed *ad libitum* throughout the day. The treatments received continuous water exchange at 2-4 L hr⁻¹ and gentle aeration. Waste was siphoned 2-3 times daily.

Table 4. Weekly density of tiger grouper *Epinephelus fuscoguttatus* fingerlings fed with two commercial feed. T-treatment; R-replicates.

T	R	Feeding	Feed Pellet	Density (ind L⁻¹)			Actual Number/Basin			Starting Age (DAH)	Water Volume per Basin (L)
				W1	W2	W3	W1	W2	W3		
1	9	*ad libitum*, 3-5 min every hour from 0700 - 1800	Imported	4	3	2	100	75	50	70	25
2			Local								

Data Analyses

The HR in E1, the SR in E2, E3 and E4, and the growth rates in E4 were all compared separately using analysis of variance and Scheffe post hoc tests. The TL and SR in E4 were compared using T-test. All analyses were performed at 5% significance level using SPSS 19.0 trial version.

RESULTS

Experiment 1 (E1): Hatching Rates of *E. fuscoguttatus* Eggs at Different Temperature Regimes

Treatment 3 had the highest HR (80.32±8.37%) although it was not significantly different ($P>0.05$) from T2 (75.43±10.64%). The HR (54.66±23.87%) in T1 was significantly lower ($P<0.05$) compared to the other treatments (Figure 1).
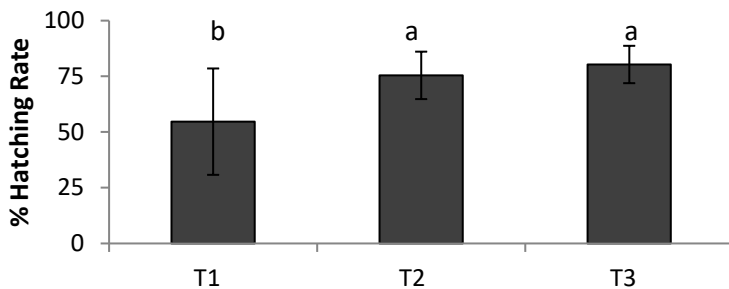
Figure 1. Average (±SD) hatching rates of *Epinephelus fuscogutatus* eggs at three temperature regimes (T1: 24-26°C; T2: 27-29°C; and T3: 30-32°C).

Experiment 2 (E2): Survival of *E. fuscoguttatus* at Different Stocking Densities

The SR was inversely proportional to density (Figure 2) and was significantly different ($P<0.05$) among treatments. The average (±SD) SR in T1 (6.86±0.54%) was significantly higher than in T3 (1.33±1.42%) but not in
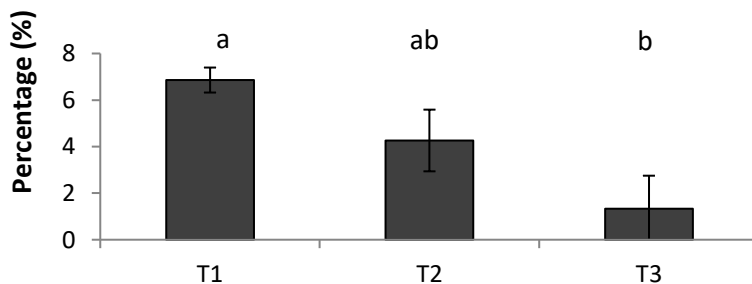
Figure 2. Average (±SD) survival of *Epinephelus fuscoguttatus* fry at three different stocking densities (T1: 3 ind L⁻¹; T2: 5 ind L⁻¹; T3: 10 ind L⁻¹) raised in concrete tanks from day 1 to 38 days after hatching.

T2 (4.26 ±1.32%). At the end of the rearing period, the fry measured 20.7 (± 0.52) mm, an average 18.7 mm TL increment. The range of average water temperature: 28.37^{o}C (±0.58) to 28.71^{o}C (±0.51); salinity: 26.14 (±0.63) to 26.29 (±0.70) ppt; pH: 8.50 (±0.18) to 8.67 (±0.19); and ammonia: 0.43 (±0.16) to 0.45 (±0.15) did not significantly differ among treatments.

