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OBJECTIVES AND SCOPE

As a multi-disciplinary journal, The Palawan Scientist aims to publish high-quality and original research in the fields of agriculture, fisheries and aquatic sciences, environment, education, engineering, mathematics, sociology, and related disciplines (including arts and humanities). It also aims to expand its circulation by having the published papers indexed in leading and globally recognized platforms.

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ABOUT THE COVER

The Philippines is one of the world's leading seaweed producers, but production is greatly affected by the occurrence of diseases and the changing climate. The study of Dangan-Galon et al. which provides a cropping calendar indicating the suitable cultivars at a particular site and season is hoped to increase the local farmers' resilience from climate change. Photos by F Dangan-Galon and RG Dolorosa.

COVER DESIGN: Jovan A. Gimarangan

EDITORIAL BOARD

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EDITORIAL

Dear Readers,

It is my great privilege and honour to write this Editorial for the December 2024 issue of **The Palawan Scientist** Journal, a publication of the Western Philippines University. Having partnered and collaborated with the institution while undertaking my environmental social science PhD fieldwork in the Philippines, I commend their ongoing commitment to both multi- and interdisciplinary research as evidenced by the range of topics and disciplines included in this issue.

Something that struck me when reading the diverse set of articles published here is the presence of two core thematic threads running through them: 1) a commitment to research that demonstrates the intrinsic connection between people and nature; and 2) a clear drive for research that benefits the public good. A number of the articles in this issue draw together important learnings related to two of the great challenges humanity has experienced in the 21st century so far: the COVID-19 pandemic (as discussed in *Lim et al. and Foronda et al.)* and the ongoing biodiversity crisis and potential impact on ecosystems and peoples' livelihoods (as discussed in *Dangan-Galon et al and Salazar et al.)*

What is evident is that these and other major challenges have and continue to impact humanity differently, both between different regions of the world and across different social groups within societies. It is thus imperative that we continue to listen to and learn about these varied experiences so that the current and future challenges we face recognise and account for these differences in the strategies we develop and undertake to address them. This is of particular importance for those whose voices may be less heard, whether that is small nation states in global governance fora, or groups on the margins of the societies we are part of.

This journal issue includes studies with a clear aim of equipping policymakers and resource-users with knowledge that can support sustainable management of natural resources, so fundamental to the lives and livelihoods of rural communities in the Philippines and across so much of the world. This knowledge can play a powerful role in complementing what is already known, for example the Indigenous wisdom and traditional ecological knowledge of Indigenous peoples and local communities that is so fundamental to the effective and equitable conservation of nature. I was delighted to see an article that shines a lens on the oft-ignored gendered differences in women's and men's use, access to, knowledge of, and actions related to natural resources and conservation (*Bauyot et al.).*

Increasing the accessibility of education (as discussed in *Junsay and Lagura)* and the continued democratisation of knowledge are key as we seek the current and future solutions to society's biggest challenges. Western Philippines University's commitment to early career researchers and support of open-access knowledge without paywalls or associated fees are pivotal steps in advancing the equity of science and academia.

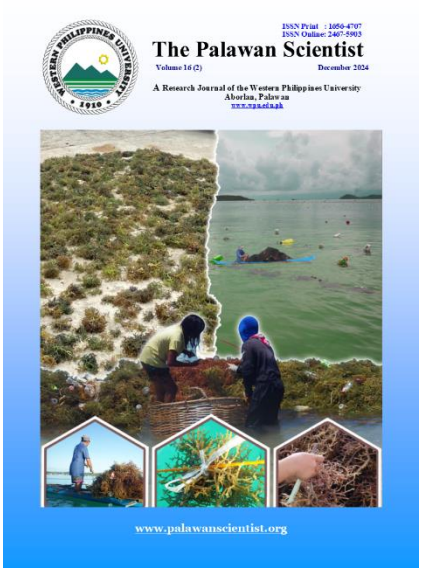
To conclude, I would like to thank the authors of all the articles published in this issue for your excellent submissions, and my fellow **The Palawan Scientist** Editorial Board members for taking the time to review these. For those reading this issue interested in submitting to this journal, we strongly encourage you and welcome your future submissions!

Let us continue to be curious and committed in pursuit of the wellbeing of people and planet!

Timur Jack-Kadıoğlu, PhD
Associate Editor – The Palawan Scientist
Technical Specialist, Fauna & Flora, Cambridge, United Kingdom

CONTENTS

Original Article



Determinants of last-mile travel mode choice under different COVID-19 alert levels: A case study of Batasan Hills, Quezon City, Philippines

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ABSTRACT

The COVID-19 outbreak has led to remarkable changes in the transport sector and people's travel behavior. The suspension of public transport leads to an increase in the number of private car users and the number of walking activities. The last mile, being one of the weakest links in the transport network, has become more challenging to manage with the imposition of different travel restrictions. Using the data collected from the households of Barangay Batasan Hills, Quezon City, Philippines, this study aimed to understand people's travel behavior during the pandemic. Specifically, a binary logit model was used to determine the significant factors that affect the last-mile travel mode choice under different alert levels. Results showed that age during the pandemic, monthly household income, the purpose of travel, travel expense, travel time, departure time, origin, compliance with COVID-19 measures, and trip duration have significant factors in last-mile travel mode choice. In addition, risk perception on public transport was also a determinant of last-mile travel mode under alert levels 1 and 2. Analyzing travel behavior during the COVID-19 pandemic is deemed beneficial in devising strategies and interventions that will help mitigate the spread of the virus while still allowing economic activity and the movement of people to happen.

Keywords: alert levels, COVID-19, last mile, mode choice, travel behavior

INTRODUCTION

The COVID-19 pandemic has emerged as a major concern for the entire world, posing unprecedented risks to the health sector, economy, labor market, food supply, and transportation. Government authorities started implementing lockdowns, community quarantines, curfews, and travel restrictions to curb the spread of the virus. Social distancing and other safety measures are practiced and have become part of the new normal. To prevent people from getting infected, only one person per household is allowed to go outdoors, essentially to buy goods and do activities. Non-essential businesses and service providers were temporarily closed. Schools and workplaces transitioned into a remote environment. Real-life social interactions and social gatherings had abruptly declined due to the imposition of physical distancing rules (Massaccesi et al. 2021). The Philippines, a third-world developing country, reported its first confirmed case on 22 January 2020 (DOH 2020). Since then, the number of infected people continued to grow. Because of its resource and

capability limitations, handling the virus has become a big challenge in the Philippines' public health sector.

In September 2020, the government introduced alert-level systems. This alert level system was first implemented in Metro Manila then in the rest of the country months after (Tantuco 2021). During the COVID-19 transmisison, the area is placed under alert level 1, total bed usage, and intensive care unit use were all low or declining (Baclig 2022). Intrazonal and interzonal movements were allowed regardless of age and comorbidity. Establishments are also allowed to operate at maximum capacity (DOH 2021). Under alert level 2, everyone was allowed to go out, but government authorities also imposed additional safety measures and restrictions. It was implemented in areas with increasing hospital admissions even if the number of infected cases were low (Baclig 2022). Gaming establishments were not allowed to operate while other establishments were allowed to open at a maximum of 50% indoor capacity and 70% outdoor capacity. When alert level 3 was imposed residents below 18 years old and belonging to the vulnerable population were restricted from going out, except when buying essential goods or doing essential activities. Areas with a high risk of transmission were not allowed to operate, while those with low to medium risk can open up to 30% indoor capacity for fully vaccinated individuals and 50% outdoor capacity. At least 60% on-site workforce was also allowed in government establishments (DOH 2021). Further, when the area had high cases and hospital admissions, alert level 4 was implemented (Baclig 2022). Intrazonal and interzonal travel was only allowed for individuals without comorbidities, not pregnant, and whose ages were between 18 to 65 years old. A maximum of 10% indoor capacity for fully vaccinated individuals and 30% outdoor capacity was given for service establishments, while at least 40% on-site workforce in the government services. Lastly, alert level 5 signified alarming cases and hospital admissions. The movement of the people was limited to accessing essential goods and services or work only. The strictest rules and guidelines like ECQ were usually implemented in this scenario (Baclig 2022). Mass gatherings were not allowed, and strict home quarantines were imposed. Government officials and authorities were also in a skeleton workforce (DOH 2021).

Along with these numerous contagion-related guidelines implemented at both local and national levels, transportation systems and services were also suspended. Restrictions began with the banning of international travel from countries with confirmed cases, followed by visa restrictions and checkpoints at the entry and exit points across every country (Pawar et al. 2020). As a result, the transport industry was greatly shaken on the economic level. Although airlines reacted differently to the implemented restrictions on air travel (Monmousseau et al. 2020), major carriers in the airline industries have experienced a 60% to 80% reduction in their capacity. In the Philippines, public transport was only allowed to operate at full capacity under alert level 1 scenario (Philippine News Agency 2022). Under alert levels 2 and 3, it was allowed to keep 70% of passenger capacity (Philippine News Agency 2022), while full suspension of its usage was imposed under alert level 5 scenario. Further, studies revealed that the mode choice behavior of working Filipinos was affected by the pandemic with the increased shift of respondents from public transportation to using private vehicles, active transportation, and shuttle services (Co et al. 2023). These results complemented the studies from other countries where private transport users gradually increased during the COVID-19 pandemic (Hasselwander et al. 2021; Shakibaei et al. 2021; Zhang et al. 2021; Abdullah et al. 2022), while a minor shift to walking activities for non-commuting was observed (de Haas et al. 2020; Borkowski et al. 2021; Paul et al. 2022). Lastly, non-motorized vehicle users also increased during the pandemic for both commuting and discretionary purposes (de Haas et al. 2020; Abdullah et al. 2022; Paul et al. 2022). These results imply that walking or another active transport mode, motorized and private vehicles lessen the risk of getting infected (Ancheta et al. 2023). There is a need to determine the factors affecting the last-mile travel mode choice under the different COVID-19 alert levels. This can contribute to the extensive studies on the effects of the pandemic on transportation by taking into consideration alert level scenarios and specifically analyzing only the last-mile travel mode of respondents.

The goal of efficiently connecting transportation linkages remains to be a challenge up to this day. Especially, this problem came out worst during the pandemic due to the lack of transportation modes available. The last mile is commonly referred to as the last leg of a transportation journey comprising the movement of passengers from a transportation hub to the destination (Chen et al. 2021) in the context of transport planning and supply chain management. It is frequently the weakest link in a transport network (Stam et al. 2021). A wide range of research investigating the factors that affect travel mode choice has been conducted (i.e. Ben-Akiva et al. 1985; Hensher 1994; Hasnine et al. 2018; Mao et al. 2018; Yang et al. 2018; Mohd Ali et al. 2022). The literature in the context of last-mile transport mode choice has been growing (i.e. Meng et al. 2016; Mo et al. 2018; Guo et al. 2020; Lu et al. 2022). The pandemic-related variables and their effects on travel mode choice are also considered in some research (i.e. Bhaduri et al. 2020; Abdullah et al. 2022; Paul et al. 2022; Zubair et al. 2022). However, there are limited studies on last-mile mode choice behavior for developing countries (e.g. Patil et al. 2020) and studies that incorporate both the pandemic-related factors and last-mile travel mode.

Managing the last mile will be even more challenging as usage of the transport modes in the country is significantly impacted by the outbreak of the virus. Although the use of various modes of transportation has already been relaxed, the transmission of the virus is still not yet fully managed and controlled. Protocols and restrictions are still changing depending on the type of alert level being imposed in an area. This means that behaviors are still affected by the pandemic. Plans and strategies should also be specific to each area and each alert level. Furthermore, the long-term heterogeneous impacts of the pandemic within different transportation sectors (Mack et al. 2021) will most likely bring transport disruptions and require adjustments from transport system providers and users.

The objective of this study is to analyze and determine the factors affecting the last-mile travel mode choice under different alert levels using the data collected from households in Barangay Batasan Hills, Quezon City, Philippines. This study did not specifically focus on the last-mile problem in passenger transport which refers to the disconnect between public transport and an individual's origin or destination (Tight et al. 2016). However, the study focused simply on the last-mile transport mode choices of individuals during the pandemic and the factors affecting their decision according to various alter level scenarios. The results of this study can be used to understand the travel behavior of the residents. Further, this can be helpful for designing strategies and plans that will help manage the last mile link and mitigate the spread of the virus at the same time.

METHODS

Study Area

Barangay Batasan Hills was chosen as the study area based on a decision criterion that includes the population, existing transport networks, travel demands, and existing establishments. Barangay Batasan Hills is one of the barangays in Quezon City, Philippines (see Figure 1). As of the 2020 Census, Batasan Hills has 166,572 residents which represents 5.63% of Quezon City's total population. Moreover, the barangay has 161,352 families, with an average of 4.67 members per household, according to the 2015 Census (PhilAtlas 2020). There are three major roads in Batasan Hills: Commonwealth Avenue (Radial Road 7/N170), Batasan (IBP) Road, and the Batasan-San Mateo Road. Batasan is also served by the Batasan Station of MRT Line 7 located a few meters south of the junction of Commonwealth Avenue and IBP Road near the Sandiganbayan Centennial Building.

The study area is composed of medium to high-density residential zones, with major and metropolitan commercial zones, institutional zones, and housing zones. Notable buildings and structures within the barangay include the Batasang Pambansa Complex which houses the House of Representatives; and the Sandiganbayan Centennial Building which is home to Sandiganbayan – one of the major courts of the country. Other government establishments in the area include the headquarters of the Civil Service Commission, the Commission on Audit, and the Department of Social Welfare and Development. Also located within the barangay are: Ever Gotesco Commonwealth (a shopping mall); Diliman Commercial Center which has branches of Starbucks and Ministop, and satellite offices of Pag-IBIG Fund and Social Security System; and St. Peter Parish: Shrine of Leaders – all mentioned are along Commonwealth Avenue. On the other hand, available transport modes in the area are bus lines, tricycles, jeepneys, PUVs, and MRT (Batasan Hills undated).

Data Collection

Data used for analysis in this study were collected from households that were randomly selected using the cluster sampling method. A survey questionnaire was designed containing four sections. The first section was intended to capture the socio-demographic and household characteristics of the respondents (gender, age, household position, civil status, educational attainment, number of household members, number of children, elderly members, person with disabilities, vehicle ownership, type and number of vehicles owned, house ownership, residential period, occupation, occupation setup, monthly income). The section on travel characteristics was designed to get the travel behavior and detailed movement of the respondents. The third section captured the variables that are related to risk perceptions, compliance with the pandemic protocols, social responsibility, travel anxiety, fear of infection, and vaccination status. Lastly, the possible factors that they prioritize when choosing their transport mode and their corresponding level of priority were obtained in the last section.

Face to face survey was conducted to obtain data used for analysis in this study. After the survey, data were encoded, checked, and validated. Missing and inconsistent data were removed. A total of 326 valid responses were obtained and coded using the dummy coding technique. Further, stepwise backward elimination was employed to select the independent variables that affect the mode choice of respondents. An initial model containing the initial list of independent variables was estimated. Then insignificant variables were removed one at a time based on their p-values until all the variables left were significant at a 95% confidence level (Washington et al. 2011). All the remaining significant variables were used as the explanatory variables for the final analysis and interpretation of the logit model of last-mile travel mode choice.

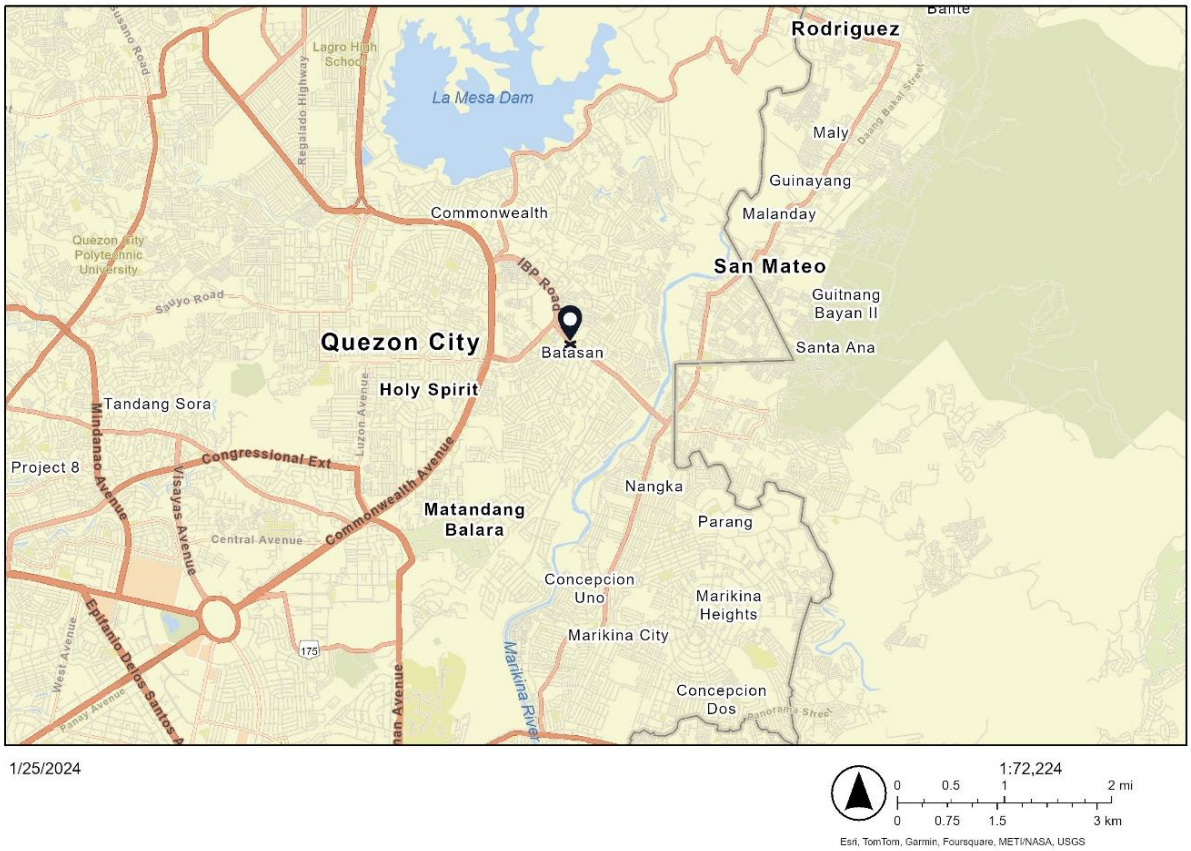

Figure 1. Batasan Hills, Quezon City Map. Source: ArcGIS (2024).

Logit Model Parameter Estimation and Validation of Model Specification

The binary logit model was used for data analysis. Any household, *h*, traveling his last mile by walking, *w*, or through a vehicle (public/private), *v*, is represented by a utility function as presented in Equations 1, and 2, respectively. *β'wh*, and *β'vh* are vectors of parameters that are estimated for the model for households, *h*, choosing walking, *w*, or vehicle, *v*, as last-mile travel mode, respectively. X_{wh} and X_{vh} are vectors of the determinants that households prioritize when choosing last-mile travel mode choice of either walking, *w*, or by vehicle, *v*, respectively. ε_{wh} and ε_{vh} are vectors that account for the effects of unobserved attributes and preferences on observed alternatives *w* and *v*, respectively.

$$U_{wh} = \beta'_{wh} X_{wh} + \varepsilon_{wh} \quad (1)$$

$$U_{vh} = \beta'_{vh} X_{vh} + \varepsilon_{vh} \quad (2)$$

P_{wh}, and P_{vh}, indicate the probability that a household chooses walking, *w*, or by vehicle, *v*, as last-mile travel mode choice, respectively. These can be determined using Equations 3 and 4, respectively.

$$P_{wh} = \frac{e^{\beta' wh X_{wh}}}{e^{\beta' wh X_{wh}} + e^{\beta' vh X_{vh}}} \quad (3)$$

$$P_{vh} = \frac{e^{\beta' vh X_{vh}}}{e^{\beta' wh X_{wh}} + e^{\beta' vh X_{vh}}} \quad (4)$$

The coefficients *β*, *X*, and *ε* were determined using the maximum likelihood estimation. STATA version 15.0 was used in estimating the parameters of the binary logit model. The significance of the independent variables to the last-mile travel mode choice was determined using the t-statistics (p-value). The final model includes determinants whose p-value is less than 0.05 (significant at 95% confidence level) or 0.01 (significant at 99% confidence level). Also, model fit was assessed using the McFadden pseudo R^2. The values of McFadden pseudo R^2 ranging from 0.2 to 0.4 indicate that the model fits the data well (McFadden 1997).

RESULTS

Socio-Demographics and Travel-Related Variables

From the 326 valid responses collected from the residents of Barangay Batasan Hills, Quezon City, it was revealed that 196 respondents traveled by foot

(60.12%), and 130 used public transportation (39.88%) in their last mile travel during the pandemic. Table 1 provides a summary of the description and frequency of the socio-demographic and travel-related variables. The descriptive analysis showed that most of the respondents have ages ranging from 15 to 50 (73.62%), have at most 4 household members during the pandemic (73.62%), and it is also worth noting that 60.43% have a monthly household income of more than Php10,000. All the interviewees indicated that they have traveled during the pandemic. During their first-mile trip, 43.56% depart from their houses at 9 AM or earlier, while 56.44% depart after 5 PM. Most of them pay at most PHP 20 which accounted for 81.29%, while 80.66% travel for at most 20 minutes, 46.94% go to the workplace, barangay hall, or school, 43.01% go to a grocery store, shopping mall, or public market, and 10.04% go to other locations such as hospitals, churches, and relatives. Also, most of the last-mile travelers originate from their workplaces/barangay halls/schools accounting for 40.80%. In addition, 288 of the last-mile travels was within 20-minute travel (88.34%).

Table 1. Descriptive summary of socio-demographic and travel-related variables used in the analysis.

Variables	Classifications	Frequency	Percent
Age of the respondents during pandemic (AGED)	15- 50	240	73.62
	>50	86	26.38
Number of household members during the pandemic (MEMD)	≤4 members	240	73.62
	>4 members	86	26.38
Household monthly income during the pandemic (MINCOMED)	≤ 10,000	129	39.57
	> 10,000	197	60.43
Travel Mode (Last Mile) (MODELM)	Walking	196	60.12
	Public Transport	130	39.88
Travel expense (First Mile) (EXPENSEFM)	0-Php20	265	81.29
	>Php20	61	18.71
Travel time (First Mile) (TRAVTIMEFM)	1min - 20mins	263	80.67
	>20 mins	63	19.33
Departure Time (Last-Mile) (TIMELM)	9 am and earlier	142	43.56
	After 5 PM	184	56.44
Origin (Last-Mile) (ORIGLM)	Others (Hospital/Relatives/Church)	34	10.43
	Workplace/Brgy. Hall/School	133	40.80
	Grocery/shopping mall/Market	159	48.77
Travel time (Last-Mile) (TRAVTIMELM)	1min - 20mins	288	88.34
	>20 mins	38	11.66

Moreover, as shown in Table 2, most of the respondents have a high perception of the risk of public transport, high compliance with COVID-19 measures, high COVID-19 fear, and high travel anxiety for all alert levels. About 80.06%, 80.06%, 87.12%, 84.66%, and 86.20% of the respondents have high perceptions of the risk of using public transport under alert levels 1, 2, 3, 4, and 5, respectively. High compliance is also observed on COVID-19 measures for alert levels 1 to 5 with proportions of the responses equal to 97.24%, 88.04%, 87.73%, 88.04%, and 90.18%, respectively. Likewise, around four-fifth of the respondents have a high level of fear of COVID-19 under alert level 1 (83.13%), alert level 2 (78.83%), alert level 3 (80.06%), alert level 4 (84.05%), and alert level 5 (80.37%). The number of respondents with high travel anxiety also increased with alert levels, with proportions of 76.07%, 80.37%, 87.42%, 88.65, and 88.96% for alert levels 1 to 5, respectively.

Table 3 shows the result of the model estimation of last-mile mode choice in all alert levels. The models are attributed from alert level 1 to alert level 5. All the models show significance at ($p = 0.000$) which indicates that there is an established relationship between independent and dependent variables. The area under curves (AUCs) calculated at 75.83 for alert level 1 and 74.53 for alert levels 2, 3, 4, and 5, indicating that the models have an excellent ability to discriminate. McFadden *pseudo-*R^2 assessed the model's goodness of fit. The model's *pseudo-*R^2 is within 0.16 to 0.17. The Correct Classification Rate (CCR) for the alert level models (alert levels 1-5) ranges from 69.02 to 70.25, and their CCR base rates are 52.05. This implies that there is an improvement in the predictive accuracy with the addition of significant variables in the model.

The model specification was further validated using the Likelihood Ratio (*LR*) test. The binary logit model for alert level 1 yielded LL_{Whole}, $LL_{Sample1}$, and $LL_{Sample2}$ values of -181.19, -86.04, and -92.77, respectively. The resulting value of *LR* with 5 degrees of freedom is 4.76. The critical value χ at a 5% level of significance and 5º of freedom, $\chi 2$ 0.05, 5, is 11.07. The lower value of calculated *LR* compared to $\chi^2_{0.05,5}$ indicates that the null hypothesis that there is

Table 2. Descriptive summary of scenario-based variables used in the analysis for different alert levels. F- frequency.

Variables	Classifications	Alert Level									
		1		2		3		4		5	
		F	%	F	%	F	%	F	%	F	%
Risk in Public Transport Use (PTL)	Low	65	19.94	65	19.94	42	12.88	50	15.34	45	13.80
	High	261	80.06	261	80.06	284	87.12	276	84.66	281	86.20
Compliance to COVID-19 measures (COMPL)	Low	9	2.76	39	11.96	40	12.27	39	11.96	32	9.82
	High	317	97.24	287	88.04	286	87.73	287	88.04	294	90.18
COVID-19 fear (CFL)	Low	55	16.87	69	21.17	65	19.94	52	15.95	64	19.63
	High	271	83.13	257	78.83	261	80.06	274	84.05	262	80.37
Travel Anxiety (TAL)	Low	78	23.93	64	19.63	41	12.58	37	11.35	36	11.04
	High	248	76.07	262	80.37	285	87.42	289	88.65	290	88.96

no significant difference between the parameters across different samples is accepted. Lastly, the LL_{Whole} of the logit models for alert levels 2, 3, 4, and 5 is equal to -183.79. The $LL_{Sample1}$ for alert levels 2 to 5 is equal to -92.81, while $LL_{Sample2}$ is equal to -88.77. From these values, the calculated *LR* for alert levels 2, 3, 4, and 5 is 4.42. The critical value χ at a 5% level of significance and 4 degrees of freedom, $\chi^2_{0.05,4,}$ is 9.49. All the values of *LR* for alert levels 2, 3, 4, and 5 are less than the $\chi^2_{0.05,4}$, which means that there is no significant difference between the parameters of the whole data and the parameters across different samples.

For the last-mile mode choice under alert level 1, the variable indicator for the departure time for the last-mile trip during the pandemic has a positive coefficient (β = 1.08), indicating that those who depart from their places after 5 PM are more likely to use public transport mode. The positive coefficient (β = 1.01) obtained for the variable indicator of COVID-19 fear under alert level 1 implies that the higher the perception of risk for COVID-19, the lower the chances that the respondents will ride public transport mode. Interestingly, those who are fully vaccinated and with high compliance with COVID-19 safety measures are less likely to choose public transport. This is derived from the coefficient β = -1.67. This only shows that despite the providence of vaccination, people are not yet lenient in complying with safety protocols and have avoided using public transport to ensure safety and curb virus spread. Lastly, the trip duration variable indicator has a negative coefficient (β = -0.74), suggesting that if the respondents highly prioritize trip duration, the higher the chances they will travel by foot in their last-mile travel.

In addition, for alert levels 2, 3, 4, and 5, positive coefficients were observed for the variable indicators for last-mile departure time (β = 1.10), and travel anxiety for those with booster shots (β = 1.53). This indicates that last-mile travelers who depart from their last-mile origin later than 5 PM and those who have booster shots but with travel anxiety tend to ride public transport. On the other hand, negative coefficients were obtained for variable indicators for compliance with COVID-19 measures for those fully vaccinated (β =-1.67), and trip duration (β = -0.68). From these coefficients, it infers that those who are fully vaccinated with high compliance with COVID-19 measures, and those who highly prioritize trip duration are more likely to walk in their last-mile travels. This may be attributed to the imposition of stringent regulations, such as travel restrictions, in response to the increasing number of infected residents and hospital admissions, which may affect the accessibility and availability of public transportation.

DISCUSSION

With the impacts of the pandemic, stretching the last mile and managing it becomes more challenging. Thus, this study examined the last-mile travel mode preferences of the households in Barangay Batasan Hills, Quezon City, Philippines under different alert level systems. Data were validated and coded. Variables were analyzed. A binary logit model was estimated to analyze the significant factors affecting the last-mile travel mode choice during the pandemic.

Table 3. Parameter estimation and model validation results of binary logit model for public transport at different alert levels. ** significant at 99%; * significant at 95%.

Parameters	Alert Level			
	1		2 to 5	
	β	P > |z|	β	P > |z|
Departure Time Last-Mile (TIMELM) indicator variable (1 for > 5 PM, 0 otherwise)	1.08**	0.000	1.10**	0.000
COVID-19 Fear Alert Level 1 (CFL1) indicator variable (1 for High, 0 for Low)	-0.95*	0.028		
Compliance to COVID-19 measures of Fully Vaccinated (COMPFV) indicator variable (1 for High, 0 for Low)	-1.67**	0.004	-1.67**	0.004
Travel Anxiety of those with Booster (TAB) indicator variable (1 for High, 0 for Low)	1.28**	0.000	1.53**	0.000
Trip Duration as a priority during pandemic (TDD) indicator variable (1 for High Priority, 0 for Low Priority)	-0.74**	0.009	-0.68*	0.014
Constant	-0.77	0.277	-0.20	0.760
LR chi^2	76.10		70.89	
Prob > chi^2	0.000		0.000	
Pseudo R^2	0.17		0.16	
Base CCR	52.05		52.05	
Correct Classification Rate (CCR)	69.02		70.25	
Area Under Curve (AUC)	75.83		74.53	
Log-Likelihood whole sample (LL_{Whole})	-181.19		-183.79	
Log-Likelihood sample 1 ($LL_{Sample1}$)	-86.04		-92.81	
Log-Likelihood whole sample 2 ($LL_{Sample2}$)	-92.77		-88.77	
Likelihood Ratio (LR)	4.76		4.42	
Degrees of Freedom	5		4	
Critical value, $\chi^2_{0.05}$	11.07		9.49	

Descriptive Summary of Variables

The descriptive analysis result of the study showed that most of the respondents in Batasan Hills, Quezon City travelled by walking during the pandemic instead of using public transportation. This result complements the study of Co et al. (2023) where they indicated that most travellers are shifting away from using public transport during the pandemic and some shift to walking activities for non-commuting (Borkowski et al. 2021). Most of their travels are for the purpose of going to their workplaces or going to school. Moreover, many of the respondents have high risk perception in using public transportation. The result of high-risk perception for public transportation use indicates that the vehicle characteristics including the number of passengers allowed, social distancing inside the vehicle, and service environment (crowding, cleanliness, comfort) are driving factors to risk perception. Previous studies revealed that most respondents perceived public transport as a high risk of infection due to its poor sanitization, ventilation, and high occupancy rate disregarding physical distancing at most times compared to private vehicles (Co et al. 2023; Abdullah et al. 2020).

Factors Affecting Last-Mile Travel Mode Choice under COVID-19 Alert Levels

The model estimation for the last-mile travel mode choices under alert levels 1 to 5 are affected by their travel characteristics such as their last-mile departure time and trip duration during the pandemic. Those who depart after 5 PM are more likely to travel with a public vehicle. When the respondents highly prioritize the trip duration, then they are more likely to travel on foot. Abdullah et al. (2020) and Zubair et al. (2022) emphasized that variables like cost, comfort, and trip duration become less priority during the pandemic compared to pandemic-related factors such as the usage of facemasks, social distancing, cleanliness, safety, and security. Risk-related variables such as COVID-19 fear, compliance with safety measures and protocols, and travel anxiety also influence their last-mile mode choices. Those who are fully vaccinated and have high compliance with pandemic protocols are also more likely to walk when stretching their last mile to avoid risk of infection. This contrasts with the study on 16 European countries regarding the influence of COVID-19 risk perception and vaccination status on the number of social contacts which revealed that vaccinated individuals were reported to have a higher number of contacts than non-vaccinated, showing leniency of compliance and safety protocols (Wambua et al. 2023). Moreover, the increasing rate of transmission in public transportation, making it unsafe to ride has reduced the chances that it will be chosen (Paul et al. 2022). On the other hand, the model estimation showed that those who received booster shots and with travel anxiety are more likely to use public transport denoted with a positive coefficient (β = 1.28). Further, the choice of mode of transportation is influenced by personal preferences for public transit, willingness to use it, and belief in its

security (Aaditya and Rahul 2021; Lee et al. 2022). Further, coefficients from the parameter estimation of the logit models for last-mile travel mode under alert level 1 show that those who show fear of COVID-19 infection are less likely to use public transport.

The findings of this study can provide useful insights into creating and devising strategies and plans that will benefit both transport service providers and consumers during the COVID-19 pandemic. It can also provide information that can be used in the development and improvement of transport systems in the country, specifically on last-mile transport. On the other hand, policies on riding public transport can also be regulated. It can also be beneficial to revise the travel guidelines under different alert levels. Although the study is deemed beneficial to understanding travel behavior during the pandemic, it can still be subjected to some limitations. It is recommended that the study area should also be expanded to nearby barangays or cities to capture a detailed analysis of the travel mode choice during last-mile travels. The study made use of two alternatives namely walking and traveling in a vehicle (private/public). To capture the specific effects of the socio-demographic and travel characteristics on different travel modes, it is suggested that public transport and private transport be analyzed as two separate alternatives. The addition of other travel modes can also be done. The last mile is as weak as the first mile in terms of transport links. Thus, it is highly recommended that the first mile should also be studied. Other travel decisions such as trip generation, destination choice, and route choice can also be a focus of future research.

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ETHICAL CONSIDERATIONS

In the conduct of data collection, participants informed consent was provided and sought. Only those who were willing to participate were interviewed. The personal information of participants is kept confidential. Only the results of the data analysis are published in this paper.

DECLARATION OF COMPETING INTEREST

We declare no competing interests in this work.

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REFERENCES

Aaditya B and Rahul T. 2021. Psychological impacts of COVID-19 pandemic on the mode choice behaviour: A hybrid choice modelling approach. Transport Policy, 108: 47-58. https://doi.org/10.1016/j.tranpol.2021.05.003

Abdullah M, Ali N, Bilal Aslam A, Ashraf Javid M and Arif Hussain S. 2022. Factors affecting the mode choice behavior before and during COVID-19 pandemic in Pakistan. International Journal of Transportation Science and Technology, 11(1): 174-186. https://doi.org/10.1016/j.ijtst.2021.06.005

Abdullah M, Dias C, Muley D and Shahin M. 2020. Exploring the impacts of COVID-19 on travel behavior and mode preferences. Transportation Research Interdisciplinary Perspectives, 8: 100255. https://doi.org/10.1016/j.trip.2020.100255

Ancheta D, Tani R and Uchida K. 2023. The relationship of social vulnerability and travel behavior with COVID-19 in Metro Manila, Philippines. Asian Transport Studies, 9: 100093. https://doi.org/10.1016/j.eastsj.2022.100093

Baclig C. 2022. EXPLAINER: The Philippines' COVID-19 alert level system. Inquirer. https://newsinfo.inquirer.net/1535963/explainer-the-philippines-covid-19-alert-level-system. Accessed on 09 November 2022.

Batasan Hills. undated. Batasan Hills. https://placeandsee.com/wiki/batasan-hills. Accessed on 09 November 2022.

Ben-Akiva ME and Lerman SR. 1985. Discrete choice analysis: theory and application to travel demand (Vol. 9). MIT press.

Bhaduri E, Manoj B, Wadud Z, Goswami AK and Choudhury CF. 2020. Modelling the effects of COVID-19 on travel mode choice behaviour in India. Transportation Research Interdisciplinary Perspectives, 8: 100273. https://doi.org/10.1016/j.trip.2020.100273

Borkowski P, Jażdżewska-Gutta M and Szmelter-Jarosz A. 2021. Lockdowned: Everyday mobility changes in response to COVID-19. Journal of Transport Geography, 90: 102906. https://doi.org/10.1016/j.jtrangeo.2020.102906

Chen S, Yan X, Pan H and Deal B. 2021. Using big data for last mile performance evaluation: An accessibility-based approach. Travel Behaviour and Society, 25: 153-163. https://doi.org/10.1016/j.tbs.2021.06.003

Co NJ, Dimaculangan K and Peralta MH. 2023. Effects of Covid-19 pandemic on mode choice behavior of working Filipinos in Metro Manila. Asian Transport Studies, 9: 100101. https://doi.org/10.1016/j.eastsj.2023.100101

de Haas M, Faber R and Hamersma M. 2020. How COVID-19 and the Dutch 'intelligent lockdown' change activities, work and travel behaviour: Evidence from longitudinal data in the Netherlands. Transportation Research Interdisciplinary Perspectives, 6: 100150. https://doi.org/10.1016/j.trip.2020.100150

DOH (Department of Health). 2020. DOH confirms first 2019-NCOV case in the country; Assures public of intensified containment measures. https://doh.gov.ph/doh-press-release/doh-confirms-first-2019-nCoV-case-in-the-country. Accessed on 09 November 2022.

DOH (Department of Health). 2021. Guidelines on the nationwide implementation of alert level system for COVID-19 response. https://doh.gov.ph/sites/default/files/health-update/Guidelines-Alert-Level-System-for-COVID-19-Response.pdf. Accessed on 09 November 2022.

Guo Y, Yang L, Huang W and Guo Y. 2020. Traffic Safety Perception, Attitude, and Feeder Mode Choice of Metro Commute: Evidence from Shenzhen. International Journal of Environmental Research and Public Health, 17(24): 9402. https://doi.org/10.3390/ijerph17249402

Hasnine MS, Lin T, Weiss A and Habib KN. 2018. Determinants of travel mode choices of post-secondary students in a large metropolitan area: The case of the city of Toronto. Journal of Transport Geography, 70: 161-171. https://doi.org/10.1016/j.jtrangeo.2018.06.003

Hasselwander M, Tamagusko T, Bigotte J, Ferreira A, Mejia A and Ferranti E. 2021. Building back better: The COVID-19 pandemic and transport policy implications for a developing megacity. Sustainable Cities and Society, 69: 102864. https://doi.org/10.1016/j.scs.2021.102864

Hensher DA. 1994. Stated preference analysis of travel choices: the state of practice. Transportation, 21: 107-133.

Lee S, Park S, Yang S, Park J and Lee J. 2022. Contributing factors to the change in travel mode choice after COVID-19 in Korea using bivariate probit model. International Journal of Sustainable Building Technology and Urban Development, 13(2): 184-197. https://doi.org/10.22712/susb.20220016

Lu Y, Prato CG, Sipe N, Kimpton A and Corcoran J. 2022. The role of household modality style in first and last mile travel mode choice. Transportation Research Part A: Policy and Practice, 158: 95-109. https://doi.org/10.1016/j.tra.2022.02.003

Mack EA, Agrawal S and Wang S. 2021. The impacts of the COVID-19 pandemic on transportation employment: A comparative analysis. Transportation Research Interdisciplinary Perspectives, 12: 100470. https://doi.org/10.1016/j.trip.2021.100470

Mao Z, Ettema D and Dijst M. 2018. Analysis of travel time and mode choice shift for non-work stops in commuting: case study of Beijing, China. Transportation, 45: 751–766. https://doi.org/10.1007/s11116-016-9749-8

Massaccesi C, Chiappini E, Paracampo R and Korb S. 2021. Large Gatherings? No, Thank You. Devaluation of Crowded Social Scenes During the COVID-19 Pandemic. Frontiers in Psychology, 12: 689162 https://doi.org/10.3389/fpsyg.2021.689162

McFadden D. 1997. Quantitative Methods for Analyzing Travel Behaviour of Individuals: Some Recent Developments. Cowles Foundation Discussion Papers.

Meng M, Koh P and Wong Y. 2016. Influence of Socio-Demography and Operating Streetscape on Last-Mile Mode Choice. Journal of Public Transportation, 19(2): 38-54. https://doi.org/10.5038/2375-0901.19.2.3

Mo B, Shen Y and Zhao J. 2018. Impact of Built Environment on First- and Last-Mile Travel Mode Choice. Transportation Research Record: Journal of the Transportation Research Board, 2672(6): 1-12 https://doi.org/10.1177/0361198118788423

Mohd Ali NF, Mohd Sadullah AF, Abdul Majeed AP, Mohd Razman MA and Musa RM. 2022. The identification of significant features towards travel mode choice and its prediction via optimised random forest classifier: An evaluation for active commuting behavior. Journal of Transport & Health, 25: 101362. https://doi.org/10.1016/j.jth.2022.101362

Monmousseau P, Marzuoli A, Feron E and Delahaye D. 2020. Impact of Covid-19 on passengers and airlines from passenger measurements: Managing customer satisfaction while putting the US Air Transportation System to sleep. Transportation Research Interdisciplinary Perspectives, 7: 100179. https://doi.org/10.1016/j.trip.2020.100179

Philippine News Agency. 2022. IATF approves amended guidelines for Alert Level 1. https://www.pna.gov.ph/articles/1168637. Accessed on 09 November 2022.

Patil GR, Basu R and Rashidi TH. 2020. Mode choice modeling using adaptive data collection for different trip purposes in Mumbai metropolitan region. Transportation in Developing Economies, 6(1): 1-10. https://doi.org/10.1007/s40890-020-0099-z

Paul T, Chakraborty R, Afia Ratri S and Debnath M. 2022. Impact of COVID-19 on mode choice behavior: A case study for Dhaka, Bangladesh. Transportation Research Interdisciplinary Perspectives, 15: 100665. https://doi.org/10.1016/j.trip.2022.100665

Pawar DS, Yadav AK, Akolekar N and Velaga NR. 2020. Impact of physical distancing due to novel coronavirus (SARS-CoV-2) on daily travel for work during transition to lockdown. Transportation Research Interdisciplinary Perspectives, 7: 100203. https://doi.org/10.1016/j.trip.2020.100203

Philippine News Agency. 2022. DOTr to keep 70% capacity in all rail lines under Alert Level 3. https://www.pna.gov.ph/articles/1164313. Accessed on 09 November 2022.

Shakibaei S, de Jong GC, Alpkökin P and Rashidi TH. 2021. Impact of the COVID-19 pandemic on travel behavior in Istanbul: A panel data analysis. Sustainable Cities and Society, 65: 102619. https://doi.org/10.1016/j.scs.2020.102619

Stam B, van Oort N and Hoogendoorn SP. 2021. Travellers' preferences towards existing and emerging means of first/last mile transport: a case study for the Almere centrum railway station in the Netherlands. European Transport Research Review, 13(1): 1-14. https://doi.org/10.1186/s12544-021-00514-1

Tantuco V. 2021. IATF completes nationwide implementation of COVID-19 alert level system. Rappler. https://www.rappler.com/nation/iatf-completes-nationwide-implementation-covid19-alert-level-system/. Accessed on 09 November 2022.

Tight M, Rajé F and Timms P. 2016. Car-Free Urban Areas: A Radical Solution to the Last Mile Problem or a Step Too Far? Built Environment 42(4): 603–616. http://dx.doi.org/10.2148/benv.42.4.603

Wambua J, Loedy N and Jarvis CI. 2023. The influence of COVID-19 risk perception and vaccination status on the number of social contacts across Europe: insights from the CoMix study. BMC Public Health, 23: 1350. https://doi.org/10.1186/s12889-023-16252-z

Washington SP, Karlaftis MG and Mannering FL. 2011. Statistical and econometric methods for transportation data analysis (2nd ed.) [Electronic version]. New York: Chapman and Hall/CRC.