Experiment 3 (E3): Growth and Survival of *E. fuscoguttatus* Fry at Different Stocking Densities fed with Commercial Feed

The weekly increase in TL was about 1 cm for all treatments. In week 1, the average (±SD) final TL in T2 (4.03±0.54 cm) was significantly bigger than the other two treatments (Table 5). The SR (Table 6) for the first week were significantly different than the second and third weeks ($P<0.05$). However, SR among treatments were not significantly different ($P>0.05$).

Table 5. Initial and final total length (cm) of *Epinephelus fuscogutatus* at different stocking densities. The same letter superscript (per column) means not significant at 5%. n-number of measured samples per treatment; TL-total length; w-week.

Treatment	Weekly Average (±SD) Total Lengths (cm)					
	W1		W2		W3	
	Initial TL (cm)	Final TL (cm)	Initial TL (cm)	Final TL (cm)	Initial TL (cm)	Final TL (cm)
1 (n=50)	2.65[a] (±0.34)	3.70[a] (±0.49)	4.39[a] (±0.35)	5.38[a] (±0.37)	5.86[a] (±0.24)	6.94[a] (±0.30)
2 (n=50)	2.98[b] (±0.40)	4.03[b] (±0.54)	4.35[a] (±0.41)	5.33[a] (±0.38)	5.84[a] (±0.31)	6.92[a] (±0.34)
3 (n=50)	2.89[b] (±0.60)	3.64[a] (±0.44)	4.33[a] (±0.45)	5.22[a] (±0.42)	5.92[a] (±0.32)	6.92[a] (±0.42)

Table 6. Weekly survival rates (%) of *Epinephelus fuscogutatus* at different stocking densities. T-treatment; w-week.

T	Weekly Survival Rates (%)		
	W1	W2	W3
1	95.73	99.20	100.00
2	94.47	99.40	99.20
3	94.84	98.73	99.73

Experiment 4 (E4): Growth and Survival of *E. fuscoguttatus* Fingerlings Fed with Different Commercial Feeds

The weekly increase in TL was less than 1 cm for both treatments. Those fed with imported commercial feed (T1) were larger on the third week and were significantly different ($P<0.05$) to the other treatment (Table 7). Survival rates (Table 8) varied between 91.67% and 99.78% and were not significantly different between treatments ($P>0.05$).

Table 7. Initial and final average (±SD) total lengths (cm) of juvenile *Epinephelus fuscoguttatus* fed with two brands of commercial grouper feed. T-treatment; n-number of samples; w-week. TL-total length.

T	Weekly Average (±SD) Total Lengths (cm)					
	W1		W2		W3	
	Initial TL (cm)	Final TL (cm)	Initial TL (cm)	Final TL (cm)	Initial TL (cm)	Final TL (cm)
1 (n=90)	6.07 (±0.70)	6.69 (±0.65)	7.03 (±0.72)	7.47 (±0.66)	7.67 (±0.47)	8.51 (±0.61)
2 (n=90)	6.17 (±0.70)	6.62 (±0.63)	7.09 (±0.64)	7.41 (±0.69)	7.50 (±0.71)	8.04 (±0.53)
remarks	$P>0.05$	$P>0.05$	$P>0.05$	$P>0.05$	$P>0.05$	$P<0.05$

Table 8. Survival rates of *Epinephelus fuscoguttatus* fed with two different commercial feed. w-week.

Treatment	Weekly Survival (%)		
	W1	**W2**	**W3**
1	91.67	98.22	99.78
2	92.78	96.74	99.11

DISCUSSION

Experiment 1 (E1): Hatching Rates of *E. fuscoguttatus* Eggs at Different Temperature Regimes

The average HR for *E. fuscoguttatus* in T2 (75.43%) and T3 (80.32%) were comparable to the following reported HR for other grouper species: 83±10.12% for *Epinephelus polyphekadion* (James et al. 1997), 84.3% for *Epinephelus akaara* (Okumura et al. 2002), and 75.7% for *E. malabaricus* (Ruangpanit et al. 1993). The high HR in T3 and T2 showed a large temperature range (27°C and 32°C) for incubating *E. fuscoguttatus* eggs. This large range is comparable to that of *E. coioides* (Kawahara et al. 1997; Fouroofghifard et al. 2012; Table 9). Ideal temperature for fertilization and hatching for other species may be narrow (28 and 30°C) as for the case of *Heterobranchus bidorsalis* (Okunsebor et al. 2015). The observed wide range for *E. fuscoguttatus* is therefore an advantage when breeding the species.

Table 9. The hatching rates of *Epinephelus fuscoguttatus* at three different temperature ranges compared with similar studies. T-treatment; D-duration

Species	T (ºC)	Stocking density/ Liter	Culture System	D (h)	Hatching Rate (%)	Source
Epinephelus fuscoguttatus	24-26	800	Cylindrical plastic containers (15 L)	24	54.66	This study
	27-29				75.43	
	30-32				80.32	
Epinephelus coioides	22	428.6	Beaker (7 L)	33	2.1 - 93.2	Kawahara et al. 1997
	24				87.2 - 96.5	
	26				86.4 - 98.3	
	28				85.1 - 98.2	
	30				67.3 - 93.8	
	32				45.7 - 84.8	
	34				1.2 - 9.6	
Epinephelus polyphekadion	29	300-500	Fiber glass tanks (2,000 to 2,800 L)	19	83	James et al. 1997
Epinephelus akaara					84.3	Okumura et al. 2002
Epinephelus malabaricus	28.15	1,500-1,600	Flow-through Pan-like tanks (30 L)	24	75.7	Ruangpanit et al. 1993
Epinephelus coioides	23-24	25	Polyethylene tanks (300 L)	24	0	Fourooghifard et al. 2012
	26-27				23	
	28-29				75	
	31-32				23	

Experiment 2 (E2): Larval Rearing of *E. fuscoguttatus* at Different Stocking Densities

Survival of grouper larvae up to metamorphosis is generally low across all species. James (et al. 1997) recorded a survival of 1.73%–2.98% for *E. polyphekadion*. Survival for *E. fuscoguttatus* reported in Reyes (2015) was between 0.109% and 0.91%. In this study, the SR were inversely proportional with density. However, these SR (1.33%, 4.26% and 6.86%) in three treatments were higher compared to the 0.9% survival of *E. fuscoguttatus* raised at 30 ind L^{-1} for a period of 45 days (James et al. 1998; Table 10). This shows that density greatly affect the survival of *E. fuscoguttatus* fry, and is also reported for many other species such as *Clarias gariepinus* (Jamabo and Keremah 2009), *Rachycentron canadum* (Hitzfelder et al. 2006), and *Soiea soiea* (Schram et al. 2006). While lower stocking densities in indoor tanks may result in higher SR, this requires increased space and resources in hatcheries. However, the use of other culture facilities, such as outdoor concrete tanks for *Epinephelus fuscoguttatus* x *lanceolatus* at 8 ind L^{-1}, had 26.9% survival (Anita and Dewi 2020). If available space permits, a trial on outdoor rearing of fry could be performed for *E. fuscoguttatus* to possibly increase SR.

Table 10. Average total lengths (TL) and survival rates (SR) of *Epinephelus fuscoguttatus* fry compared with other similar studies. D-duration; T-treatments.

Species	T	Density (ind L⁻¹)	D (day)	Mean TL (mm)	Feed	SR (%)	Culture System	Source
Epinephelus fuscoguttatus	1	3	38	20.7	Natural/ commercial feed	6.86	Concrete tank (5,000 L)	This study (E2)
	2	5				2.26		
	3	10				1.33		
Epinephelus fuscoguttatus	1	30	45	34.40	Natural/ artificial diet	0.9	Fiberglass tank (2,800 L)	James et al. 1998
Epinephelus polyphekadion	2			19.77		1.7		
Epinephelus fuscoguttatus x lanceolatus	1	8	30	28	Natural/ artificial diet	26.9	Concrete pond (10,000 L)	Anita and Dewi 2020
Epinephelus fuscoguttatus	1	15	30	7.47 – 9.70	Rotifer/ *Artemia*	0.38 - 0.91	Concrete tank (3,000 L)	Reyes 2015
	2		43	15.7– 17.39		0.109 – 0.115	Concrete tank (5,000 L)	
Epinephelus polyphekadion		30	50		Natural/ artificial feeds	1.7 – 2.98	Round fiberglass tank (2,800 L)	James et al. 1997