Yang Y, Wang C, Liu W and Zhou P. 2018. Understanding the determinants of travel mode choice of residents and its carbon mitigation potential. Energy Policy, 115: 486-493. https://doi.org/10.1016/j.enpol.2018.01.033

Zhang J, Hayashi Y and Frank LD. 2021. COVID-19 and transport: Findings from a world-wide expert survey. Transport Policy, 103: 68-85. https://doi.org/10.1016/j.tranpol.2021.01.011

Zubair H, Karoonsoontawong A and Kanitpong K. 2022. Effects of COVID-19 on Travel Behavior and Mode Choice: A Case Study for the Bangkok Metropolitan Area. Sustainability, 14(15): 9326. https://doi.org/10.3390/su14159326

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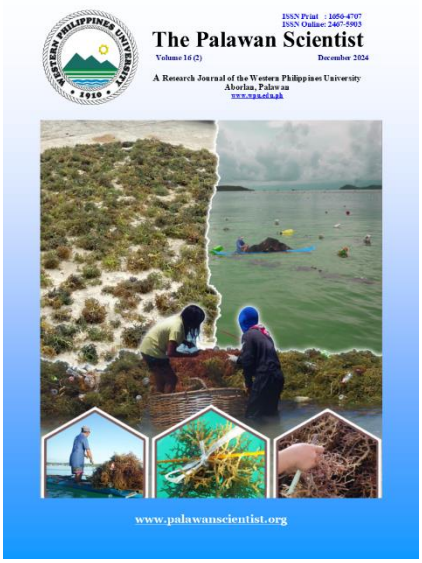

Selection of fast-growing seaweed cultivars in Palawan, Philippines

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ABSTRACT

Seaweed farming in Palawan currently involves different local cultivars. At least 12 of these cultivars were successfully grown in an indoor facility employing the branch culture techniques and were sea-out planted in Puerto Princesa Bay since 2015. Six of these cultivars yielded relatively high daily growth rates and were selected for the year-round field-testing experiment to compare the growth rates among cultivars and species, between farming sites, and across seasons from 01 July 2021 until 15 August 2022. Monitoring of cultivars' daily growth rates (DGRs) was conducted in 100 m^2 experimental floating monoline plots in Green Island and Sitio Amogues of the municipalities of Roxas and Taytay, Palawan, respectively. Findings revealed that seaweed DGRs significantly varied among cultivars and species (p = 0.001; p = 0.008). The "spinosum" brown from Puerto Princesa and "sacol" green from Green Island, Roxas had higher DGRs, 4.28% and 4.10%, respectively. Grouping the cultivars per species, the cultivars of *Eucheuma denticulatum* (L. Burmann) Collins & Hervey had higher DGRs compared to *Kappaphycus striatus* (F. Schmitz) L. M. Liao and *Kappaphycus alvarezii* (Doty) L. M. Liao. Spatial and seasonal variabilities in cultivar DGRs were also evident. Four cultivars obtained significantly different DGRs between planting sites. The "tambalang" (p = 0.010) and "magnolia" (p = 0.006) with DGRs of 3.26% and 4.08%, respectively in Green Island Roxas, while the "spinosum" brown from Puerto Princesa (p < 0.001; 4.86% DGR) and San Vicente (p < 0.001; 4.45% DGR) in Amogues, Taytay. Three cultivars in Green Island, Roxas, obtained significantly higher DGRs during the wet season. These were the "tambalang" (p = 0.000; 3.98% DGR), "magnolia" (p = 0.000; 4.57% DGR), and "spinosum"-brown from Puerto Princesa (p = 0.006; 5.23% DGR). In Amogues, Taytay, all six cultivars obtained significantly higher DGRs during the wet season: "tambalang" (p = 0.210; 3.17% DGR); "lakatan" (p = 0.004; 2.69% DGR); "spinosum" brown from Puerto Princesa (p = 0.00; 3.97% DGR); and San Vicente (p = 0.00; 3.39% DGR). A cropping calendar that indicates the fast-growing cultivars to be planted at a particular site and season is provided in this study. This information shall aid local farmers in cultivar selection towards a sustainable seaweed farm management in Palawan.

Keywords: cultivation, daily growth rates, farmers, planting sites, seasons.

INTRODUCTION

Palawan has accounted for a major share of seaweed production in the Philippines. Holding an annual average record of 370,000 MT from 1997–2021, the area represents 84% of Region 4B's seaweed production, or 20% of the entire Philippines. (PSA 2021). Approximately 5,567 ha of *Kappaphycus* and *Eucheuma* farms can be found in 23 seaweed-producing municipalities in the province (Quiaoit et al. 2018). Year-round production was reported for the municipalities of Agutaya, Cuyo-Magsaysay, Cagayancillo, Balabac, and the Calamian Group of Islands, benefiting 7,604 coastal dwellers in the island province of Palawan (BFAR 2022).

The success of seaweed farming in the province is not without challenges. From 2004 to 2007, annual average production was at 360,378.00 MT. In the succeeding years, 2008 to 2012, the volume increased to 455,473.00 MT, and in the most recent years, 2013 to 2021, only 326,832 MT, or a decrease of 20.8% from the previous years (PSA 2021). Aside from extensive die-offs on farms due to ice-ice disease (Zabala and Gonzales-Plasuz 2020), the scarcity of stable supply of quality seedlings is also a limiting factor to seaweed farm productivity in Palawan (PEMSEA 2016).

To initially address the problem of shortage and decreasing quality of farmed *Kappaphycus* and *Eucheuma*, the Department of Science and Technology-Philippine Council for Agriculture, Aquatic, and Natural Resources Research Division (DOST-PCAARRD) launched the Seaweed Research and Development Program in 2014. One of the outputs of the program is the establishment of seaweed culture facilities at Palawan State University, Tiniguiban, Puerto Princesa City, Palawan. Currently, the facility houses 20 cultivars of commercially farmed seaweeds from different sites, mostly from Palawan. Six of these cultivars have been successfully maintained through branch culture technology in the laboratory and underwent cultivation at various sea-based nurseries in Palawan (Dangan-Galon, unpublished data). With the increasing demand for quality seedlings (Roleda et al. 2021), this study attempted to determine the growth performance of the six successfully cultured cultivars to select better planting materials on farms while new or novel strains of genetically viable seedlings are not yet available for large-scale farming or production.

The selection of fast-growing crops is a promising approach in seaweed aquaculture. This approach was done with 23 morphotypes of farmed seaweeds, which isolated, at that time, *Kapppaphycus alvarezii* (Doty) L.M. Liao as a fast-growing and disease-resistant species among other farmed seaweeds (Doty and Alvarez 1975). The other two widely farmed species, the *Kappaphycus striatus* (Schmitz) L.M. Liao, and *Eucheuma denticulatum* (L. Burmann) Collins & Hervey were also products of the 1996 crop selection program (Ask and Azanza 2002). From these species, the 61 named seaweed cultivars have since been used. The term cultivars were coined by seaweed farmers to refer to crops grown on farms. Cultivars are different from "varieties," which pertain to an identity of taxonomic differentiation (Dumilag et al. 2023).

The measurement of seaweed growth rates to select quality cultivars has been performed in different countries of Asia and in Brazil and South Africa (Simatupang et al. 2021; Rama Rama et al. 2018; Tandel et al. 2017; Kotiya et al. 2011; de Paula et al. 2002; Gerung and Ohno 1997; Ohno et al. 1994). In the Philippines, studies to select fast-growing cultivars have been done mostly in Bohol, Pangasinan, Zamboanga City, Sulu, and Lanao del Norte (Orbita 2013; Hurtado et al. 2012; Borlongan et al. 2011; Luhan and Sollesta 2010; Naguit et al. 2009; Trono et al. 2000; Dawes et al. 1994; Trono and Luisma 1992; Trono and Ohno 1989; Doty 1987; Parker 1974). In most of these studies, variabilities in the growth performance of *Kappaphycus* and *Eucheuma* in relation to species and cultivar types, seasons, and planting sites were recorded.

METHODS

Study Sites and Experimental Species

The branch culture of seaweed cultivars is maintained at Palawan State University-Marine Science Research Center (PSU-MSRC), Tiniguiban, Puerto Princesa City (9º46'32.0" N; 118º43'58.0" E). The field-testing sites were located in Green Island, Tumarbong, Roxas (10º15'46.9" N; 119º29'31.0" E), and Sitio Amogues, Calawag Bay, Taytay, Palawan (10º43'03.1" N; 119º36'16.5" E) (Figure 1). The planting site in Green Island, Roxas, is nearshore-exposed with an average sea surface temperature of 30ºC and salinity of 36‰. The dissolved Oxygen was 4.9 mg. L^{-1}. In Amogues, Taytay, the farm is nearshore-sheltered, with an average sea surface temperature of 31ºC, salinity of 35‰, and dissolved Oxygen of 5.5 mg. L^{-1}.

The six cultivars being cultured at PSU-MSRC and vegetatively cultivated in Puerto Princesa Bay were used in this study. These included the *Kappaphycus alvarezii* cultivar "tambalang" from the land-based seaweed culture facility of the Bureau of Fisheries and Aquatic Resources (BFAR) in Giuan, Samar (14 May 2014); "lakatan" from Maranggas, Bataraza, collected on 14 February 2020; *Kappaphycus striatus* cultivars "sacol green" and "magnolia" from Green Island, Roxas (01 January 2016; 21 January 2020 respectively); *Eucheuma denticulatum* cultivar "spinosum" from Honda Bay,

Puerto Princesa, and Panindigan, San Vicente (16 June 2014; 21 January 2020, respectively) (Figure 2).

Control cultivars were used in Green Island, Roxas, and Amogues, Taytay, Palawan. These control cultivars refer to the types of *Kappaphycus* and *Eucheuma* being farmed at the planting sites during the course of the study. Particularly the *K. alvarezii* cultivar "cottonii" served as the control cultivar for "tambalang" and "lakatan" while the *K. striatus* cultivar "bukoy" and *E. denticulatum* cultivar "butay" for "sacol" green and "magnolia" and "spinosum'' brown, respectively (Figure 3). Table 1 presents the summary of field-testing experiment conducted in Green Island, Roxas and Amogues, Taytay, Palawan.

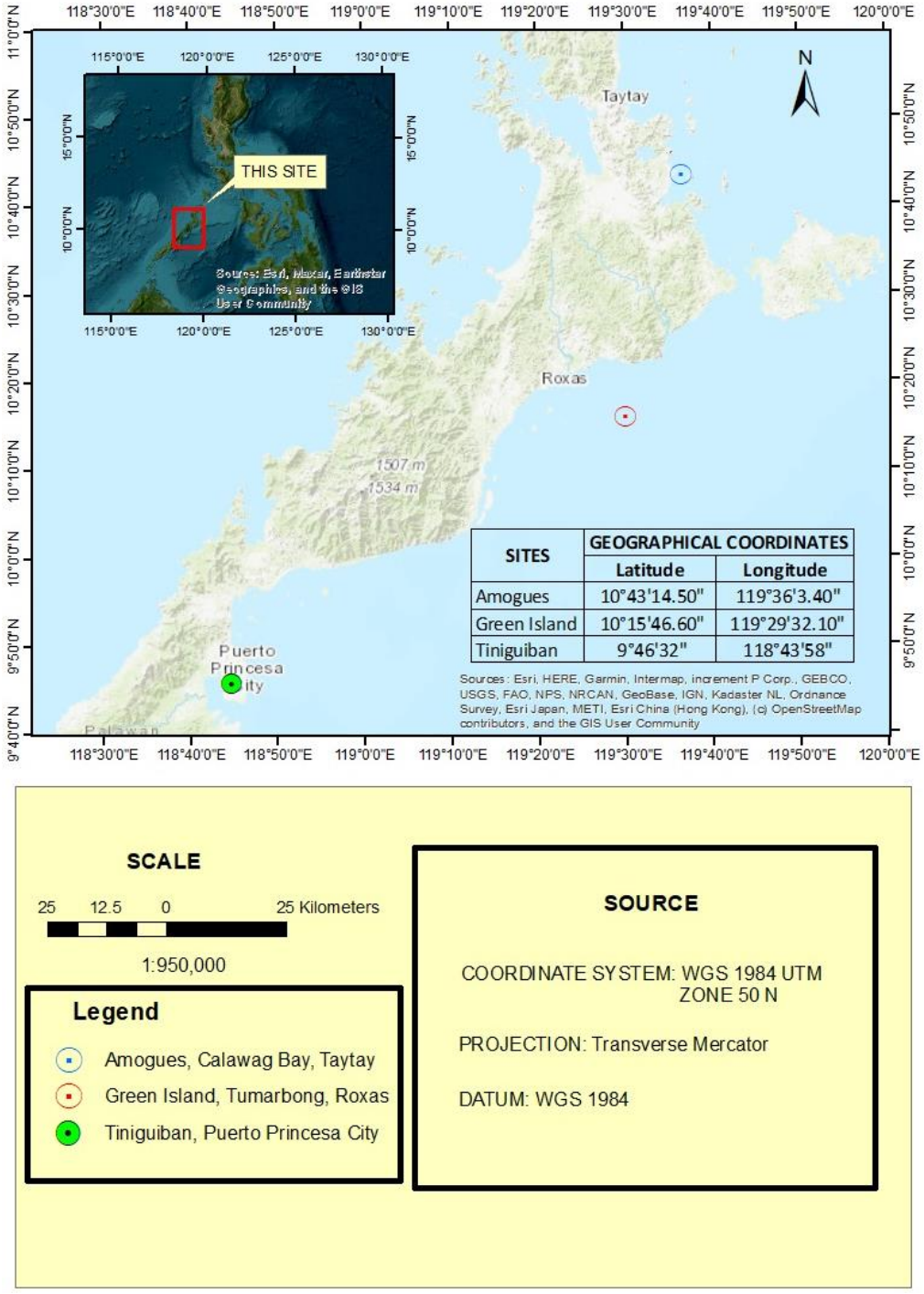

Figure 1. Map of the study sites in Palawan. The inset indicates the location of Palawan within the Philippines.

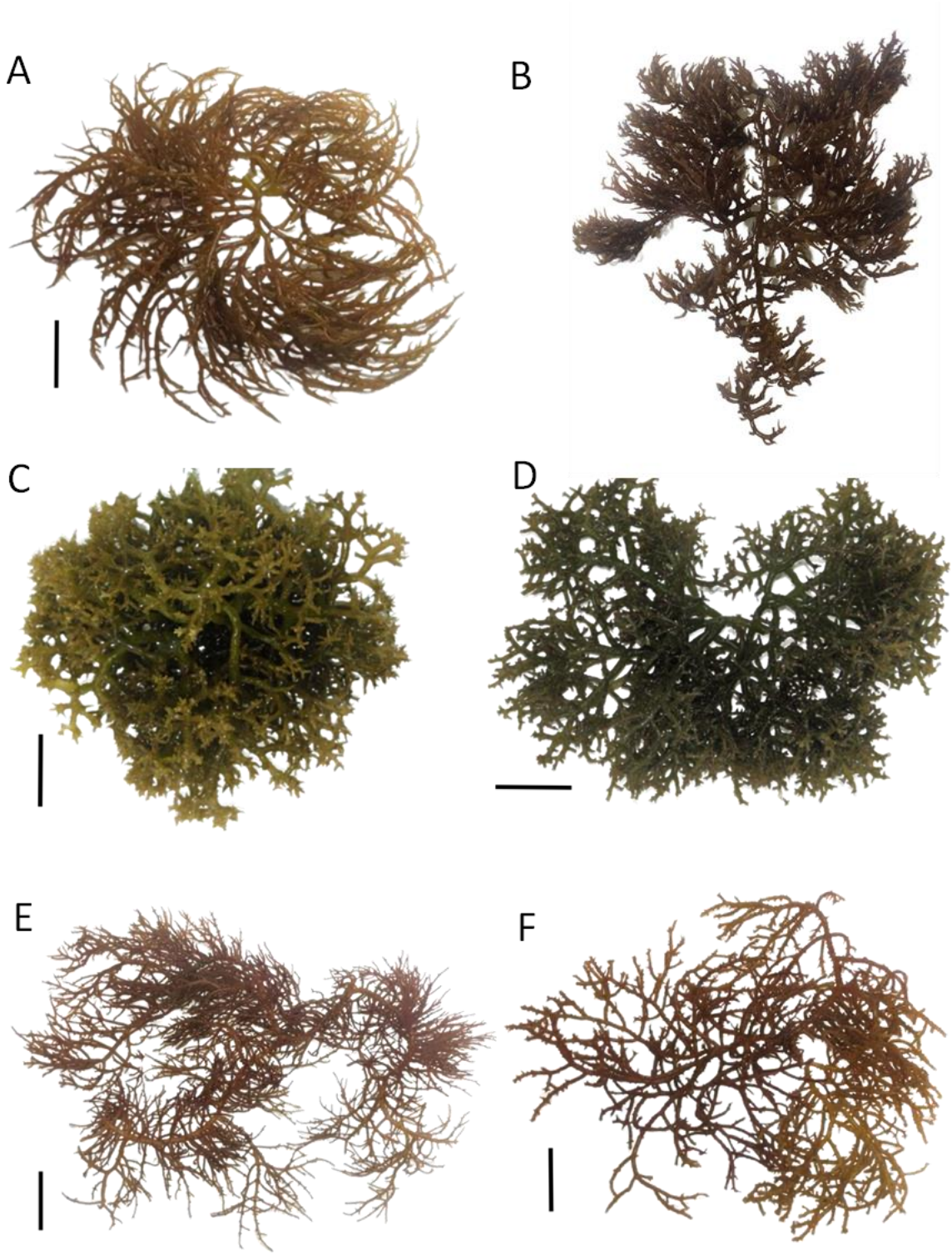

Figure 2. Seaweed cultivars used in this study "tambalang" (A); "lakatan" (B); "sacol" green (C); "magnolia" (D); "spinosum" brown from Honda Bay, Puerto Princesa; (E) and "spinosum" brown from San Vicente Palawan (F). Scale bar length: 7 cm.

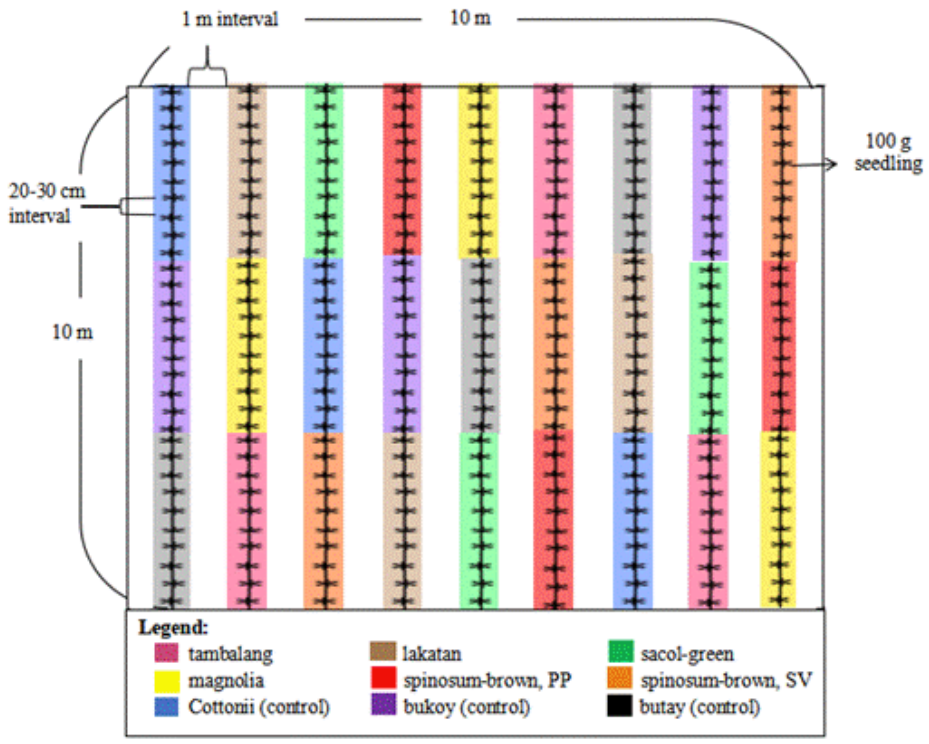

Figure 3. Experimental lay-out of the field-tested cultivars at Green Island and Sitio Amogues in the municipalities of Roxas and Taytay, Palawan.

Table 1. Summary of field-testing experiment conducted in Green Island, Roxas and Amogues, Taytay, Palawan.

Sites	Activities	Cultivars		Duration of Culture	Number of Cropping Cycles	
		Field-tested	Control		Wet Season	Dry Season
Tiniguiban, Puerto Princesa City	Mass propagation of seedlings	tambalang lakatan sacol-green magnolia spinosum- brown PP spinosum-brown SV	None	24 July 2017 to 29 June 2021 24 July 2020 to 19 June 2021 24 July 2017 to 29 June 2021 27 February 2020 to 29 June 2021 27 March 2020 to 29 June 2021 January 2021-29 June 2021	Not recorded	Not recorded
Green Island, Roxas, Palawan	Field-testing of the six cultivars	tambalang lakatan sacol-green magnolia spinosum- brown PP spinosum-brown SV	cottonii cottonii bukoy bukoy butay butay	01 July 2021 to 30 June 2022	5	3
Sitio Amogues, Taytay, Palawan	Field-testing of the six cultivars			16 August 2021 to 15 August 2022	5	3

Measurement of Cultivars' Daily Growth Rates

The daily growth rates of at least 10 individual thalli per cultivar were measured at 15-day intervals per 45-days cropping cycle, covering 01 July to 30 December 2021 and 01 July to 15 August 2022 for the wet season (225 days) and 16 February to 30 June 2022 for the dry season (135 days). The DGRs per cropping cycle represent the average DGR of the three measurements done (every 15th, 30th, and 45th day of cultivation). The computed DGRs were compared among cultivars, between planting sites, and across planting seasons. The % DGRs was computed using the formula recommended by Yong et al. (2013):

$$DGR\ (\%) = \left[\left(\frac{W_t}{W_0}\right) \times \frac{1}{t-1}\right] \times 100$$

where W_t is the final weight, W_o is the initial weight, and t refers to days of culture.

A cropping calendar was developed, indicating the viable cultivars for cultivation on farms. This included cultivars with DGRs higher than those of the control cultivars.

Statistical Analysis

Descriptive statistics (i.e., averages and ranks) were employed to summarize the data. Statistical analyses were performed using RStudio software version 2021.09.0 (R Core Team 2018). All statistical testing was performed at $\alpha = 0.05$. The assumption of normality was confirmed by the Shapiro-Wilk test. To determine the differences in the average DGRs among cultivars and species, the one-way ANOVA and the Tukey-Kramer (post-hoc) test were implemented. The T-test for independent samples was performed to test whether the average DGRs of cultivars differ significantly between planting sites and seasons.

RESULTS

Cultivars' Daily Growth Rates

The mean daily growth rates of the six cultivars in two planting sites over eight cropping cycles (360 days) are presented in Figure 4. Among these cultivars, "spinosum" brown from Puerto Princesa and "sacol" green had the highest mean DGRs, 4.28% and 4.10%, respectively. The "spinosum" brown from San Vicente followed with a mean DGR of 3.65%, then the "lakatan" (3.55%), and "magnolia" (3.26%). The "tambalang" obtained the lowest mean DGR with only 3.24%. A comparison of mean DGRs among cultivars ($p < 0.001$) and species ($p = 0.008$) revealed significant differences at alpha 0.05 , or significance level. Post-hoc results suggested that the mean DRG of "spinosum"- brown from Puerto Princesa was significantly higher than than that of "spinosum"-brown from San Vicente. Similarly, the mean DGR of "sacol"-green was significantly higher than that of "magnolia," while "tambalang" and "lakatan" DGRs did not vary significantly with each other. Consequently, the cultivars of the species *Eucheuma denticulam* had significantly higher DGR compared to the cultivars of *Kappaphycus striatus* and the cultivars of *Kappaphycus alvarezii*. Between the *K. striatus* and *K. alvarezii*, the former had significantly higher DGR than that of the later.

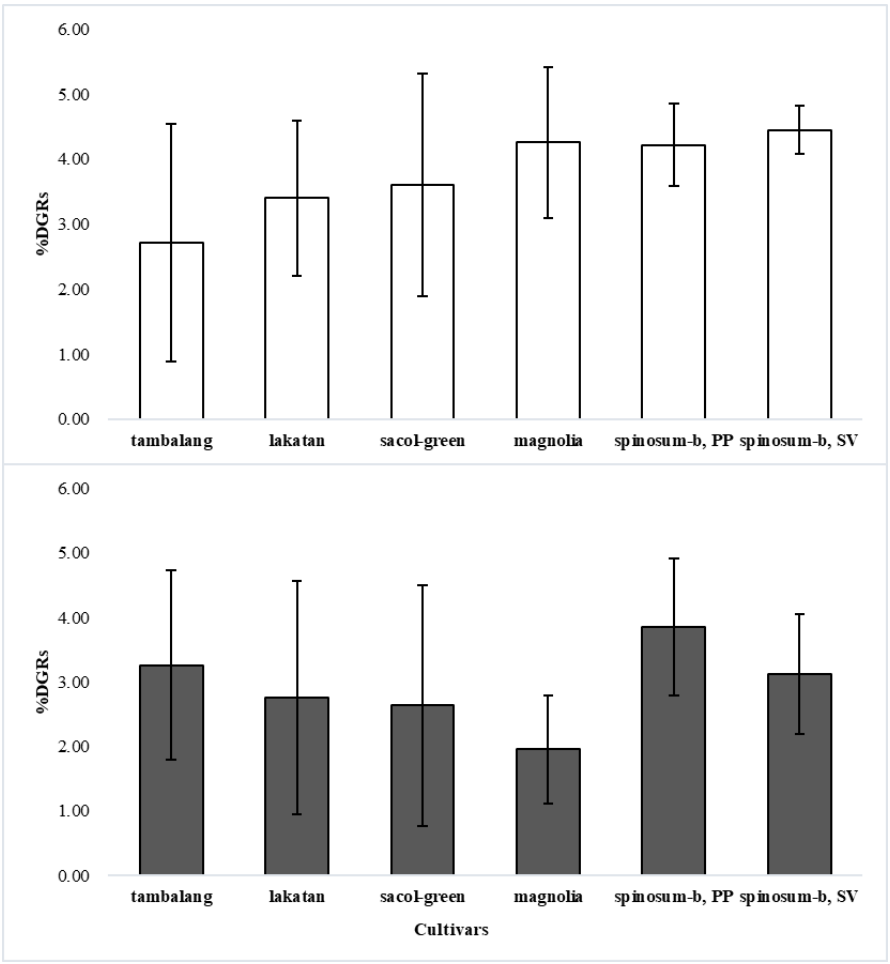

Figure 4. Comparative mean percent daily growth rates of the six field-tested cultivars in Green Island, Roxas (top) and Amogues, Taytay (bottom), Palawan. Bar lines indicate the standard deviations.

Spatial and Seasonal Variations in Cultivars' Daily Growth Rates

The DGRs of cultivars in two planting sites, Green Island, Roxas, and Amogues, Taytay, in Palawan, are presented in Figure 5. Four cultivars obtained significantly different DGRs between planting sites. The "tambalang" *($p = 0.010$)* and "magnolia" ($p = 0.006$) had DGRs of 3.26% and 4.08%, respectively, in Green Island, Roxas, while the "spinosum" brown from Puerto Princesa ($p < 0.001$) and San Vicente ($p < 0.001$) in Amogues, Taytay, had DGRs of 4.86% and 4.45%, accordingly. In particular, except for the "tambalang", all other cultivars planted in Green Island, Roxas had relatively higher DGRs than their respective control cultivars, the "cottonii" (2.84% DGR) for "lakatan and "bukoy" (1.73% DGR) for "sacol"- green and "magnolia"; and the "butay" (3.3% DGR) for "spinosum" brown PP, and "spinosum" brown SV. In Amogues, Taytay, the "lakatan" and "spinosum"- brown SV obtained a relatively lower DGRs than their respective control cultivars, the "cottonii" and "butay", respectively.

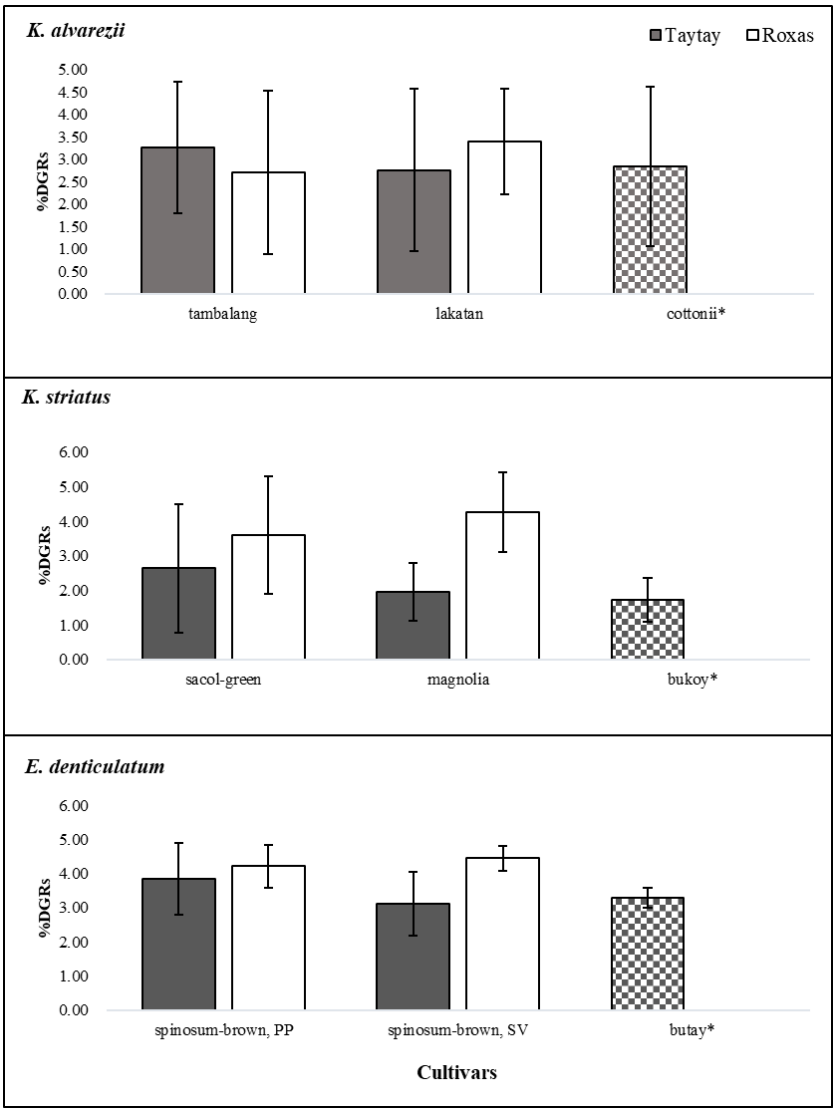

Figure 5. Comparative mean percent daily growth rates of field-tested and control cultivars (with asterisk) in Palawan with respect to planting sites. Bar line indicates the mean standard deviation.

A comparison of cultivar DGRs between seasons (wet and dry) in Green Island, Roxas, and Amogues, Taytay, is shown in Figure 6. Three cultivars grown from Green Island, Roxas, obtained significantly higher DGRs during the wet season. These were the "tambalang" ($p = 0.000$; 3.98% DGR), "magnolia ($p = 0.000$; 4.57% DGR), and "spinosum"- brown from Puerto Princesa ($p = 0.006$; 5.23% DGR). In Amogues, Taytay, all six cultivars obtained significantly higher DGRs during the wet season:

"tambalang" (*p = 0.210*; 3.17%DGR); "lakatan" (*p = 0.004*; 4.15%DGR); "sacol"-green (*p = 0.000*; 3.23%DGR); "magnolia" (*p = 0.004*; 2.69%DGR); "spinosum"- brown from Puerto Princesa (*p = 0.000*; 3.97%DGR) and San Vicente (*p = 0.00*; 3.39%DGR). In general, the "lakatan", "sacol", and "magnolia" grew best during the months of July to December in Green Island, Roxas but only during the months of October to November in Amogues, Taytay. The two "spinosum" cultivars can be planted year-round in Green Island, Roxas, but in Amogues, Taytay, only during the months of August to December. The ideal season for "tambalang" planting in Green Island, Roxas, was from September to October, while in Amogues, Taytay, it is from October to November (Figure 7). Relative to the average DGRs of the control cultivars, a cropping calendar showing the recommended cultivars to be planted in the two sites at a particular cropping season is developed from this study (Figure 8).

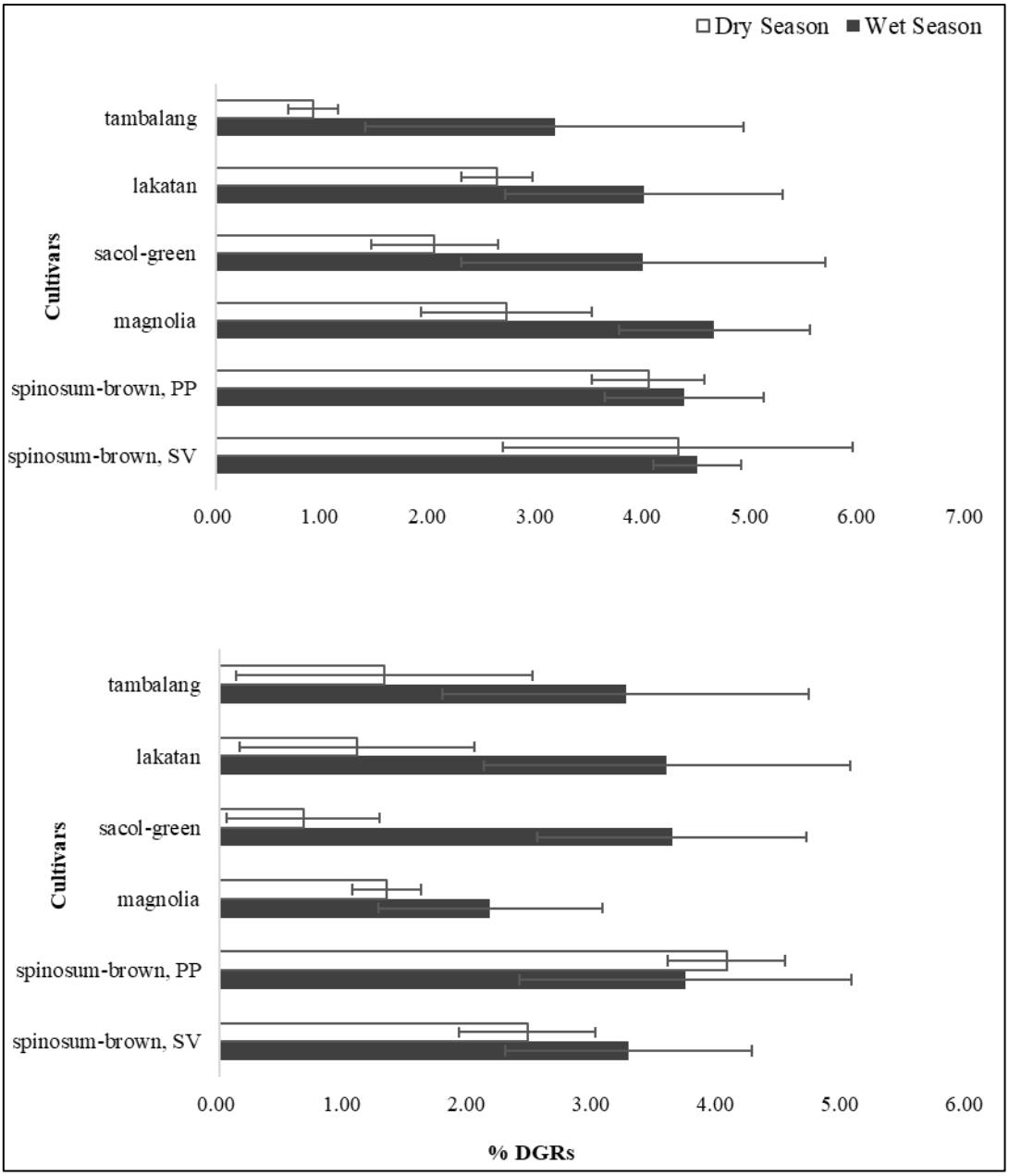

Figure 6. Comparative mean percent daily growth rate of seaweed cultivars in Green Island, Roxas (top) and Amogues, Taytay (bottom), Palawan with respect to cropping seasons (wet and dry). Bar line indicates the mean standard deviation.

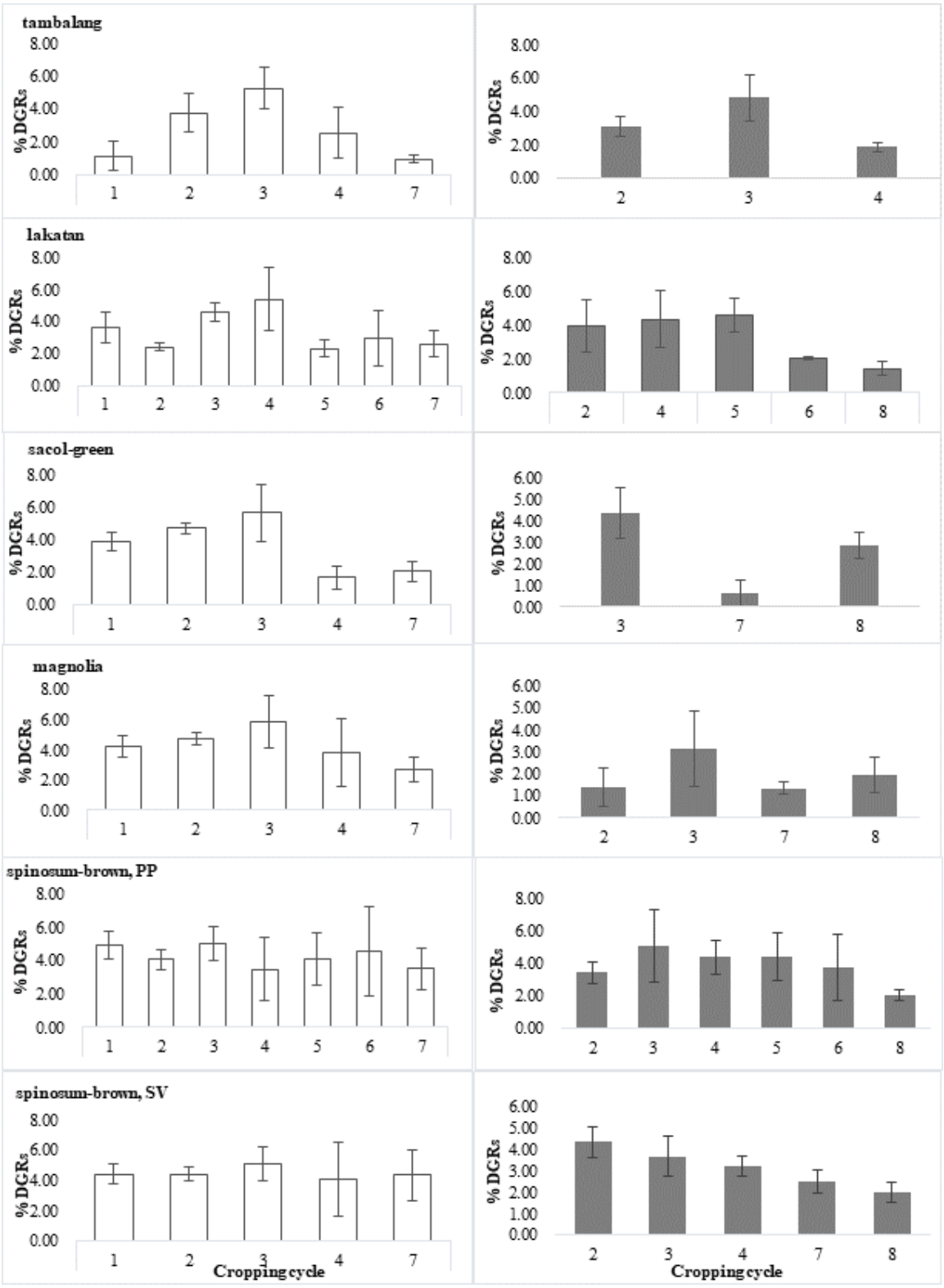

Figure 7. Comparative mean percent daily growth rate of seaweed cultivars in Green Island, Roxas (left) and Amogues, Taytay (right), Palawan with respect to cropping cycle (1 = 01 July-15 August 2021; 2 = 16 August-20 September 2021; 3 = 01 October-15 November2021; 4 = 16 Nov-31 December 2021; 5 = 16 February-31 March 2022; 6 = 01 April-15 May 2022; 7 = 16 May -30 June 2022; 8 = 01 July-15 August 2022). Bar line indicates the standard deviation.

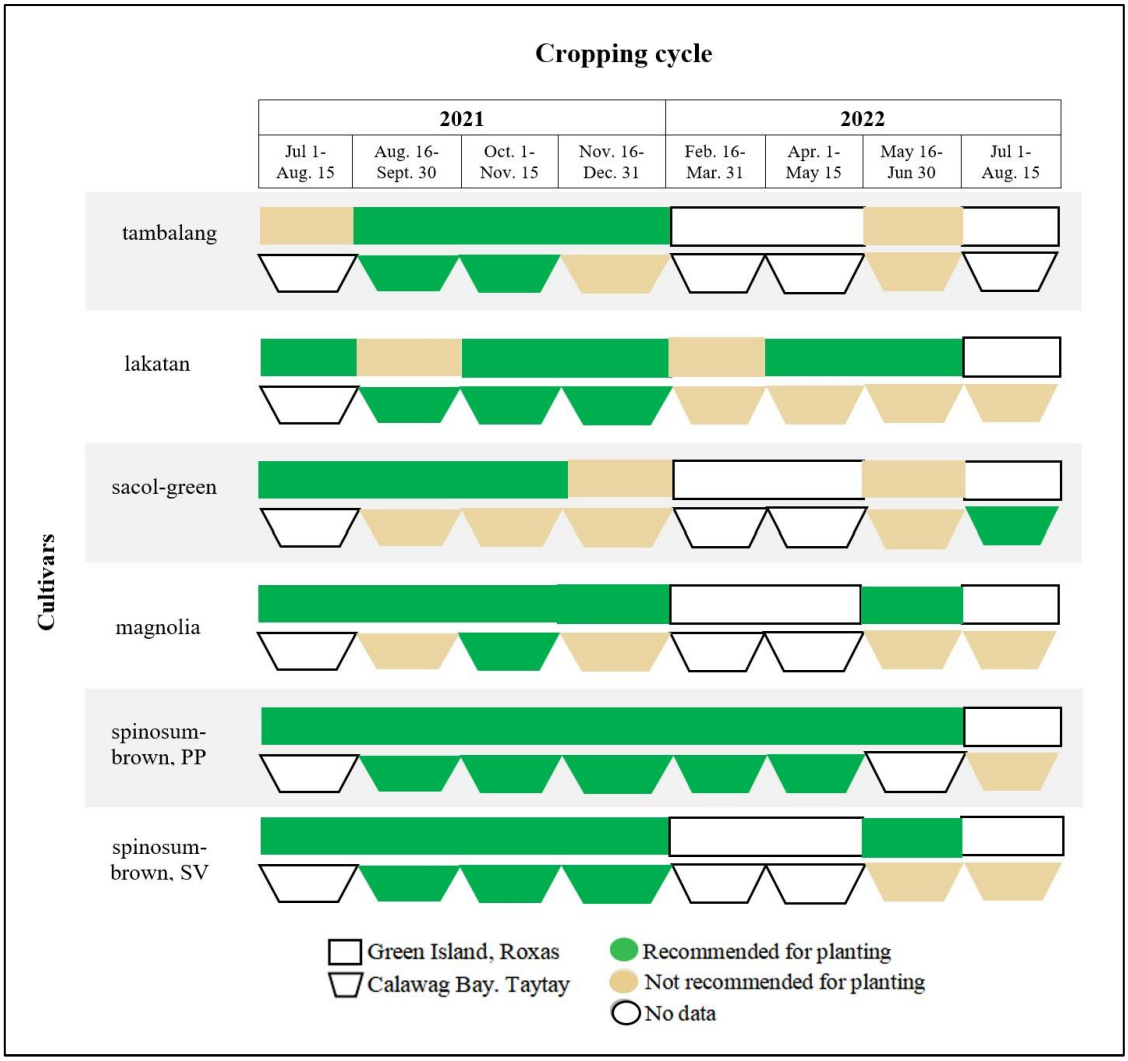

Figure 8. Cropping calendar recommended for seaweed cultivation in Palawan based from the selection dataset (average %DGRs) presented in this study.