In commercial hatchery operations, it is not only the SR that is of importance, but also the overall performance of the hatchery (the combination of survival, and growth rate). The grouper in this study completed the development into juveniles and reached 20 mm average TL at 38 DAH. This is much faster than in the study of Sugama et al. (2012), where *E. fuscoguttatus* completely metamorphosed at 45 DAH (TL reached 20–28 mm), and juvenile *E. lanceolatus* metamorphosed at 45 DAH at 35.4 mm TL (Garcia-Ortega et al. 2013). It could be noted however that Sugama et al. (2012) suggested a density of 10 ind L⁻¹ which could attain 5 to 40% survival. These variations in larval development and survival could be related to water conditions and nutrition. The early occurrence of complete metamorphosis in this study could be attributed to the lower stocking densities which promoted faster growth. Reduced stocking density promotes good water conditions, and minimizes the chances of serranid larvae of becoming entangled with each other via their elongated dorsal and pelvic spines (Sugama et al. 2012).

Experiment 3 (E3): Growth and Survival of *E. fuscoguttatus* Fry at Different Stocking Densities fed with Commercial Feed

The results in this study were comparable to that of Salari et al. (2012) where stocking density did not significantly affect the survival of *E. fuscoguttatus* juveniles (Table 11). Severe cannibalism often occurs at this

stage, but this was not observed even when the densities were much higher than the recommended density by Ismi et al. (2012).

Table 11. Average total lengths (TL) and survival rates (SR) of *Epinephelus fuscoguttatus* in Experiment 3 in comparison with a similar study. CP-commercial pellets; T-treatment; D-duration; F-feed.

T	Starting Density (ind L⁻¹)	Final Density (ind L⁻¹)	D (day)	SR (%)	Final TL (cm)	Final Weight (g)	F	Culture System	Source
1	6	2		100.00	6.94	6.16			
2	12	4	21	99.20	6.92	6.00	CP	Basin (25 L)	This Study
3	18	6		99.73	6.92	5.82			
1	1	1		80.83	7.615	7.77			
2	3	3		82.77	8.492	10.45		Flow through Round Fiberglass tanks (80 L)	
3	5	5	42	80.91	7.852	8.90	CP		Salari et al. 2012
1	1	1		78.33	7.211	6.92			
2	3	3		84.86	6.942	6.90			
3	5	5		79.58	7.212	6.74			

The culture systems and stocking densities affect the growth performances, feed utilization and water quality (Samad et al. 2014). The rearing of fish at higher densities optimizes productivity of the facilities but increases the demand for dissolved oxygen, higher chances of cannibalism and disease outbreaks. However, the survival in this study (99.2 to 100%) are higher than the estimated 60% survival for *E. fuscoguttatus* upon reaching 7 cm TL (Ismi et al. 2012). The weekly manual thinning which was carried out by removing the smallest and the largest individuals to reduce both the density and variations in sizes could have efficiently prevented cannibalism. Although frequent grading has been reported to cause stress which may lead to disease outbreak (Ismi et al. 2012), this did not occur during the experiment. The use of small basins and manual sorting could have facilitated efficient cleaning, water exchange, faster sorting, and reduced disturbance to the fish. The low mortality could have been caused by other factors, but this was not investigated due to limited laboratory facilities and equipment. Future studies may deal on these unknown aspects in the nursery rearing of this species.

In terms of growth, the fish reached 6.94 cm from an initial of 3.65 cm TL after three weeks or 21 days, which was comparable to the estimates of Ismi et al. (2012), that *E. fuscoguttatus* juveniles from an initial TL of 3 cm, could reach a final TL of 7 cm in 30 days. However, it is worth reiterating that our study used small basin with densities several times higher than the recommended density in tanks and cages (Ismi et al. 2012).

Factors affecting fast fish growth includes the maintenance of optimum water conditions, good nutrition and reduced stress (Ismi et al. 2012; Hien et al. 2016). The use of small basin instead of concrete tanks could further significantly reduce the cost in setting up a large hatchery, making this better suited for backyard or small-scale hatcheries. The results suggest that hatchery-produced *E. fuscoguttatus* could be raised at higher stocking densities in plastic basins without affecting their growth and survival. Other higher stocking densities maybe tested to optimize the use of space in small-scale hatcheries.

Experiment 4 (E4): Growth and Survival of *E. fuscoguttatus* Fingerlings Fed with Different Commercial Feeds

In this experiment, the fish in T1 having an initial 6.07 cm TL on the first week reached 8.51 cm TL during the final sampling on the third week (Table 12), suggesting 0.81 cm weekly average increase. Treatment 2 on the other hand performed a little slower having 0.62 cm average increase per week. This variation could be sampling or nutrition related. Samples were unmarked and were randomly taken each week for size measurement thus causing possible variations. However, the variation due to sampling could be minimal with 90 fish samples per treatment per week, and the relatively similar SD for both treatments. The faster growth in T1 could have been mainly influenced by the quality of the feed. The imported commercial feed used in T1 listed nutritional information (11% moisture, 44% crude protein, 7% crude fat, 16% ash and 3% crude fiber) in its label and manufactured to industry standards. By contrast, the label of local commercial feed used in T2 did not contain such information. The use of good-quality pelleted feed is one of the best practices during the nursery phase as low-quality feeds result in poor nutrition and increase the chance of cannibalism (Ismi et al 2012). In addition, Alvarez-González (2001) and Hien et al. (2016) reported the significant effect of the quality of feed on the grouper growth. The limited laboratory facilities hindered the conduct of independent proximate analysis for both feeds, which should be considered when doing future growth studies involving the use of commercial feed.

For *E. fuscoguttatus* measuring between 5 cm and 9 cm TL, Ismi et al. (2012) recommended stocking densities between 400 and 1,000 ind m^{-3} (equivalent to 0.4 to 1 ind L^{-1}) for both tanks and cages. Our study however, showed that this could be increased up to 2-4 ind L^{-1} with high SR (99.11% to 99.78%) when small basins were used as rearing containers. Information on the survival of grouper having similar size with the fish we used are limited. Ahmad et al. (1999) reported 85.5% to 93.8% survival for *E. coioides* raised in tanks and cages at 1 ind L^{-1}, while James et al. (1998) did not mention the survival of *E. fuscoguttatus* raised in fiberglass tanks for 30 days (Table 12). The densities used in this study were much higher than the recommended

number in tanks and cages, but we obtained a much higher SR compared to the 60% estimate of Ismi et al. (2012).

Table 12. Average total lengths (TL) and survival rates (SR) of *Epinephelus fuscoguttatus* in Experiment 4 compared with other similar studies. T-treatment; D-duration.

Species	T	Starting Density (ind L⁻¹)	Final Density (ind L⁻¹)	D (day)	SR (%)	Final TL (cm)	Final BW (g)	Feed	Culture system	Source
Epinephelus fuscoguttatus	1	4	2	21	99.78	8.51	12.1	Pellet Brand A	Basin (25 L)	This Study
	2				99.11	8.04	10.06	Pellet Brand B		
Epinephelus coioides	1	1	1	30	93.80		10.9	Pellet	Tank (2,800 L)	Ahmad et al. 1999
	2				85.50		10.6		Cage (1,000 L)	
Epinephelus fuscoguttatus	1	0.2	0.2	30			14.28	Pellet	Rounded fiberglass (2,800 L)	James et al. 1998
Epinephelus polyphekadion	2						8.84			

In aquaculture, cannibalism can cause considerable problems in larval culture (Liu et al. 2017). *Epinephelus fuscoguttatus* tend to eat other fish very close to their own size (Ismi et al. 2012), but the absence of cannibalism in this study proved that the use of basin is a good practice in hatchery management to facilitate fast and effective grading of grouper fingerlings. Basins are also less expensive and easier to manage than concrete tanks and could easily be adopted in small-scale hatcheries.

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