DISCUSSION

Cultivars' Daily Growth Rates

The daily growth rates of cultivars differed among the three species. The *E. denticulatum*, had the highest growth rate compared to *K. alvarezii*, and *K. striatus*. In contrast, a similar study conducted in Bolinao, Pangasinan, revealed a higher DGR for *K. alvarezii*, 6.75% as opposed to only 5.06% for *E. denticulatum* (Dawes et al. 1994). The average DGR of *K. alvarezii* cultivars in this study, (3.39%) was relatively higher than those from Guimaras (2.06%) and Negros Oriental (2.44%) (Naguit et al. 2009), but lower than those from Pangasinan (6.75%) (Dawes et al. 1994); Zamboanga del Norte (3.52%) (Naguit et al. 2009); Zamboanga City (5.01%) (Hurtado et al. 2012); and Lanao del Norte (4.88%) (Orbita 2013). As observed in this study, cultivars of *K. alvarezii* were more vulnerable to ice-ice disease and changing environmental conditions (e.g., such as prolonged high sea surface temperatures and abrupt moderate to strong rainfall). This negative shift over the years in the growth performance among farmed eucheumatoids can be attributed to genetic instability and modifications due to the vegetative manner of propagating these seaweeds (Brakel et al. 2021). The repetitive use of the same old-age planting material can result in the production of an inferior line of propagules that are genetically inferior (Dumilag et al. 2003). The "cottonii" (*Kappaphycus*) propagules are highly preferred by farmers because of their higher market value, whether sold as fresh or raw dried seaweeds. The "spinosum" (*Eucheuma*), on the other hand, is less exploited for farming because of its lower market value and has retained its resistance to "ice-ice" disease, making it easier to propagate (De San 2012). The *Eucheuma denticulatum* produces volatile halocarbons (VHCs) when exposed to strong light and

carbon dioxide-deficient environments (Mtolera et al. 1996). The VHCs act against microorganism infections, herbivore grazing, space competitors, and detrimental fouling by different kinds of epiphytes (Pang et al. 2015).

Spatial and Seasonal Variabilities in Cultivars' Daily Growth Rates

The cultivars daily growth rates differed significantly between planting sites. This variability can be attributed to the location of seaweed farms in Green Island, Roxas, and Amogues, Taytay. It appeared that farm sites nearshore-exposed (in Green Island, Roxas) are more ideal for farming than the nearshore-sheltered sites (in Amogues, Taytay). These marine environment categories, including offshore and reef-protected areas, were recognized to discriminate ideal seaweed farms. Seaweed farm productivity in nearshore-sheltered coastal areas of tropical countries is extremely affected by rising upper surface ocean temperatures and is more susceptible to slowing water movement and the spread of diseases and pests Tullberg et al. (2022).

The cultivars daily growth rates also varied across planting seasons. Higher growth rates of cultivars were attained during the rainy season, with optimum growth in October to November. During this period, the surface seawater was colder and more turbulent due to monsoon rains and winds. Such a condition, as previously reported, is ideal for seaweed growth (Azanza and Sa-a 1990; Orbita 2013; Simatupang et al. 2021). The lower growth rates during the dry season can be attributed to a warmer seawater surface temperature and the occurrence of ice-ice disease. This scenario was previously observed in the growth rates of *K. alvarezii* in Antique, Philippines (Hurtado et al. 2001) and Cam Ranh Bay, Vietnam (Hung et al. 2009) during the months of April and May. Several other factors such as water movement, salinity, dissolved oxygen, pH, and nutrient contents can likewise affect the growth performance of seaweed cultivars (Orbita 2013; Kasim et al. 2017; Perenrengi et al. 2020).

The daily growth rates can be one of the criteria for seaweed selection in farming. The selected fast-growing cultivars should be the ones recommended for mass cultivation on farms to increase farm yields. However, this is just one of the many approaches toward a sustainable seaweed farming operation in Palawan, or in the entirety of the country. Given the overall decreasing trend in cultivars' growth performance over the years due to the changing climate, urgent action to characterize the seaweed farms in the province is highly suggested. Deteriorating seawater quality caused by local stressors or threats (i.e., sewage input, use of commercial fertilizer in seaweed farming) might have a significant impact on seaweed productivity. Site exploration to locate wild populations of *Kappaphycus*, *Eucheuma*, and other carrageenan-bearing seaweeds are equally important. Cultivars from the wild that are not yet exploited in farming, are genetically more viable and are good candidates for strain selection experiments. Nevertheless, the selected fast-growing cultivars from this study can be used for future micropropagation, tissue culture, and hybridization studies to advance the selection and dispersal of quality seedlings to the farmers of Palawan.

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ETHICAL CONSIDERATION

There are no human or animal subjects in this article and informed consent is not applicable.

DECLARATION OF CONFLICTING INTEREST

No potential conflict of interest was reported by the authors.

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REFERENCES

Ask E and Azanza RV. 2002. Advances in cultivation of technology of commercial eucheumatoid species: A review with

suggestions for future research. Aquaculture, 206(3-4): 257-277. https://doi.org/10.1016/S0044-8486(01)00724-4

Azanza-Corrales R and Sa-a P. 1990. The farmed *Eucheuma* species (Gigartinales, Rhodophyta) in Danajon Reef, Philippines: Carrageenan properties. Hydrobiologia, 204(1): 521-525. https://doi.org/10.1007/BF00040280

BFAR (Bureau of Fisheries and Aquatic Resources). 2022. The Philippine Seaweed Industry Roadmap (2022-2026). Department of Agriculture-Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines. pp203.

Borlongan IAG, Tibubos KR, Yunque DAT, Hurtado AQ and Critchley AT. 2011. Impact of AMPEP on the growth and occurrence of epiphytic *Neosiphonia* infestation on two varieties of commercially cultivated *Kappaphycus alvarezii* grown at different depths in the Philippines. Journal of Applied Phycology, 23(3): 615-621. https://doi.org/10.1007/s10811-010-9649-9

Brakel J, Sibonga RC, Dumilag RV, Montalescot V, Campbell I, Cottier-Coo EJ, Ward G, Le Masson V, Liu T, Msuya FE, et al. 2021. Exploring, harnessing and conserving marine genetic resources towards a sustainable seaweed aquaculture. Plants People Planet, 3(4): 337-349. https://doi.org/10.1002/ppp3.10190

Dawes CJ, Lluisma AO and Trono GC. 1994. Laboratory and field growth studies of commercial strains of *Eucheuma denticulatum* and *Kappaphycus alvarezii* in the Philippines. Journal of Applied Phycology, 6(1): 21-24. https://doi.org/10.1007/BF02185899

de Paula EJ, Toledo R, Pereira L and Ohno M. 2002. Growth rate of the carrageenophyte *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) introduced in subtropical waters of Sao Paulo State, Brazil. Phycological Research, 50(1): 1-9. https://doi.org/10.1046/j.1440-1835. 2002.00248.x

De San M. 2012. The Farming of Seaweeds. Europian Union. 29pp. https://www.fao.org/3/bl759e/bl759e.pdf. Accessed on 10 March 2023.

Doty MS. 1987. The production and use of *Eucheuma*. In: Doty MS, Caddy JF and Santilices B. (eds). Case studies of seven commercial seaweed resources. Food and Agriculture Organization Fisheries Technical Paper 281. FAO, Rome, pp. 123-161.

Doty MS and Alvarez VB. 1975. Status, problems, advances and economics of *Eucheuma* farms. Marine Technological Society Journal, 9: 30-35.

Dumilag RV, Crisostomo BA, Aguinaldo ZZA, Hinaloc LAR, Liao LM, Roa- Quiaoit HA, Dangan-Galon F, Zuccarello GC, Guillemin ML, Brodie J, et al. 2023. The diversity of eucheumatoid seaweed cultivars in the Philippines. Reviews in Fisheries Science and Aquaculture, 31(1): 47-65. https://doi.org/10.1080/23308249.2022.2060038

Gerung GS and Ohno M. 1997. Growth rates of *Eucheuma denticulatum* (Burman) Collins et Harvey and *Kappaphycus striatum* (Schmitz) Doty under different conditions in warm waters of Southern Japan. Journal of Applied Phycology, 9(5): 413-415. https://doi.org/10.1023/A:1007906326617

Hung LD, Hori K, Namg HQ, Kha T and Hoa LT. 2009. Seasonal changes in growth rate, carrageenan yield and lectin content in three red alga *Kappaphycus alvarezii* cultivated in Camranh Bay, Vietnam. Journal of Applied Phycology, 21(3): 265-272. http://dx.doi.org/10.1007/s10811-008-9360-2

Hurtado AQ, Agbayani RF, Sanares R and Castro-Mallare MTR de. 2001. The seasonality and economic feasibility of cultivating *Kappaphycus alvarezii* in Panagatan Cays, Caluya, Antique, Philippines. Aquaculture, 199(3-4): 295-310. https://doi.org/10.1016/S0044-8486(00)00553-6

Hurtado AQ, Joe M, Sanares RC, Fan D, Prithiviraj B and Critchley AT. 2012. Investigation of the application of Acadian Marine Plant Extract Powder (AMPEP) to enhance the growth, phenolic content, free radical scavenging, and iron chelating activities of *Kappaphycus* Doty (Solieriaceae, Gigartinales, Rhodophyta). Journal of Applied Phycology, 24: 601-611. https://doi.org/10.1007/s10811-011-9785-x

Kasim M and Mustafa A. 2017. Comparison growth of *Kappaphycus alvarezii* (Rhodophyta, Solieriaceae) cultivation in floating cage and longline in Indonesia. Aquaculture Reports, 6: 49-55. http://dx.doi.org/10.1016/j.aqrep.2017.03.004

Kotiya AS, Gunalan B, Parmar HV, Jaikumar M, Dave T, Solanki Jitesh B and Makwana NP. 2011. Growth comparison of the seaweed *Kappaphycus alvarezii* in nine different coastal areas of Gujarat coast, India. Advances in Applied Science Research, 2(3): 99-106.

Luhan MRJ and Sollesta H. 2010. Growing the reproductive cells (carpospores) of the seaweed, *Kappaphycus striatum*, in the laboratory until outplanting in the field and maturation to tetrasporophyte. Journal of Applied Phycology, 22(5): 579-585. https://doi.org/10.1007/s10811-009-9497-7

Mtolera, MSP, Collen, J, Pedersen, M, Ekdahl, A, Abrahamsson, K, and Semesi, AK. 1996. Stress induced production of volatile halogenated organic compounds in *Eucheuma denticulatum* (Rhodophyta) caused by elevated pH and high light intensities. European Journal of Phycology. 31(1): 89-95. https://doi.org/10.1080/09670269600651241

Naguit MR, Tisera W and Lanioso A. 2009. Growth performance and carrageenan yield of *Kappaphycus alvarezii* (Doty) and *Eucheuma denticulatum* (Burman) Collins et Harvey, farmed in Bais Bay, Negros Oriental and Dipolog City. The Threshold, 4: 38-51.

Ohno M, Largo DB and Ikumoto T. 1994. Growth rate, carrageenan yield and gel properties of cultured kappa-carrageenan producing red alga *Kappaphycus alvarezii* (Doty) Doty in the subtropical waters of Shikoku, Japan. Journal of Applied Phycology, 6(1): 1-5.

Orbita ML. 2013. Growth rate and carrageenan yield of *Kappaphycus alvarezii* (Rhodophyta, Gigartinales) cultivated in Kolambugan, Lanao del Norte, Mindanao, Philippines. Advances in Agriculture & Botanics, 5(3): 128-139.

Pang T, Liu J, Liu Q, Li H and Li J. 2015. Observations on pests and diseases affecting a eucheumatoid farm in China. Journal of Applied Phycology, 27(5): 1975-1984. https://doi.org/10.1007/s10811-014-0507-z.

Parenrengi A, Dworjanyn S, Syah R, Pong-Masak PR and Fahrur M. 2020. Strain selection for growth enhancement of wild and cultivated eucheumatoid seaweed species in Indonesia. Sains Malaysiana, 49(10): 2453-2464. https://doi.org/10.17576/jsm-2020-4910-11

Parker HS. 1974. The culture of the red algal genus *Eucheuma* in the Philippines. Aquaculture, 3(4): 425-439. https://doi.org/10.1016/0044-8486(74)90009-X

PEMSEA (Partnerships in Environmental Management for the Seas of East Asia). 2016. Impact investment for a business venture for community-based seaweed farming in northern Palawan, Philippines, PEMSEA and BLUEYOU Consulting LTD. Zürich, Switzerland.

PSA (Philippine Statistics Authority) 2021. Technical notes on Fisheries Statistics of the Philippines. https://psa.gov.ph/technical notes/fsp-2021. Accessed on 14 February 2023.

Quiaoit HR, Uy WH, Bacaltos DGG and Chio PBR. 2016. Seaweed Area GIS-based Mapping Production Support System for Sustainable Seaweed Farming in the Philippines, 2016 Report. Xavier University Press, Cagayan de Oro, Philippines, 140pp.

Rama Rama A, Aslan LOM, Iba W, Nurdin AR, Armin A and Yusnaeni Y. 2018. Seaweed cultivation of micropopagated seaweed *(Kappaphycus alvarezii)* in Bungin Permai coastal waters, Tinanggea Sub-district, South Konawe Regency, South East Sulawesi. IOP Conference Series: Earth and Environmental Science 175: 012219. https://doi.org/10.1088/1755-1315/175/1/012219

R Core Team. 2018. R: A language environment for statistical computing. R Foundation for Statistical Computing, Vienna, Australia. https://www.R-project.org/. Accessed on 21 February 2023.

Roleda, MY, Aguinaldo, Crisostomo BA, Hinaloc, LAR, Projimo, VZ, Dumilag, RV and Lluisma, AO. 2021. Discovery of novel haplotypes from wild populations of *Kappaphycus* (Gigartinales, Rhodophyta) in the Philippines. Algae, 36(1): 1-12. https://doi.org/10.4490/algae.2021.36.2.18

Simatupang NF, Pong-Masak PR, Ratnawati P, Agusman Paul NA and Rimmer MA. 2021. Growth and product quality of the seaweed *Kappaphycus alvarezii* from different farming locations in Indonesia. Aquaculture Reports, 20: 100685. https://doi.org/10.1016/j.aqrep.2021.100685

Tandel KV, Josh NH, Tandel GM, Halai RR, Patel MR and Tandel JT. 2017. Study on the growth performance of red seaweed *Kappaphycus alvarezii* through different cultivation methods at Okha Port, Gujarat, India. Ecology, Environment and Conservation, 23(2): 801-807. https://doi.org/10.13140/RG.2.2.28218.64967

Trono Jr GC and Lluisma AO. 1992. Differences in biomass production and carrageenan yields among four strains of farmed carrageenophytes in Northern Bohol, Philippines. In: Jaccarini V and Martens E (eds). The Ecology of Mangrove and Related Ecosystems. Developments in Hydrobiology, Vol 80. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-3288-8_24

Trono Jr. GC, Lluisma AO and Montaño MNE. 2000. Primer on farming and strain selection of *Kappaphycus* and *Eucheuma* in the Philippines. Philippine Council for Agriculture, Marine Resources Development; University of the Philippines-Marine Science Institute and United Nations Development Program, Quezon City, 33pp.

Trono Jr. GC and Ohno M. 1989. Seasonality in the biomass production of the *Eucheuma* strains in Northern Bohol, Philippines. In: Umezaki I (ed). Scientific Survey of marine algae and their resources in the Philippine Islands. Monbushio International Scientific Research Program, Japan, pp. 71–80.

Tullberg RM, Nguyen HP and Wang CM. 2022. Review of the status and developments in seaweed farming infrastructure. Journal of Marine Science and Engineering, 10(10): 14-47. https://doi.org/10.3390/jmse10101447

Yong YS, Yong WTL and Anton A. 2013. Analysis of formulae for determination of seaweed growth rate. Journal of Applied Phycology, 25(6): 1831-1834. https://doi.org/10.1007/s10811-013-0022-7

Zabala Jr EC and Gonzales-Plasus, MM. 2020. Diseases and pest encountered on seaweeds *Eucheuma-Kappaphycus* production in the selected municipalities in the province of Palawan, Philippines. Asian Journal of Biodiversity, 23: 1-16. http://dx.doi.org/10.7828/ajob.v11i1.1384

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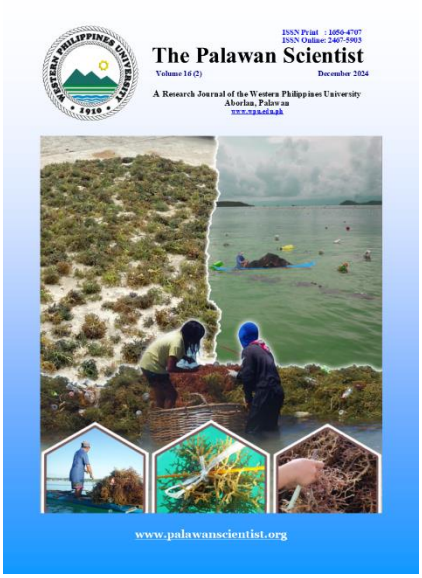

Demersal stock assessment in Leyte Gulf, Philippines

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ABSTRACT

A demersal stock assessment was conducted in Leyte Gulf from 24 April to 08 May 2020, within the 19 established fishing stations, using a bottom otter trawl with a 71 m length and a 43 m head rope. This study focused on determining the total catch, catch composition, catch per unit effort (CPUE), and biomass. A total catch of 4.22 t comprised of 230 fish species and invertebrates which belongs to 74 families was recorded in the survey. The majority of the catch belongs to family Leiognathidae, comprising 39.45%, followed by Lutjanidae, and Gerreidae, with 8.05% and 7.07%, respectively. Top species were Orangefin ponyfish *Photopectoralis bindus* with a composition of 25.49%, followed by Toothpony *Gazza minuta* (both are locally known as "sap-sap"), and Longfin mojarra *Pentaprion longimanus* "hubad" with 7.42%, and 5.80%, respectively. Mean CPUE and biomass were approximately 222.08 kg hr^{-1} and 2.81 t km^{-2}, respectively. A 68.26% increase in biomass compared to previously conducted study in 2014 of M/V DA-BFAR was recorded. The shifting of catch composition from economically valuable to low-valued, non-targeted, and small-sized species was observed. A continuous resource assessment activity is essential to determine the changes in fishing patterns, catch rates, and catch composition, which will serve as a basis for policy formulation and future management plans and measures.

Keywords: biomass, CPUE, trawl, *Photopectoralis bindus*

INTRODUCTION

Leyte Gulf is among the significant fishing grounds in the Philippines, covering the islands of Samar and Leyte, including San Pedro Bay with an area of 2,724 km^2 (Tan et al. 2017; Francisco et al. 2018; BFAR 2018). The gulf serves as the primary source of food, income, and livelihood for many coastal fishers in the area (Tan et al. 2017). According to Francisco et al. (2018), the average annual fish catch from 2001 to 2011 in the gulf was estimated at 18,308.2 tons (t). Further, as indicated in their study, the trawl fishing gear contributed 16.61% and 4.01% of catch percentages from commercial and municipal

fisheries in Leyte Gulf, respectively. However, the use of trawl fishing gear is prohibited under Fisheries Administrative Order (FAO) 201, series of 2000. While it is prohibited, continued fishing operation utilizing trawl fishing gear within the gulf was observed. As mentioned by Kelleher (2005) and Francisco et al. (2018), trawling is one of the most destructive ways of fishing and often leads to overfishing and its operation destroys coral reefs and seagrass beds located in the municipal waters.

Globally, several studies about trawl fisheries and demersal stock assessment were conducted, that includes the analysis of Warfel and Manacop (1950) in the Philippine waters; Silvestre et al. (1987) in Manila Bay; Biradar (1987) in Karnataka Coast, India; Pauly (1988) in Southeast Asia; Smith et al. (2000) in Eastern Mediterranean; Valinassab et al. (2006) in Persian Gulf and Oman Sea; Madrid-Vera et al. (2007) in Southern Gulf of California; Fraser et al. (2007) in North Sea; Hashemi and Valinassab (2011) in West Northern of Persian Gulf Water; Diocton (2016) in Samar Sea; Bendaño et al. (2017) in Manila Bay and Hosseini et al. (2018) in Persian Gulf, Iran. However, published studies particularly in Leyte Gulf in the Philippines are scarce.

In 2014, trawl fishing research in Leyte Gulf recorded a demersal stock biomass of 1.67 t km^{-2} (Dela Cruz 2014), which served as a baseline study as there is no other available recent comprehensive survey in the gulf. However, from 1984 to 1988, Edralin et al. (1992) conducted a survey in the area but data on trawl landings were only gathered from fish landing centers. This study was conducted to provide information on the status of demersal fisheries in Leyte Gulf. Specifically, the study aimed to determine the total catch, catch composition, CPUE, and biomass. The result of this study could be used as the basis for policy formulation, future management plans, and measures for sustainable and optimal utilization of resources.

METHODS

Study Site

A trawl fishing survey was conducted onboard M/V DA-BFAR, a 60 meters (m) and 1,186 gross tonnage (gt) multi-purpose vessel operated by the Bureau of Fisheries and Aquatic Resources (BFAR) from April 24 to May 8, 2020. The sampling was conducted within 19 established fishing stations, situated between the coordinates of 10°31'28.20"N to 11° 8'11.04"N Latitude and 125° 3'52.98"E to 125°39'47.39"E Longitude (Table 1) within the vicinities of the northern (Tacloban City, Palo, Tanauan, Tolosa, Dulag) and southern parts of Leyte (Silago, Abuyog, Mc Arthur), and the eastern part of Samar (Manicani Island, Giporlos, Balangiga, Maslog) (Figure 1).

Table 1. Coordinates of the 19 established fishing station in Leyte Gulf, Philippines.

Station Number	Start		End	
	Start dragging (Latitude, N)	Start dragging (Longitude, E)	End dragging (Latitude, N)	End dragging (Longitude, E)
1	11°03.530'	125°07.660'	11°05.370'	125°03.310'
2	10°56.280'	125°06.570'	10°52.750'	125°09.560'
3	10°46.840'	125°04.020'	10°51.730'	125°03.050'
4	10°45.060'	125°36.850'	10°49.660'	125°34.170'
5	10°57.230'	125°32.190'	10°55.180'	125°27.170'
6	10°52.970'	125°28.960'	10°56.870'	125°24.930'
7	10°53.280'	125°20.930'	10°58.710'	125°16.000'
8	10°59.540'	125°20.930'	11°03.780'	125°18.010'
9	10°57.650'	125°27.470'	11°01.840'	125°25.840'
10	10°53.060'	125°38.200'	10°54.590'	125°33.450'
11	11°00.860'	125°13.380'	10°56.330'	125°10.250'
12	10°54.860'	125°03.190'	10°59.050'	125°05.310'
13	10°49.590'	125°16.880'	10°53.410'	125°13.090'
14	10°47.420'	125°32.330'	10°45.330'	125°27.230'
15	10°50.230'	125°21.280'	10°47.930'	125°25.100'
16	10°46.980'	125°11.110'	10°51.310'	125°13.040'
17	10°41.160'	125°15.810'	10°45.580'	125°18.890'
18	10°39.400'	125°13.760'	10°37.600'	125°19.110'
19	10°32.670'	125°15.280'	10°35.300'	125°19.550'

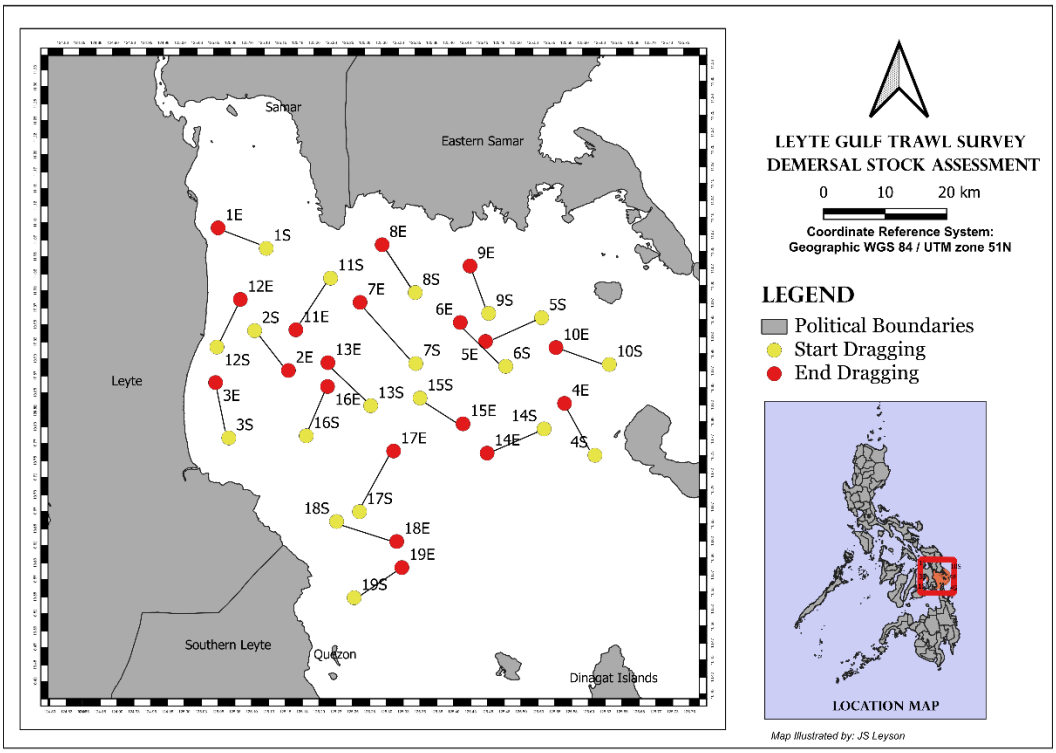

Figure 1. Map showing the 19 established trawl sampling stations in Leyte Gulf, Philippines.

Sampling

An otter trawl measuring about 71 m in length with a head rope of 43 m was used during the survey. Initially, all stations were verified by tracking the area using an acoustic sounder to ensure its suitability for trawl operations. Trawling was done during the daytime and dragging time was maintained at one hour or whenever possible (trawl operations are vulnerable to unexpected damage to the gear during dragging). Trawl operations were assisted by M/V DA-BFAR officers and crew for manpower. Fishing details and other relevant data were recorded in specific forms. Depth, dragging speed, and dragging duration are reflected in Table 2.

Catch was poured on deck, if the total catch was workable, all the catch was treated as samples. However, if not, samples were mixed homogenously to avoid bias and sub-samples were taken randomly from this. Samples were categorized as population (big and rare species) and sub-samples. Big-sized fish individuals quickly taken from the pile first and was separated, identified, and weighed. Sub-samples were segregated according to groups and was identified to the nearest possible taxon with the aid of various fish identification guides (Nakabo 2002; Allen et al. 2003; Gonzales 2013; Alava et al. 2014). The weight of every species in the sub-samples per station were subsequently raised from the total catch.

Data Analyses

The total catch in tons (t) was computed by adding the catch of all sampling stations. Catch composition was categorized by species and family, calculated by dividing the weight of specific species or families by the total catch weight, and then multiplied by 100 to determine the relative abundance (%).

For calculating the CPUE values, the total catch weight (kg) was divided by the dragging duration in hours (hr).

Formula 1:

$$\text{CPUE} = \frac{\text{total weight (kg)}}{\text{dragging duratin (hr)}}$$

The Biomass in tons per square kilometers (t km^{-2}) was computed following the concept of swept area method and expressed as;

Formula 2:

$$B=2\,\frac{\text{catch (t)}}{\text{swept area}}$$

Two (2) is constant (the catch rate is twice the standing biomass to account for escapement) (Sparre and Venema 1998).

The swept area method was estimated as follows:

Formula 3:

$$a = D*hr*X_2, \text{ where } D= V*t$$

Where (a) total area swept by the gear; (D) distance swept, (V) velocity of the trawl over the ground when trawling, (t) time spent for trawling, (hr) is the length of the head rope and X_2 is the fraction of the head rope length which is equal to the width of the path swept by the trawl and the wing spread. The value of X_2 used was 0.5 as a compromised value suggested by Bendaño et al. (2017). Data consolidation and analysis were done using Microsoft Excel. The results are presented in tables and graphs.

Table 2. Average depth (m), dragging speed (km hr^{-1}) and dragging duration (hr) of each station during trawl survey in Leyte Gulf.

Stations	Depth (m)	Dragging Speed (km hr^{-1})	Dragging Duration (hr)
1	28	7.22	1.00
2	42	7.22	1.00
3	38	7.41	1.00
4	89	7.96	0.98
5	88	7.59	1.05
6	100	7.04	1.02
7	101	7.59	1.78
8	76	7.04	1.03
9	89	7.41	0.67
10	94	6.85	1.00
11	60	7.22	1.02
12	24	7.04	1.00
13	93	7.41	1.00
14	103	8.52	1.03
15	111	7.41	1.02
16	75	6.30	0.98
17	101	7.22	1.03
18	89	7.59	1.12
19	96	6.11	1.10
Average	**79**	**7.27**	**1.04**

RESULTS

Total Catch

This trawl survey recorded a total catch of 4.22 t of fish and invertebrates with about 33,839 individuals belonging to 74 different families, which comprised 230 identified species (202 fishes, 7 cephalopods, 11 crustaceans, 6 echinoderms, and 4 mollusks) however, 14 samples or 5.74% remained unidentified.

Catch Composition

The majority of the catch belongs to Family Leiognathidae (locally known as "sap-sap"), comprising 39.45% (12 species), followed by Lutjanidae "maya-maya", and Gerreidae "amurok", with 8.05% (6 species), and 7.07% (5 species), respectively. Additionally, other families such as Mullidae "salmonyete" (5.64%, 6 species), Nemipteridae "bisugo" (4.92%, 15 species), and Carangidae "talakitok" / "matambaka", "galunggong" and "tonto" (4.64%, 24 species), and Dasyatidae "pagi" (4.09%, 3 species) also dominated the catch (Figure 2). The occurrence of families Loliginidae "pusit", Carcharinidae "pating", and Myliobatidae "pagi"/eagle ray were recorded. Further, the dominance of the non-commercially important family like Fistularidae was also documented.

The Orangefin ponyfish *Photopectoralis bindus* dominated the catch during the recent survey in Leyte Gulf with a composition of 25.49%, followed by Toothpony *Gazza minuta*, and Longfin mojarra *Pentaprion longimanus* with 7.42%, and 5.80%, respectively. The presence of shark (Silky shark *Carcharinus falciformis*) (0.98%) and stingray (Jenkins whipray *Pateobatis jenkinsii*) (3.55%) species, as well as the Indian squid *Uroteuthis duvaucelli* (1.07%) were noted in top 20 dominant species (Figure 3). Aside from the top 20 dominant species in the area, the gulf is also rich in highly valued/commercially important species such as Yellow spotted trevally *Carangoides fulvoguttatus* (0.08%), Areolate grouper *Epinephelus areolatus* (0.3%), Narrow-barred spanish mackerel *Scomberomorus commerson* (0.24%), Yellowtail amberjack *Seriola lalandi* (0.63%), and Black-banded trevally *Seriolina nigrofasciata* (0.58%).

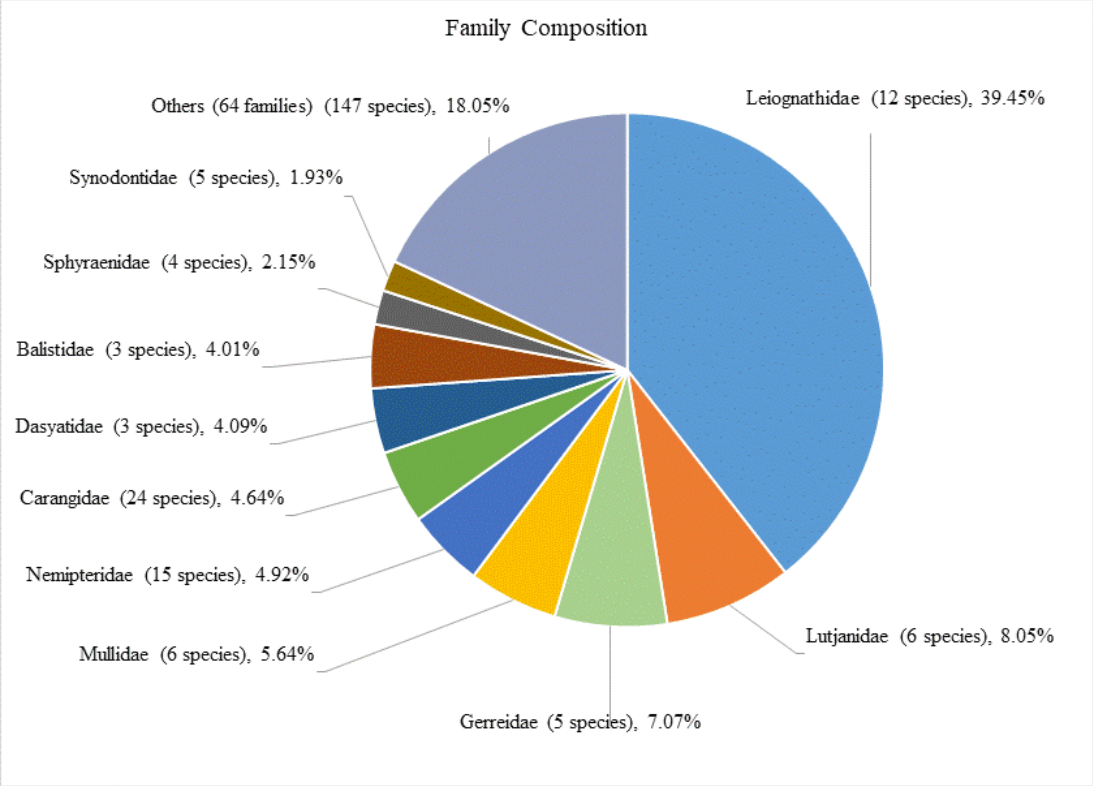

Figure 2. Top 10 families caught during the trawl survey in Leyte Gulf.

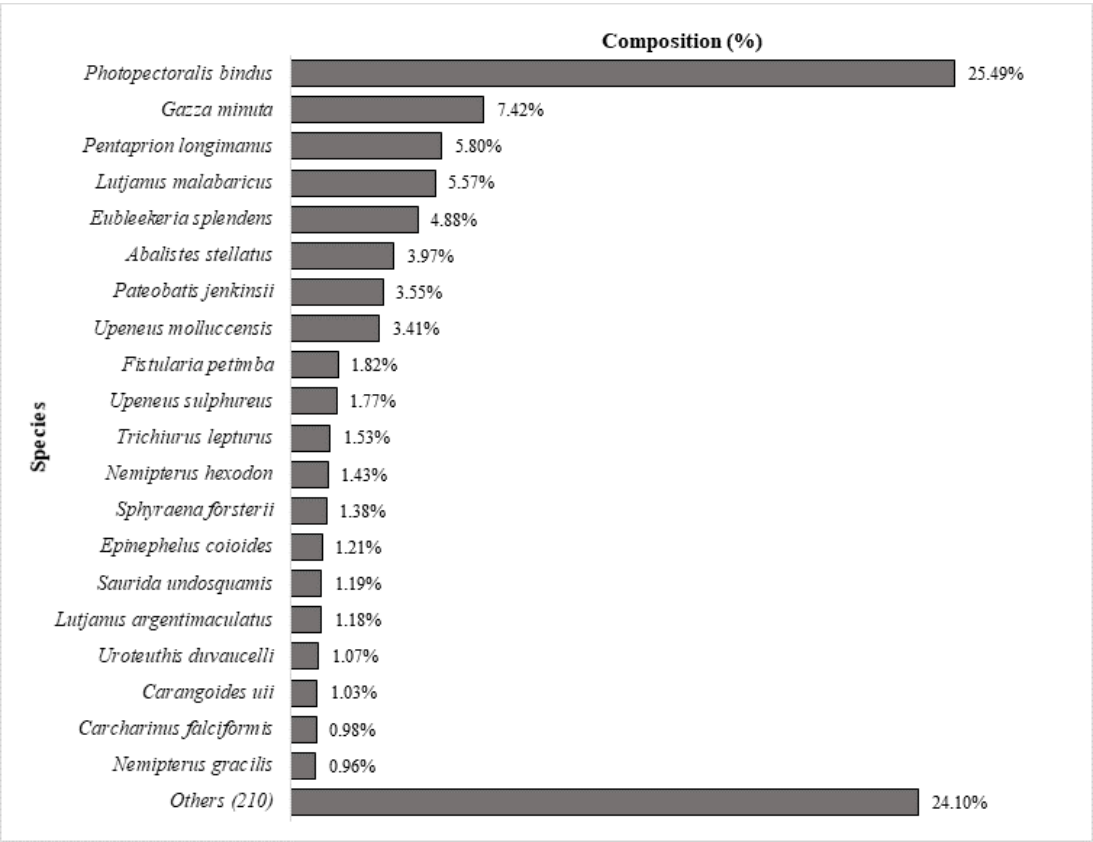

Figure 3. Top 20 species during trawl survey in Leyte Gulf.

Catch Per-Unit-Effort (CPUE)

The CPUE varies in every station during the recent trawl fishing survey in the gulf. An average CPUE of 222.08 kg hr^{-1} was recorded. Noticeably, Station 9 recorded the highest CPUE among other stations with 74.20 kg hr^{-1}, while the lowest was at Station 19 with 8.90 kg hr^{-1} (Figure 4).

Biomass

As shown in Figure 4, the computed biomass in every station differs from each other, with Station 9 having the highest (9.97 t km^{-2}) and Station 19 having the lowest (0.14 t km^{-2}). The recorded average biomass was at 2.81 t km^{-2}.

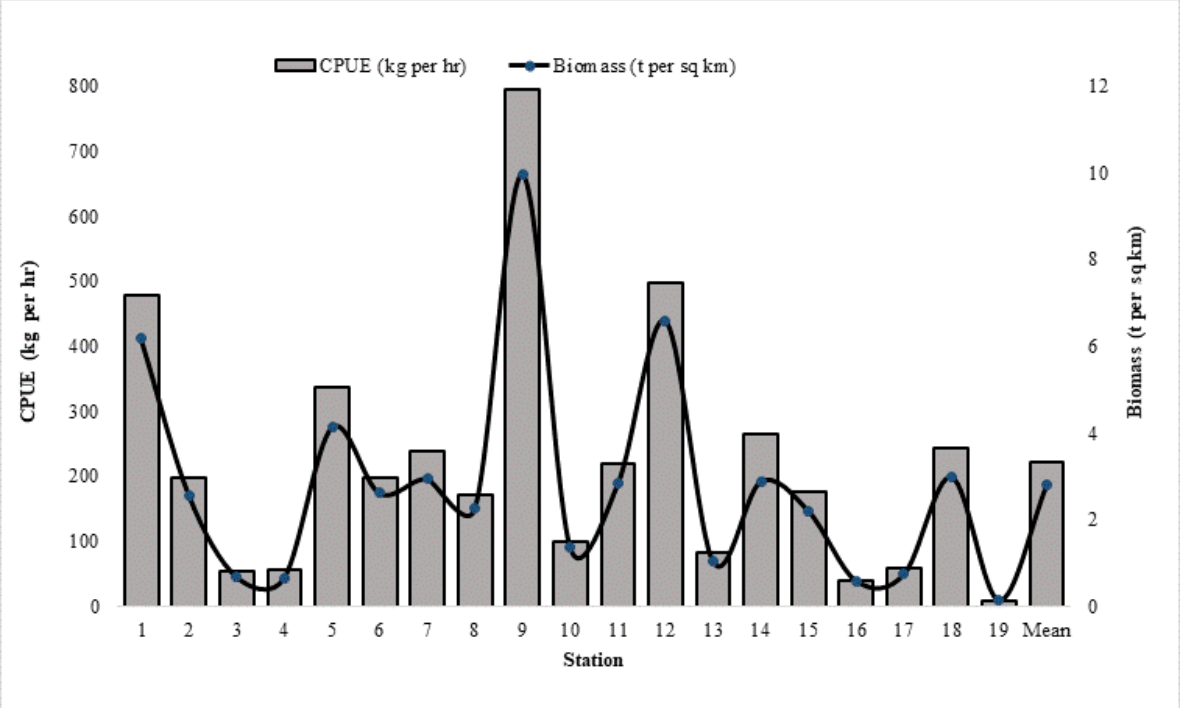

Figure 4. Computed Catch Per-Unit-Effort (CPUE) and biomass per station in Leyte Gulf, Philippines.

DISCUSSION

Total Catch

The total recorded catch in this study was 4.22 t which is found to be much higher than the previous survey in 2014, with 3.10 t (36.13% increased). On the contrary, Edralin et al. (1992) documented a relative decline in catch of 99.7% from the five-year fish landing survey in Leyte Gulf from 1984 to 1988. Additionally, the result of this study is much higher than the recorded catch from West Basilan-Sulu Shelf and Turtle Island, Tawi-Tawi, with only 2.48 t and 0.67 t total catch, respectively (Ramiscal et al. 2008; Dela Cruz 2016). However, the total catch in the gulf was found to be lower than in Manila Bay (Bendaño et al. 2017) and Samar Sea (Diocton 2016), with 8.14 t and 298.5 t, respectively. This could indicate that the stocks are recovering due to a combination of management measures in Leyte Gulf, as discussed in the works of Pipitone et al. (2000), McClanahan et al. (2006 a, b), Samoilys et al. (2007), Alcala et al. (2008), Yamazaki et al. (2014), and Chirico et al. (2017).

Catch Composition

The Family Leiognathidae dominated the catch in Leyte Gulf, specifically the species of *P. bindus* and *G. minuta*. Similarly, in San Miguel Bay, the dominance of the small-sized Leiognathids such as *P. bindus*, *Secutor ruconius*, and *S. insidiator* was noted (Pauly and Mines 1982). In Lingayen Gulf, Leiognathidae was the top family in trawl catches during the late 1940s, 1970s, and 1980s (McManus and Chua 1990).

The *P. bindus*, and *G. minuta* belongs to a low trophic level (3 and 4.2, respectively) which are smaller in size and non-targeted (Murugesan et al. 2012). In comparison, herbivores and detritivores are assigned to a trophic level 2, while most marine mammals comprise a trophic level ranging from 3 to 5 (Trites 2019). The dominance of Leiognathids in the Lingayen Gulf is an indication that the demersal stocks are heavily fished (Villoso and Aprieto 1983). In 1988, Edralin et al. (1992) stated that Carangidae and Scombridae dominated the catch, with *Decapterus macrosoma* and *Rastrilleger kanagurta* as the most dominant species in Leyte Gulf. However, in this study, these families only ranked 6th and 13th,

respectively. The decrease in the composition of targeted fish families like Carangidae and Scombridae was notable in the Samar Sea, with an increasing composition of non-targeted species (e.g., slipmouths/ponyfish) (Dela Cruz and Gino 2017). With these findings, annual resource assessment activity within the gulf is needed to determine the changes in fishing pattern, catch rates and catch composition.

The shifting of catch composition from economically valuable species to low-valued species and the dominance of low trophic level species suggests an overexploited fishing ground and deterioration in fisheries (Edralin et al. 1992; Bendaño et al. 2017). This situation also happened in the Gulf of Thailand (Supongpan 2001). Additionally, various studies claimed that the increased in the abundance of forage or bait fish is mainly due to the cascading effects caused by decreasing predator abundance because of human exploitation (Carscadden et al. 2001; Worm and Myers 2003; Coll et al. 2013; Christensen et al. 2014). Moreover, a decreasing trend of trawl landings and fish catch noted in the gulf was mainly due to recruitment overfishing, the occurrence of illegal fishing in the area, and the number of fishers (Edralin et al. 1992, Francisco et al. 2018). The dominance of Leiognathids in the area and the presence of some high-valued species suggest that some part of the area is replenishing its stock. A diverse number of species identified in this study is comparable with the studies of Ramos et al. (2018) but much lower than Olaño et al. (2009 a, b) and Dela Cruz and Gino (2017). On the other hand, the results were found to be higher than other studies (Table 3). This study proved that the Leyte Gulf harbors an abundance of marine resources. According to Francisco et al. (2018) and Tan et al. (2017), the gulf is the principal fishing grounds in the Philippines, and it serves as the source of livelihood, food, and income for many of the coastal communities. Relative to this, a socio-economic survey should be conducted to distinguish the profit of the fisherfolks that mainly rely on the resources of the gulf.

Table 3. Different trawl study areas in the Philippines with number of family and species observed.

Area	No. of Family	No. of Species	Author
Lingayen Gulf	80	166	Aprieto and Villoso 1982
Turtle Islands, Tawi-Tawi	50	150	Ramiscal et al. 2008
Sorsogon Bay	73	270	Olaño et al. 2009a
Lagonoy Gulf	106	658	Olaño et al. 2009b
West Basilan-Sulu Shelf	55	184	Dela Cruz 2016
Samar Sea	-	117	Diocton 2016
Manila Bay	48	146	Bendaño et al. 2017
Visayan Sea	81	247	Dela Cruz and Gino 2017
Tayabas Bay	58	230	Ramos et al. 2018
Leyte Gulf	74	230	This study

Catch-Per-Unit-Effort (CPUE)

The CPUE is an index of the abundance of supply in the wild and an important indicator for the fishery (Hoggarth et al. 2006), usually obtained by interviewing fishers upon landing their catch. In this study, the CPUE was based on an actual trawl fishing operation. The average CPUE (222.08 kg hr^{-1}) recorded is much higher than the results of Francisco et al. (2018) with 27.7 kg hr^{-1}, Ramiscal et al. (2008) with 61 kg hr^{-1}, and Bendaño et al. (2017) with 79.6 kg hr^{-1}. The station with the highest CPUE recorded was mainly due to the higher total catch and shorter dragging time among other stations. It is worth noting that Station 19, located in the southern part of Leyte, recorded a high abundance of *Lutjanus malabaricus*. As this assessment is limited to a one-hour dragging duration at each station, it is advisable to perform observations and sampling on the municipal boats and gears operating in the gulf to yield a more comprehensive dataset for calculating CPUE.

Biomass

The recorded average biomass in this study (2.81 t km^{-2}) was about 68.26% higher than the average biomass recorded during the 2014 trawl survey in the area (Dela Cruz 2014). In comparison with the demersal trawl survey conducted by M/V DA – BFAR in various fishing grounds in the Philippines, the average biomass of Leyte Gulf during the recent study was found to be higher than Davao Gulf, which only had an average biomass of 0.13 t km^{-2}, and the Visayan Sea with 1.63 t km^{-2} and 1.55 t km^{-2} average biomass during the 2007 and 2016 surveys, respectively. The highest biomass in the country was estimated in Samar Sea (3.72 t km^{-2}) and West Basilan-Sulu Shelf (3.69 t km^{-2}). The computed biomass of other significant fishing grounds was reflected in Table 4.

Assessment of the status of fisheries using trawl surveys in various major fishing grounds in the Philippines began in the late 1950s up to these days.

The recorded biomass in this study is comparable with the results in Imuruan Bay and Bacuit Bay in Palawan (Ronquillo and Gabral-Llana 1987) but relatively higher in other previous studies in the Philippines (Table 5). The increase in biomass is a result of the implementation of various management measures in Leyte Gulf, such as the establishment of marine reserves and implementation of several laws and ordinances. No-take zones were used in marine reserves as a conservation and the management strategy for the sustainability of marine resources (Yamazaki et al. 2014). In the report of Alcala et al. (2008), Leyte and its associated islands have 77 no-take zone marine reserves. The Binangalan and Sag-ang Fish Sanctuaries were the two established marine reserves in Leyte Gulf. Moreover, the establishment of community Marine Protected Areas (MPAs) increases the biomass and size of reef-associated fish and the density of fish families (McClanahan et al. 2006; Samoilys et al. 2007; McClanahan et al. 2016b; Chirico et al. 2017). As part of the management measures, the Local Government Unit (LGU) of Leyte created Ordinance No. 02, Series of 2017, "Amended municipal basic fishery ordinance of the Municipality of McArthur, Leyte". In pursuant to Fisheries Administrative Order 201, series of 2000 and provided in Department of Agriculture - Administrative Order No. 10, series of 2015, the ban on fishing with active gears within the municipal waters, bays, and fishery management areas was implemented nationwide. A year-round trawling ban and illegal fishing regulations are suitable for fish biomass increase (Pipitone et al. 2000; Yamazaki et al. 2014). During the survey, law enforcers approached the vessel since it was publicly known that trawl is an active gear and is prohibited.

Table 4. Computed biomass (t km^{-2}) of the demersal trawl survey conducted by M/V DA-BFAR in various fishing grounds.

Fishing Ground	Year	Biomass (t km^{-2})	Authors/Source
Visayan Sea	2003	2.08	MV DA-BFAR, GTZ
	2007	1.63	MV DA-BFAR, UPV, Guests
Turtle Island, Tawi-Tawi	2008	2.35	MV DA-BFAR
	2011	2.24	MV DA-BFAR
Visayan Sea	2013	3.09	MV DA-BFAR, BFAR 5,6,7,8
Samar Sea		3.72	MV DA-BFAR, BFAR 5,6,7,8
Davao Gulf	2014	0.13	MV DA-BFAR, BFAR-XI
West Basilan-Sulu Shelf	2015	3.69	MV DA-BFAR, BFAR 9 & ARMM
Visayan Sea	2016	1.55	MV DA-BFAR, BFAR 5,6,7,8
Samar Sea		2.24	MV DA-BFAR, BFAR 5,6,7,8
Palawan		3.20	MV DA-BFAR, NFRDI, NSAP
Visayan Sea	2017	2.77	MV DA-BFAR, BFAR 5,6,7,8
Samar Sea		1.80	MV DA-BFAR, BFAR 5,6,7,8
Leyte Gulf	2020	2.81	This study

Table 5. Computed biomass (t km^{-2}) of the demersal trawl survey in other fishing grounds in the Philippines.

Fishing Ground	Year	Biomass (t km^{-2})	Authors/Source
Manila Bay	1947	4.61	Warfel and Manacop 1950
	1968-72	1.71	Silvestre et al. 1987
Malampaya Sound, Palawan	1977-78	6.5-9.7	Ronquillo and Gabral-Llana 1987
Imuruan Bay, Palawan		2.0-2.8	
Bacuit Bay		2.7-3.8	
Manila Bay		0.8-1.2	
Lingayen Gulf	1978-79	1.33	Villoso and Aprieto 1983
San Miguel Bay	1979-82	2.13	Mines et al. 1986
San Pedro Bay	1994-95	1.73	Armada 1996
Manila Bay	2014	0.32	Bendaño et al. 2017
	2015	0.48	
Leyte Gulf	2020	2.81	This study

However, the objective of the survey was later explained to the enforcers which is for research purposes only. These management measures, along with strong enforcement, may have contributed to the increase in biomass in the area.

The shifting of catch composition from economically valuable species to low valued, non-targeted and small-sized species is notable in the gulf. The presence of Leiognathids as a dominant species signifies that the area is already over-exploited. High CPUE recorded in the area is mainly due to higher catch with shorter dragging time. Further, the increase in biomass is documented in Leyte Gulf based on 2014 to recent year of trawl survey. These findings suggest to have a continuous observation and strict implementation of the existing laws and regulations to prevent the decline of fishery resources in the gulf.

FUNDING

The Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) funded this study.

ETHICAL CONSIDERATIONS

This research followed the standard procedure in the conduct of the study and in handling the captured marine organisms.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests to any authors.

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REFERENCES

Alava MNR, Gaudiano JPA, Utzurrum JAT, Capuli EMC, Aquino MTR, Luchavez-Maypa MMA and Santos MD. 2014. An Identification Guide to Sharks, Batoids and Chimaeras of the Philippines. Bureau of Fisheries and Aquatic Resources-National Fisheries Research and Development Institute. Quezon City, Philippines. 204pp.

Alcala A, Bucol AA and Nillos-Kleiven P. 2008. Directory of Marine Reserves in the Visayas, Philippines. Foundation for the Philippine Environment and Silliman University-Angelo King Center for Research and Environmental Management (SUAKCREM). Dumaguete City, Philippines. 178pp. http://dx.doi.org/10.13140/RG.2.1.1871.5924

Allen G, Steene R, Humann P and DeLoach N. 2003. Reef Fish Identification Tropical Pacific. New World Publications, Incorporated and Odyssey Publishing, United States of America. 484pp.

Aprieto VL and Villoso EP. 1982. Demersal fish resources of Lingayen Gulf. Fisheries Research Journal of the Philippines, 7 (2): 40-49.

Armada NB. 1996. The fisheries of San Pedro Bay, Philippines. Final Report on Capture Fisheries Component of the Resource and Ecological Assessment of San Pedro Bay 5: 67p. IMFO Technical Report 16. Institute of Marine Fisheries and Oceanology, College of Fisheries, University of the Philippines in the Visayas (UPV), Miag-ao, Iloilo.

Bendaño AP, Lopez GDV, Perez MA, Santos MD and Torres FSB Jr. 2017. Species composition, distribution, biomass trends and exploitation of dominant fish species in Manila Bay using experimental trawl survey. The Philippine Journal of Fisheries, 24(1): 31-46. http://dx.doi.org/10.31398/tpjf/24.1.2016A0002

Bureau of Fisheries and Aquatic Resources. 2002. Philippine Fisheries Profile. PCA Compound Elliptical Road, Quezon City, 42pp. https://www.bfar.da.gov.ph. Accessed on 03 March 2021.

Bureau of Fisheries and Aquatic Resources. 2018. Philippine Fisheries Profile. PCA Compound Elliptical Road, Quezon City, 70pp. https://www.bfar.da.gov.ph. Accessed on 03 March 2021.

Biradar RS. 1987. Stock Assessment of the Demersal Offshore Fishery Resources off Karnataka Coast. Fishery Technology, 24(2): 83-87.

Carscadden JE, Frank KT and Leggett WC. 2001. Ecosystem changes and the effects on capelin (*Mallotus villosus*), a major forage species. Canadian Journal of Fisheries and Aquatic Sciences, 58: 73−85. https://doi.org/10.1139/f00-185

Cermeño P, Chouciño P, Fernández-Castro B, Figueiras FG, Marañón E, Marrasé C, Mouriño-Carballido B, Pérez-Lorenzo M, Rodríguez-Ramos T, Teixeira IG et al. 2016. Marine Primary Productivity Is Driven by a Selection Effect. Frontiers in Marine Science, 3(173): 1-10. https://doi.org/10.3389/fmars.2016.00173

Chirico AAD, McClanahan TR and Eklof JS. 2017. Community- and government-managed marine protected areas increase fish size, biomass and potential value. PLoS ONE, 12(8): 1-19. https://doi.org/10.1371/journal.pone.0182342

Christensen V, Coll M, Piroddi C, Steenbeek J, Buszowski J and Pauly D. 2014. A century of fish biomass declines in the ocean. Marine Ecology Progress Series, 512: 155–166. https://doi.org/10.3354/meps10946

Coll M, Navarro J, Olson R and Christensen V.2013. Assessing the trophic position and ecological role of squids in marine ecosystems by means of food-web models. Deep-Sea Research Part II, 95: 21−36. http://dx.doi.org/10.1016/j.dsr2.2012.08.020

Dela Cruz WS. 2014. Demersal Fisheries Stock Assessment in Leyte Gulf. M/V DA BFAR Technical Report. Bureau of Fisheries and Aquatic Resources, National Marine Fisheries Development Center.

Dela Cruz WS. 2016. Demersal Fisheries Stock Assessment in West Basilan–Sulu Shelf. 7th Fisheries Scientific Conference. Bureau of Fisheries and Aquatic Resources, National Fisheries Research and Development Institute. 73pp.

Dela Cruz WS and Gino CF. 2017. Northeast and Southwest Monsoon Fisheries Assessment in Visayan and Samar Seas. M/V DA BFAR Technical Report. Bureau of Fisheries and Aquatic Resources, National Marine Fisheries Development Center. 18pp.

Department of Agriculture Administrative Order No. 10, Series of 2015. The Implementing Rules and Regulations of Republic Act No. 8550 as amended by Republic Act No. 10654. Department of Agriculture, Office of the Secretary,

Elliptical Road, Diliman, Quezon City. https://faolex.fao.org/docs/pdf/phi184513.pdf . Accessed on 22 February 2021.

Diocton RC. 2016. Trawl catch and by-catch survey in Samar Sea, Philippines. Strategies for trawl fisheries by-catch management project (REBYC-II CTI; GCP/RAS/269/GFF). College of Fisheries and Marine Sciences, Samar State University - Mercedes Campus, Catbalogan City. 17pp.

Duffy JE, Lefcheck JS, Stuart-Smith RD, Navarrete SA and Edgar GJ. 2016. Biodiversity enhances reef fish biomass and resistance to climate change. Proceeding of the National Academy of Sciences of the United States of America, 113(22): 6230-6235. https://doi.org/10.1073/pnas.1524465113

Edralin DT, Alducente F, Ganaden SR and Lavapie-Gonzales F.1992. Trawl Fishing of Leyte Gulf. The Philippine Journal of Fisheries, 23: 89-118.

Fisheries Administrative Order No. 201, Series of 2000. Ban on Fishing with Active Gear. Department of Agriculture, Office of the Secretary, Elliptical Road, Diliman, Quezon City https://www.bfar.da.gov.ph/wp-content/uploads/2021/04/FAO-No.-201-s.-2000.pdf?fbclid=IwAR2HMVvkaNTgBGrD2lUu33SICmymLd_wkJMU2jwjtHjuE9g68iJPMtY1IwU . Accessed date on 08 April 2021.

Francisco MC, Dayap NA, Tumabiene1 LA, Francisco RA Sr., Candole MJ, De Veyra JH and Bautista E. 2018. Status of Leyte Gulf Fisheries CYs 2001-2011. The Philippine Journal of Fisheries, 25(1): 136-155. https://doi.org/10.31398/tpjf/25.1.2017C0011

Fraser HM, Greenstreet SPR and Piet GJ. 2007. Taking account of catchability in groundfish survey trawls: implications for estimating demersal fish biomass. ICES Journal of Marine Science, 64 (9): 1800–1819. https://doi.org/10.1093/icesjms/fsm145

Gonzales BJ. 2013. Field Guide to Coastal Fishes of Palawan. Coral Triangle Initiative on Corals, Fisheries and Food Security. Quezon City, Philippines. 107pp.

Hashemi SR and Valinassab T. 2011. Stock assessment of demersal resources in the West Northern of Persian Gulf waters. World Journal of Fish and Marine Sciences, 3 (6): 480-484. https://idosi.org/wjfms/wjfms3(6)11/2.pdf?fbclid=IwAR1D3DUM_TRNmTAReykw4z74dTBiyERFsgV3rmWcxaArKYPgRSEltks95BE. Accessed date on 09 September 2021.

Hoggarth DD, Abeyasekera S, Arthur RI, Beddington JR, Burn RW, Halls AS, Kirkwood GP, McAllister M, Medley P, Mees CC et al. 2006. Stock Assessment for Fishery Management. A framework guide to the stock assessment tools of the fisheries management science programme. FAO Fisheries Technical Paper No. 487. Rome, Italy. 261pp. https://www.gov.uk/research-for-development-outputs/stock-assessment-for-fishery management-a-framework-guide-to-the-stock assessment-tools-of-the-fisheries-management-science-programme. Accessed on 13 July 2021.

Hosseini SMS, Paighambari SY, Pouladi M and Shabani MJ. 2018. Estimation of CPUE and CPUA of three caught fish by bottom trawler in the Motaf fishing ground, Bushehr Province, Persian Gulf, Iran. Biodiversitas, 19(4): 1434-1440. https://doi.org/10.13057/biodiv/d190433

Kelleher K. 2005. Discards in the World'S Marine Fisheries. An Update. FAO Fisheries Technical Paper, 470. Food and Agriculture Organization of the United Nations. Rome, Italy. 119pp. https://www.researchgate.net/publication/269576296_Discards_in_the_World%27S_Marine_Fisheries_An_Update. Accessed on 15 July 2021

Madrid-Vera J, Amezcua F and Morales-Bojorquez E. 2007. An assessment approach to estimate biomass of fish communities from bycatch data in a tropical shrimp-trawl fishery. Fisheries Research, 83(1): 81-89. https://doi.org/10.1016/j.fishres.2006.08.026

McClanahan TR, Marnane MJ, Cinner JE and Kiene WE. 2006. A comparison of marine protected areas and alternative approaches to coral-reef management. Current Biology, 16(14): 1408–1413. https://doi.org/10.1016/j.cub.2006.05.062

McClanahan TR, Maina JM, Graham NAJ and Jones KR. 2016a. Correction: Modeling reef fish Biomass, recovery potential, and management priorities in the Western Indian Ocean. PLoS ONE, 11(6): 1-5. https://doi.org/10.1371/journal.pone.0156920

McClanahan TR, Muthiga NA and Abunge CA. 2016b. Establishment of community managed fisheries' closures in Kenya: Early evolution of the tengefu movement. Coastal Management, 44(1): 1–20. https://doi.org/10.1080/08920753.2016.1116667

McManus LT and Chua TE.1990. The coastal environmental profile of Lingayen Gulf, Philippines. International Center for Living Aquatic Resources Management, Manila, Philippines. ICLARM Technical Reports 22. 69pp.

Mines AN, Smith IR and Pauly D. 1986. An Overview of the Fisheries of San Miguel Bay Philippines. In: JL Maclean, LB Dizon and LV Hosillo (eds). The first Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines. 385-388pp.

Murugesan P, Purusothaman S and Muthuvelu S. 2012. Trophic Level of Fishes Associated in the Trawl Bycatch from Parangipettai and Cuddalore, Southeast Coast of India. Journal of Fisheries and Aquatic Science, 7(1): 29-38. https://dx.doi.org/10.3923/jfas.2012.29.38

Nakabo T. 2002. Fishes of Japan with Pictorial Keys to the Species, English edition. Tokai University Press, 2-28-4, Tomigaya, Shibuya-ku, Tokyo, Japan. 1749pp.

Olaño VL, Vergara MB and Gonzales FL. 2009a. Assessment of the Fisheries of Sorsogon Bay (Region 5). Bureau of Fisheries and Aquatic Resources- National Fisheries Research and Development Institute (BFAR NFRDI). Technical Paper Series, 12(4): 1-33.

Olaño VL, Vergara MB and Gonzales FL. 2009b. Assessment of the Fisheries of Lagonoy Gulf (Region 5). Bureau of Fisheries and Aquatic Resources- National Fisheries Research and Development Institute (BFAR NFRDI). Technical Paper Series, 12(5): 1-31.

Ordinance No. 02, Series of 2017. Amended municipal basic fishery ordinance of the Municipality of McArthur, Leyte. Local Government Unit of Leyte.

Pauly D. 1988. Fisheries research and the demersal fisheries of Southeast Asia. In: JA Gulland (ed). Fish Population Dynamics (2nd edition). Wiley Interscience, Chichester, pp. 329-348.

Pauly D and Mines AN. 1982. Small-scale fisheries of San Miguel Bay Philippines: Biology and stock assessment. ICLARM Technical Reports 7. Institute of Fisheries Development and Research, College of Fisheries, University of the Philippines in the Visayas, Quezon City, Philippines; International Center for Living Aquatic Resources Management, Manila, Philippines; and the United Nations University, Tokyo, Japan. 124pp.

Pipitone C, Badalamenti F, D'Anna G and Patti B. 2000. Fish biomass increase after a four-year trawl ban in the Gulf of Castellammare (NW Sicily, Mediterranean Sea). Fisheries Research, 48:23-30. http://dx.doi.org/10.1016/S0165-7836(00)00114-4

Philippine Statistics Authority (PSA). 2020. OpenSTAT Database Portal. https://openstat.psa.gov.ph/Metadata/Agriculture-Forestry-Fisheries/Fisheries. Accessed September 30, 2023

Ramiscal RV, Yleaña J, Viron J, Bacordo RS, Ampoyos R, Escriba R and Fortaliza R. 2008. Preliminary Demersal Trawl Survey of the Turtle Islands, Tawi-Tawi, Philippines. M/V DA BFAR Technical Report. Bureau of Fisheries and Aquatic Resources, National Marine Fisheries Development Center. 13pp..

Ramos MH, Mendoza EM, Fajardo WO Jr. and Lavapie-Gonzales F. 2018. Assessment of the Tayabas Bay Fisheries. The Philippine Journal of Fisheries, 25(1): 34-51. https://doi.org/10.31398/tpjf/25.1.2017C0005

Ronquillo IA and Gabral-Llana ME. 1987. Biological effects of fishery management measures in the Philippines. RAPA Report. Food and Agriculture Organizations of the United Nations. 248pp. https://www.fao.org/3/bm733e/bm733e.pdf. Accessed on 15 July 2021.

Samoilys MA, Martin-Smith KM, Giles BG, Cabrera B, Anticamara JA, Brunio EO and Vincent ACJ. 2007. Effectiveness of five small Philippines' coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history. Biological Conservation, 136(4): 584–601. https://doi.org/10.1016/j.biocon.2007.01.003

Smith CJ, Papadopoulou KN and Diliberto S. 2000. Impact of otter trawling on an Eastern Mediterranean commercial trawl fishing ground. ICES Journal of Marine Science, 57: 1340-1351. https://doi.org/10.1006/jmsc.2000.0927

Sparre P and Venema SC. 1998. Introduction to tropical fish stock assessment. Part I. Manual. FAO Fisheries Technical Paper. No. 306-1, Revision 2. Rome, Food and Agriculture Organization. 407pp.

Supongpan M. 2001. Possible indicators for improved management of marine capture fisheries in ASEAN countries. In: Proceedings of the Regional Technical Consultation on Indicators for Sustainable Fisheries Management in ASEAN Region. SEAFDEC, Thailand. pp. 122–135.

Tan BCA, Anticamara JA and Villanueva MCS. 2017. Modeling of degraded reefs in Leyte Gulf, Philippines in the face of climate change and human-induced disturbances. Climate, Disaster and Developments Journal, 3 (1): 1-12. http://dx.doi.org/10.18783/cddj.v003.i01.a01

Trites AW. 2019. Marine mammal trophic level and interactions. Encyclopedia of Ocean Sciences (Third Edition), 2:589-594. https://doi.org/10.1016/B978-0-12-409548-9.11618-5

Valinassab T, Daryanabard R, Dehghani R and Pierce GJ. 2006. Abundance of demersal resources in the Persian Gulf and Oman Sea. Journal of the Marine Biological Association of the United Kingdom, 86: 1455-1462. http://dx.doi.org/10.1017/S0025315406014512

Villoso EP and Aprieto VL. 1983. On the relative abundance and distribution of slip mouths (Pisces: Leiognathidae) in Lingayen Gulf, Philippines. Fisheries Research Journal of the Philippines, 8(1): 26-43.

Warfel HE and Manacop PR. 1950. Otter trawl exploration in Philippine waters. Research Report 25, Fish and Wildlife Service, U.S. Department of the Interior, Washington DC. 49pp.

Worm B and Myers RA. 2003. Meta-analysis of cod–shrimp interactions reveal top-down control in oceanic food webs. Ecology Society of America, 84(1): 162−173. https://doi.org/10.1890/0012-9658(2003)084[0162:MAOCSI]2.0.CO;2

Yamazaki S, Hoshino E and Resosudarmo BP. 2014. No-take marine reserves and illegal fishing under imperfect enforcement. The Australian Journal of Agriculture and Resource Economics, 58: 1-21. http://dx.doi.org/10.1111/1467-8489.12078

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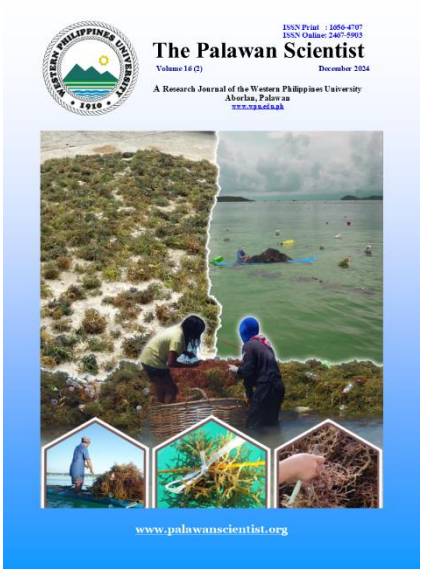

Predictors of students' academic performance during the COVID-19 Pandemic

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ABSTRACT

The COVID-19 pandemic has changed the educational system, wherein the students' learning process has been confronted with many factors that could affect their academic performance. Thus, this study aimed to determine the student's academic performance and its predictors during the COVID-19 pandemic. A total of 143 students from a state university in Cagayan Valley, Philippines participated in the study by completing an online questionnaire via Google Forms. Multiple regression analysis was conducted to determine the predictors of academic performance. The results revealed that despite the pandemic, the students had shown very satisfactory academic performance. Moreover, certain socio-economic factors emerged as significant factors. These factors included monthly household income, the number of siblings employed, and the father's employment status. Hence, teachers might design instructional activities and strategies that actively promote equity within the classroom.

Keywords: academic shift attitude, readiness, self-efficacy, self-esteem, socio-economic status

INTRODUCTION

The World Health Organization (WHO 2020) declared the coronavirus pandemic a Public Health Emergency of International Concern on 11 March 2020. The pandemic has affected education in many ways, as it has proven to be a challenge for education systems around the globe. In 195 nations, school closures impacted 1.5 billion children and youth by April 2020, with 1.3 billion students in 186 nations still unable to attend school. Over 65% of the 195 nations that closed schools in April 2020 have yet to finalize plans for resuming face-to-face instruction (UNESCO 2020). The pandemic forced schools and universities to innovate adopting online classes and learning modules to ensure continuous, high-quality education (World Economic Forum 2020). Asynchronous learning in digital media is recommended to enhance remote teaching, supplemented by diverse activities and projects contextualizing COVID-19 historically and globally (Daniel 2020). Alternative learning platforms such as electronic and non-electronic learning methods, should be utilized to achieve the course outcomes (CHED 2020).

In the Philippines, the Commission on Higher Education (CHED) implemented flexible learning in all public and private Higher Education Institutions (HEIs) through Memorandum Order No. 04 in 2020. This aimed to address the challenge of virus

transmission within the academic community. The Commission adopted a policy of a flexible learning system to ensure the continuation of inclusive and accessible education when traditional modalities of instruction are not feasible, such as during national emergencies (CHED 2020). The design of programs addresses learners' individual needs in terms of place, pace, process, and learning but is not solely focused on using technology. The schools must use available distance learning, e-learning, and other alternative delivery modes in residential education, if they have the resources to do so. Along with the standard course material, teachers are advised to incorporate various activities and projects contextualizing COVID-19 into their curriculum.

However, the inability to fully experience university life was hampered by home confinement, impacting academic study and limiting the ability to gain social support for coping with the challenges of the university environment (Elmer et al. 2020; Sun et al. 2020). The impacts of the COVID-19 outbreak have also affected the student's academic performance, particularly with the shift to distance education replacing traditional face-to-face instruction. Lockdowns significantly impacted students' learning performance (Kapasia et al. 2020). Students reported various difficulties during online classes, including social exclusion, sadness, bad internet, and hostile home learning environments, which are made worse for those from disadvantaged backgrounds (Kapasia et al. 2020). In another study, students believed online education was unsuccessful due to difficulties like a lack of student social engagement, inadequate communication, ICT tools, and subpar academic results (Adarkwah 2021).

The widespread impact of COVID-19 on education that led to the closure of universities and schools has disrupted educational stability worldwide, potentially harming students' mental and emotional health, which may alter their attitude, readiness, self-efficacy, and self-esteem, which could affect their academic performance (Copeland et al. 2021; Fawaz et al. 2021). A Chinese study found that the COVID-19 pandemic had a psychological impact on approximately 25% of college students, who experienced anxiety of varying severity levels, substantially connected with adverse effects on everyday living and academic performance (Cao et al. 2020). Similarly, an investigation found that students exhibited higher anxiety and depressive symptoms than university staff (administrative and teaching staff), indicating that students were the most affected psychologically by the COVID-19 health emergency (Odriozola-Gonzalez et al. 2020). Students' high levels of symptomatology appeared to be exacerbated by uncertainty and the possible detrimental influence on academic development. Another study discovered that students were anxious about their education, exams, progression to the next academic year, and overall well-being (Cuschieri and Calleja 2020).

Consequently, the pandemic has impacted student's socio-economic status due to retrenchment. The financial consequences exacerbated existing educational disparities, which could hinder progress toward higher education aspirations (Cao et al. 2020). The COVID-19 pandemic highlighted differences in the availability and quality of learning technologies in the United States education system, wherein low-income and minority students and their families were disadvantaged regarding full access to hardware and software technologies for learning (Gandolfi et al. 2021). Moreover, an undergraduate medical students survey (Saraswathi et al. 2020) discovered a substantial increase in stress and anxiety levels, with depression remaining unchanged during COVID-19, regardless of gender, year of study, place of residence, or family monthly income; poor sleep quality and higher baseline levels of anxiety, stress, and depression were significant predictors of adverse mental health. Students needed psychological preparation for such a transition, making them more anxious about their success in an unfamiliar learning environment. This psychological impact may result in changes to their attitude, readiness, self-efficacy, and self-esteem, which could affect their academic performance. Furthermore, students' socio-economic status may play a great importance in the success of their academic performance. The shift in the educational system brought about by the pandemic gives rise to a new level of student academic performance predictors. Hence, this current study aims to investigate students' academic performance and its predictors during the COVID-19 Pandemic.

METHODS

Research Design

This study utilized retrospective predictive quantitative non-experimental research (Johnson 2001) to predict students' academic performance during the pandemic. The term "retrospective" indicates that academic performance data from the previous semester were collected without manipulation or experimentation. The study's variables, framed within the Independent Variable-Dependent Variable framework (Figure 1), aimed to identify predictors of academic performance during the COVID-19 pandemic. The predictors included socioeconomic status, academic shift attitude, readiness, self-efficacy, and self-esteem.

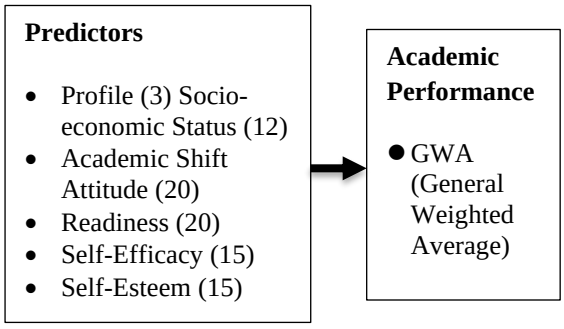

Figure 1. Predictors of academic performance model.

Sample and Sampling Technique

This study involved 143 regular tertiary students with a 21unit load from a state university in Cagayan Valley, Philippines. Tabachnick and Fidell's formula (2013) determined the sample size, considering the number of independent variables. The researchers used: N > 50 + 8m, where m is the number of independent variables. The formula is 8 (m) + 50 = N; the letter N is the number of minimum respondents. With five (5) identified independent variables, the minimum sample size of respondents was 90, but to account for potential outliers and meet the requirement for multiple regression, a sample size of 143 was considered in this study (Fidell et al. 2003). The sampling technique ensured equal representation through simple random sampling using an online random number generator.

Instruments

Academic performance. The General Weighted Average (GWA) during the first semester of the academic year 2020-2021 measured student's academic performance. The GWA was computed based on the average grade, unit values, and standard computation in the university. The GWA of the students was retrieved from the Office of the Dean and verified from the Office of the Registrar to ensure the reliability and validity of data. Informed consent from the students and approval from the Head of Office were secured so as not to violate the students' data privacy.

Predictors of academic performance. Profile predictors included sex, religion, and ethnicity. The socio-economic status had 12 categories: homeownership, household income, father's educational attainment, father's employment status, mother's educational attainment, mother's status of employment, number of siblings, siblings are employed, siblings are studying, and number of available gadgets.

The Academic Shift Attitude predictor was measured using a questionnaire of 20 positive statements relating to technological, instructional, and emotional aspects. Similarly, the readiness instrument included 20 positive comments encompassing the learning readiness activities of the students during the pandemic. At the same time, the self-efficacy questionnaire had 15 positive statements about the ability of the students to perform a specific task. Likewise, the self-esteem questionnaire comprised 15 combinations of positive and negative opinions about the students' confidence in learning situations during the pandemic. The academic shift attitude, readiness, self-efficacy, and self-esteem were scaled using the 5-point Likert scale developed by Rensis Likert in1932 (Sullivan and Artino 2013) with the following verbal interpretations:

Scale	Range		Descriptions	
5	4.51-5.00	Strongly Agree	Always Ready	Poor
4	3.51-4.50	Agree	Often Ready	Unsatisfactory
3	2.51-3.50	Neutral	Sometimes Ready	Satisfactory
2	1.51-2.50	Disagree	Rarely Ready	Very Satisfactory
1	1.00-1.50	Strongly Disagree	Not Ready	Outstanding

Data Collection

In the pre-collection, the online survey was conducted by obtaining the agreement of the target respondents. The data were collected through a Google form. Respondents were assured of confidentiality, and participation was optional.

During the implementation, the link of the Google form was sent to the email addresses of the 150 selected respondents; however, only 143 (95.33%) of the target respondents answered and responded to the questionnaire. Still, the sample is 59% more than the computed minimum sample (90). The respondents were asked to provide information about their profile and choose the options conforming to their choices or views concerning their socio-economic status, academic shift attitude, readiness, self-efficacy, self-esteem, and GWA for academic performance.

The collected data were stored in a safe file protected by a password to safeguard the privacy of the respondents. The Google Form link was terminated after all the necessary data were extracted to prevent information linkage. Moreover, after collecting and processing the gathered data, the respondents were informed of the study's results for their input and reference.

Data Analysis

The student's academic performance level was described using a 5-point scale discussed previously through the mean and standard deviation. Similarly, academic predictors like academic shift attitude, academic readiness, self-efficacy, and self-esteem were expressed on a 5-point scale using the mean and standard deviation (Table 1). In contrast, the profile variables such as sex, age, religion, and ethnicity were presented using frequency and percentage to show the distribution of the respondents. However, in the data processing, the variables sex, religion, and ethnicity were transformed into binary codes (1 and 2), and scores presented using mean and standard deviation were used for Socio-Economic Status predictors to convert the data into an interval level of measurement to meet the assumptions of multiple linear regression. No transformation on the age was made as the variable is already a ratio scale. Finally, a Stepwise linear regression analysis in IBM SPSS statistics licensed software identified significant predictors of students' academic performance. The five critical assumptions of regression analysis, such as linear relationship, multivariate normality, no or little multicollinearity, no auto-correlation, and homoscedasticity, were essentially met before drawing inferences regarding the model estimates.

RESULTS

Academic Performance of the Students During the Pandemic

Table 1 shows the academic performance of 143 students during the pandemic. Among the respondents, 72.7% (104) were very satisfactory, 26.6% (38) were outstanding, and only 0.7% (1) were satisfactory in their academic performance during the pandemic. The student's academic performance during the pandemic measured by their general weighted average (GWA) from the previous grading or semester, reflects very satisfactory ($\bar{x}$ = 1.71; SD = 0.258).

Table 1. Academic performance of the 143 students during the pandemic.

GWA	Frequency	Percent	Description
1.00-1.50	38	26.6	Outstanding
1.51-2.50	104	72.7	Very Satisfactory
2.51-3.00	1	0.7	Satisfactory
$\bar{x}$=1.71	**SD=0.258**	**Very Satisfactory**	

Predictors of Academic Performance of the Students During the Pandemic

As regards to the profile variables (Table 2), almost if not the majority of the respondents of this study were female (81.9%), aged 19 (27.3%), identified as Christian (97.9%), and belonged to a major ethnic group (93.7%). In addition, more than the majority owned houses (90.2%), had an income below PHP 5,000 (41.3%), and have parents who did not graduate from college (85.4%), primarily high school graduates (28.7%). Both fathers (96.5%) and mothers (64.3%) were employed. The majority had two siblings (25.9%), with most not employed (53.1%), but pursuing studies (69.2%). Also, the respondents possessed own gadgets for studying during the pandemic (Table 3).

The respondents of this study generally exhibited a positive attitude ($\bar{x}$ = 3.49; SD = 0.580). They also demonstrated high readiness ($\bar{x}$ = 3.64; SD = 0.686), high self-efficacy ($\bar{x}$ = 3.88; SD = 0.613), and high self-esteem ($\bar{x}$ = 3.76; SD = 0.513) toward the academic shift – from face-to-face learning to online learning, as indicated in Tables 4, 5, 6, and 7, respectively.

Linear Regression Model

A Stepwise linear regression was conducted to predict academic performance using GWA from household monthly income, siblings employed, and father's employment status. These variables significantly predicted academic performance, F (3, 139) = 6.828, $P < 0.0005$, $R^2 = 0.128$, as presented in Tables 8 and 9. All three variables added statistically significantly to the prediction, $P < 0.05$. In Table 10, the estimated model coefficients predicted academic performance = 2.270 + (0.023 x household monthly income) + (0.121 x siblings employed) + (0.288 x father's employment status). This model suggests that for a unit increase in household monthly income, there is an increase in the GWA of 0.023. Also, for a 1 unit increase in siblings who are employed, there is an increase in the GWA of 0.121, and finally, a unit increase in the employment of the father, there is an increase in the GWA of 0.288.

Table 2. Profile of the students in online class during the pandemic.

Profile variables	Frequency	Percent
Sex		
Male	27	18.88
Female	116	81.12
Age		
17	4	2.80
18	30	21.0
19	39	27.3
20	23	16.1
21	37	25.9
22	7	4.90
24	1	0.700
27	1	0.700
29	1	0.700
Religion		
Christian	140	97.9
Non-Christian	3	2.10
Ethnicity		
Major ethnic group	134	93.7
Minor ethnic group	9	6.30

Table 3. Socio-economic status of the students in online class during the pandemic.

Socio-economic variables	Frequency	Percent
Home ownership		
Owned	129	90.2
Not owned	14	9.80
Household income		
Less than 5,000	59	41.3
5,000 - 9,999	25	17.5
10,000 - 14,999	18	12.6
15,000 - 19,999	10	7.00
20,000 - 24,999	12	8.40
25,000 - 29,999	2	1.40
30,000 - 34,999	4	2.80
35,000 - 39,999	1	.700
40,000 - 44,999	2	1.40
45,000 - 49,999	2	1.40
Above 50,000	8	5.60
Father's educational attainment		
Elementary Undergraduate	36	25.2
Elementary Graduate	30	21.0
High School Undergraduate	21	14.7
High School Graduate	30	21.0
College Undergraduate	14	9.80
College Graduate	11	7.70
Master Degree Undergraduate (with units)	1	.700
Master Degree Graduate	0	0
Doctorate Degree Undergraduate (with units)	0	0
Doctorate Degree Graduate	0	0
Father's status of employment		
Employed	138	96.5
Unemployed	5	3.50
Mother's educational attainment		
Elementary Undergraduate	19	13.3
Elementary Graduate	20	14.0
High School Undergraduate	26	18.2
High School Graduate	41	28.7
College Undergraduate	16	11.2
College Graduate	20	14.0
Master Degree Undergraduate (with units)	1	.70
Master Degree Graduate	0	0

Socio-economic variables	Frequency	Percent
Doctorate Degree Undergraduate (with units)	0	0
Doctorate Degree Graduate	0	0
Mother's status of employment		
Employed	92	64.3
Unemployed	51	35.7
Number of siblings		
0	8	5.60
1	26	18.2
2	37	25.9
3	26	18.2
4	18	12.6
5	13	9.10
6	5	3.50
7	4	2.80
8	2	1.40
9	1	0.70
10	1	0.70
12	1	0.70
13	1	0.70
Siblings are employed		
Yes	67	46.90
No	76	53.10
Siblings are studying		
Yes	99	69.20
No	44	30.80
Number of available gadgets		
1	66	46.20
2	61	42.70
3	9	6.30
4	4	2.80
5	3	2.10

Table 4. Academic shift attitude of the students in online class during the pandemic.

Academic shift attitude items	$\bar{x}$	SD	Description
I was generally having a hard time learning virtually.	3.24	0.849	Neutral
I have the opportunity to get guidance for my learning difficulties.	3.36	0.817	Neutral
I get to develop my understanding by attending class online.	3.90	0.867	Agree
I get sufficient information about matters related to my studies. I get sufficient information about matters related to my studies.	3.61	0.796	Agree
I have it easy transitioning to flexible learning.	3.23	0.802	Neutral
I have found online class motivating.	3.29	0.933	Neutral
I have a lot of unwanted academic pressure on me as a student.	3.44	0.893	Neutral
I think the workload is too heavy compared to when Face-to-Face learning.	3.55	0.984	Agree
I have enough necessary tools and equipment for me to study online.	3.10	1.05	Neutral
I noticed teaching aids are always available.	3.32	0.836	Neutral
I find the materials for teaching was useful.	3.68	0.844	Agree
I think flexible learning helped me excel in my study.	3.41	0.952	Neutral
I viewed the teaching instructions online as intellectually stimulating.	3.47	0.785	Neutral
I felt a part of students who are committed to learning.	3.64	0.859	Agree
I was normally given helpful feedback on my progress by my lecturer.	3.55	0.793	Agree
I presumed that the lecturer or professors made a real effort delivering their teaching expertise to their students.	3.85	0.971	Agree
I suppose the learning and teaching methods encourages participation.	3.72	0.867	Agree
I believe the academic expectations/standards on this New Curriculum were too high.	3.55	0.954	Agree
I am satisfied with the overall quality of the support from my lecturer.	3.59	0.883	Agree
I am satisfied with the overall quality of learning online.	3.34	0.920	Neutral
Overall $\bar{x}$/SD Overall academic shift attitude description scale 3.00-5.00 (Positive attitude) 1.00-2.99 (Negative attitude)	**3.49**	**0.580**	**Positive Attitude**

Table 5. Readiness of the students in online class during the pandemic.

Readiness items	$\bar{x}$	SD	Description
I am able to do the tasks given together at the same time.	3.62	0.956	Often Ready
I am able to cope up with my fellow students with or without an Internet connection	3.20	0.990	Sometimes Ready
I am able to pass my requirements at a given time.	4.13	0.963	Often Ready
I plan my work in advance so that I can turn my schoolwork on time.	3.94	1.002	Often Ready
I am ready to engaged in online class.	3.71	0.954	Often Ready
I have a variety of applications and resources used in attending my classes online.	3.62	1.013	Often Ready
I am ready financially and emotionally in given task and activities.	3.29	0.976	Sometimes Ready
I am ready enough to send my time in online class.	3.73	0.964	Often Ready
I have developed good ways to solve problems I encountered in learning online.	3.73	0.927	Often Ready
I am mentally ready to participate on activities given online by the teacher.	3.70	0.979	Often Ready
I am fairly good at using computer and other devices for my online class.	3.54	0.870	Often Ready
I am willing to use email and other online tools to ask my classmate and instructor questions.	3.83	1.002	Often Ready
I am connected to the Internet with a fairly fast, reliable connection such as DSL or cable modern.	3.19	1.113	Sometimes Ready
I am comfortable surfing the Internet.	3.48	0.978	Sometimes Ready
I am comfortable conducting searches, setting bookmarks, and downloading files.	3.55	0.878	Often Ready
I am prepared to learn from things I hear and watch, like online lectures, video lessons, and audio recordings.	3.75	0.923	Often Ready
I can keep myself in track and on time whenever there is a virtual meeting for my classes.	3.78	0.943	Often Ready
I will not quit my study just because online learning is difficult.	4.28	0.899	Often Ready
I have the necessary digital tools such as a computer/laptop, headphones or speaker, and a microphone to use if a class has a videoconference.	3.32	1.059	Sometimes Ready
I have a study place where I can attend my virtual class, read, and work on my assignments without distraction.	3.36	1.097	Sometimes Ready
Overall $\bar{x}$/SD Overall readiness description scale 3.00-5.00 (High readiness) 1.00-2.99 (Low readiness)	**3.64**	**0.686**	**High Readiness**

Table 6. Self-efficacy of the students in online class during the pandemic.

Self-efficacy items	$\bar{x}$	SD	Description
I will be able to achieve most of the goals that I have set for myself.	4.27	0.847	Agree
When faced with the difficult tasks caused by the pandemic, I am sure I can do it.	4.14	0.819	Agree
In general, in my study during online classes, I will get outcomes that are important to me.	4.02	0.791	Agree
Amidst of pandemic, I believe I can succeed in any endeavor for my dreams.	4.36	0.817	Agree
I will be able to overcome many academic challenges in the new normal.	4.38	0.776	Agree
I am sure that I can perform effectively in many different tasks, especially in my studies online.	4.03	0.872	Agree
Compared to others students, I can do most tasks very well.	3.57	0.931	Agree
Even if the learning situation is difficult, I will still overcome the challenges.	4.23	0.828	Agree
I am very unsure of my abilities to use digital technology for my online class.	3.48	0.948	Agree
I can learn without being in the same room as the instructor and other students.	3.61	0.967	Agree
I seem to have difficulties with most of the tools or online applications I have tried to use for my online classes.	3.48	0.948	Neutral
At times, I find using digital technology very confusing during this time of Flexible Learning.	3.49	0.895	Neutral

Self-efficacy items	$\bar{x}$	SD	Description
I am able to focus on schoolwork when faced with distractions during this pandemic.	3.42	0.982	Neutral
I am able to search the internet to find the answer to a course-related question.	3.65	0.898	Agree
I can communicate using synchronous and asynchronous technologies (Google Meet, Zoom, discussion boards, email, etc.) on my classes amidst this pandemic.	4.042	0.8791	Agree
Overall $\bar{x}$/SD Overall self-efficacy description scale 3.00-5.00 (High self-efficacy) 1.00-2.99 (Low self-efficacy)	**3.88**	**0.613**	**High self-efficacy**

Table 7. Self-esteem of the students in online class during the pandemic.

Self esteem items	$\bar{x}$	SD	Description
I feel like I am a valued student; somehow, I can help other students like me.	3.92	0.835	Agree
I feel like I have good qualities to share with my fellow students during the pandemic.	3.82	0.828	Agree
Sometimes, I feel frustrated and have difficulty with the new learning situation.	3.78	0.840	Agree
I can do things as well as most other student during this New Normal mode of learning.	3.84	0.802	Agree
I feel I do not have much any learning that I acquired from online class.	3.31	0.929	Neutral
I take a positive attitude toward myself about online learning.	4.03	0.851	Agree
On the whole, I was satisfied with myself and my accomplishments.	3.93	0.924	Agree
I fear that learning online will make me incompetent someday.	3.59	0.937	Agree
Because of the pandemic, I was losing my self-confidence.	3.16	1.085	Neutral
Sometimes I think I'm not doing well with my fellow students.	3.45	1.026	Neutral
I am responsible for my thoughts and action during online class.	4.10	0.729	Agree
I feel comfortable and confident in speaking during online class recitation.	3.55	0.991	Agree
I appreciate compliment from my teacher and my fellow students.	4.01	0.809	Agree
I find it challenging learning online.	4.00	0.842	Agree
I feel that I have the confidence to acquire a passing grade during this New Normal setup.	3.90	0.858	Agree
Overall $\bar{x}$/SD Overall self-esteem description scale 3.00-5.00 (High self-esteem) 1.00-2.99 (Low self-esteem)	**3.76**	**0.531**	**High self-esteem**

Table 8. Model Summary showing how well the model fits the data.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.358	0.128	0.110	0.24340

Table 9. ANOVA showing the overall regression model is good fit for the data. Dependent Variable:GWA; Predictors: (Constant), H. Income, Siblings Employed, Father's Employment.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.213	3	0.404	6.828	0.000
Residual	8.235	139	0.059		
Total	9.448	142			

Table 10. Relationship between SES variables and academic performance. Dependent variable: GWA. Predictors: (Constant), H. Income Siblings Employed, Father's Employment.

Model	Unstandardized Coefficients		Standardized Coefficients	R^2	t	Sig.
	B	Std. Error	Beta			
(Constant)	2.270	0.146			15.56	0.000
Household Monthly Income	0.023	0.007	0.252	0.211	3.148	0.002
Siblings Employed	0.121	0.041	0.235	0.185	2.927	0.004
Father's Status of Employment	0.288	0.112	0.206	0.155	2.568	0.011

DISCUSSION

Academic Performance of the Students During the Pandemic

A recent study investigating academic successes, as measured by students' grade point average (GPA) and curricular objectives during distance education in the COVID-19 pandemic, found similar results regarding academic performance and exams taken during distance education. The study revealed that only 30% of students had higher GPAs, 40% experienced no GPA change, and 30% had declined GPAs. Moreover, approximately 60% of students expressed the need to complete their educational objectives (Elsalem et al. 2021). These results were similar with a study conducted at a prestigious state university in Northern Mindanao, where the students' general weighted average (GWA) is excellent (128), ranging from 1.00-1.25 (Napoles et al. 2023). Considering the report of the Office of the Registrar on the respondents' academic performance before the pandemic, their general weighted average ranges from 1.51 to 2.50, which is also considered very satisfactory. Likewise, the result of the academic performance of the respondents signifies that even though the learning modality has changed during this pandemic, the student's average academic performance is still high considering the situation. Comparing the GWA of the respondents before and during the pandemic means that the respondents could maintain and sustain their academic performance even in the changing learning modality. The very satisfactory academic performance could be associated with providing the needed assistance in expecting more outstanding communication and interactivity towards the students' learning, such as giving support in creating interactive online materials to supplement learning difficulties, providing extra resources, and responding to student's queries (Joosten and Cusatis 2019).

While it might be expected that learning during the pandemic would result in a poor learning experience, students' performance in terms of their grades remains unaffected (El Said 2021). The learners' adaptability, self-regulation, perseverance, and attitude to the new learning approach were ascertained to keep them focused and engaged in their study at times of the pandemic (Limniou et al. 2021). Hence, the teachers and parents must ensure that the students' learning environment enhances, if not sustains, their adaptability, self-regulation, perseverance, and attitude toward learning in whatever modality they are in.

Predictors of Academic Performance of the Students During the Pandemic

The profile variables such as religion and ethnicity were recategorized to meet the assumptions of linear regression. Though the respondents were randomly selected, it can be noted from the data that there is a wide disparity in the distribution of respondents across categories per profile variable. However, this disparity in the distribution did not affect the data needed in the study. Moreover, most of the respondents are from low-income families, with parents lacking an educational degree, hence, the majority of the respondents came from low socio-economic status.

Though the respondents came from a low socio-economic status, their attitude toward academic shift is still positive. The findings are consistent with a recent study conducted with a small-scale student and teacher sample (Hebebci et al. 2020) that focused on positive and negative attitudes toward distance education, such as online learning. Students appeared to value the opportunity to use new academic resources, such as video classes, to better and more independently manage their study activities. Similar findings were reported in a larger sample (Shatakshi and Nardev 2020). The authors discovered a strong appreciation for distance education among just over 70% of the students, who preferred learning through online classes because the study period became flexible, and they could study whenever they wanted. The off-site students appreciated the reduced travel time and cost savings (Sindiani et al. 2020). This implies that the sudden academic shift, from face-to-face learning to online learning, brought about by the pandemic did not hinder the students from positively approaching education. This positive attitude of the students can be attributed to the fact that these students are already exposed to technologies used in online learning. Hence, familiarity with online learning modalities can contribute to their positive attitude toward academic shift during the pandemic. As all lecture meetings were carried out online, making efficient use of technologies or ICTs, especially during the COVID-19 pandemic, can significantly benefit students by providing them with more flexible scheduling, additional access to learning resources, and learning experiences (Bentyet al. 2020). Although most respondents positively appreciated the implementation of distance education, some students did not favor it. Therefore, it is necessary to determine their reasons for this attitude so that appropriate assistance can be given to them. The teacher may design instructional activities in a manner that will promote an appreciation of distance learning. Also, the institution may implement a scheme to help students who cannot attend distance learning, such as online classes, due to financial constraints.

However, a study by Bozkurt et al. (2020) state that this sudden shift would be associated with a negative impression due to the disruptions in learning and the regular academic flow. On the other hand, Hjelsvold et al. (2020), indicate that learners at the

Norwegian University of Science and Technology in Norway adapted well and had a positive attitude towards the transition. The students' annoyance with all the changes and difficulties did not make them give up. Students are challenged to achieve their personal goals and curiosity, studying with determination and responsibility, satisfaction, gratitude, social support, staying healthy, and having the opportunity to attend a university. The impediments to learning brought by the COVID-19 pandemic kept them positive and motivated to learn and maintain good grades despite all the challenges and limitations they faced. This serves as a driving force for them to become resilient and able to thrive through the current adversity of learning (Hjelsvold et al. 2020; Rahiem 2021).

Similarly, the readiness of the students has not decreased or been affected during the pandemic. The high readiness of the respondents can be ascribed to their exposure and previous experiences in using modern technologies. The present curriculum in the country has already incorporated the use of technologies in teaching. Thus, using technologies for online learning is not new to the students considering the advancement of technologies.

E-learning integrates any form of technology that represents a teaching solution for distance education, facilitated by the massive penetration of the internet as a form of communication. E-learning is rapidly growing as an acceptable way of education and remarkable progress has been made in e-learning in the last couple of decades (Raymond 2000). Naji et al. (2020) found that four factors had an impact on their level of readiness: initial preparedness and motivation for online learning, self-efficacy beliefs about online learning, self-directed online learning, and support for online learning. The fact that the students are more familiar with technology and internet use and constantly use the computer in their courses reveals this situation, thus the students (Adnan and Yaman 2017).

Similarly, the students in this study believe that they can succeed in online learning during the pandemic. This set of beliefs of the students can be rooted in their familiarity and exposure to the different online learning platforms and applications. Moreover, the students' high self-efficacy could be attributed to their desire for learning or the power of learning. Students already have high self-efficacy towards the internet, which impacts their appreciation for understanding and their aim to use it in their studies. Students with higher academic self-efficacy progress more by pursuing challenging tasks and using efficient methods to complete them (Walker et al. 2006). Students with high self-efficacy tend to perceive themselves capable of regulating their learning, especially during this time of the pandemic. Most students were pleased because the online learning platforms they chose, such as Zoom, WhatsApp, Edmodo, and other social media, were simple to access and use. Growing up in the digital age, digital natives are knowledgeable about fundamental technologies and social media and communication tools (Lei 2009).

Similarly, the students have high self-esteem amidst the pandemic, which can be attributed to their self-verification of their online learning abilities, or they have a firm understanding of their skills as supported by their high self-efficacy. Also, the students understand their needs and can express them. The students' level of self-efficacy in learning online possesses superior levels of such, which they believe could enhance human accomplishment and well-being in multiple ways. Self-esteem is concerned with a person's way of thinking, behaving, and reacting to different experiences in online education. Moreover, the results showed positive personal perceptions towards online learning and other academic-related activities (Rameli et al. 2020).

It also reiterated that the ultimate success of online education is to have self-confidence, self-efficacy (Malureanu et al. 2021), and self-esteem (Rameliet al. 2020). Self-efficacy combined with self-esteem overcomes challenges and improves academic performance during the pandemic. Albert Bandura's perception towards self-esteem involves perseverance and determination in overcoming an interfering negative mindset. Thus, good self-esteem and self-efficacy motivate and guide the learners to support different learning skills (Hassan et al. 2021; Rameli et al. 2020). Considering the importance of a positive attitude, readiness, self-efficacy, and self-esteem in the mental health and well-being of the students, the learning environment, particularly during a pandemic or other unforeseen academic disruptions, should sustain, promote, guide, and motivate the learner's acquisition of different learning skills. Thus, the students' learning activities, whether online or face-to-face, amidst a pandemic or not, should be crafted or created by the teacher according to the skill set needed in the workforce.

Linear Regression Model

Student academics are affected by social, psychological, economic, environmental, and personal factors. These factors strongly influence student performance, but they vary from person to person and country to country (Mushtaq 2012). Based on the multiple regression analysis of this study, an important result is the impact of household monthly income on academic performance. Income is a crucial material resource for families (Shuani 2016), and research suggests that household or family income is a major factor contributing to students' competitive ability, educational level, and performance (Smith et al. 2002; Hill et al. 2004; Rothestein 2004). Adzido et al. (2016) concluded that family income can affect students'

learning process, implying that a strong or financially stable income can lead to improved motivation and better academic performance. It is disheartening that 41.3% of the respondents reported a family income below PHP 5,000. According to the Office of Student Services, 56.92% of the total population of 7,169 students have a family income ranging from PHP 9,000 to PHP 11,000. The financial status of the students has prompted the institution to collaborate with government and non-governmental organizations to provide scholarships and other forms of economic aid to help low-income students overcome their financial constraints. Additionally, the institution has programs such as student labor and financial assistance aid programs.

The employment of siblings contributes significantly to the additional income of a household and serves as a good financial support for students' education (Adzido et al. 2016). Siblings who are employed can provide this additional financial support as valuable resources. Resources, as mentioned by Lacour and Tissington (2011), can include financial, emotional, mental, relationships, and role models. Moreover, a father's employment plays a crucial role in providing a stable financial foundation for the family (Parcel 2016). Paternal employment is associated with sufficient income to support their child's education.

A study by Ali et al. (2013) explored factors affecting the academic performance of 100 students at Islamia University and found that a higher income status of a father/guardian significantly contributes to higher academic performance. On the other hand, parental, specifically a father's unemployment can negatively affect a child's schooling performance, potentially leading to a higher risk of dropout (Raychaudhuri et al. 2010). In general, high academic performance can be achieved if a student's parents, specifically the father, are employed and able to support and cover the educational expenses and needs of their child (Ali et al. 2013). Additionally, high academic performance can also be related to effective learning programs, interventions, and meeting the necessary pace, place, process, and learning products for students, resulting in consistent and progressive learning (Parrocha 2020).

Considering the functional brain organization, Finn et al. (2017) found that higher family income is associated with larger working memory capacity and more activation of the fronto-parietal executive network for challenging working memory tasks, resulting in higher scores on statewide tests. Higher math achievement scores were also associated with greater parietal activation during working memory tasks. On the other hand, Lacour and Tissington (2011) examined how poverty directly impacts students' academic achievement due to a lack of accessible resources to support their success. As a result, low academic achievement is strongly linked to a need for more resources, particularly financial resources. They suggested that by providing students with the support they need to excel academically, instructional techniques and initiatives at the classroom, school, district, and governmental levels can help in close the achievement gap. Considering monthly household income, employed siblings and a father's employment status as factors related to the family's financial situation that significantly predicts students' academic performance, instructional activities and strategies should promote equity among privileged and underprivileged students in the classroom.

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ETHICAL CONSIDERATIONS

Informed consent and assent were secured from the participants before the conduct of the study.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests to any authors.

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REFERENCES

Adarkwah MA. 2021. "I'm not against online teaching, but what about us?": ICT in Ghana post Covid-19. Education and Information Technologies, 26(2): 1665-1685. https://doi.org/10.1007/s10639-020-10331-z

Adnan M and Yaman BB. 2017. Mühendislik öğrencilerinin e-öğrenmeye dair beklenti, hazır bulunuşluk ve memnuniyet düzeyleri. Türk Bilgisayar ve Matematik Eğitimi Dergisi, 8(2): 218-243.

Adzido RYN, Dzogbede OE, Ahiave E and Dorkpah OK. 2016. Assessment of family income on academic performance of tertiary students: The case of Ho Polytechnic, Ghana. International Journal of Academic Research in Accounting, Finance and Management Sciences, 6(3): 154-169. http://dx.doi.org/10.6007/IJARAFMS/v6-i3/2221

Ali S, Haider Z, Munir F, Khan H and Ahmed A. 2013. Factors contributing to the students' academic performance: A case study of Islamia University Sub Campus. American Journal

of Educational Research, 1(8): 283-289. https://doi.org/10.12691/education-1-8-3

Andersen SH. 2013. Common genes or exogenous shock? Disengtangling the causal effect of paternal unemployment on children's schooling efforts. European Sociological Review, 29(3): 477-488. https://doi.org/10.1093/esr/jcr088

Benty DDN, Kusumaningrum DE, Santoso FB, Prayoga AG, Ubaidillah E and Wardani AD. 2020. Use of information and communication technology in leaming in the covid-19 pandemic period to improve student learning outcomes. IEEE 2020 6th International Conference on Education and Technology (ICET): 165-169. https://doi.org/10.1109/ICET51153.2020.9276617

Bozkurt A, Jung I, Xiao J, Vladimirschi V, Schuwer R, Egorov G and Paskevicius M. 2020. A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis. Asian Journal of Distance Education, 15(1): 1-126. https://doi.org/10.5281/zenodo.3878572

Cao W, Fang Z, Hou G, Han M, Xu X, Dong J and Zheng J. 2020. The psychological impact of the COVID-19 epidemic on college students in China. Psychiatry research, 287(112934): 1-5. https://doi.org/10.1016/j.psychres.2020.112934

CHED (Commission on Higher Education) 2020. Guidelines for the Prevention, Control and Mitigation of the Spread of Coronavirus Disease 2019 (COVID-19) in Higher Education Institutions (HEIs). CHED Advisory No. 6-2020. https://ched.gov.ph/wp-content/uploads/CHED-COVID-19- Advisory-No.-6.pdf . Accessed on 17 June 2021.

Copeland WE, McGinnis E, Bai Y, Adams Z, Nardone H, Devadanam V and Hudziak JJ. 2021. Impact of COVID-19 pandemic on college student mental health and wellness. Journal of the American Academy of Child & Adolescent Psychiatry, 60(1): 134-141. https://doi.org/10.1016/j.jaac.2020.08.466

Cuschieri S and Calleja AJ. 2020. Spotlight on the shift to remote anatomical teaching during Covid-19 pandemic: perspectives and experiences from the University of Malta. Anatomical Sciences Education, 13(6): 671-9. https://doi.org/10.1002/ase.2020

Daniel SJ. 2020. Education and the COVID-19 pandemic. Prospects, 49(1): 91-96. https://doi.org/10.1007/s11125-020-09464-3

Elmer T, Mepham K and Stadtfeld C. 2020. Students under lockdown: Comparisons of students' social networks and mental health before and during the COVID-19 crisis in Switzerland. Plos one, 15(7): e0236337. https://doi.org/10.1371/journal.pone.0236337

Elsalem L, Al-Azzam N, Jum'ah AA and Obeidat N. 2021. Remote E-exams during Covid-19 pandemic: a cross-sectional study of students' preferences and academic dishonesty in faculties of medical sciences. Ann Med Surg (Lond), 62: 326–33. https://doi.org/10.1016/j.amsu.2021.01.054

El Said GR. 2021. How did the COVID-19 pandemic affect higher education learning experience? An empirical investigation of learners' academic performance at a university in a developing country. Advances in Human-Computer Interaction, 2021: 1-10. https://doi.org/10.1155/2021/6649524

Fawaz M and Samaha A. 2021. E-learning: Depression, anxiety, and stress symptomatology among Lebanese university students during COVID-19 quarantine. In Nursing forum, 56(1): 52-57. https://doi.org/10.1111/nuf.12521

Fidell LS and Tabachnick BG. 2003. Preparatory Data Analysis. In: Handbook of psychology: Research methods in psychology (2nd). John Wiley and Sons, Hoboken, NJ, pp. 115-141.

Finn AS, Minas JE, Leonard JA, Mackey AP, Salvatore J, Goetz C, ... and Gabrieli JD. (2017). Functional brain organization of working memory in adolescents varies in relation to family income and academic achievement. Developmental Science, 20(5): e12450. https://doi.org/10.1111/desc.12450

Gandolfi E, Ferdig RE and Kratcoski A. 2021. A new educational normal an intersectionality-led exploration of education, learning technologies, and diversity during COVID-19. Technology in Society, 66: 101637. https://doi.org/10.1016/j.techsoc.2021.101637

Hassan O and Ibourk A. 2021. Burnout, self-efficacy and job satisfaction among primary school teachers in Morocco. Social Sciences & Humanities Open, 4(1): 100148. https://doi.org/10.1016/j.ssaho.2021.100148

Hebebci MT, Bertiz Y and Alan S. 2020. Investigation of views of students and teachers on distance education practices during the coronavirus (COVID-19) pandemic. International Journal of Technology in Educational Sci., 4(4): 267–82. https://doi.org/10.46328/ijtes.v4i4.113

Hill NE, Castellino DR, Lansford JE, Nowlin P, Dodge KA, Bates JE and Pettit GS. 2004. Parent academic involvement as related to school behavior, achievement, and aspirations: Demographic variations across adolescence. Child development, 75(5): 1491-1509. https://doi.org/10.1111/j.1467-8624.2004.00753.x

Hjelsvold R, Bahmani A and Lorås M. 2020. First impressions from educators as NTNU transitions to an online only mode of learning. Norwegian University of Science and Technology's: Trondheim, Norway. https://www.ntnu.edu/excited/first-impressions-from-educators-and-students-as-ntnu-transitions-to-an-online-only-mode-of-learning . Accessed on 06 June 2021.

Johnson B. 2001. Toward a new classification of nonexperimental quantitative research. Educational researcher, 30(2): 3-13. https://doi.org/10.3102/0013189X030002003

Joosten T and Cusatis R. 2019. A Cross-Institutional Study of Instructional Characteristics and Student Outcomes: Are Quality Indicators of Online Courses Able to Predict Student Success? Online Learning, 23(4): 354-378.

Kapasia N, Paul P, Roy A, Saha J, Zaveri A, Mallick R and Chouhan P. 2020. Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal, India. Children and youth services review, 116: 105194. https://doi.org/10.1016/j.childyouth.2020.105194

Lacour M and Tissington LD. 2011. The effects of poverty on academic achievement. Educational Research and Reviews, 6(7): 522-527.

Lei J. 2009. Digital natives as preservice teachers: What technology preparation is needed? Journal of Computing in teacher Education, 25(3): 87-97. http://dx.doi.org/10.1080/10402454.2009.10784615

Limniou M, Varga-Atkins T, Hands C and Elshamaa M. 2021. Learning, student digital capabilities and academic performance over the COVID-19 pandemic. Education Sciences, 11(7): 361. https://doi.org/10.3390/educsci11070361

Malureanu A, Panisoara G and Lazar I. 2021. The relationship between self-confidence, self-efficacy, grit, usefulness, and ease of use of elearning platforms in corporate training during the COVID-19 pandemic. Sustainability, 13(12): 6633. https://doi.org/10.3390/su13126633

Mushtaq I and Khan SN. 2012. Factors Affecting Studentsa Academic Performance. Global journal of management and business research, 12(9): 17-22.

Naji KK, Du X, Tarlochan F, Ebead U, Hasan MA and Al-Ali AK. 2020. Engineering Students' Readiness to Transition to Emergency Online Learning in Response to COVID-19: Case of Qatar. EURASIA Journal of Mathematics, Science and Technology Education, 16(10): em1886 2020. https://doi.org/10.29333/ejmste/8474

Napoles MA, Altubar JAB and Anding HKT. 2023. The Role of Time Management to the Academic Performance of the College Students During Pandemic. International Journal of Social Sciences and Humanities Invention, 10(02): 7731-7741. https://doi.org/10.18535/ijsshi/v10i02.05

Odriozola-Gonzalez P, Planchuelo-Gomez A, Irurtia MJ and de Luis-Garcia R. 2020. Psychological effects of the COVID-19 outbreak and lockdown among students and workers of a Spanish university. Psychiatry Research, 290: 113108. https://doi.org/10.1016/j.psychres.2020.113108

Parcel TL. 2016. Parental Employment in the United States. In Encyclopedia of Family Studies, CL, Shehan, pp. 1-5.

Parrocha A. 2020. HEIs may hold limited face-to-face classes in MGCQ areas. https://www.pna.gov.ph/articles/1105160 . Accessed on 18 June 2022.

Rahiem MD. 2021. Remaining motivated despite the limitations: University students' learning propensity during the COVID-19 pandemic. Children and youth services review, 120: 105802. https://doi.org/10.1016/j.childyouth.2020.105802

Rameli MRM, Alhassora NSA, Bunyamin MAH and Hanri C. 2020. Student teachers' attitude and self-esteem towards online learning: Application of Rasch measurement model. Universal Journal of Educational Research, 8(11C): 37-44. https://doi.org/10.13189/ujer.2020.082305

Raychaudhuri A, Debnath M, Sen S and Majumder BG. 2010. Factors Affecting Students' Academic Performance: A case study in Agartala Municipal Council Area. Bangladesh e-journal of Sociology, 7(2): 34-41.

Raymond III FB. 2000. Delivering distance education through technology: A pioneer's experience. Campus-Wide Information Systems, 17(2): 49-55. https://doi.org/10.1108/10650740010317005

Rothstein R. 2004. Class and schools: Using social, economic, and educational reform to close the Black–White achievement gap. https://policycommons.net/artifacts/1412001/class-and-schools/2026264/ . Accessed on 20 May 2022.

Saraswathi I, Saikarthik J, Senthil Kumar K, Madhan Srinivasan K, Ardhanaari M and Gunapriya R. 2020. Impact of COVID-19 outbreak on the mental health status of undergraduate medical students in a COVID-19 treating medical college: a prospective longitudinal study. PeerJ, 8: e10164. https://doi.org/10.7717/peerj.10164

Shatakshi L and Nardev S. 2020. CoVid-19: unmasking the new face of education. International Journal of Research in Pharmaceutical Sciences, 11(SPL1): 48–53. https://doi.org/10.26452/ijrps.v11iSPL1.2122

Shuani F. 2016. Family income types: Money, real and psychic income. International Journal of Academic Research in Accounting, Finance and Management Sciences, 6(3): 154-169. https://doi.org/10.24059/olj.v23i4.1432

Sindiani AM, Obeidat N, Alshdaifat E, Elsalem L, Alwani MM, Rawashdeh H, et al. 2020. Distance education during the COVID-19 outbreak: a cross-sectional study among medical students in North of Jordan. Annals of Medicine Surgery, 59: 186–94. https://doi.org/10.1016/j.amsu.2020.09.036

Smith L, Fagan JF and Ulvund SE. 2002. The relation of recognition memory in infancy and parental socioeconomic status to later intellectual competence. Intelligence, 30(3): 247-259. https://doi.org/10.1016/S0160-2896(01)00099-X

Sullivan G and Artino A. 2013. Analyzing and interpreting data from Likert-Type scales. Journal of Graduate Medical Education, 5(4): 541–542. https://doi.org/10.4300/JGME-5-4-18

Sun Y, Lin SY and Chung KKH. 2020. University students' perceived peer support and experienced depressive symptoms during the COVID-19 pandemic: The mediating role of emotional well-being. International Journal of Environmental Research and Public Health, 17(24): 9308. https://doi.org/10.3390/ijerph17249308

Tabachnick BG and Fidell LS. 2013. Using multivariate statistics. Pearson, Boston, MA. 497-516pp.

UNESCO (United Nations Educational, Scientific and Cultural Organization) 2020. Press release. https://en.unesco.org/news/13-billion-learners-are-still-affected-school-university-closures-educational-institutions . Accessed on 13 June 2022

Walker CO, Greene BA and Mansell RA. 2006. Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. Learning and Individual Differences, 16(1): 1–12. https://doi.org/10.1016/j.lindif.2005.06.004

WEF (World Economic Forum) 2020. The COVID-19 pandemic has changed education forever. https://www.weforum.org/agenda/2020/04/coronavirus-education-global-covid19-online-digital-learning/. Accessed on 15 June 2022.

WHO (World Health Organization) 2020. Global research on coronavirus disease (COVID-19). https://www.who.int/emergencies/diseases/novel-coronavirus-2019/global-research-on-novel-coronavirus-2019-ncov . Accessed on 15 June 2022.

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Gender roles of Obu Manuvu women and leaders in the conservation of the Philippine Brown Deer *Rusa marianna* Desmarest, 1822

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ABSTRACT

Philippine brown deer *Rusa marianna* Desmarest 1822, has been considered a conservation priority following its declaration as an endangered species by the Philippine Red List of Threatened Fauna in 2020. The research study analyzed the gender roles of women and men in the conservation of the Philippine brown deer (*R. marianna*) in the Obu Manuvu Ancestral Domain (OMAD) in Baguio District, Davao City, Philippines. Using the Harvard Analytical Framework (HAF), the study explored women's and men's (1) activity profile, (2) access to and control over resources, (3) knowledge, beliefs, and perceptions, (4) decision-making power, (5) laws, legal rights, policies, and institutions, and (6) priorities, and needs/ opportunities, and constraints. Sixteen individuals participated in the key informant interviews (KIIs), represented by chieftains, elders, and women. The results of the gender analysis conveyed that women and men are primarily involved in deer conservation. Gender gaps have been documented in education, employment, and resource management, showing that men have better access than women. However, both genders are provided access to information and training as part of the capacity-building for conservation works. In terms of employment preference, Obu Manuvu men largely dominated the farming jobs, while women worked home-based. They are also given equal rights regarding their participation in the decision-making process and property ownership. A livelihood program is considered one of the needs of the indigenous community, which includes the opportunity to economize their conservation services. Therefore, the study recommends that gender roles be integrated into formulating a conservation model. Providing equal education, employment, and livelihood opportunities for women and men is vital to the deer's sustainable conservation.

Keywords: conservation, gender analysis, gender roles, Harvard analytical framework

INTRODUCTION

Conservation work has historically been dominated by men. The roles of women are often undocumented and underrepresented, which has led to the ever-increasing need to integrate a gender lens in conservation (James 2023). Gender in conservation involves dealing with how women and men interact

with their resources and how that impacts knowledge use, and priorities for conservation (Leisher et al. 2015). Gender is considered a social determinant of conservation success, especially when the voices of women and men are both accounted for. The inclusion of gender analysis in conservation is a novel underpinning and is underexplored across the country (Parks et al. 2015; CBD 2017).

There is an increasing demand to examine the labor responsibilities, priorities, decision-making power, and knowledge of women and men in conservation. For example, women in one of the Pacific Island countries were not consulted in coastal fisheries management because men are primarily responsible for fishing. Still, it was found that women are involved in agricultural activity, which has a downstream impact through increasing sedimentation (MacKay 2017). Gender disparity has also been observed in wildlife-dependent recreation in the United States, where women feel alienated in the male-dominated control of wildlife populations (Rizzolo et al. 2023). In Madagascar, locals at a marine conservation site also proposed that women should be involved in decision-making and management (Evans 2017). Therefore, if gender is not considered in conservation, biodiversity loss may result from mismanagement and unsustainable practices, and the gradual loss of traditional knowledge, skills, and experiences will become more evident (Leisher et al. 2015).

The Philippine brown deer *Rusa marianna* Desmarest 1822, also known as the Philippine sambar, is endemic to the islands of the Philippines, particularly Luzon, Mindanao, Samar, and Leyte. However, its population has significantly declined in the last three decades due to forest cover loss, habitat fragmentation, and human persecution (Ravenelle and Nyhus 2017). Anthropogenic pressures on natural landscapes have driven the deer to hide in the remaining forest patches (Foley et al. 2005; Villegas et al. 2022a). The most prevalent anthropogenic threat is subsistence hunting, especially among locals who lack sufficient livelihood options (Tanalgo 2017). The same scenario was observed within the Obu Manuvu Ancestral Domain (OMAD), where deer hunting remains evident despite the customary policies in place (Villegas et al. 2022a). As a consequence, the deer is now considered endangered on the Philippine Red List of Threatened Fauna (BMB-DENR 2020). Its wild population is vulnerable and rapidly declining, according to the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species (MacKinnon et al. 2015).

The present study aimed to analyze the gender roles of Obu Manuvu women and leaders in deer conservation in the OMAD in Baguio District, Davao City, Philippines. Specifically, the study investigated women's and leaders' (1) activity profile, (2) access to and control over assets and resources, (3) knowledge, beliefs, and perceptions, (4) decision-making power, (5) laws, legal rights, policies, and institutions, and (6) priorities, and needs/ opportunities, and constraints relative to deer conservation. The study intends to provide insights into the development of deer conservation models through the lenses of Indigenous Peoples (IPs), especially women and leaders.

METHODS

Study Area

This study was conducted in the OMAD, with a total land area of 36,713.52 hectares in Baguio District, Davao City, Davao del Sur, Philippines. Specifically, the locale of this study includes four barangays: Carmen, Salaysay, Tambobong, and Tawan-Tawan (Figure 1). The ancestral domain falls within the unprotected regions of Mt. Apo Range and is a known watershed area in Davao City, Philippines (Villegas et al. 2022a).

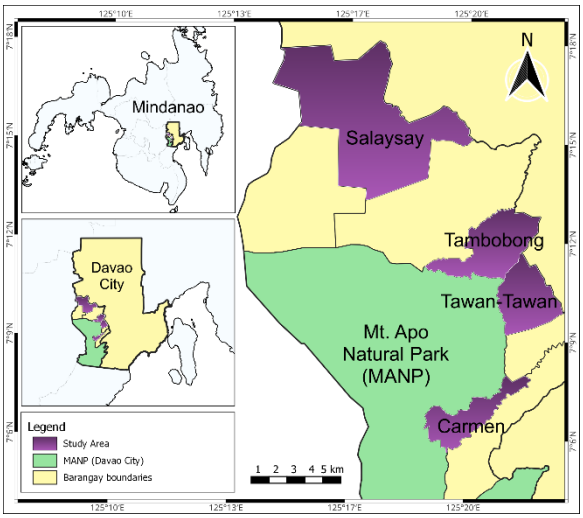

Figure 1. Map of the study area in the Obu Manuvu Ancestral Domain, Davao City, Mindanao Island, Philippines. Cartographer: Ricksterlie C. Verzosa.

Harvard Analytical Framework

The study used a qualitative research design. Through the lens of the Harvard Analytical Framework (HAF), a gender analysis of the roles of Obu Manuvu women and men in deer conservation was explored (Figure 2). The framework is usually utilized in determining and explaining the differences between women and men in terms of economic participation. A framework-based gender analysis is helpful for policymakers to understand the economic case for allocating development resources to women and men (Ochola et al. 2010). The framework is also used as a practical tool to determine the type and

amount of work women and men do in households, farms, or communities (March et al. 1999). The framework is useful for organizing information and can be adapted to many situations including biological conservation. While this framework has been widely used in agriculture, this paper introduces using the same framework in biodiversity conservation, especially concerning lands that are governed by indigenous communities. In the study area, agricultural lands and Indigenous Peoples and Community-Conserved Areas (ICCAs) are proximal and are regulated by the same customary laws and practices. The Local Government Units (LGUs) complement the biodiversity conservation initiatives by providing monetary remuneration to the forest guards and financial support for monitoring activities. Data gathered on the ground are also transmitted to them for appropriate action and coordination with relevant public and private agencies (i.e., the Department of Environment and Natural Resources and the Philippine Eagle Foundation). This study explored six components: (1) activity profile, (2) access to and control of assets and resources, (3) knowledge, beliefs, and perceptions, (4) decision-making power, (5) laws, legal rights, policies, and institutions, (6) and people's priorities and needs, opportunities, and constraints.

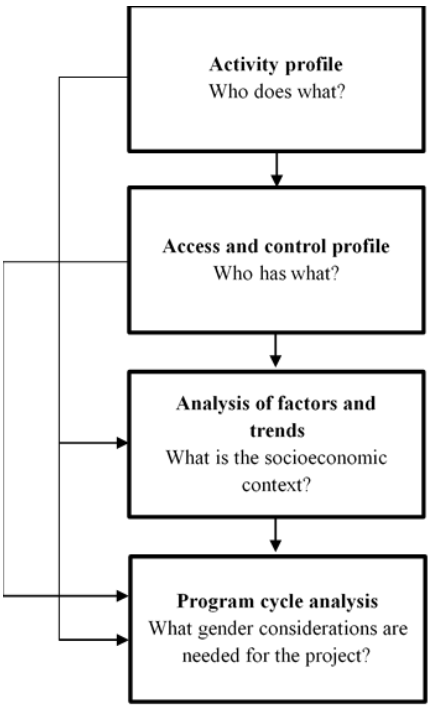

Figure 2. Gender analysis of projects using the Harvard Analytical Framework (Srinivas 2015).

Key Informant Interview (KII)

Sixteen participants, consisting of eight women and eight men, were interviewed in December 2020 using a semi-structured interview tool developed by the researchers. The interview questions were formulated and based on the HAF. During the interviews, the questions were translated into Visaya, a dialect widely spoken by the indigenous people (IP) community. All participants provided free prior and informed consent (FPIC) before the interviews took place. They represented the Obu Manuvu indigenous community as chieftains, elders, and women of legal age. They were all involved in local conservation work as forest guards (Visaya: Bantay Bukid) and were *bona fide* residents of the study area. As forest guards, their primary role was to monitor wild flora and fauna within the ancestral domain, particularly the cultural keystone species (CKS) such as deer. They conducted regular foot patrols (i.e., at least once a month) to inventory the species and record conservation threats. The Obu Manuvu is a sub-tribe of the Bagobo, originating from intermarriages between Bagobo-Klata and Bagobo-Tagabawa. They inhabit three provinces in Mindanao, including northeastern Davao, northeastern Cotabato, and Bukidnon (TUOMTC 2017). All discussions were conducted on a one-on-one basis, audio-recorded and transcribed verbatim for use as a reference in data analysis.

Thematic Analysis

The HAF was utilized as an approach to analyze the qualitative responses of the participants. Based on the six components of the framework, a thematic analysis was employed to analyze the qualitative data collected (Creswell 2014). This technique involves analyzing qualitative data, such as transcriptions of responses obtained during key informant interviews. The analysis began with familiarization of the data, followed by data coding, including data reduction and compilation, and then clustering the codes to identify emerging themes.

RESULTS

The *Rusa marianna* is a sacred species for the Obu Manuvu indigenous community, making the deer a priority for conservation. To achieve this goal, the tribe has implemented various systems and policies aimed at reducing human impact on the deer population and promoting its sustainability within the ancestral domain. One key strategy involves the establishment of a forest guarding scheme with both women and men. They both play critical roles in managing the forests and protecting the deer. While men tend to lead conservation efforts and make policy decisions, women are equally important partners who contribute by documenting and disseminating information. Both genders have unique roles to play, and their contributions are essential to ensuring a holistic approach to conservation (Table 1).

Table 1. Gender roles of the Obu Manuvu women and men using the Harvard Analytical Framework.

Analytical parameter	Women	Men
Activity profile	• Perform reproductive roles such as working at home and taking care of the needs of their children	• Perform productive roles such as working in farms or private companies as laborers
Access to and control over assets and resources	• Support deer conservation efforts made by men • Support the information dissemination on deer conservation • In terms of employment services, women forest guards are assigned to clerical jobs such as encoding and bookkeeping	• Lead in deer conservation by accessing the right training programs • Lead in information dissemination on deer conservation • In terms of employment services, men forest guards are engaged in species monitoring and roving patrol jobs
Knowledge, beliefs, and perceptions	• Women work at home such as doing household chores and caring for their children and their husbands. • Women work overseas as domestic helpers	• Men do more strenuous labor • More men work on farms and in private companies as laborers
Decision-making power	• Participate in community discussions and the decision-making process	• Lead in community discussions and the decision-making process
Laws, Legal Rights, Policies, and Institutions	• Follow laws and policies in deer conservation and speak their brand of conservation	• Lead in the formulation of laws and policies that protect their ancestral domains and in deer conservation
Priorities and Needs/ Opportunities and Constraints	• Support their husbands in providing for the needs of the family • Seek livelihood opportunities for the family	• Provide the needs of the family • Seek livelihood opportunities for the family

Activity Profile

One hundred eighty-eight forest guards are engaged in conserving the deer within the ancestral domain. Out of the 188 forest guards, 25 of them are women. None of the forest guards have completed elementary education. All of them are married and have children. While working as forest guards, both women and men are also engaged in farming as another means of livelihood. The forest guards receive a minimal monthly honorarium from the Philippine government. Both genders share the responsibility of fulfilling their duties as forest guards in their ancestral domains to protect their forests from anthropogenic dangers such as illegal logging, "*kaingin"* (slash and burn agriculture), and hunting wild animals. One forest guard summarized the reason behind this:

> *Our main source of livelihood here in Barangay Salaysay is mainly farming but we also worked as forest guards. Our work as forest guards, involved more men than women. As forest guards and as member of the community, we really protect our ancestral domains. We even have a "datu" in our community that we respected, who has the control against anyone who would try to harm our ancestral domains. Women here in the community are working at home, while men work in their farms. (Ang among panginabuhian dinhi sa Barangay Salaysay mao ang pagpanguma apan nagtrabaho usab kami isip mga guwardiya sa kalasangan. Ang among trabaho isip magbalantay sa lapsang, naglangkob ug mas daghan lalaki kaysa sa mga babaye. Isip mga guwardiya sa kalasangan ug isip miyembro sa komunidad, giprotektahan gyud nato ang atong ancestral domains. Aduna gani kami "datu" sa komunidad nga amoa ginarespeto, nga aduna control batok sa mga gusto nga maghilabot sa ancestral domanis.)* Forest guard, Barangay Salaysay, Davao City, Interview number 2.

Access to and Control Over Assets and Resources

Access to education. The Obu Manuvu indigenous community has a large population of adults under 40 and above who lack the education needed to secure formal employment. Although boys and girls in the community are provided with the opportunity to attend school, poverty hinders the completion of their elementary education. Despite the Philippine government's provision of free grade school education, the Obu Manuvu people still struggle to complete their education. This is because they must also cover expenses such as uniforms, school materials, other school fees, school allowances, and daily necessities. The lack of education for both genders is considered to be the main reason behind their low socio-economic status and the limited

availability of formal employment opportunities. The statements provided by the respondent in an interview best illustrate this, which stating that:

> *Many of us here did not finish elementary because of poverty. Our parents cannot afford to send us to school back then. The same is true with our children right now. While the government provides us free education in elementary, but we also have to pay for our uniforms, schools requirements and other fees in school. We also have daily needs such as the food that we eat and other needs at home. These are some of the reasons why many of us not able to get a good job. We only get a living by farming. (Daghan sa amoa diri ang wala makahuman ug elementary tungod sa kapobrehon. Ang amoa mga ginikanan dili makakaya ng paeskwelahon mi. Mao gihapon ang sitwasyon sa amoang mga anak sa kasamtangan. Bisan pa ug ang gobyerno muhatag ug libre nga edukasyon sa elementarya, kami gihapon ang magbayad sa amoa mga uniporme, requirements sa eskwelahan ug uban pang mga bayrunon. Aduna pod kami mga panginahanglan kada adlaw sama sa mga pagkaon ug ubna pa. Mao usab kini ang maong mga rason ngano maglisod mi ug kuha ug maayong trabaho. Mabuhi lang kami pinaagi sa pagpanguma.)* Forest guard, Barangay Carmen, Davao City, Interview number 5.

Access to information and training programs. Access to correct information and training programs has supported conservation efforts made by women and men. Both genders have been equipped with the knowledge and necessary skills to understand the conservation process, especially regarding deer. As part of a long-term conservation program with the Obu Manuvus, various information dissemination programs were provided to enable forest guards to fulfill their roles. Training programs and other information dissemination initiatives are available to all community members through agencies such as local government units and non-government organizations (e.g., the Philippine Eagle Foundation). In addition, the researchers of this paper spearheaded the project titled "Population status, community values, and gender roles in the conservation of the Philippine brown deer (*R. marianna*) in the OMAD in Davao City, Philippines." This project has also provided community members with better solutions to deer conservation. The provision for training and seminars to effectively disseminate information on deer conservation highlights the opportunities that both women and men have benefited from. One of the forest guards mentioned:

> *We were given trainings and seminars in terms of deer conservation. There were non-government organizations that provided us with trainings. The government also gave us seminars. Also, the Philippine Eagle Foundation gave us inputs and other needed trainings in conserving the deer in our ancestral domains (Gitagaan kami ug mga trainings ug seminars kabahin sa pag konserba sa usa. Adunay mga non-government organizations nga naghatag ug training. Ang gobyerno naghatag ug mga seminars. Ang Philippine Eagle Foundation naghatag pod ug mga input ug uban pang mga kinahanglanon nga mga training ug seminar kabahin sa pakonserba sa mga osa sa amoang ancestral domain.)* Forest guard, Barangay Salaysay, Davao City, Interview number 2).

Another forest guard also reported:

> *They have research projects conducted in the past that also helped us more fully understand our responsibilities as forest guards. For example, the research project titled "Population Status, Community Values, and Gender Roles in the Conservation of the Philippine Brown Deer (R. marianna) in the Obu Manuvu Ancestral Domain in Davao City, Philippines," has also provided us ideas in deer conservation. (Aduna sila research project nga gihimo kaniadto nga nakatabang kanamo aron masabtan namo ang amoang mga responsibilidad isip gwardya sa kalasangan. Pananglitan kaning proyekto nga gitituluhan: Philippine Brown Deer (R. marianna) in the Obu Manuvu Ancestral Domain in Davao City, Philippines," gitagaan pod mi ug kahibalo sa pagkonserba sa mga osa.* Forest guard, Barangay Tambobong, Davao City, Interview number 4.

Access to employment services. Deer conservation within the OMAD has provided both women and men with access to employment as forest guards. In the course of conserving the deer, Obu Manuvu women and men were hired as forest guards with specific duties and tasks to fulfill and comply with. However, it is worth noting that a higher number of men were hired and involved in deer conservation. Despite the higher number of men, monetary benefits were equal among all employees. As forest guards, women are assigned to housekeeping and clerical jobs such as encoding and bookkeeping, while men are

engaged in monitoring and roving patrol jobs to protect the forest and wildlife sanctuary. Access to employment services is best exemplified through the statements provided by the forest guard:

> *Our main job is to conserve the deer in our ancestral domains. Because of this, we were given the chance to work and be employed. As forest guards, men are assigned to monitoring and roving patrol jobs to protect the forest and wildlife sanctuary, while women worked in housekeeping and doing clerical jobs such as encoding and bookkeeping. (Ang amoa gyud panguna nga trabaho ang maong pagkonserba sa mga osa sa ancestral domain. Isip guwardiya sa kalasangan, ang mga lalaki ang gi-assign sa monitoring, ug pagpatrolya or roving arun maprotektahan ang kalasangan ug mga puluy-anan sa mga wild animals samtang ang mga babae nagatrabaho ug pambalay ug klerikal nga mga trabaho sama sa encoding ug bookkeeping.)* Forest guard, Barangay Tawantawan, Davao City, Interview number 7.

Knowledge, Beliefs, and Perception

Employment preferences. Employment for women and men in the Obu Manuvu community is dominated by farming and manual labor. However, men are more commonly hired for these jobs. More men work on farms and in private companies as laborers, while women are more likely to work overseas as domestic helpers. This pattern is observed in the Obu Manuvu community, as locals believe men should do more strenuous labor than women. Furthermore, women are expected to work at home, such as doing household chores and caring for their children and husbands. This is also evident in the work women are assigned as forest guards. Women forest guards are expected to fulfill clerical roles such as recordkeeping, bookkeeping, and secretariat duties. Women often jot down the group's observations during conservation work. On the other hand, men perform productive functions such as foot patrols and species monitoring, especially in difficult terrains. A forest guard from Barangay Tawantawan, Davao City, stated:

> *Aside from being a forest guard, our work here in our barangay is mainly into farming. If we don't have work in the farm, we also do manual labor. We are hired for other farms and in some in private companies to work as laborers. Women also work as domestic helpers abroad* (Forest guard, Barangay Tawantawan, Davao City, Interview number 8). This is further elaborated by a lady forest guard from the same Barangay: *At home, we do household chores and care for our children and husbands. (Gawas sa pagka-guwardiya sa lasang, pagpanguma ang amoa gyud trabaho sa barangay. Kung wala kami pagabuhaton sa uma, nagapanghornal pod kami. Gina-hire pod kami sa laing mga uma ug sa mga pribado nga kompaniya isip laborer. Ang ubang mga babae nanarbaho pod sa laing nasod isip domestic helper.)* Forest guard, Barangay Tawantawan, Davao City, Interview number 7.

Decision-Making Power

Equal participation. The entire community of the Obu Manuvu tribe is allowed to participate in the decision-making process. Women and men are organized into groups so that everyone will have the opportunity to express their concerns and participate in community discussions and decisions. They have organized a women's organization to ensure that women have equal opportunities to participate in the process. Community members are also given the chance to voice their opinions on deer conservation in their ancestral domain, allowing them to advocate for their views to higher authorities such as the local government units (LGUs), non-government organizations (NGOs), and the Pusaka Council. The following statements by a female forest guard best illustrate this:

> *As members of the community, we are given the opportunity to participate in meetings and discussions. Whenever there are decisions that need to be done in the community, we are being consulted. We voice out our opinions in terms of conserving the deer. That is why our organization is being organized in the barangay* (Forest guard, Barangay Carmen, Davao City, Interview number 6). This is further elaborated by a forest guard from Barangay Tambobong, Davao City: *We also have a woman-leader. Through her, we are represented in meetings and in some discussions in the community. If we have issues and concerns, we lobby these to our leader. (Isip miyembro sa komunidad, gihatagan kami ug oportunidad nga mupartisipar sa mga meeting ug diskusyon. Kung aduna man desisyon nga pagabuhaton sa komunidad, ginakonsulta kami. Makapahayag kami sa amoa tingog kabahin sa pagkonserbar sa mga osa. Maong ang amoa grupo giila sa barangay.)* Forest guard, Barangay Tambobong, Davao City, Interview number 4.

Laws, Legal Rights, Policies, and Institutions

Property ownership. The legal rights of the Obu Manuvu tribe have been defined by Philippine laws stipulated in the Indigenous People's Rights Act (IPRA) of 1997, or Republic Act No. 8371. Laws and policies that protect the rights of the members of the community and their ancestral lands are also provided by the Pusaka council/council of elders, following the policies stipulated in RA 8371. Pusaka council is a community-based association or organization of the indigenous group of Obu Manuvu. It strengthens IP protection and management of local conserved areas, enforces IP customary laws on sacred areas and policies for conservation actions, and increases local commitment through conservation initiatives. Through Pusaka, women and men in the OMAD are now allowed to speak about their brand of conservation and receive commendations from other IP groups. In performing their forest guard functions, women and men are also guided and protected by laws. Property ownership is best illustrated through the following statements:

> *In our work as forest guards, law protects us all. One of the laws that protect us is the Indigenous People's Right Act (IPRA) of 1997 or Republic Act No. 8371. The Pusaka Council also governs us. This Pusaka Council is our council of elders from the Indigenous People of Obu Manuvu that also protect our rights in the community, and our ancestral lands. (Sa amoang trabaho isip gwardiya sa kalasangan, ang balaod nagaprotekta kanamo. Isa sa mga balaod nga nagaprotekta kanamo mao ang Indigenous People's Rights Act (IPRA) 1997 o gitawag nga Republic Act No. 8371. Gidumalaan pod kami sa Pusaka Council. Ang Pusaka Council ang amoang council of eleders gikan sa Indigenous People sa Obu Manuvu nga nagaprotekta sa amoang katungod sa komunidad, ug sa amoang ancestral land.)* Forest guard, Barangay Salaysay, Davao City, Interview number 1.

People's priorities and needs/ opportunities and constraints

Need for livelihood programs. The livelihood program is considered one of the priorities and needs of some members of the Obu Manuvu community. Providing livelihood programs, as emphasized by community members, especially the forest guards, is seen as a way to alleviate poverty. If both women and men can benefit from these programs, it is expected that the employment rate will increase and the needs of their families will be met. Unfortunately, due to limited support for their ecosystem services or labor in forest conservation, forest guards often have to use their own materials and funds such as bags and food allowance during conservation activities. This means that instead of earning a livelihood, some of the forest guards spend their resources for conservation work. A forest guard best expresses the need for livelihood programs:

> *We would like to let you know of our concerns. Our number one problem is to get a main source of income. While our allowances as forest guards helped us with some of our needs at home, it is not enough to feed the whole family. That is why we appeal to government to provide us with livelihood programs. (Gusto namo ipahibalo ang amoa mga mulo. Ang numero uno namo nga problema mao ang makakuha ug main source of income. Samtang ang among mga allowance isip mga guwardiya sa kalasangan nakatabang kanamo sa pipila sa among mga panginahanglan sa balay, kini dili igo sa pagpakaon sa tibuok pamilya. Mao nga naghangyo kami sa gobyerno nga hatagan kami mga programa sa panginabuhi.)* Forest guard, Barangay Tambobong, Davao City, Interview number 3.

DISCUSSION

Gender Gaps

Access to education and employment preferences. Gender gaps have appeared in access to education for women and men in the Obu Manuvu population. Although these gaps have narrowed over time, significant disparities still exist among indigenous peoples (Reimão and Tas 2017). Among the Obu Manuvus, the gaps are linked to poverty, as indicated by the average monthly income of the forest guards, which ranges from PHP 900.00 to PHP 11,250.00. The Obu Manuvus heavily rely on their ancestral domains, particularly forest resources like deer meat, for their food and livelihood. This is consistent with the socio-economic reliance on forest products and wildlife observed in rural areas of developing countries (Mukul et al. 2015; Garekae et al. 2017; Ali et al. 2020). The rural poor often depend on various natural resources and ecosystem services, and therefore, they are affected by its degradation (Adams et al. 2012; Matos 2022).

Both women and men in the Obu Manuvu community are involved in the conservation of Philippine brown deer. Men, in particular, have a duty to protect their ancestral domains. The Obu Manuvus derive their livelihood from farming on their traditional lands. However, due to poverty, both women and men face challenges in completing formal education. Addressing gender issues in conservation

is crucial, as it requires considering the challenges faced by women and men in terms of workload, perception, and traditional gender roles and expectations (Evans 2017).

Moreover, gender relations play an essential role in biodiversity conservation (Alvarez and Lovera 2016) partly because women and men have different roles within the farming household (Al Mubarak 2021). These roles entail additional responsibilities related to variety selection and maintenance. For example, women are often required to travel to distant areas to collect water, timber, plants, and animal products (Al Mubarak 2021). Furthermore, women and men have different perspectives on farm-related matters, contributing to a more holistic approach to farming. While it is difficult to determine who can better represent the farming system, acknowledging the significance of differentiating women's and men's needs and knowledge is crucial.

Gender Parity

Access to information and training programs, employment services, equal participation, and property ownership. Women and men have equal access to information and training programs, employment services, and property ownership. Biodiversity conservation offers an opportunity for conservation practitioners and local communities to access comprehensive guidelines and training by addressing gender equality in their activities (Westerman 2021). Advances in science, technology, and social sciences provide significant opportunities for developing alternative solutions and disseminating information. This means that both genders are equally capable of engaging in conservation decisions and actions.

Moreover, biodiversity conservation initiatives provide an opportunity for local communities to engage and contribute to addressing biodiversity degradation while creating employment opportunities. In recent years, business corporations have integrated biodiversity conservation into their operational strategies (Torelli and Balluchi 2022). Working with local partners who possess knowledge of the status of regional or national ecosystems is key to identifying the long-term benefits of biodiversity and effective conservation measures. Potential partners include, but are not limited to, government agencies, local communities, conservation NGOs, and private sector actors, such as timber concessionaires.

Collaborative efforts involving various stakeholders can be facilitated by local, national, or international NGOs (Visseren-Hamakers et al. 2012; Romero-Brito et al. 2016). By adopting a "gendered approach" to conservation, organizations such as NGOs and LGUs believe can achieve environmental and social outcomes by involving women in community discussions and management (Evans 2017; Yang et al. 2018). Similarly, it is essential to document the gender roles of Obu Manuvu women and men as a baseline for promoting equal rights, inclusive participation, and women's empowerment.

Issues and Concerns

Need for livelihood programs. Although the Obu Manuvus were provided with an opportunity in terms of their access to training programs to pursue deer conservation, it was also reported that the need for livelihood programs greatly concerned them (Villegas et al. 2022a, b). Many studies have been conducted on the association between the degree of engagement of indigenous peoples in conservation programs and livelihood interventions (Bridgewater et al. 2015; Oldekop et al. 2015; Nguyen et al. 2019; Fa et al. 2020; Di Sacco et al. 2021). For conservation initiatives to be successful, it is also necessary to simultaneously enhance local livelihoods. There is a need to prioritize payment for ecosystem services to sustain local conservation efforts (Bhatta et al. 2014; Kaiser et al. 2021).

The main reason gender is considered in conservation is to protect nature for the well-being of people. When making decisions about conservation, it is important to consider that both women and men should have the right and ability to participate, as they are both users of natural resources (Evans 2017). To sustain and strengthen these efforts, it is crucial to provide adequate training and support, including capacity-building initiatives and financial remuneration for the forest guards. There is a need to ensure that the Obu Manuvu community can continue to protect and preserve this sacred species for generations to come.

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ETHICAL CONSIDERATIONS

Before conducting this study, all necessary consents were secured according to the Indigenous Peoples Rights Act of 1997 and other related laws and regulations promulgated by the Philippine government. Foremost is the Free, Prior, and, Informed Consent (FPIC) to ensure the protection of the indigenous community's economic, social, and cultural well-being. The Obu Manuvu tribal leaders and elders issued Resolution No. 1, s. 2019, approving the study conduct. Finally, all participants in this study were

asked to sign a consent form, wherein the objectives, procedures, risks, and confidentiality terms were elaborated.

DECLARATION OF COMPETING INTEREST

The authors declare no competing interests.

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REFERENCES

Adams WM. 2012. Conservation in the Anthropocene: Biodiversity, Poverty and Sustainability. In: Roe D, Elliott J, Sandbrook C and Matt Walpole (eds). Biodiversity Conservation and Poverty Alleviation: Exploring the Evidence for a Link. John Wiley and Sons, Ltd., pp. 304-315.

Al Mubarak R. 2021. Why women have an essential role in biodiversity conservation. Climate Champions. https://climatechampions.unfccc.int/why-women-have-an-essential-role-in-biodiversity-conservation/. Accessed on 24 June 2022.

Ali N, Hu X and Hussain J. 2020. The dependency of rural livelihood on forest resources in northern Pakistan's Chaprote Valley. Global Ecology and Conservation, 22: e01001. https://doi.org/10.1016/j.gecco.2020.e01001

Alvarez I and Lovera S. 2016. New times for women and gender issues in biodiversity conservation and climate justice. Development, 59: 263–265. https://doi.org/10.1057/s41301-017-0111-z

Bhatta LD, Van Oort BE, Rucevska I and Baral H. 2014. Payment for ecosystem services: Possible instrument for managing ecosystem services in Nepal. International Journal of Biodiversity Science, Ecosystem Services and Management, 10(4): 289-299. https://doi.org/10.1080/21513732.2014.973908

BMB-DENR (Biodiversity Management Bureau – Department of Environment and Natural Resources). 2020. Philippine Red List of threatened wild fauna. 120pp. https://www.biodiversity.ph/wp-content/uploads/2020/08/PRLC-Book-vertebrates.pdf. Accessed on 24 June 2022.

Bridgewater P, Régnier M and García RC. 2015. Implementing SDG 15: Can large-scale public programs help deliver biodiversity conservation, restoration and management, while assisting human development? Natural Resources Forum, 39(3-4): 214-223. https://doi.org/10.1111/1477-8947.12084

CBD (Convention on Biological Diversity). 2017. What is gender and biodiversity? https://www.cbd.int/gender/biodiversity. Accessed on 21 January 2023.

Creswell J. 2014. Research Design (4th ed.). California, United States of America: SAGE Publications, Inc. 42pp.

Di Sacco A, Hardwick KA, Blakesley D, Brancalion PHS, Breman E, Rebola LC, Chomba S, Dixon K, Elliott S and Ruyonga G et al. 2021. Global Change Biology, 27(7): 1328-1348. https://doi.org/10.1111/gcb.15498

Evans R. 2017. Why gender matters in conservation. Mongabay. https://news.mongabay.com/2017/05/qa-with-a-champion-of-the-gendered-approach-to-conservation/#. Accessed on 24 June 2022.

Fa JE, Watson JE, Leiper I, Potapov P, Evans TD, Burgess ND, Molnár Z, Fernández-Llamazares Á, Duncan T and Wang S et al. 2020. Importance of Indigenous Peoples' lands for the conservation of intact forest landscapes. Frontiers in Ecology and the Environment, 18(3): 135-140. https://doi.org/10.1002/fee.2148

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin S, Coe MT, Daily GC, Gibbs HK, et al. 2005. Global Consequences of Land Use. Science, 309: 570-574. http://dx.doi.org/10.1126/science.1111772

Garekae H, Thakadu OT and Lepetu J. 2017. Socio-economic factors influencing household forest dependency in Chobe enclave, Botswana. Ecological Processes, 6: 40. https://doi.org/10.1186/s13717-017-0107-3

James R. 2023. Breaking the bias: How to deliver gender equity in conservation. Nature. https://doi.org/10.1038/d41586-023-00779-7

Kaiser J, Haase D and Krueger T. 2021. Payments for ecosystem services: A review of definitions, the role of spatial scales, and critique. Ecology and Society, 26(2): 12. https://doi.org/10.5751/es-12307-260212

Leisher C, Temsah G, Booker F, Day M, Agarwal B, Matthews E, Roe D, Russell D, Samberg L and Sunderland T et al. 2015. Does the gender composition of forest and fishery management groups affect resource governance and conservation outcomes: A systematic map protocol. Environmental Evidence, 4: 13. https://doi.org/10.1186/s13750-015-0039-2

MacKay F. 2017. Indigenous Peoples' rights and conservation: Recent developments in human rights jurisprudence. Forest Peoples Programme. https://www.forestpeoples.org/en/rights-based-conservation/news-article/2017/indigenous-peoples-rights-and-conservation-recent. Accessed on 24 June 2022.

MacKinnon JR, Ong P and Gonzales J. 2015. *Rusa marianna*. The IUCN Red List of Threatened Species 2015: e.T4274A22168586. https://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T4274A22168586.en. Accessed on 24 June 2022.

March C, Smyth I and Mukhopadhyay M. 1999. A Guide to Gender-Analysis Frameworks. Oxfam. Retrieved from Oxford. www.ndi.org/files/Guide%20to%20Gender%20Analysis%20Frameworks.pdf. Accessed 15 December 2023.

Matos A. 2022. Poverty alleviation, ecotourism, and biodiversity protection in Principe Island. In: Information Resources Management Association (ed). Research Anthology on Ecosystem Conservation and Preserving Biodiversity. IGI Global, Hershey, pp. 1640-1656. https://doi.org/10.4018/978-1-6684-5678-1.ch079

Mukul SA, Rashid AZ, Uddin MB and Khan NA. 2015. Role of non-timber forest products in sustaining forest-based livelihoods and rural households' resilience capacity in and around protected area: A Bangladesh study. Journal of

Environmental Planning and Management, 59(4): 628-642. https://doi.org/10.1080/09640568.2015.1035774

Nguyen T, Lawler S, Goldoftas B and Le C. 2019. Biodiversity conservation or Indigenous People's welfare: A dilemma for forest management in Vietnam's BU Gia Map National Park. Community Development, 50(4): 406-421. https://doi.org/10.1080/15575330.2019.1642927

Ochola WO, Sanginga PC and Bekalo I. 2010. Managing Natural Resources for Development in Africa: A Resource Book. International Development Research Centre. Ontario, pp. 212-214.

Oldekop JA, Holmes G, Harris WE and Evans KL. 2015. A global assessment of the social and conservation outcomes of protected areas. Conservation Biology, 30: 133-141. https://doi.org/10.1111/cobi.12568

Parks MH, Christie ME and Bagares I. 2015. Gender and conservation agriculture: constraints and opportunities in the Philippines. Geography Journal, 80: 61–77. https://doi.org/10.1007/s10708-014-9523-4

Ravenelle J and Nyhus PJ. 2017. Global patterns and trends in human-wildlife conflict compensation. Conservation Biology, 31(6): 1247-1256. https://doi.org/10.1111/cobi.12948

Reimão ME and Taş EO. 2017. Gender education gaps among Indigenous and Non-Indigenous groups in Bolivia. Development and Change, 48(2): 228-262. https://doi.org/10.1111/dech.12292

Rizzolo JB, Delie J, Carlson SC and Dietsch AM. 2023. Gender differences in wildlife-dependent recreation on public lands. *Frontiers in* Conservation Science, 4. https://doi.org/10.3389/fcosc.2023.1006150

Romero-Brito TP, Buckley RC and Byrne J. 2016. NGO partnerships in using ecotourism for conservation: Systematic review and meta-analysis. PLOS ONE, 11(11): e0166919. https://doi.org/10.1371/journal.pone.0166919

Srinivas H. 2015. The GDRC Framework on Gender and Development. The Global Development Research Center. https://www.gdrc.org/gender/gdrc-genderframework.html. Accessed on 22 February 2024.

Tanalgo KC. 2017. Wildlife hunting by indigenous people in a Philippine protected area: A perspective from Mt. Apo National Park, Mindanao Island. Journal of Threatened Taxa, 9(6): 10307-10313. https://doi.org/10.11609/jott.2967.9.6.10307-10313

TUOMTC (The Unified Obu Manuvu Tribal Council). 2017. Caring for Pusaka: A Primer. Obu Manuvu of Davao City, Philippines. 5pp.

Torelli R and Balluchi F. 2022. Biodiversity management approaches in small and innovative businesses: insights from a systems thinking perspective. Social Responsibility Journal, 19(7): 1297-1319. https://doi.org/10.1108/SRJ-03-2022-0113

Visseren-Hamakers IJ, Leroy P and Glasbergen P. 2012. Conservation partnerships and biodiversity governance: Fulfilling governance functions through interaction. Sustainable Development, 20(4): 264-275. https://doi.org/10.1002/sd.482

Villegas JP, Ibañez JC and Cabrido CKT. 2022a. Abundance and distribution of the Philippine Brown Deer (*Rusa marianna* Desmarest, 1822) in the Obu Manuvu Ancestral Domain, Mindanao Island, Philippines. Acta Biologica Universitatis Daugavpiliensis, 22(1): 68-89.

Villegas JP, Ibañez JC and Rosales JR. 2022b. Conservation and population status of the Philippine warty pig (*Sus philippensis*) within the Obu Manuvu Ancestral Domain in Davao City, Mindanao Island, Philippines. Sylvatrop, 32(1): 1-14.

Westerman K. 2021. Unpacking the perceived benefits and costs of integrating gender into conservation projects: Voices of conservation field practitioners. Oryx, 55(6): 853-859. https://doi.org/10.1017/s0030605320001295

Yang YE, Passarelli S, Lovell RJ and Ringler C. 2018. Gendered perspectives of ecosystem services: A systematic review. Ecosystem Services, 31: 58-67. https://doi.org/10.1016/j.ecoser.2018.03.015

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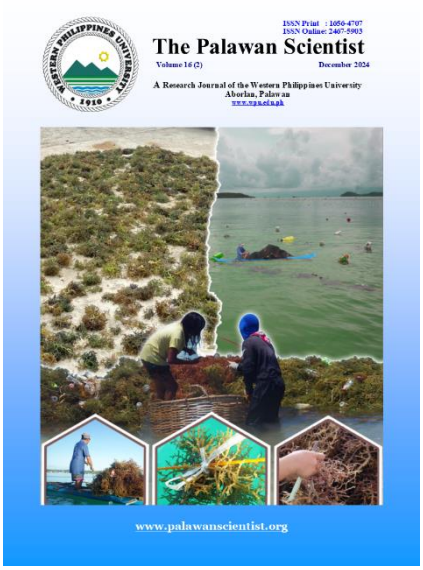

Flexible learning in graduate education of State Universities and Colleges in the Davao Region, Philippines

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ABSTRACT

This concurrent mixed-methods study investigates the landscape of flexible learning in graduate education among 41 coursework academic programs at five State Universities and Colleges (SUCs) in the Davao Region, Philippines. Data collection included an online survey with 422 graduate students and interviews with ten graduate program enrollees. The study employed a combination of statistical mean analysis and Colaizzi's phenomenological data analysis framework for data interpretation. Through the Community of Inquiry (CoI) framework, this research indicates high ratings for the three essential dimensions of CoI Theory - teaching, social, and cognitive presence, reflecting a significant level of satisfaction with flexible learning in the graduate education programs offered by State Universities in the Davao Region. Guided by Schlossberg's Transition (ST) Theory, this study uncovers promising opportunities associated with flexible learning. Graduate students are presented with the prospects of self-directed learning, financial and time savings, enhancement of digital skills, multitasking abilities, and the cultivation of crucial soft skills. However, flexible learning is not exempt from limitations, including challenges on unreliable internet connectivity, power interruptions, electronic device-related risks, financial stress, and balancing multiple work and academic responsibilities. To surmount these challenges, graduate students employ various coping strategies such as effective time management, maintaining a positive outlook, and seeking support from family, colleagues, classmates, friends, and their institutions. This research contributes to enhancing the sustainability and enrichment of flexible learning in graduate education. It strongly advocates for a comprehensive analysis of a multifaceted framework, alignment of flexible learning with graduate students' preferences, and a nuanced understanding of the evolving landscape of flexible learning in graduate education.

Keywords: colleges, concurrent mixed-methods design, flexible learning, and state universities

INTRODUCTION

Flexible learning, also known as blended learning, has gained widespread adoption in academic institutions in response to the COVID-19 pandemic, reshaping conventional learning paradigms. In response, institutions started implementing web-based learning and traditional place-based classroom methods (Singh et al. 2021). However, despite its success, scholars like Gacotano et al. (2021) have highlighted a plethora of challenges, including the lack of network access, economic instability, the digital

divide, a shortage of digital devices, distractions in the learning environment, expensive internet data, health-related problems, resource scarcity, digital illiteracy, and reduced motivation. Rotas et al. (2020) further underscore the problems of unstable internet connectivity, inadequate learning resources, power interruptions, vague learning contents, overloaded lesson activities, limited teacher guidance, poor peer communication, conflicts with home responsibilities, subpar learning environments, financial constraints, compromised physical health, and mental health challenges in flexible learning.

Moreover, student perceptions of flexible learning during the pandemic, as reported by Al-Mawee et al. (2021), reflect a spectrum of emotions, indicating a complex picture. The study by Xu and Jaggars (2014) reveals that students who previously struggled academically in traditional face-to-face settings may face even more significant hurdles when transitioning to distance learning, resulting in lower grades. Notably, hybrid learning, as a form of flexible learning, presents its challenges, including the need for reliable internet access, the imperative for effective time management to complete virtual coursework, and the risk of distractions (Carlton 2020). However, it is essential to acknowledge that flexible learning has empowered students with enhanced self-regulated learning abilities, enabling them to effectively engage in learning activities within this evolving educational landscape (Turan et al. 2022).

While an expanding body of literature acknowledges the transformative potential of flexible learning in reshaping contemporary education, a conspicuous research gap remains, particularly in its application to graduate education within State Universities and Colleges (SUCs) in the Davao Region, Philippines. As Müller and Mildenberger (2021) aptly recommended, there is a pressing need for additional high-quality primary studies across diverse academic disciplines to investigate flexible learning in graduate education. These studies should adhere to rigorous methodological standards to validate existing findings and assess the efficacy of flexible learning in diverse academic disciplines and settings. It is essential to include a broad spectrum of disciplines, enabling a comprehensive examination of the contextualization of flexible learning and its suitability for various subject areas.

This concurrent mixed-methods study explores the future of education by closely examining the adoption and sustained incorporation of flexible learning within graduate programs at State Universities and Colleges (SUCs) in the Davao Region, Philippines. Furthermore, it delves into the educational journeys of graduate students within the domain of flexible learning, utilizing the lenses of the CoI and ST theories to offer insightful perspectives. To this end, it uses a survey to assess the dimensions of teaching, cognitive, and social presence, providing valuable insights into the educational journeys of graduate students. In addition, in-depth interviews are employed to unearth the nuanced experiences of graduate students engaged in flexible learning. By artfully integrating both quantitative and qualitative research designs, this study aspires to offer a comprehensive understanding of graduate students' experiences in flexible learning, affording a well-rounded and insightful perspective on the subject. The study's primary objectives include: 1. To determine the teaching, social, and cognitive presence in the educational experiences of graduate students engaged in flexible learning; and 2. To explore the educational encounters of graduate students, including the opportunities, limitations, coping strategies, and support mechanisms that contribute to effective flexible learning.

METHODS

This section presents a comprehensive overview of the fundamental elements necessary for the research conducted in this study. It includes detailed explanations of key components, including the research design, study participants, research site, sampling methodology, research instruments employed, data collection approach, and the subsequent data analysis process. These elements collectively establish the framework that guides the research endeavors of this study.

Research Design

This study used a concurrent mixed-methods approach, as outlined by Sukiman et al. (2022), allowing for the simultaneous collection of quantitative and qualitative data. A concurrent mixed-methods procedure involves the researcher's adept integration of quantitative and qualitative data to provide a thorough and holistic analysis of the research problem (Creswell 2009).

In the quantitative phase, an online survey was conducted to determine the levels of teaching, social, and cognitive presence in graduate students' educational experiences in flexible learning. The qualitative phase explored the diverse aspects of graduate students' educational experiences, encompassing their perceptions of opportunities, limitations, coping strategies, and support structures in flexible learning.

Research Site

The study was carried out across five State Universities and Colleges (SUCs) in the Davao Region, Philippines, namely Davao del Norte State College, Davao del Sur State College, University of Southeastern Philippines, Davao Oriental State University, and Southern Philippines Agri-Business

and Marine and Aquatic School of Technology, offer a diverse array of graduate programs.

Sampling Procedure

For this study, a combination of sampling methods was thoughtfully employed. As Rahman et al. (2022) advocated, simple random sampling was used in the quantitative phase, while purposive sampling was employed in the qualitative, step in line with Thomas (2022). In the quantitative phase, the study involved 422 respondents, all graduate students enrolled in State Universities and Colleges (SUCs) in the Davao Region and actively participating in flexible learning programs. This diverse group of graduate students represented 41 academic disciplines clustered to 11 areas and was selected based on their availability and willingness to provide valuable insights (Table 1). In the qualitative phase, ten informants were chosen purposively from the pool of graduate students participating in flexible learning programs. The aim is to ensure a balanced representation of perspectives, including positive, negative, or mixed experiences with flexible learning. All participants are currently enrolled in a graduate program, contributing to a comprehensive understanding of the flexible learning landscape in the region. It is worth noting that the sampling criteria excluded indigenous peoples, minors, and pregnant women in the research's quantitative and qualitative phases.

Table 1. Respondents of the study (n = 422).

Graduate Programs per Cluster	Number of Respondents	Percentage of Respondents
Doctor of Education (Educational Leadership and Management/Educational Management) Doctor of Philosophy in Education major in Educational Leadership and Educational Management	83	20
Doctor of Philosophy (Biology/Development Research Administration/Horticulture)	4	1
Master in Business Administration/Public Administration/Economics/Econometrics	48	11
Master in Agriculture/Environmental Science/ Fisheries Management/Marine Biodiversity/Engineering	30	7
Master of Arts in Educational Management/Master of Educational Management	153	36
Master in Education/Extension Education/Technology Education	24	6
Master of Arts in Education/Basic Education/Special Education/Guidance and Counseling/Master of Education	32	8
Master of Arts in Language Teaching/Teaching English/English Language Teaching/Master in Education in Language Teaching	15	4
Master of Science in Teaching Mathematics/ Master of Arts in Mathematics Education/Teaching Math	5	1
Master of Science Teaching (General Science/Biology)/Master of Arts in Science Teaching	28	7
Total	422	100

Research Instrument

This study employed two primary data collection tools: a survey questionnaire and an interview guide. For the quantitative phase, the research utilized a well-established and validated questionnaire developed by Arbaugh et al. (2008). It was adapted, contextualized, and validated by validators who are experts in this field. This questionnaire features structured questions centered around teaching, social, and cognitive presence and employs a five-point Likert scale to measure responses. Additionally, a pilot test was done among graduate students from the five SUCs to ensure questionnaire validity and reliability. The adapted questionnaire has a Cronbach alpha coefficient of 0.968. A Cronbach's Alpha of 0.70 or higher is considered good, 0.80 or higher is better, and 0.90 or higher is outstanding. A Cronbach's Alpha of 0.60 or higher is deemed satisfactory (UCLA 2021).

Conversely, an interview guide was developed in the qualitative phase, and its validity was confirmed through consultation with two experts. Additionally, the guide underwent a trial run with two individuals not participating in the study, ensuring its effectiveness and clarity. The interview guide consisted of open-ended questions designed to elicit detailed insights from students concerning their academic experiences in flexible learning, focusing on promising opportunities, encountered limitations, coping strategies, and the presence of necessary support for effective learning.

Data Collection Procedures

This study harnessed the power of Google Forms, a platform outlined by Ball (2019), to administer online surveys and streamline capturing responses from in-depth interviews. Before data collection, formal permissions were diligently obtained from the presidents of the concerned State Universities and Colleges (SUCs) in the Davao

Region. Before the commencement of interviews, the study adhered to ethical protocols by obtaining informed consent from all participants. This process ensured that individuals understood the study's objectives and willingly participated in the interview process.

Data Analysis

The analysis of data involved both quantitative and qualitative approaches. Quantitative data on the levels of teaching, social, and cognitive presence in students' academic experiences were assessed using the mean, as outlined by Bland (2015). Collaizi's phenomenological data analysis framework, guided by Praveena and Sasikumar (2021), was employed for the qualitative data. The analysis process commenced with a comprehensive reading of each transcript to better understand flexible learning in graduate education. Subsequently, notable statements on flexible learning in graduate education were extracted from each transcript. From these significant statements, meaningful insights were formulated. These formulated meanings were then organized into categories, clusters of themes, and overarching themes using the approach advocated by Wirihana et al. (2018). The study's findings were synthesized to provide a comprehensive portrayal of the landscape of flexible learning in graduate education. This synthesis illuminated the fundamental structure of flexible learning within the context of graduate education, offering an in-depth understanding of this educational modality.

RESULTS

Teaching, Social, and Cognitive Presence in Flexible Learning of Graduate Education of State Universities and Colleges in the Davao Region

Table 2 reveals the summary of the quantitative result of flexible learning of graduate education of state universities and colleges in the Davao Region in terms of the three domains, namely teaching, social, and cognitive presence. Each domain acquired a mean of 4.34, 4.03, and 4.18 respectively. The quantitative investigation from the lens of (CoI) revealed that the three domains of the educational experiences of the graduate students engaged in flexible learning have a high descriptive level.

Promising Opportunities, Limitations Coping, Strategies, and Support in Flexible Learning of Graduate Education at State Universities and Colleges in the Davao Region

From the lens of Schlossberg's Transition Theory, this research uncovers various opportunities within flexible learning for graduate students, encompassing autonomous self-learning, cost and time efficiency, digital skill advancement, multitasking finesse, and honing essential soft skills. Conversely, the canvas of flexible learning also presents its share of constraints, ranging from the vexation of unreliable internet connectivity and sporadic power disruptions to the potential risks posed by electronic devices, financial burdens, and the juggling act of work and academic responsibilities. In response, graduate students employ adaptive strategies such as prioritization, seeking guidance, diligent reading, relaxation techniques, fostering a positive mindset, and effectively managing their multifaceted responsibilities. A robust support network for optimizing flexible learning emanates from various quarters, including family, peers, colleagues, classmates, friends, and the institution (Table 3).

DISCUSSION

Teaching, Social, and Cognitive Presence in Flexible Learning of Graduate Education of State Universities and Colleges in the Davao Region

The study's findings, indicating a high teaching presence in the flexible learning context for graduate students, find substantial support in the literature reviewed. Pawan et al. (2003) emphasized teachers' interaction, facilitation, and direction in higher-order learning, aligning with the study's high teaching presence. Akyol et al. (2009) and Jackson et al. (2010) highlighted teaching presence as effective in online learning, influencing course structure and student satisfaction. The study's findings echo these observations, emphasizing the impact of teachers' actions on students' learning experiences and contentment. Additionally, Shea et al. (2006) and Akyol et al. (2009) stressed the importance of teaching presence in maintaining a community of learners, which resonates with the study's identification of high teaching presence fostering a sense of community among graduate students. Furthermore, Zhang et al. (2016) and Law et al. (2019) pointed out the role of teaching presence in enhancing social and cognitive engagement, mirroring the study's findings that teachers' interactions and direct instructions improve these aspects among graduate students. This result indicates that the planning, coordination, and management of cognitive and social processes to achieve learning outcomes that are personally meaningful and educationally valuable (Anderson et al. 2019) are already in place. Moreover, the ability of graduate students to identify with the community, communicate purposefully in a trusting environment, and develop interpersonal relationships by protecting their personalities is also very satisfactory. The extent to which learners can construct and confirm meaning through sustained reflection and discourse is very satisfactory.

Table 2. Teaching, social, and cognitive presence in flexible learning of graduate education of State Universities and Colleges in Davao Region, Philippines (n = 422).

Variables n =3	Mean (4.20 sd)	Descriptive Level
Teaching Presence	4.34	High
Social Presence	4.03	High
Cognitive Presence	4.18	High

Table 3. Promising opportunities, limitations, strengths, and support in flexible learning of graduate education of SUCs in the Davao Region, Philippines.

Flexible Learning in Graduate Education of SUCs in Davao Region, Philippines			
Promising Opportunities	**Limitations**	**Strategies**	**Support**
• Self-learning • Cost and time saving • Digital upskilling • Multitasking • Soft skills sharpening	• Poor internet connectivity • Electric power interruption • Hazards of electronic devices • Financial stress • Multiple work and school related tasks	• Consultation • Getting things done • Reading • Taking time to relax • Having positive attitude • Managing multiple tasks	• Family: moral and financial support • Colleagues: academic support • Classmates and friends: technical support • University or college: affordable tuition, online databases, mental health support, internet-savvy and inspiring faculty

Teachers have consistently emerged as significant catalysts for students' academic achievements, as demonstrated by Whittle et al. in their 2018 study. This research underscores the enduring presence and impact of teachers within the educational journey of graduate students, whether through online or in-person instruction. In recognition of their invaluable contribution, teachers should be lauded for their unwavering support as they navigate alongside students through the ever-evolving landscape of new learning modes. It is imperative for educational management to continually prioritize the recruitment and retention of dedicated teachers who are poised to adapt to and thrive within the dynamic educational landscape.

This study found a high social presence among graduate students in flexible learning settings, supported by literature. Shea et al. (2003) showed how social presence helps students project themselves into the learning community. This idea fits with the study's findings that authentic peer connections empower and engage students in learning. Bulu (2012) found that social presence boosts student satisfaction psychologically. The study found that graduate students' learning experiences are more satisfying and enriching when they feel socially present. Wei et al. (2012) added to this discussion by linking social presence, interaction, and collaborative learning. The study found that authentic connections empower and engage graduate students, and high social presence improves graduate students' enjoyment and collective learning experiences. Sung and Mayer (2012) stressed the importance of leaders in creating a learning community through positive influences, rapport, and peer connections. Social presence is crucial to a supportive and inclusive learning environment. In this context, Wei et al. (2012) emphasize that learners must perceive an appropriate degree of social presence to feel comfortable interacting with others, which, in turn, significantly enhances and improves student-to-student interactions. Effective communication social bonds within the group are crucial for maintaining an open conversation and social bonds to sustain the learning community (Thompson and MacDonald 2005).

Social presence plays a significant role in the educational journey of graduate students. They find peer support that inspires them to finish their studies. Thus, looking for a support system may help in graduate education. Additionally, the domain of cognitive presence is also defined as high, which means that the student's exploration and construction of ideas, technical resolution, and understanding is through collaboration and reflection in the learning group. Garrison (2003) stated that cognitive presence is the primary key to successful higher education. The essential element in the academic endeavor focuses on the student's talent and ability to encrypt meaning through reflection and continuous discussion (Garrison et al. 2000). Cognitive presence indicates that the teachers had a better understanding of the difficulty and development of the students as well as measuring the learning environment, which manifested to be an essential part of the learning setting (Garrison and Vaughan 2007).

This study demonstrates that flexible learning in graduate education aligns with the principles of andragogy, catering to the specific needs of adult learners. Within graduate education, a pivotal focus lies in refining higher-order thinking skills among graduate students. In this pursuit, the administration of graduate programs plays a crucial role in nurturing and sustaining the development of these critical higher-order thinking skills. Indeed, the paramount objective of graduate education is to foster the growth of these cognitive capabilities among students.

Promising Opportunities, Limitations Coping, Strategies, and Support in Flexible Learning of Graduate Education at State Universities and Colleges in the Davao Region

This study unveiled promising opportunities within flexible learning, enabling graduate students to

embark on self-directed learning, harness cost and time savings, elevate their digital prowess, master the art of multitasking, and refine essential soft skills. The following paragraphs delve into these transformative themes.

Self-learning. The program outcome of graduate education lies in fostering self-reliant, independent learners, whether working individually or collaboratively within teams. In the wake of the pandemic, adopting flexible learning has led graduate students to truly embrace this self-driven learning paradigm that empowers them to take charge of their educational journey at their own pace. As Milligan and Littlejohn (2014) astutely observed, this newfound autonomy allows students to determine how and when they engage with knowledge and educational activities. This shift in behavior and approach aligns seamlessly with Zimmerman's (2000) concept of self-regulation. Consequently, students have become more mindful of their responsibility for learning, relinquishing dependency and, in turn, supporting their peers in their learning endeavors, as articulated by Ayish and Deveci (2019).

Flexible learning is exceptionally well-suited for graduate education, primarily because the students are adult learners. Adult learners, as they already possess a degree of maturity and independence, typically require less direct oversight from professors and often prefer a self-directed learning approach. Nevertheless, it's vital to establish a robust feedback mechanism between students and professors. This feedback serves as a crucial communication bridge, affording professors insights into the student's progress and level of attainment. With this information, professors can make informed decisions regarding the students' individualized learning paths and program adjustments.

Cost and timesaving. Flexible learning is a beacon of cost-effectiveness and time efficiency for graduate students. In this mode of education, graduate students significantly curtail their expenditures by eliminating travel-related costs and the need for physical course materials. Notably, Belille (2022) emphasized that universities increasingly acknowledge the credits earned through online courses, often at a fraction of the cost of traditional in-person classes. Furthermore, the expenses associated with flexible learning remain minimal or virtually nonexistent, as there are no transportation costs, and the need for conventional course materials becomes obsolete. This notion aligns with Kumari's (2021) observation that learning via electronic devices and gadgets streamlines the educational process, allowing students to engage in lectures and coursework efficiently. Students can complete a week's worth of academic activities in approximately 70 hours, all from the comfort of their devices.

Flexible learning offers distinct advantages in graduate education, delivering substantial financial benefits to students and higher education institutions. It translates to significant student savings by minimizing transportation expenses and eliminating the need for costly course materials. Beyond the individual level, it's equally beneficial for higher learning institutions, as they experience reduced overhead costs related to electricity consumption and the maintenance of physical facilities. Moreover, flexible learning enables institutions to efficiently accommodate a larger student population by requiring fewer physical classrooms, ultimately promoting scalability and accessibility in higher education.

Digital upskilling. Digital technology is pivotal in flexible learning, significantly enhancing digital competence among graduate students. Hatlevik et al. (2015) noted that this heightened level of digital competence encompasses what can be referred to as "internet skills." Furthermore, Janssen et al. (2013) astutely observed that these digital technologies have become more intuitive and user-friendly. This transformation has profound implications, as it empowers students in terms of technical proficiency and the development of higher-order skills such as collaboration, creativity, and the ability to construct and refine ideas.

Flexible learning serves as a vital bridge, facilitating the journey of graduate students, particularly those needing to be more tech-savvy, to acclimate and excel in the new technologies. Within the flexible learning framework, graduate students are thrust into a dynamic landscape that requires familiarity with various learning platforms. For those facing challenges, particularly older students who may need to be more tech-fluent, there is a proactive response in the form of training or mentoring. This tailored support equips them with the necessary skills and knowledge to navigate the diverse digital platforms effectively. They are empowered to adapt to and thrive within the evolving technological landscape.

Multi-tasking. The allure of flexible learning for graduate students lies in its unique ability to accommodate multitasking. Graduate students can seamlessly integrate their academic commitments with the demands of their professional and household responsibilities. This phenomenon finds validation in the findings of Moreno et al. (2012), which underscore that students exhibit a greater tendency for multitasking in online courses compared to traditional face-to-face settings. In the online sphere, students engage in many concurrent activities, aided by the versatile nature of the internet. Reinforcing this notion, Manwaring et al. (2017) assert that when courses incorporate a blend of online and face-to-face components, students exhibit an even higher degree of multitasking within the online segment of the course. This way underscores the adaptability of flexible

learning in accommodating the multitasking proclivities of graduate students.

Soft-skill sharpening. Flexible learning goes beyond developing technical competencies and provides an ideal environment for nurturing essential soft skills among graduate students. The acquisition of these soft skills not only boosts their self-confidence but also equips them to become more effective colleagues, students, and future leaders. Online courses, specifically designed to facilitate dynamic and interactive learning experiences, encourage students to actively communicate and establish connections with their fellow learners. They actively participate in group discussions on course forums and confidently express their perspectives and ideas by virtually "raising their hands." This phenomenon is supported by the insights of Ramakrishnan (2002), who emphasizes that networking and effective communication are among the new proficiencies that can be developed through online classes, adding value dimension to the skill set of graduate students.

Drawing from the lens of the Community of Inquiry (CoI) framework, it becomes evident that the three dimensions of CoI play a significant role in fostering a deeply satisfying experience with flexible learning among graduate students in State Universities and Colleges (SUCs). Moreover, when considering Schlossberg's Transition Theory (ST Theory), flexible learning emerges as promising avenue. Graduate students utilize this modality to embark on a journey of self-directed learning, enjoy tangible cost and time savings, enhance their digital skills, effectively multitask, and sharpen their soft skills.

Flexible learning serves as a catalyst for honing a range of vital soft skills among graduate students. These skills include adept time management, effective communication, networking skills, and adaptability. Consequently, the continued integration of flexible learning is poised to produce graduates with a balanced blend of hard and soft skills – a quality highly sought-after by employers.

Limitations of Flexible Learning in Graduate Education

This study explores the dynamic landscape of flexible learning in graduate education, which presents both opportunities and challenges. These limitations include insufficient internet connectivity, occasional power disruptions, risks associated with electronic devices, financial stressors, and the need to balance work and academic responsibilities. Each of these challenges is examined in detail below.

Internet connectivity challenge. The first challenge is inadequate internet connectivity, which is a significant obstacle for flexible learning in graduate education, particularly for students in remote locations or areas with slow internet access. This connectivity issue can greatly hinder the learning process. Research by Hampton et al. (2021) emphasizes the profound impact of this challenge, as it reveals that students who rely solely on mobile phones due to poor connectivity often receive lower grades compared to those with better internet access. This aligns with the findings of Das (2020), who highlights that slow internet speeds and data usage restrictions further impede students'ability to effectively utilize educational resources. Poor internet connectivity remains a significant concern in flexible learning, particularly for graduate students in remote areas. These students are encouraged to explore potential solutions, such as finding a location with stable internet access during online classes. By taking proactive steps, connectivity issues can be managed, allowing for seamless participation in online learning.

Electric power interruptions. Another challenge in flexible learning is electric power interruptions. Since online classes rely on electronic devices, power outages can significantly disrupt the smooth conduct of these classes. Research by Castillo (2020) emphasizes that power outages are a primary concern for online learning, especially for students in areas with long-standing electricity problems. Verawardina et al. (2020) further highlight the plight of students in rural areas, where frequent power outages and interruptions necessitate support to ensure continuous connectivity in online classes.

Given the inevitability of power outages, whether planned or unexpected, teachers can adopt a practical approach by uploading learning resources well in advance to the learning management system. This strategy empowers students to utilize their time productively when the power is restored, ensuring that learning can continue without significant disruption. During downtime, students can access and engage with the uploaded materials, allowing for a continuous educational process.

Hazard of electronic devices. The use of electronic devices in online learning also presents potential hazards and health risks for graduate students. Research by Cheever et al. (2014) reveals that individuals who develop a dependency on their devices may experience anxiety when separated from them. Mobile and smartphones, as highlighted by Wacks and Weinstein (2021), can contribute to conditions such as depression, stress, and diminished self-esteem. Al Rashidi and Alhumaidan (2017) underscore the profound impact of electronic devices on personal lifestyles, which has resulted in a concerning increase in public health issues attributed to prolonged usage. Additionally, Klamm and Tarnow (2015) elucidate some of the adverse effects of electronic devices, including headaches, eye strain, sleep disturbances, social challenges, and dietary issues.

It is crucial to acknowledge that these hazards extend beyond the control of online learners.

Therefore launching an awareness campaign targeting educators and students is essential to promote responsible and healthy device usage in online learning.

Financial stress. While it is true that graduate students can save on travel expenses and educational institutions can curtail electricity and physical facility maintenance costs, adopting flexible learning can introduce its financial stressors. This stress stems from the necessity of acquiring remote learning devices and gadgets, which can be a significant financial burden. Matswetu et al. (2013) have highlighted students' prevalent financial challenges in online distance learning settings. Saavedra (2020) further underscores the struggles experienced by students in securing the means to sustain their academic requirements, particularly when accessing remote learning essentials like computers and devices. These difficulties are magnified in times of global crises and emergencies.

Attending graduate education indeed comes with its own set of expenses. Graduate students should be academically prepared and financially equipped as they embark on this academic journey. Graduate education, being a privilege, carries financial responsibilities. Graduate students are encouraged to explore avenues such as scholarships or financial support to assist them in managing their academic finances effectively.

Multiple work and school-related tasks. Graduate students often struggle with the demanding juggling of numerous works, school-related responsibilities, and family matters, which can pose a considerable challenge. This confluence of roles, encompassing work, academic pursuits, and family commitments, has elicited concerning feedback from students. Research by Carrier et al. (2015) sheds light on the cognitive consequences of multitasking. Attempting to tackle multiple tasks simultaneously can lead to the division of finite mental capacity among these functions, potentially resulting in reduced cognitive engagement in each task and a subsequent decline in overall task performance. Bellur et al. (2015) further elucidate the impact of this multitasking on academic performance, noting a negative relationship between concurrently managing multiple schoolwork and tasks and a student's Grade Point Average.

In conclusion, this journey has its set of challenges. These include grappling with issues such as unreliable internet connectivity, disruptive power interruptions, potential hazards of electronic devices, financial burdens, and juggling multiple work and school-related responsibilities. Managing these multifaceted responsibilities is undoubtedly challenging, and students must develop effective strategies for time management and task prioritization to ensure optimal performance across all domains.

Coping Strategies in Flexible Learning in Graduate Education

Graduate students effectively address the constraints of flexible learning by adopting various adaptive strategies. These approaches encompass proactively accomplishing tasks, seeking guidance and consultation when needed, engaging in comprehensive reading, taking moments for relaxation, maintaining a positive mindset, and skillfully managing the demands of multiple tasks. The following sections elaborate on these resourceful coping mechanisms.

Consulting. In the flexible learning landscape, consultation is a pivotal tool graduate students utilize for several purposes. It maps out the course, seeks clarity on lessons, and adopts it as a strategic approach to enhance their learning experience. As illuminated by Jordan et al. (2013), consultation is instrumental in helping students unlock their full potential and acquire the necessary skills, often under the nurturing guidance of the teacher. This process entails the teacher providing direction and creating meaningful learning experiences. Additionally, as Lenz (2015) underscores, consultation fosters a positive teacher-student relationship in the academic sphere. It encourages open dialogue and emotional sharing, fostering a supportive, collaborative skills development and leadership environment. Cadosales (2017) further reinforces the significance of consultation in facilitating students' engagement with their academic journey, leading to self-examination, emotional connections, and the development of the ability to assess their strengths and weaknesses in detail.

Consulting is vital in addressing uncertainties and challenges in the flexible learning context of graduate education. It provides graduate students and teachers an avenue for in-depth discussions, whether in face-to-face or online settings. Given the accessibility of teachers through various online platforms, educators need to make themselves readily available to assist graduate students, with the expectation that students observe online etiquette in their interactions. The combination of support and engagement enhances the quality of the learning experience.

Getting things done. In the face of various demanding tasks, graduate students demonstrate their exceptional ability to complete these undertakings, reflecting remarkable self-efficacy effectively. This self-efficacy drives students to excel by amplifying their commitment, unwavering perseverance, and wholehearted endeavor (Pintrich 2003). Getting things done signifies self-efficiency and significantly reduces the likelihood of academic setbacks, as those with robust self-efficacy tend to experience fewer failures (Kurbanoglu and Akim 2010). High levels of self-efficacy enable learners to become more self-reliant,

emboldening them to confront and overcome complex challenges inherent in their educational journey (Sadi and Uyar 2013).

Graduate students find themselves compelled to fulfill their academic requirements, as they need to do so to improve their academic performance and grades. In cases where graduate students encounter challenges in completing their school requirements, a practical approach may involve advising them to consider reducing their course load. This arrangement enables students to receive coursework that aligns with their individual capabilities and specific academic needs, thus ensuring a more manageable and effective learning experience.

Reading. In flexible learning, graduate students benefit immensely from robust reading practice, bolstering their understanding and comprehension of course material and empowering them to tackle the challenges of this mode of education effectively. As Eagleton and Dobler (2015) suggest, reading is a valuable tool for assessing the credibility of online information. Moreover, as Clarke et al. (2013) highlighted, academic success hinges on a student's ability to gather information from reading and comprehend, apply, and analyze it. Unrau and Alvernmann (2013) stress that reading comprehension skills are indispensable for students to meet their academic requirements, as reading transforms text into meaningful symbols that facilitate comprehension.

Critical reading is paramount to success in graduate education, particularly as adult learners are expected to undertake independent learning. To achieve this, graduate students must actively use various learning resources, including online databases, for their research projects. Given the proliferation of online resources, graduate students must develop discerning judgment when evaluating the utility of these resources for their educational journey.

Taking time to relax. Graduate students recognize the importance of relaxation as a vital coping strategy. Setting aside time for relaxation effectively reduces stress levels, enhances cognitive function, and elevates overall performance and productivity. Research conducted by Cornell University lends empirical support to this practice, revealing that taking breaks after study sessions leads to increased energy, heightened focus, improved productivity, and mental rejuvenation. Furthermore, indulging in enjoyable activities during relaxation, such as cooking, listening to music, or engaging in conversation, fosters happiness, amplifying productivity (Yeung, 2018).

Maintaining a work-life balance is crucial for graduate students. Pausing for moments of respite and rejuvenation is an essential component of their journey. They can explore various relaxation techniques that align with their preferences. Additionally, universities and colleges often provide facilities and programs to facilitate and promote these much-needed moments of relaxation.

Having a positive attitude. Maintaining a positive attitude plays a pivotal role in bolstering the morale of graduate students as they confront the challenges inherent in flexible learning. This optimistic outlook shapes their future with hope and empowers them to engage wholeheartedly in endeavors aimed at success. Research by Carver et al. (2010) underscores the substantial benefits of maintaining a positive attitude, as it equips individuals with enhanced coping skills, bolsters physical health, mitigates stress levels, and propels them toward the relentless pursuit of objectives. Furthermore, Scott (2022) notes that embracing the brighter side of situations leads to positive experiences characterized by reduced stress levels and a heightened appreciation for the significance of a healthy life. A positive attitude serves as a beacon of resilience and motivation for graduate students, guiding them through the intricate terrain of flexible learning and inspiring them to strive for success persistently.

Positivity, often described as a magnet for good vibes, significantly eases the academic journey of graduate students. It infuses their lives with optimism, making avoiding worries and negative thinking more attainable. A positive attitude, therefore, becomes an essential companion for every graduate student, enabling them to savor the educational experience and flourish in their academic pursuits. Its influence in fostering resilience and promoting an atmosphere of success is undeniable.

Managing multiple tasks. Graduate students can handle various tasks, and they can improve productivity. Effective management allows graduate students to finish their assignments in less time because their attention is focused, and they are not wasting time on distractions. Auld (2019) stressed that by properly managing the tasks, students can complete their work on time, stay connected and engaged with their learning, and have more time for their other activities and hobbies and spending time with family and friends.

Those who excel in time management relish a harmonious work-life balance and often earn accolades for their academic performance, completing their programs within the expected timeframe. In contrast, graduate students struggling with time management may experience academic setbacks, reflected in incomplete grades and prolonged program completion. Giving them clear task timelines and establishing a close monitoring system is advisable to help them enhance their management skills.

Resilient and adaptable graduate students employ various coping strategies to overcome these hurdles. These strategies include resourceful problem-solving, insightful consultations, voracious reading, well-deserved moments of relaxation, the cultivation

of positive mindsets, and the art of efficient multitasking.

Support for Effective Learning in Flexible Learning of Graduate Education

In flexible learning within graduate education, graduate students are not alone in their academic journey. They receive valuable support from a network encompassing family, colleagues, classmates, friends, and educational institutions. The ensuing sections delve into the significance and roles of these support systems.

Family financial and moral support. Graduate students often find invaluable encouragement through financial and moral support from their families, which fuels their determination to pursue advanced studies. This observation aligns with the research by Ghazi et al. (2010), emphasizing that students' motivation surges when their parents express appreciation for their achievements and performance. Further underscoring this familial influence, Chohan and Kohan (2010) reveal that learners attain tremendous academic success when their parents actively support their educational endeavors. Moneva et al. (2020) provide deeper insights, noting that the level of financial support from parents is closely linked to students' motivation, with optimism playing a key role in motivating learners to tackle their tasks. Interestingly, a higher degree of financial support from parents significantly amplifies students' motivation for academic success. This body of evidence underscores the importance of parents' financial and moral support in shaping learners' academic success.

Even as adults pursuing their graduate studies, graduate students greatly benefit from the unwavering support of their families. Financial assistance from family members can significantly alleviate the financial burden, especially during the demanding phases of thesis or dissertation writing. It proves advantageous to have a family member with a stable income who can contribute to the financial requirements of advanced studies. In cases where such familial financial support is not available, responsible financial planning, including budgeting for school fees and associated expenses, becomes essential. Beyond financial aid, the moral support provided by family members plays a pivotal role in maintaining high spirits and motivation throughout the academic journey. Encouragement, belief, and understanding from loved ones serve as an anchor that fortifies a graduate student's resolve and resilience as they navigate the challenges of higher education.

Colleagues for academic support. Graduate students find invaluable academic support from their colleagues, who play pivotal roles in their academic pursuits. These peers serve as valuable sources of information for data collection in research projects and provide crucial technological assistance. The significance of colleague support becomes evident in the findings of Boyle et al. (2010), where it is observed that students experience heightened motivation and engagement when they receive support from their peers. Additionally, their study skills improve, and they can discuss their academic workload and resolve personal challenges when colleague-mentoring support is in place. The importance of the colleague support system is further underscored by Muljana and Luo (2019), who emphasize their essential role in assisting online learners in surmounting barriers to learning. This support system also plays a critical part in fostering learner development, promoting engagement, and ultimately ensuring success in online education.

This result reinforces the timeless adage that "no man is an island." Graduate students thrive when they have the support of their peers in the academic journey. Having supportive colleagues in the academic sphere is a cornerstone of success in graduate education.

Classmates and friends for technical support. Graduate students, particularly those grappling with technical challenges, find essential assistance from their classmates and friends. Brindley (2014) highlights that engaging in distance learning demands qualities such as maturity, multitasking ability, goal-oriented focus, and the capacity to work independently and cooperatively. Consequently, online learners often establish effective collaborations with peers in virtual groups, forming the basis for creating their learning networks. Rumble (2000) underscores that the success of online students heavily hinges on the support they receive from peers. This perspective is reinforced by the research of McLoughlin and Alam (2014), which reveals that students are substantially aided in enhancing their skills for working with social media. Additionally, they report tangible benefits regarding collaboration with friends and peer networking online. Classmates and friends play a pivotal role in addressing technical challenges and fostering a supportive environment for effective collaboration and skill development in the digital landscape.

Implementing a "buddy system" proves to be a highly beneficial approach, particularly in the context of graduate education within flexible learning environments. This system involves the collaboration of two individuals who work as a cohesive unit, offering mutual support and guidance to one another.

University or college for affordable tuition, online databases, mental health support, and internet-savvy and inspiring faculty. State universities and colleges offer a range of invaluable resources that graduate students sincerely appreciate. These institutions are known for providing free tuition, granting access to comprehensive online databases, offering crucial mental health support programs, and

boosting a faculty that is both internet-savvy and inspirational. Graduate students enrolled in government-funded higher education institutions find immense satisfaction in the affordability of their education. They also benefit from unrestricted access to their institutions' online databases, which serve as invaluable tools for research and skill development, as noted by Reynolds (2021), Sult et al. (2013), and Mery et al. (2014). Equally crucial are the mental health support programs made available by these institutions. These programs foster a positive learning environment by ensuring that students are mentally healthy, willing to learn, actively engaged in school activities, well-connected within the school community, and contributors to a positive school culture, following Youth.gov (2005). Moreover, Frazer et al. (2017) observe that the faculty, equipped with the requisite internet proficiency and inspirational teaching skills, plays an essential role in online education. This alignment with effective online teaching, as emphasized by the Dominican University (2017), inspires students to succeed and fully realize their potential.

Universities and colleges are responsible for ensuring that graduate students receive the necessary support in flexible learning. To fulfill this mandate, these institutions should continue in offering programs that combine affordability delivering quality education. This provision should be complemented by state-of-the-art facilities, easily accessible databases, pertinent mental health support programs, and a dedicated faculty of high caliber guided by compassionate hearts. Furthermore, these educational institutions should continually refine their flexible learning approaches, using the insights and findings from studies like the one presented here. In doing so, they can provide graduate students with an ever improving and more enriching educational experience that aligns with the evolving needs of the academic landscape.

In conclusion, the value of a robust support system cannot be understated; it spans family, colleagues, classmates, friends, and the university or college itself. This study's findings provide a solid foundation for the sustainability and enhancement of flexible learning in graduate education both locally and on the global stage and underscore the critical importance of nurturing pedagogical, social, and cognitive presence within the flexible learning context. Graduate students' remarkable resilience and adaptability, underpinned by effective coping strategies and robust support systems, are central to the vision of enriching graduate education in the Davao Region and beyond. As a result of these compelling findings, further avenues for research are unveiled. The investigation of comprehensive frameworks, exploration of graduate student preferences, and examination of the evolving landscape of flexible learning in graduate education beckons, promising a future of ever-improving educational experiences.

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ETHICAL CONSIDERATIONS

The study meticulously adhered to a comprehensive set of ethical principles. The research instruments contained a concise orientation segment, elucidating the research's nature and the extent of participation required from the respondents and informants to ensure ethical compliance. Additionally, a robust framework of ethical safeguards was established. Before data collection, informed consent was thoughtfully administered, granting the respondents and informants the autonomy to freely accept or decline their participation. It is important to note that studies involving minors or individuals under 18 were conducted with the securement of consent statement forms. The significance of voluntary participation was emphatically communicated to all respondents and informants, allowing them to partake in the data gathering of their own volition. Their identities were cloaked using code names, respecting the respondents' and informants' right to privacy. This way safeguarded their anonymity and instilled a sense of security. The formulation of questions and the choice of language underwent rigorous scrutiny to ensure the utmost respect for respondents and informants, fostering a setting devoid of disrespect. Recognizing that the respondents and informants are professionals, they were accorded the respect and regard commensurate with their status. The study underscored the value of respecting individual differences and cultivating an inclusive environment that embraced diversity. Following the Data Protection Act of 2012, the study diligently upheld the privacy and security of personal data, safeguarding individuals from unwarranted intrusion. Potential risks that may have arisen while the study was diligently addressed, ensuring the safety and well-being of all involved parties. These ethical considerations fortified the research's integrity, guaranteeing the welfare and rights of all participants.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests to any authors.

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REFERENCES

Akyol Z, Arbaugh JB, Cleveland-Innes M, Garrison DR, Ice P, Richardson JC and Swan K. 2009. A response to the review of the community of inquiry framework. Journal of distance education, 23(2): 123-135.

Al-Mawee W, Kwayu KM and Gharaiber T. 2021. Student's perspective on distance learning during COVID-19 pandemic: A case study of Western Michigan University, United States. International Journal of Educational Research,2(100080): 1-13. https://doi.org/10.1016/j.ijedro.2021.1000800

Al Rashidi SH and Alhumaidan H. 2017. Computer vision syndrome prevalence, knowledge and associated factors among Saudi Arabia University Students: Is it a serious problem? International journal of health sciences, 11(5): 17.

Arbaugh JB, Cleveland-Innes M, Diaz SR, Garrison DR, Ice P, Richardson JC and Swan KP. 2008. Developing a community of inquiry instrument: Testing a measure of the Community of Inquiry framework using a multi-institutional sample. The Internet and Higher Education, 11(3-4): 133-136. https://doi.org/10.1016/j.iheduc.2008.06.003

Auld S. 2019. Time management skills that improve student learning. Australian Christian College. https://www.acc.edu.au/blog/time-management-skills-student-learning/. Accessed on 14 March 2023.

Ayish N and Deveci T. 2019. Student perceptions of responsibility for their own learning and for supporting peers' learning in a project-based learning environment. International Journal of Teaching and Learning in Higher Education, 31(2): 224-237.

Ball HL. 2019. Conducting online surveys. Journal of Human Lactation, 35(3):413-417. doi:10.1177/0890334419848734

Belille J. 2019. Benefits of flexible online learning environments for professionals. Washington State University Online Master in Business Administration. https://onlinemba.wsu.edu/blog/benefits-of-flexible-online-learning-environments-for-professionals/. Accessed on 14 March 2023.

Bellur S, Nowak KL and Hull KS. 2015. Make it our time: In-class multitaskers have lower academic performance. Computers in Human Behavior, 53: 63-70. https://doi.org/10.1016/j.chb.2015.06.027

Bland M. 2015. An introduction to medical statistics. 4th ed. Oxford: Oxford University Press.

Boyle F, Kwon J, Ross C and Simpson O. 2010. Student–student mentoring for retention and engagement in distance education. Open Learning: The Journal of Open, Distance, and e-Learning, 25(2): 115-130. https://doi.org/10.1080/02680511003787370

Brindley JE. 2014. Learner Support in Online Distance Education: Essential and Evolving. Richter O and Wiley D(eds). Online Distance Education: Towards a Research Agenda. Athabasca University Press, Athabasca University, Edmonton, Alberta, Canada, pp. 287-310. https://doi.org/10.15215/aupress/9781927356623.01

Bulu ST. 2012. Place presence, social presence, co-presence, and satisfaction in virtual worlds. Computers and Education. 58(1): 154-161. https://doi.org/10.1016/j.compedu.2011.08.024

Cadosales MNQ. 2017. Students' experiences with academic consultation. International Journal of Advanced Research, 5(5): 2092-2097. https://doi.org/10.21474/ijar01/4354

Carlton G. 2020. Hybrid classes: What are they, and pros and cons. 3. TheBestSchools. https://thebestschools.org/magazine/hybrid-classes-pros-cons/. Accessed on 10 October 2023

Carrier LM, Cheever NA, Rosen LD, Benitez S and Chang J. 2009. Multitasking across generations: Multitasking choices and difficulty ratings in three generations of Americans. Computers in Human Behavior, 25(2): 483-489.

Carver CS, Scheier MF and Segerstrom SC. 2010. Optimism. Clinical Psychology Review, 30(7): 879-889.https://doi.org/10.1016/j.cpr.2010.01.006

Castillo J. 2020. Distance learning? Don't take power availability for granted. Manila Bulletin. https://mb.com.ph/2020/09/25/distance learning-don't-take-power-availability-or-granted/. Accessed on 15 January 2023

Cheever NA, Rosen LD, Carrier LM and Chavez A. 2014. Out of sight is not out of mind: The impact of restricting wireless mobile device use on anxiety levels among low, moderate, and high users. Computers in Human Behavior, 37: 290-297. https://doi.org/10.1016/j.chb.2014.05.002

Chohan BI and Khan RM. 2010. Impact of parental support on the academic performance and self-concept of the student. Journal of Research and Reflections in Education, 4(1): 14-26.

Clarke PJ, Truelove E, Hulme C and Snowling MJ. 2013. Developing reading comprehension. John Wiley and Sons, Ltd. West Sussex, United Kingdom. 224pp.

Creswell JW. 2009. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 3rd ed. Sage Publications, Inc. 270pp.

Commission on Higher Education. Memorandum Order 04, Series 2020 on the Guidelines on the implementation of flexible learning. https://chedro3.ched.gov.ph/wpcontent/uploads/2020/10/CMO-No.-4-s.-2020-Guidelines-on-the-Implementation-of-Flexible-Learning.pdf. Accessed on 15 March 2023.

Cornell University. Study breaks and stress busters. https://health.cornell.edu/about/news/study-breaks-stress-busters. Accessed 15 March 2023.

Das R. 2020. Researchers show how slow the internet is leaving rural students behind. https://www.8newsnow.com/news/error-404-researchers-show-how-slow-internet-is-leaving-rural_students-behind/. Accessed on 15 March 2023.

Dominican University. 2017. Be an inspiring teacher. Online professional development courses for teachers - Dominican California Online. https://dominicancaonline.com/coaching-life-lessons/be-an-inspiring-teacher/. Accessed on 15 March 2023.

Eagleton MB and Dobler E. 2012. Reading the web. Guilford Press. New York, United States of America. 292pp.

Frazer C, Sullivan DH, Weatherspoon D and Hussey L. 2017. Faculty perceptions of online teaching effectiveness and indicators of quality. Nursing Research and Practice, 1: 1-6. https://doi.org/10.1155/2017/9374189

Gocotano TE, Jerodiaz MAL, Banggay JCP, Nasibog HBR and Go MB. 2021. Higher education students' challenges on flexible online learning implementation in the rural areas: A Philippine case. International Journal of Learning, Teaching and Educational Research, 20(7): 262-290. https://doi.org/10.26803/ijlter.20.7.15

Garrison DR, Anderson T and Archer W. 2000. Critical inquiry in a text-based environment: Computer conferencing in higher education. The Internet and Higher Education, 2(2-3): 87-105. https://doi.org/10.1016/S1096-7516(00)00016-6

Garrison DR. and Vaughan ND. 2007. Blended learning in higher education. Jossey-Bass. San Francisco, United States of America. 272pp.

Garrison DR. 2003. E-Learning in the 21st century. A Framework for Research and Practice, Routledge, London. 184pp.

Ghazi SR, Ali R, Shahzad S and Hukamdad H. 2010. Parental involvement in children academic motivation. Asian Social Science, 6(4): 93-99. https://doi.org/10.5539/ass.v6n4p93

Hampton KN, Robertson CT, Fernandez L, Shin I and Bauer JM. 2021. How variation in internet access, digital skills, and media use are related to rural student outcomes: GPA, SAT, and educational aspirations. Telematics and Informatics, 63: 101666. https://doi.org/10.1016/j.tele.2021.101666

Hatlevik OE, Ottestad G and Throndsen I. 2014. Predictors of digital competence in 7th grade: a multilevel analysis. Journal of Computer Assisted Learning, 31(3): 220-231. https://doi.org/10.1111/jcal.12065

Jackson LC, Jones SJ and Rodriguez RC. 2010. Faculty actions that result in student satisfaction in online courses. Journal of Asynchronous Learning Networks, 14(4): 78-96.

Janssen J, Stoyanov S, Ferrari A, Punie Y, Pannekeet K and Sloep P. 2013. Experts' views on digital competence: Commonalities and differences. Computers and Education, 68: 473-481.

Jordan P, Miller MA and Drake JK. 2013. Academic advising approaches: Strategies that teach students to make the most of college. John Wiley and Sons, New Jersey, United States of America. 304pp.

Klamm J and Tarnow K. 2015. Computer vision syndrome: a review of literature. Medsurg Nursing. 24(2): 89.

Kumari M. 2022. The effects of electronic gadgets in student life. https://www.kopykitab.com/blog/effects-of-electronic-gadgets-in-student-life/. Accessed on 15 March 2023.

Kurbanoglu N and Akin A. 2010. The relationships between university students' chemistry laboratory anxiety, attitudes, and self-efficacy beliefs. Australian Journal of Teacher Education (Online), 35(8): 48-59.

Law KMY, Geng S and Li T. 2019. Student enrollment, motivation, and learning performance in a blended learning environment: The mediating effects of social, teaching, and cognitive presence. Computer and Education. 136: 1-12. https://doi.org/10.1016/j.compedu.2019.02.021

Lenz B, Wells J and Kingston S. 2015. Transforming schools using project-based learning, performance assessment, and common core standards. John Wiley and Sons, New Jersey, United States of America. 304pp.

Manwaring KC, Larsen R Graham CR. Henrie CR and Halverson LR. 2017. Investigating student engagement in blended learning settings using experience sampling and structural equation modeling. The Internet and Higher Education, 35: 21-33. https://doi.org/10.1016/j.iheduc.2017.06.002

Matswetu VS, Munakandafa W, Munodawafa V and Mandoga E. 2020. Science student teachers' challenges and coping strategies in an open and distance learning environment in Zimbabwe. Makarere Journal of Higher Education, 4(2): 125-137. https://doi.org/10.4314/majohe.v4i2.1

McLoughlin CE and Alam SL. 2014. A case study of instructor scaffolding using Web 2.0 tools to teach social informatics. Journal of Information Systems Education, 25(2): 125-136.

Mery Y, DeFrain E, Kline E and Sult L. 2014. Evaluating the effectiveness of tools for online database instruction. Communications in Information Literacy, 8(1): 70-81.

Milligan C and Littlejohn A .2014. Supporting professional learning in a massive open online course. The International Review of Research in Open and Distributed Learning, 15(5): 197-213. https://doi.org/10.19173/irrodl.v15i5.1855

Moneva JC, Pestano RFL and Vertulfo RM. 2020. Parental financial support and students' motivation in learning. Issues in Social Science, 8(1): 9. https://doi.org/10.5296/iss.v8i1.16908

Moreno MA, Jelenchick L, Koff R, Eikoff J, Diermyer C and Christakis DA. 2012. Internet use and multitasking among older adolescents: An experience sampling approach. Computers in Human Behavior, 28(4): 1097-1102. https://doi.org/10.1016/j.chb.2012.01.016

Muljana PS and Luo T. 2019. Factors contributing to student retention in online learning and recommended strategies for improvement: A systematic literature review. Journal of Information Technology Education: Research, 18: 19-57. doi:10.28945/4182

Pawan F, Paulus TM, Yalcin S and Chang CF. 2003. Online Learning: Patterns of engagement and interaction among in-service teachers. Language Learning & Technology, 7(3): 119-140. http://dx.doi.org/10125/25217

Pintrich PR. 2003. A motivational science perspective on the role of student motivation in learning and teaching contexts. Journal of Educational Psychology, 95(4): 667-686. https://doi.org/10.1037/0022-0663.95.4.667

Praveena KR and Sasikumar S. 2021. Application of Colaizzi's method of data analysis in phenomenological research. Medico Legal Update, 21(2): 914-918. https://doi.org/10.37506/mlu.v21i2.2800

Rahman M, Tabash M, Salamzadeh A, Abduli S and Rahaman M.2022.Sampling techniques (probability) for quantitative social science researchers: A Conceptual Guidelines with examples. Southeast European University Review, 17(1): 42-51. https://doi.org/10.2478/seeur-2022-0023

Ramakrishnan M. 2022. How online learning can help improve these top 3 soft skills. Emeritus Online Courses. https://emeritus.org/blog/does-online-learning-improve-soft-skills/. Accessed on 15 March 2023.

Reynolds R. 2021. The impact of affordability. www.tel-education.org/the-impact-of-affordability/. Accessed on 15 March 2023.

Rotas EE. and Cahapay MB. 2020. Difficulties in remote learning: Voices of Philippine University students in the wake of COVID-19 Crisis. Asian Journal of Distance Education, 15(2): 147-158. https://doi.org/10.5281/zenodo.4299835

Rumble G. 2000. Student support in distance education in the 21st Century: Learning from service management. Distance Education, 21(2): 216-235.

Saavedra J. 2020. Educational challenges and opportunities of the Coronavirus (COVID-19) pandemic. World bank Blogs, https://blogs.worldbank.org/education/educational-challenges-and-opportunities-covid-19-pandemic. Accessed on 15 January 2023.

Sadi O and Uyar M. 2013. The relationship between self-efficacy, self-regulated learning strategies and achievement: a path model. Journal of Baltic Science Education, 12(1): 21-33. https://doi.org/10.33225/jbse/13.12.21

Scott E. 2022. The differences between optimists and pessimists. Very well Mind. www.verywellmind.com/the-benefits-of-optimism-3144811. Accessed on 15 March 2023.

Shea P, Sau Li C and Pickett A. 2006. A study of teaching presence and student sense of learning community in fully online and web-enhanced college courses. The Internet and Higher Education, 9(3): 175-190. https://doi.org/10.1016/j.iheduc.2006.06.005

Shea P, Pickett A and Pelz W. 2003. A follow-up investigation of teaching presence in the State University of New York Learning Network. Journal of Asynchronous Learning Networks, 7(2): 61-80. https://doi.org/10.24059/olj.v7i2.1856

Singh J, Steele K and Singh L. 2021. Combining the best of online and face-to-face learning: Hybrid and blended learning approach for COVID-19, post vaccine, & post-pandemic world. Journal of Educational Technology Systems, 50(2):140-171. https://doi.org/10.1177/00472395211047865

Sult L, Mery Y, Blakiston R and Kline E. 2013. A new approach to online database instruction: Developing the Guide on the Side. Reference Services Review, 41 (1), 125-133. https://doi.org/10.1108/00907321311300947

Sukiman S, Haningsih S and Rohmi P. 2022. The pattern of hybrid learning to maintain learning effectiveness at the higher education level post-COVID-19 pandemic. European Journal of Educational Research, 11(1): 243-257. https://doi.org/10.12973/eu-jer.11.1.243

Thomas FB. 2022. The role of purposive sampling technique as a tool for informal choices in a social science in research methods. Accessed on 15 March 2023.

Thompson TL and MacDonald CJ. 2005. Community building, emergent design and expecting the unexpected: Creating a quality eLearning experience. The Internet and Higher Education, 8(3): 233-249. https://doi.org/10.1016/j.iheduc.2005.06.004

University of California, Los Angeles: Statistical Consulting Group. 2021. What does Cronbach's Alpha mean? | SPSS FAQ. Stats.oarc.ucla.edu. https://stats.oarc.ucla.edu/spss/faq/what-does-cronbachs-alpha-mean/. Accessed on 15 October 2023.

Unrau N and Alvermann D. 2013. Literacies and their investigation through theories and models. Theoretical Models and Processes of Reading, New York, United States of America. 47-90pp.

Verawardina U, Asnur L, Lubis AL, Hendriyani Y, Ramadhani D, Dewi IP, Darni R, Betri TJ, Susanti W and Sriwahyuni T. 2020. Reviewing online learning facing the COVID-19 outbreak. Journal of Talent Development and Excellence, 12: 385-392.

Wang Y, Zhao L, Shen S and Chen W. 2021. Constructing a teaching presence measurement framework based on the Community of Inquiry Theory. Frontiers.https://www.frontiersin.org/articles/10.3389/fpsyg.2021.694386/full. Accessed on 15 March 2023.

Wacks Y and Weinstein AM. 2021. Excessive smartphone use is associated with health problems in adolescents and young adults. Frontiers in Psychiatry, 12: 669042. https://doi.org/10.3389/fpsyt.2021.669042

Wei CW, Chen NS and Kinshuk. 2012. A model for social presence in online classrooms. Educational Technology Research and Development, 60(3): 529-545. https://doi.org/10.1007/s11423-012-9234-9

Wirihana L, Welch A, Williamson M, Christensen M, Bakon S and Craft J. 2018. Using Colaizzi's method of data analysis to explore the experiences of nurse academics teaching on satellite campuses. Nurse Researcher, 25(4): 30-34. https://doi.org/10.7748/nr.2018.e1516

Whittle R, Telford A and Benson A. 2018. Teacher's perceptions of how they influence student academic performance in Victorian Certificate Education Physical Education. Australian Journal of Teacher Education, 43(2): 1-25. https://doi.org/10.14221/ajte.2018v43n2.1

Xu D and Jaggars SS. 2014. Performance gaps between online and face-to-face courses: Differences across types of students and academic subject areas. The Journal of Higher Education, 85(5): 633-659. https://doi.org/10.1080/00221546.2014.11777343

Yeung E. 2018. The importance of study breaks. https://collegeadmissions.uchicago.edu/uncommon-blog/importance-study-breaks. Accessed on 15 March 2023.

Youth.Gov. 2019. School-Based Supports | Youth.gov. Youth.gov. https://youth.gov/youth-topics/youth-mental-health/school-based. Accessed on 15 March 2023.

Zhang H, Lin L, Zhan Y and Ren Y. 2016. The impact of teaching presence on online engagement behaviors. Journal of Educational Computing Research, 54(7): 887-900. https://doi.org/10.1177/0735633116648171

Zimmerman BJ. 2000. Attaining Self-regulation: A Social Cognitive Perspective. Boekaerts M, Pintrich P and Zeidner M (eds). Handbook of Self-Regulation. Elsevier Academic Press, San Diego, California. pp. 13-39. https://doi.org/10.1016/b978-012109890-2/50031-7

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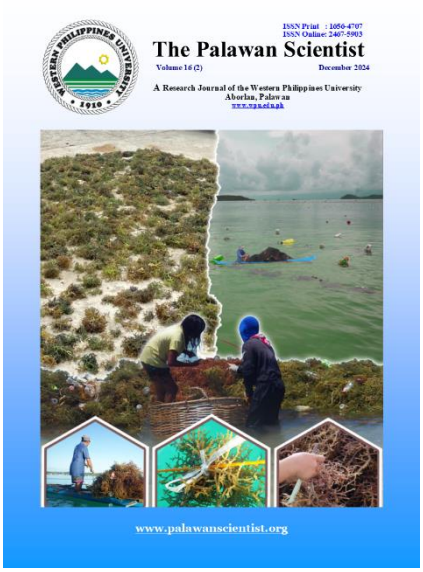

An experimental study of liquefied petroleum gas refrigeration system

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ABSTRACT

Despite prevalent electrical shortages in various regions, refrigeration remains imperative for diverse applications. This study explored the viability of recovering underutilized energy in the context of sustained demand for electricity in both urban and rural areas of the Philippines. Liquefied petroleum gas (LPG), commonly used in the Philippines for heating and cooking, has properties that can be used as refrigerant, and stands out for its zero-ozone depletion potential (ODP) and low global warming potential (GWP). The study focused on the design and development of a refrigerator using LPG as the refrigerant and compressor. Various factors, such as pressure drop, temperature change, enthalpy change, and heat loss, were analyzed throughout the experimental process, encompassing design formulation, analysis, simulation, fabrication, experimentation, and performance evaluation. Raw data from three 3-hour tests were collected and analyzed. Results indicated a time-dependent decrease in pressure, a notable water temperature change, and an increase in the coefficient of performance (COP) value over time. The maximum COP achieved was 1.78, coupled with a water temperature of -3.50 ˚C. Despite the obtained COP being lower than that of a typical domestic refrigerator, the observed refrigeration effect was evident. The findings underscore LPG's potential as a viable and environmentally responsible alternative in refrigeration systems.

Keywords: alternative refrigeration, COP, evaporator, refrigerant, refrigerating effect

INTRODUCTION

Refrigerants are the working medium used in refrigerating systems which evaporates by taking the heat from the space that is to be cooled, thus producing the cooling effect (Emani et al. 2017). Domestic refrigerators commonly use refrigerants that contain chlorofluorocarbon (CFC) and hydrofluorocarbon (HFC) which contribute to very high ozone layer depletion and global warming (Hashim et al. 2020). CFCs and HFCs contribute to ozone depletion by releasing free chlorine radicals into the atmosphere and the continuous reaction of chlorine and oxygen results in the destruction of ozone molecules (Raiyan

and Rehman 2017). National Aeronautics and Space Administration (NASA) (2015) explained that the effects of these refrigerants are a serious threat to our natural habitat, as they have contributed a negative impact on the variety of life on earth (biodiversity). That being explained, many researchers studied the use of hydrocarbon refrigerants as substitutes for ozone-depleting fluids. Fernando (2022) defined hydrocarbon as an organic chemical compound that is composed exclusively of hydrogen and carbon atoms. He added that hydrocarbons are naturally occurring and form the basis of crude oil, natural gas, coal, and other important energy sources and that they are highly combustible and are highly effective as a source of fuel. Hydrocarbons have excellent environmental characteristics, good miscibility with mineral oils, and acceptable compatibility with common materials employed in refrigeration equipment (Liu et al. 1995). Air Conditioning and Refrigeration Industry Board (ACRIB) (2001) reported that hydrocarbon refrigerants are fully compatible with most of the lubricants, elastomers, plastic refrigeration materials used as 'O' rings, valve seats, seals and gaskets used in refrigeration systems and that hydrocarbon refrigerants use the same evaporator and condenser sizes as fluorocarbon refrigerants operating at the same pressures and are compatible with most compressor types. The study of Iyer et al. (2006) found that no problems were encountered with the compressor, and no degradation of lubrication oil was detected after 5000 h of operation using different hydrocarbon mixtures as alternative refrigerants.

Liquefied petroleum gas (LPG) is comprised of hydrocarbons and normally contains propane (C3H8) and butane (C4H4) as major constituents along with small amounts of some other hydrocarbons (Rehman et al. 2023). LPG is available in a variety of mixes, ranging from pure propane to various ratios of butane and propane to pure butane (Raslavicius et al. 2014). Rayos (2017) discussed that in the Philippines, LPG is a combination of 40% propane and 60% butane. According to Satwik et al (2016), LPG is colorless, non-toxic, heavier than air, half the weight of water, and odorless, and it is odorized only for detection of leaks. Extensive research and guidelines were published on the compatibility and flammability of hydrocarbon as refrigerants (Mohanraj et al. 2011). In the study of Manohar et al. (2020), the LPG refrigeration system was compared with a domestic refrigerator. They concluded in their study that LPG refrigeration system has a very low initial and operating cost and does not require any external energy source to operate, unlike domestic refrigerators. Additionally, the system contains no moving components, which reduces maintenance costs even further.

Srinivas et al. (2014) investigated the use of LPG as an alternative to R134a as a refrigerant in a household refrigerator. It has been discovered in their study that LPG has a greater cooling impact than R134a refrigerant which are used in domestic refrigerators. They added that LPG has all of the necessary qualities to qualify as a refrigerant. Moreover, in the study conducted by Oyelami and Bolaji (2016), an experimental refrigerator was developed as a test rig and the findings revealed that the system operated better with LPG than with R134a. As a result, the LPG refrigerant can be successfully implemented. Furthermore, according to the research study by Manohar et al. (2020), the coefficient of performance (COP) of an LPG refrigerator is higher than that of a domestic refrigerator, and a domestic refrigerator has more moving components and is, therefore, less ecologically friendly. The maintenance requirements for a household refrigerator are higher, and the operation is noisier as well. With all the gathered advantages of LPG as a refrigerant, somehow LPG as a refrigerant has disadvantages, and one of them is flammability. Hydrocarbons are highly flammable substances and must be handled with caution (El-Morsi 2015). Although LPG is flammable, according to the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) (2013), small factory-sealed appliances can have a flammable refrigerant charge of up to 150 g in each separate refrigerant circuit and can be located anywhere without restriction. Qurashi and Wankhede (2013) reported that refrigerators designed to work with R-134a had a charge that varied from 105 to 150 g. However, the charge can be reduced to 70 to 90 g when hydrocarbon refrigerants are used. Also, ACRIB (2001) states that sealed systems containing a hydrocarbon charge of less than 150 g can be situated in any location, regardless of room volume.

In the Philippines, LPG is primarily used for cooking. Convenience is one of the reasons why most of the households use LPG in their homes. Not only is it used for households but also for businesses. Street food vendors use LPG because it is locally available and can easily be transported from one place to another. Thus, the researchers came up with the idea of utilizing the high consumption of LPG through the concept of refrigeration, thereby eradicating the use of R134a, an HFC refrigerant that is still widely used in the Philippines that has high Global Warming Potential. This study was conducted to develop a refrigeration system utilizing LPG as both the compressor and refrigerant. The objective is to investigate the feasibility and efficiency of this unconventional approach, addressing design considerations, material compatibility, and overall system performance. Specifically, the study aimed to design and simulate an LPG refrigeration system, utilizing SOLIDWORKS software to determine design parameters, identify

optimal materials, and conduct Computational fluid dynamics (CFD) simulations of the refrigeration chamber; to fabricate and experiment with an LPG refrigeration system by constructing the system according to the designed specifications; and to determine the fabrication parameters for the developed system design and, subsequently, conduct experimentation to collect raw data, including gauge pressure measurements at the inlet and outlet in pounds per square inch (psi), initial and final water temperatures in degrees Celsius, mass consumption in kilograms, and mass flow rate in kilograms per second; the performance analysis of the LPG refrigeration system involves calculating the system's power output (W), heat loss from the water (Q), and coefficient of performance (COP).

METHODS

Working Principle

According to Heisler (2002), the refrigerant's state upon entering the evaporator is liquid, however, once it exits, it has absorbed the heat from the load thus evaporating it into vapor. He added that this process allows the heat from inside the cold compartment to be absorbed and transferred preferably away from the system. As a replacement for freon, the system uses LPG as a refrigerant. The LPG tank contains the refrigerant (LPG), which is the main source of the process. According to Elgas (2019), LPG in a cylinder exists both as a liquid and a vapor. The upper portion of the cylinder contains pressurized LPG vapor, whereas the lower portion contains LPG liquid. LPG cylinders are generally filled to 80% capacity which means 80% liquid and 20% vapor (ES Systems 2021). In this case of the LPG as the refrigerant, it must be in liquid form and at a lower pressure to produce refrigeration in the system. Thus, in this study, the LPG tank was turned upside down so that only the liquid would pass through the hose which was connected to the evaporator. The outlet pressure of a regular LPG cylinder without a regulator is approximately 70-50 psi. The LPG pressure must be dropped to 15 psi to produce a refrigerating effect (Sathayan et al. 2018). In order to attain the required pressure drop, a throttling device was used in this study. It was installed at the inlet part of the evaporator which was connected to the inlet hose. Based on the study of Adhav et al. (2017), the actual cooling effect is provided by circulating the LPG through the evaporator coil. In this study, the evaporator coil was attached inside the evaporator compartment. The discharged LPG in the outlet of the evaporator coil which was already a vapor was then directed to a burner through a hose. The burner stove must constantly be used to run the LPG from the cylinder and get a cooling effect in the cooler setup. To maintain the cooling temperature of the refrigerator when in times the burner is not used in accordance with the absence of the LPG input, the evaporator was filled with water.

Material Selection

The approaches that were employed in the study of Manohar et al. (2020) to construct the LPG refrigeration system was used in this study. The refrigeration system were included in the LPG tank, ball valve, evaporator, and burner. The materials chosen were based on prior study and their availability in Cagayan de Oro. A commercially available 2-L capacity insulated plastic water jug was selected as an evaporator compartment due to its availability. It was also insulated with polyurethane which has good insulation properties according to Demharter (1998). Holes were drilled 5 and 20.32 cm below the upper mouth of the jug for the inlet and outlet of the evaporator coil which in this case is a copper tubing. This copper tube was coiled inside the wall of the cylindrical evaporator compartment. It was coiled in a cylindrical shape for lesser friction loss and easy coiling of copper tube as shown in Figure 1A. Copper tube was used in this study as it has good heat transfer capacity, good resistance to corrosion, and is cheaper in cost (Hashim et al. 2020). A copper tube was coiled inside the water jug connected to a fitting for the throttling valve and hoses as illustrated in Figure 1B. The evaporator coil comprises 0.476 cm copper tubing in 18 revolutions with a diameter of 8.89 cm at 22.86 cm height to facilitate the rapid entry and escape of LPG in the upper and bottom portions, respectively. To attain a pressure drop from the tank, a throttling device was installed at the inlet part of the evaporator so there was a pressure decrease throughout the system. The throttling device that was used in this study is a simple ball valve since it is widely available and adjustable. An iron-cast heavy-duty stove which measures 55.88 cm x 40.64 cm x 24.13 cm was used to exhaust the LPG. Commercial gas and liquid hoses with a diameter of 3/8" were utilized since they were more affordable and fittings were readily available. An 11-kg-LPG tank was used in this experiment for easy grip and mobility. The LPG tank and LPG composition used were Prycegas, which is locally available. An innovative set-up also was implemented by the researchers to make the system easier to move from one place to another. Aside from the main components, angle bars that were cut and wielded were added. This was the most used method in fabricating this innovative set-up.

Data Gathering Instruments

The LPG tank was weighed in its emptied state and full state using a weighing scale as shown in Figure 1C. This device is used to measure the mass flow rate of the system during the experiment. After

measuring the mass of the LPG, the pressure experimentation parameters were set to approximately 15 psi and measured by a Bourdon-type pressure gauge as shown in Figure 1D. Two temperature probes shown in Figure 1E were attached to the inlet and outlet part of the evaporator. This measures the water temperature of heated or chilled water and other liquids in mechanical systems. Additionally, another temperature probe was utilized to measure the water temperature in the evaporator chamber. It was programmed with respect to the code language of Arduino as shown in Figure 1F. The temperature reading of the refrigeration chamber was recorded in different time intervals in 10 min within 180 min of run time.

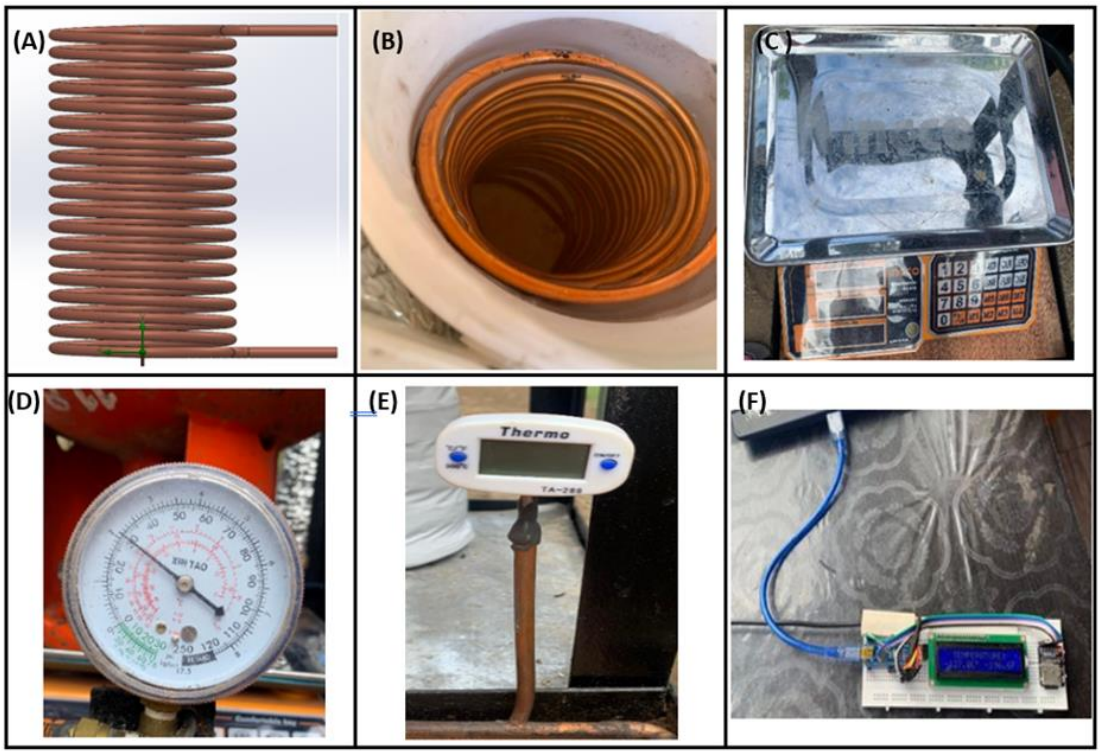

Figure 1. (A) 3D drawing of the Copper Tube coiled cylindrically; (B) Actual Copper Tube coiled inside the Evaporator Chamber; (C) Weighing Scale used for measuring the LPG mass; (D) Pressure Gauge used in measuring the outlet and inlet pressure; (E) Temperature Probe used in measuring the inlet and outlet temperature of the evaporator; and (F) Arduino set used in measuring the Evaporator temperature.

Experimental Setup

After gathering all the instruments and materials needed for the study, the design system was constructed as shown in Figure 2A. Its setup with labeled instruments and materials used is shown in Figure 2B. Necessary fittings were carefully connected and a leak test was conducted through the bubble method.

Calculation of Performance

The researchers determined the raw data during the experimentation. The raw data for the LPG refrigeration system includes pressure drop, mass flow rate, and change of temperature which was obtained from the data gathering instruments. The researchers then calculated the performance of the system based on the raw data from the experimentation. The calculation of the performance data for the LPG refrigeration system includes enthalpies, heat loss of water, work, and coefficient of performance (COP).

The LPG cylinders are generally filled with 80% liquid and 20% vapor ES Systems (2021), and by using the properties of propane and butane, enthalpies were acquired with respect to the composition ratio of LPG (60% butane, 40% propane). Work was solved through the unsteady state formula by finding the internal energies and enthalpies with respect to temperature from the starting and final time. Conservation of energy of unsteady state Heat loss of water was acquired by using the heat removed formula, using the specific heat capacity of water, the mass of water, and the change of temperature as can be seen in Equation 1. Finally, COP was determined by dividing the heat loss of water (Q) by the work (W) of the system. Thermal insulation was used to reduce heat loss to the atmosphere. Therefore, any heat loss or addition to the environment as a result of conduction,

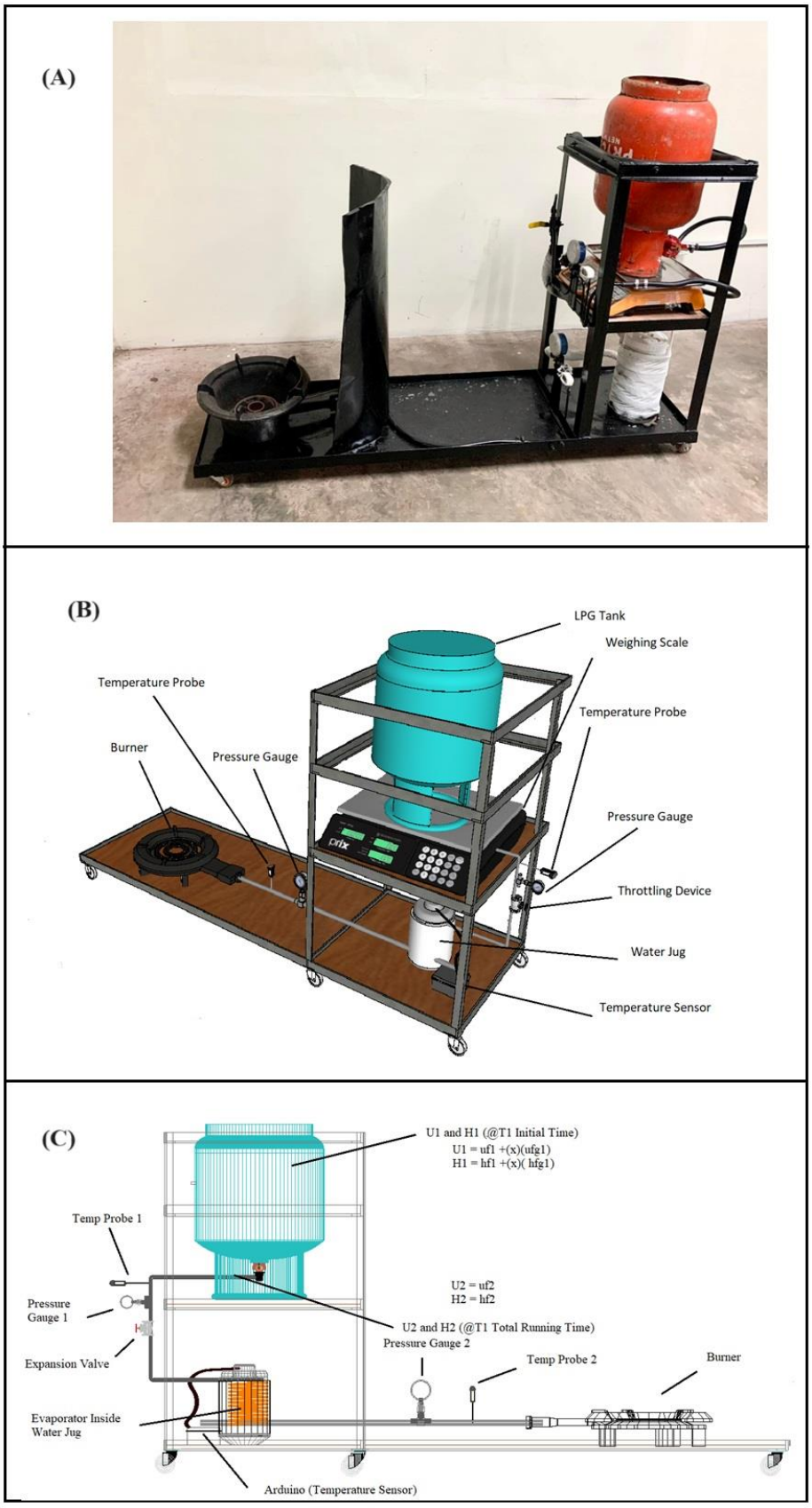

Figure 2. (A) Actual setup of LPG Refrigeration System; (B) LPG Refrigeration Set-Up with labeled parts; and (C) Schematic Diagram of LPG Refrigeration System.

convection, or radiation is negligible. The change in kinetic and potential energy in the evaporator is negligible.

In a steady flow process, it is assumed that the system's mass and energy are constant and do not change over time. In a process with an unsteady flow, mass and energy inside the control volume fluctuate continually. The fluid flows into and out of the system (Avinash 2018).

Conservation of energy of unsteady state,

$$m_2(u_2+KE_2+PE_2)-m_1(u_1+KE_1+PE_1)= m_{in}\sum(h_{in}+KE_{in}+PE_{in})-m_{out}\sum(h_{out}+KE_{out}+PE_{out})+Q-W \quad \text{(Eq. 1)}$$

The LPG refrigeration system has only one exit and no inlet mass flow (refer to Figure 2C). Therefore, the summation of terms involving the inlet mass can be omitted. Since there is no heat transfer between the LPG inside the tank and the surroundings, the system is adiabatic. Potential energy (PE) and kinetic energy (KE) were neglected as can be seen in Equation 2.

$$m_2u_2-m_1u_1=-m_{out}h_{out}-W \quad \text{(Eq. 2)}$$

where:

- inlet temperature of the system is equal to the temperature of the LPG inside the tank
- $u_1 = u_f + xu_{fg}$ (internal energy at two-phase mixture), @ inlet temperature in initial time
- $u_2 = u_f$ (internal energy at saturated liquid), @ inlet temperature in final time
- $h_1 = h_f + xh_{fg}$ (enthalpy at two-phase mixture), @ inlet temperature in initial time
- $h_2 = h_f$ (enthalpy at saturated liquid), @ inlet temperature in final time
- $h_{out} = (h_1 + h_2) / 2$
- $m_{out} = m_1 – m_2$

Heat loss is the reduction of space's heat due to heat transmission through walls, roofs, windows, and other building surfaces. The heat loss is computed by multiplying the mass, the temperature differential between the inside and outside surfaces, and the material's specific heat capacity, as can be seen in Equation 3. The total heat loss of the object consists of radiation, convection, and conduction losses. There is no substance capable of totally preventing heat loss; materials can only lessen it. The unit of heat loss is the Watt.

$$Q=\frac{mC_p\Delta T}{t} \quad \text{(Eq. 3)}$$

where:

- m = mass of water
- C_{pw} = specific heat capacity of water (4.187 kJ/kg-K)
- C_{pi} = specific heat capacity of ice (2.0935 kJ/lg-K)
- DT = change of temperature
- t = running time

The COP of a refrigerator is defined as the heat extracted from the cold reservoir Q_{cold} (i.e., inside a refrigerator) divided by the amount of work W performed to remove the heat (i.e., the work done by the compressor), as can be seen in Equation 4. The COP varies heavily on the outdoor temperature and the desired inside temperature. At a temperature differential of approximately 25°C, the COP may be approximately 2.5, although it may approach 3.5 for a difference of approximately 8°C (Connor 2019).

$$COP=\frac{Q_A}{W} \quad \text{(Eq. 4)}$$

where:

W = work input (W)
Q_A = refrigerating capacity (W)
COP = coefficient of performance

Experimental Procedure

Examining the status of all system components. The system must be fully functional and devoid of leaks and faulty components. Due to the combustible nature of LPG, all personnel operating the prototype wore protective gear. All connection points were checked using the soap solution method in order to check for leaks. Before each test, the tubing and evaporator were cleaned with a vacuum pump to eliminate moisture and blockages.

System Components Setup. The container was filled with water (about 2 L), and a temperature measurement device was positioned within the evaporator without contacting it. At the beginning of data collection, the researchers made sure that the water was at temperature ranging from 22℃ to 29℃. Data acquisition devices were then turned on. Additionally, the LPG cylinder was then placed on the digital scale. To transfer liquid LPG into the system, the cylinder was turned upside down. With the burner valve open and the ball valve closed, the ball valve was gradually opened and the burner valve was adjusted to achieve 15 psi at exit pressure.

Determining the raw data. Raw data was determined using the measuring device that was attached to the system, such as a pressure gauge, which measures the pressure of LPG from the system's inlet and outlet in pounds per square inch (psi), a temperature sensor, which measures the water's temperature in degrees Celsius, and weighing scale, which measures the mass flow rate. In order to determine the mass flow rate, LPG was weighed on a scale, and the mass loss of LPG was computed by dividing it to the time interval.

Data Gathering. LPG intake and outlet pressures, water temperature, and LPG cylinder mass were measured at ten-minute intervals at the end of three hours or 180 min of operation. In addition, water temperature was measured at 5 min intervals throughout three more 60 min periods.

Calculating the enthalpies and heat loss of LPG based on raw data. In determining enthalpies, the pressure derived from the dataset served as a reference point for the computation of enthalpies, with respect to the LPG composition properties table. The composition of LPG in the Philippines is 60% butane and 40% propane. Consequently, in calculating enthalpies, it is necessary to multiply by 60% of the butane properties and 40% of the propane properties.

Calculating the work of the system. Using the enthalpies and the mass flow rate from the raw data, the work (kW) of the system was computed. The heat loss formula from the water was also used to calculate the heat loss of water in the system. Then the performance of the system (COP) was determined by dividing the heat loss from the water by the work of the system.

RESULTS

CFD Simulation

The simulation solely concentrates on the refrigerated chamber up until the point where the mass enters the upper portion of the evaporator as shown in Figure 3. It has been found that the temperature was low near the evaporator coils and it is highest in the lower section of the coiled evaporator. A time-dependent approach was used to collect the data in the software. The simulation ran for a maximum of 60 min. Iterations were done at 5 min intervals for maximum, minimum, and average temperatures inside the refrigeration chamber. The result is illustrated in Figure 4A. The graph in Figure 4B compares the experimental and simulated values of computational fluid flow on the temperature gradient in relation to time from the SOLIDWORKS program.

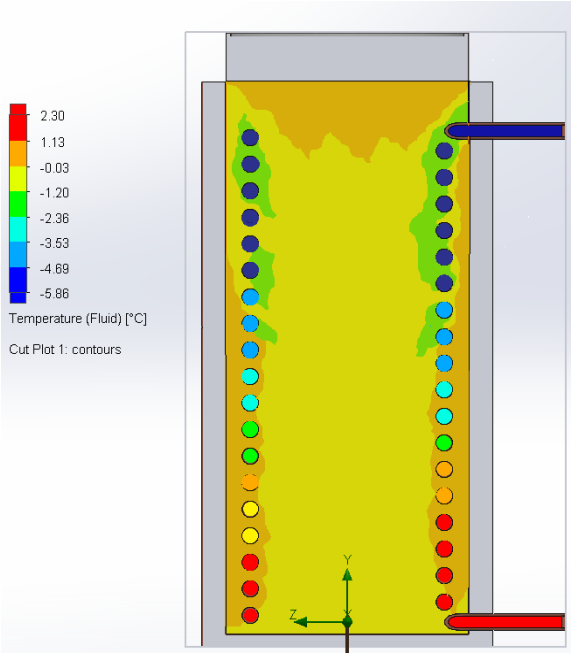

Figure 3. Simulation cut plot of Evaporator Chamber.

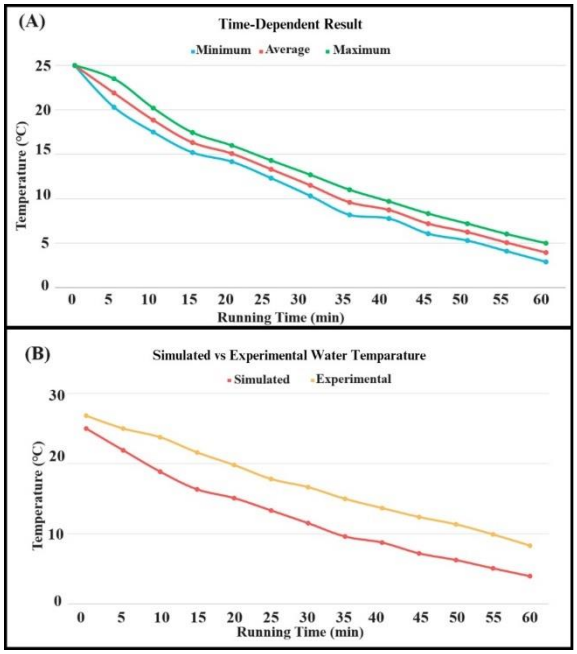

Figure 4. (A) Temperature vs running time using computational fluid dynamics simulation; and (B) temperature graph comparison of simulated and experimental results.

Experimental Performance of LPG

The researchers conducted five test experiments in total, where each test ran for 180 min with a 10 min interval. Table 1 shows the LPG consumed by the system in a 3-hour duration with a 10-minute interval. Rapid consumption of LPG was observed during the first half of the duration time with approximately 1.8 kg of LPG. In every 10 min, the average consumption is 0.218 kg. The curve of the absolute pressure at which the LPG refrigerant leaves the evaporator with respect to time has been plotted in Figure 5A. From the graph, a linear relationship can be observed between the two parameters. Pressure drop is the difference between the outlet and inlet pressure. As time increased, the pressure drop also increased from 4.8 psi to 17 psi every 10 min. Similarly, Figure 5B shows how the water temperature behaves against time. A drastic temperature change was also observed in 80 min from 25℃ down to 2℃. As time increased, moderate changes were observed that upon approaching the freezing point, it further extended towards negative values. In this study, the system has reached -3.5 degrees Celsius in 3 h with an average inlet pressure of 30.4 psi.

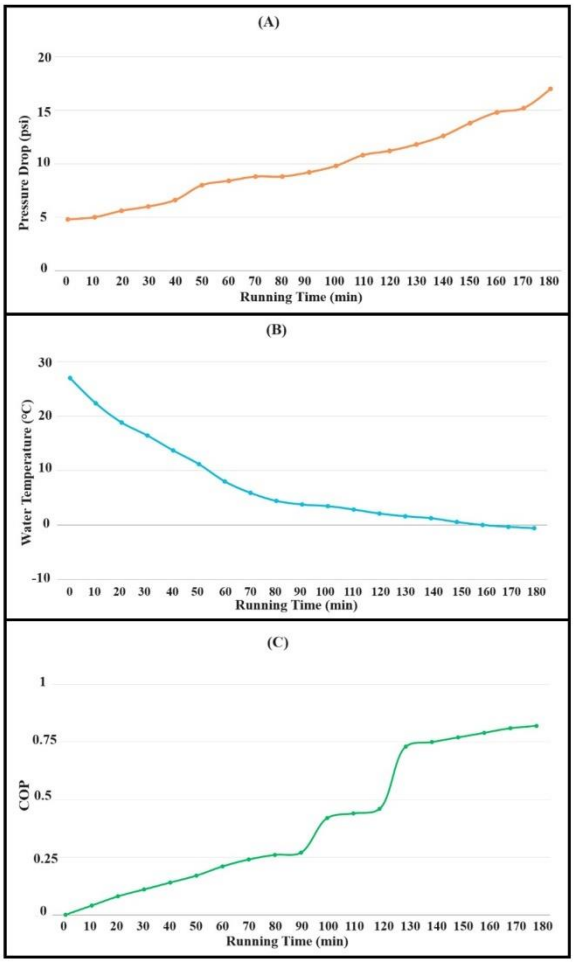

Figure 5. (A) Pressure drop vs time graph of experimental result; (B) water temperature vs time graph of experimental result; and (C) COP vs time graph of experimental result.

Table 1. Average consumption of mass from experiment.

Test	Average Consumption Every 10 min (kg)
1	0.222
2	0.203
3	0.184
4	0.258
5	0.221
Average	0.218
Standard Deviation	0.0274

Coefficient of Performance

The COP of the system was calculated based on the raw data collected. In a duration of 3 h with 10 min intervals, COP ranging from 0.02 to 1.78 was achieved. This proves that the value of COP increases with respect to time as can be seen in Figure 5C. In this study, the properties of butane and propane which are the components of LPG in the Philippines are considered in the calculation of work.

DISCUSSION

CFD Simulation

Comprehensive and nuanced comparison was undertaken between Computational Fluid Dynamics (CFD) simulation results and experimental data to enhance the understanding of fluid flow phenomena in this study. This aimed to provide a comprehensive assessment of the reliability and precision of both sets of data within the context of this study. By using simulation, researchers were able to vary input parameters to analyze their influence on the system's behavior. Detailed examination of specific flow characteristics, and visual representations, such as contour plots were utilized to facilitate a clear and insightful comparison. Furthermore, with CFD simulation, researchers were able to assess the performance of coil orientation and whether or not it can create a cooling effect, thus, it facilitated virtual prototyping and design optimization. Additionally, insights into the temperature at different points of the refrigerant inside the copper coil and water inside the evaporator chamber were drawn. Based on the simulated design, the temperature is significantly lower at the entrance of the evaporator and higher in the lower section. When comparing the time-dependent results obtained from the simulation with the actual experimental outcomes, it was observed that the actual results exhibited slight variations. These discrepancies can be attributed to the influence of weather conditions during the experimental trials. It became evident that factors such as temperature and humidity have contributed to the observed differences in the time-dependent behavior between the simulated and actual scenarios. Recognizing this condition, external environmental factors are significant in the interpretation of experimental results and highlights the challenges associated with precisely replicating conditions in simulations when natural variables, such as weather, come into play.

Fabrication and Experimentation with LPG Refrigeration System

As the refrigerant circulates through the system, its pressure and temperature change. For the refrigeration cycle to function, it encompasses three main stages: mass consumption, pressure drop, and temperature change. Mass consumption is an essential part of the refrigeration system since it is used for the calculation of work done by the system. An average mass consumption of 0.218 kg was recorded after the five experimental tests. This result of mass consumption was dependent on the starting pressure of 30 psi and the outlet pressure that ranged from 28 psi to 10 psi. When the outlet pressure is high, the mass consumption of the system increases and when the outlet pressure drops, the mass consumption decreases. This means that the mass consumption and the outlet pressure are directly proportional. The system has shown a pressure drop of 15 psi on average. This pressure drop occurred when the LPG refrigerant passed through the expansion valve. The discussion of Blackwell (2015) stated that to cool the refrigeration chamber, the refrigerant is transmitted through the expansion valve, which reduces its pressure by restricting the amount of flow through the valve. This restriction means that there will be less refrigerant in the next section of the conduit, allowing the refrigerant that passes through to expand slightly. This was supported by the study of Shah and Gupta (2014), where an average pressure drop of 20 psi was recorded with an initial pressure of 80 psi from which a high-pressure regulator was utilized. In addition, they have stated that the use of a low-pressure regulator will result in a different pressure change. After passing through the expansion valve, the LPG refrigerant then enters the evaporator which is housed in the refrigerating chamber and reduces the water temperature. Blackwell (2015) explained that the refrigerant enters the evaporator as a low-temperature, low-pressure liquid. Upon entering the evaporator, the refrigerant begins to boil and evaporate, causing a cooling effect in the chamber. The refrigerant exits the evaporator as a low-pressure, saturated gas and then flows through the pipes to the burner for combustion. The inverted elevated LPG setup is more effective in minimizing the cooling time than the usual setup. Using the 0.476 cm diameter copper tube with 18 revolutions, the lowest temperature achieved was -3.50°C in 3 h and a water temperature of 11.19°C as achieved in 50 mins. Correspondingly, Manohar et al (2020) achieved a water temperature of 23.4°C after 50 min; a 0.70-cm OD copper tube with a thickness of 0.15 cm was used. This implies that the size of the copper tube used in this study provides faster cooling than that of the size used in the study previously mentioned. However, under continuous operation, the LPG lasts for 10 h only.

Performance of LPG Refrigeration System

The efficiency of the refrigeration system is measured in terms of its COP. The higher the value of COP, the more efficient the system is (Connor 2019). The highest COP calculated for this unsteady state system is about 1.78 which is comparatively smaller than the domestic refrigerator which is 2.5 (Shah and Gupta 2014). The investigation conducted by Manohar et al. (2020) demonstrated an elevated COP of 6.3. This achievement was attributed to a higher mass flow rate, leading to an increased refrigerating effect, coupled with a reduced work input, specifically 42.39 watts. Their assumption, wherein the work input is considered equivalent to the power required for filling one cylinder, resulted in a lower value for work. As compared to this study, the work done in the LPG refrigeration system has been meticulously calculated

using empirical formulas and LPG properties. Through a detailed analysis of pressure drop, temperature change, and enthalpy change, along with a comprehensive understanding of LPG's thermodynamic characteristics, the computation of work done is accurately derived. This approach not only ensures the precision of the results but also contributes to a thorough comprehension of the system's performance based on empirical correlations and the specific properties of LPG.

The discrepancies noted between simulated results and experimental data underscore the significant impact of external environmental variables, thus emphasizing the need for careful consideration of real-world conditions in simulation models to enhance predictive accuracy and reliability. The exploration through fabrication and experimentation reveals critical insights into the system's operational dynamics, notably the direct relationship between mass consumption and outlet pressure and the cooling efficiency of specific system configurations. These findings illuminate the practical aspects of system design, such as component selection and setup orientation, that directly influence performance outcomes. The limitation observed in the system's continuous operation duration indicates that there is a need for further refinement in design to extend usability and efficiency in real-world applications. Lastly, the performance evaluation, centered on the Coefficient of Performance (COP), sheds light on the LPG refrigeration system's efficiency compared to conventional systems. The evaporator achieved a cooling effect of -3.5°C, resulting in the formation of ice within the chamber. This indicates that the refrigeration system effectively met the specified parameters as stipulated in this study. Moreover, the system has reached a coefficient of performance of 1.78 which is lower than that of a domestic refrigerator. It is recommended to use a plate-tube type of evaporator in the chamber to achieve a greater value of refrigerating effect, which will then lead to a higher value of COP.

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ETHICAL CONSIDERATIONS

This research does not have any animal or human subjects.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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REFERENCES

Adhav AS, Dudhe SS, Jadhav VD, Pagar SA and Salunke GB. 2017. Electricity Free Refrigeration using LPG.https://www.academia.edu/31673800/Electricity_Free_Refrigeration_using_LPG. Accessed on 20 July 2023.

AIRAH (Australian Institute of Refrigeration, Air-Conditioning and Heating Incorporated) 2013. Flammable refrigerants safety guide. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=308694f4fef24df206277b9061aeb322695d4541. Accessed on 26 March 2023.

Blackwell W. 2015. Sustainable Retail Refrigeration. John Wiley & Sons Ltd. The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK. pp 351.

Connor N. 2019. What is Coefficient of Performance - COP - Refrigerator, Air Conditioner - Definition. Thermal Engineering. https://www.thermal-engineering.org/what-is-coefficient-of-performance-cop-refrigerator-air-conditioner-definition/. Accessed on 26 March 2023.

Demharter A. 1998. Polyurethane rigid foam, a proven thermal insulating material for applications between +130°C and −196°C. Cryogenics, 38(1): 113–117. https://doi.org/10.1016/s0011-2275(97)00120-3.

Elgas. 2019. How Much Pressure is in LPG & Propane Gas Cylinder-Bottle. https://www.elgas.com.au/blog/1969-how-much-pressure-is-in-lpg-propane-cylinders-in-what-state/. Accessed on 14 April 2023.

ES Systems. 2021. What is liquefied petroleum gas and how does it work? https://esenssys.com/liquefied-petroleum-gas-guide/#. Accessed on 14 April 2023.

El-Morsi M. 2015. Energy and exergy analysis of LPG (liquefied petroleum gas) as a drop in replacement for R134a in domestic refrigerators. Energy, 86: 344-353. https://doi.org/10.1016/j.energy.2015.04.035

Emani MS, Roy R and Mandal BK. 2017. Development of refrigerants: a brief review. Indian Journal of Scientific Research , 14(2): 175-181.

Fernando J. 2022. Hydrocarbons: Definition, Companies, Types, and Uses. https://www.investopedia.com/terms/h/hydrocarbon.asp. Accessed on 20 May 2023.

Heisler H. 2002. Advanced Vehicle Technology. Elsevier. Linacre House, Jordan Hill, Oxford. 654pp.

Iyer GV, Mastorakis NE and Theologou AI. 2006. Experimental investigations on eco-friendly refrigeration and air conditioning systems. In Proceedings 4th WSEAS International Conference on Fluid Mechanics and

Aerodynamics, 2017: 445-450. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=a01a977fed030c1098719b0e668baaeb922f8afe. Accessed on 21 July 2023

Liu BY, Tomasek ML and Radermacher R. 1995. Experimental results with hydrocarbon mixtures in domestic refrigerator/freezers (No. CONF-950104-). American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA (United States). https://www.osti.gov/biblio/87488. Accessed on 10 March 2024.

Manohar M, Sahu PK, Sahu PK, Singh D and Chandra A. 2020. Design Analysis and Performance of Low Cost Refrigeration System using LPG. https://www.ijesc.org/upload/1c58ceee9a810532dab0c45ce2b82687.Design%20Analysis%20and%20Performance%20of%20Low%20Cost%20Refrigeration%20System%20using%20LPG.pdf. Accessed on 20 July 2023.

Mohanraj M, Muraleedharan C and Jayaraj S. 2011. A review on recent developments in new refrigerant mixtures for vapour compression-based refrigeration, air-conditioning and heat pump units. International Journal of Energy Research, 35(8): 647-669. https://doi.org/10.1002/er.1736

NASA (National Aeronautics and Space Administration). 2015. NASA Study Shows That Common Coolants Contribute to Ozone Depletion. https://www.nasa.gov/press-release/goddard/nasa-study-shows-that-common-coolants-contribute-to-ozone-depletion. Accessed on 11 January 2023.

Oyelami S and Bolaji BO. 2016. Design and construction of a vapour compression refrigeration system as test rig to investigate the performance of Liquefied Petroleum Gas (LPG) as refrigerant. http://repository.fuoye.edu.ng/handle/123456789/2308. Accessed on 20 July 2023.

Rehman HU, Awan A, Khan N, Naseer F and Ali K. 2023. Using Liquefied Petroleum Gas (LPG) as an Environmentally Friendly Alternative Refrigerant. https://www.xisdxjxsu.asia/V19I03-60.pdf. Accessed on 22 July 2023.

Raiyan MF and Rehman OA. 2017. Effects of Chlorine-based refrigerants on atmosphere and search for alternative refrigerants-A review. https://www.researchgate.net/publication/324830749_Effects_of_Chlorine_based_refrigerants_on_atmosphere_and_search_for_alternative_refrigerants-A_review. Accessed on 21 July 2023.

Rayos AH. 2017. LPG Industry Regulatory Framework (Household LPG) and Gasoline Station Training and Loan Fund. Department of Energy. https://www.doe.gov.ph/sites/default/files/pdf/announcements/epower_fontana_04_04_lpg_industry_regulatory_framework.pdf?withshield=1. Accessed on 27 May 2023.

Sathayan S, Gopakumar MG, Krishnan SJ, Gopan N and Nithin S. 2018. Design of Lpg Refrigeration System. International Journal of Innovative Research in Science, Engineering and Technology, 7(6): 2319-8753. https://doi.org/10.15680/IJIRSET.2018.0705054

Satwik N, Kumar BS, Krishna TG, Ravinda M and Kumar BK. 2016. Refrigeration System by using LPG (Liquefied Petroleum Gas). International Journal and Magazine of Engineering, Technology, Management and Research, 3(5): 226-235.

Shah IH and Gupta K. 2014. Design of LPG refrigeration system and comparative energy analysis with domestic refrigerator. International Journal of Engineering Sciences & Research Technology, 3(7): 206-213.

Srinivas P, Chandra RP, Kumar MR and Reddy N. 2014. Experimental investigation of LPG as refrigerant in a domestic refrigerator. Journal of Mechanical Engineering Research and Technology, 2(1): 470-476.

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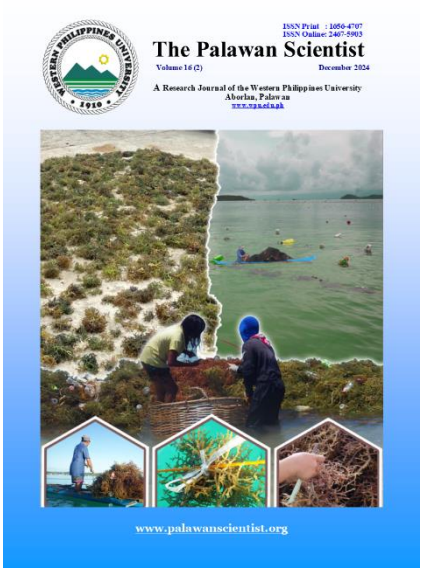

Preservice teachers' proficiency in fraction subconstructs as predictors of conceptual understanding in fraction arithmetic

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ABSTRACT

The study aimed to determine whether the Kieren-Behr model holds true when examining the relationship between knowledge of fraction subconstructs and conceptual understanding of fraction arithmetic. Specifically, the study argued that the proficiency of pre-service teachers in fraction subconstructs can contribute to the development of conceptual knowledge in fraction arithmetic. It asserted that performance in problem-posing tasks, which reflect conceptual understanding, is significantly related to proficiency in different subconstructs of fractions. The proficiency of pre-service teachers in fraction subconstructs and their problem-posing performance were assessed using the expert-validated Fraction Subconstruct Test (FST) and Problem-Posing Test (PPT). The collected data were analyzed using descriptive statistics and standard multiple linear regression. Overall, the pre-service teachers only achieved a "beginning level" of proficiency in fraction subconstructs and performed unsatisfactorily in the PPT. Their proficiency in the measure subconstruct predicted conceptual understanding of adding fractions; their proficiency in the quotient subconstruct predicted conceptual understanding of subtracting fractions; their proficiency in the operator and quotient subconstructs predicted conceptual understanding of multiplying fractions; and their proficiency in the part-whole subconstruct predicted conceptual understanding of dividing fractions. The study suggests that teacher education institutions should develop intervention and enrichment programs to enhance the numerical competency of pre-service teachers, particularly in fractions. Additionally, curriculum writers are encouraged to emphasize mastery of each fraction subconstruct in order to promote successful development of conceptual understanding.

Keywords: education, mathematics, teaching

INTRODUCTION

The teachers' weak conceptual understanding of fractions is manifested in their poorly structured word problems. Consequently, this lack of understanding will burden the teaching-learning process when teachers are faced with contextual problems. Moreover, as teachers are entrusted with the

role of developing their students to be good "problem posers," chances are, this aspect is being neglected in mathematics classrooms due to the inefficacy of posing quality problems to engage the students in a higher-order learning experience. This problem is prominent in literature (Copur-Gencturk 2021), specifically in fractions arithmetic, where most teachers and pre-service teachers fail to grasp its procedural and conceptual nature (Nillas, 2003; Lee and Lee 2023; Perry 2023; Tossavainen and Johansson 2023).

The difficulties in learning fractions can be attributed to the fact that fractions can have multiple meanings. A growing body of research suggests that fractions comprise a multifaceted construct, and each contributes to the student's proficiency in fraction arithmetic (Charalambous and Pitta-Pantazi 2005, 2007; Baker et al. 2012). For instance, Kieren (1980) proposed that fractions should be conceptualized as a set of interrelated constructs: the part-whole, ratio, operator, quotient, and measure subconstruct. He argues that exposure to numerous rational number subconstructs is necessary to fully understand fractions. Later, Behr et al. (1983) extended Kieren's (1980) ideas on fraction subconstructs by linking the different fraction subconstructs to the operations on fractions, fraction equivalence, and problem-solving procedures (Kieren-Behr model). The model (Figure 1) is hierarchical, with the part-whole subconstruct being the most basic subconstruct that is fundamental to understanding the other four subconstructs (ratio, operator, quotient, and measurement). The knowledge of the ratio, operator, and measurement subconstructs contributes to the understanding of equivalence, multiplication, and addition of fractions, respectively. All five subconstructs are essential for problem-solving. Charalambous and Pitta-Pantazi (2007) tested the hypothesis of the model on young learners (fifth and sixth graders), and Baker et al. (2009, 2012) tested it on adult learners (college students). Their studies found that adult and young learners have different fraction schemas and only provided partial support for the hypotheses of the model. It is important to note that the said model claims its hypothesis on operations with fractions solely under procedural competency.

However, more than procedural fluency is required for pre-service teachers to meet the demand for a great learning experience that promotes deeper learning of fraction operations. Hence, several studies have gone beyond the analysis of procedural fluency on fractions and have analyzed pre-service teachers' conceptual understanding through problem-posing tasks (Osana and Royea 2011; Kar and Işık 2014; Kilic 2015; Rosli et al. 2020). Although we agree that conceptual understanding cannot be directly measured and quantified, we can create opportunities for them to manifest this (Tichá and Hošpesová 2013; Cai and Hwang 2023). If supplemented by appropriate prompts, problem-posing tasks can be cognitively demanding activities requiring students' mastery of the concept to formulate solvable and real-life problems. The prompt is essential to force students to pose problems that are not easily solvable by known methods or just restatements of old problems with just changed givens; thus, problems posed by students can demonstrate their conceptual understanding (and misconceptions) as it is related to high math achievement and cognitive transfer (Donovan and Bransford 2005; Matsko and Thomas 2015).

With these arguments, the researchers of the present study subscribe to the assumption that proficiency in fraction subconstructs must have a significant relationship to the conceptual understanding of fraction arithmetic. Thus, considering the arguments above and the researchers' positionality, this paper will argue that pre-service teachers' knowledge of fraction subconstructs can also contribute to the development of conceptual knowledge in fraction arithmetic. This proposition can be supported by asserting that their performance in problem-posing tasks that manifest their conceptual understanding of fraction arithmetic significantly relates to their knowledge of the different subconstructs of fractions.

More specifically, this study aimed to address the following problems:

1. What are the pre-service teachers' level of proficiency in each fraction subconstruct, specifically the (a) part-whole, (b) measure, (c) operator, and (d) quotient subconstruct?

2. Which of the fraction subconstructs can be a predictor of conceptual understanding of (a) adding fractions, (b) subtracting fractions, (c) multiplying fractions, and (d) dividing fractions?

METHODS

Research Design

This study is descriptive and, at the same time, inferential as it uses a non-experimental predictive research design to address the research problems. The study used a descriptive research design, utilizing a questionnaire to describe the respondent's proficiency in fraction subconstructs, particularly on part-whole, measure, operator, and quotient. Thereafter, a regression analysis was followed to determine the significant predictors of the conceptual understanding of fraction arithmetic among the fraction subconstructs.

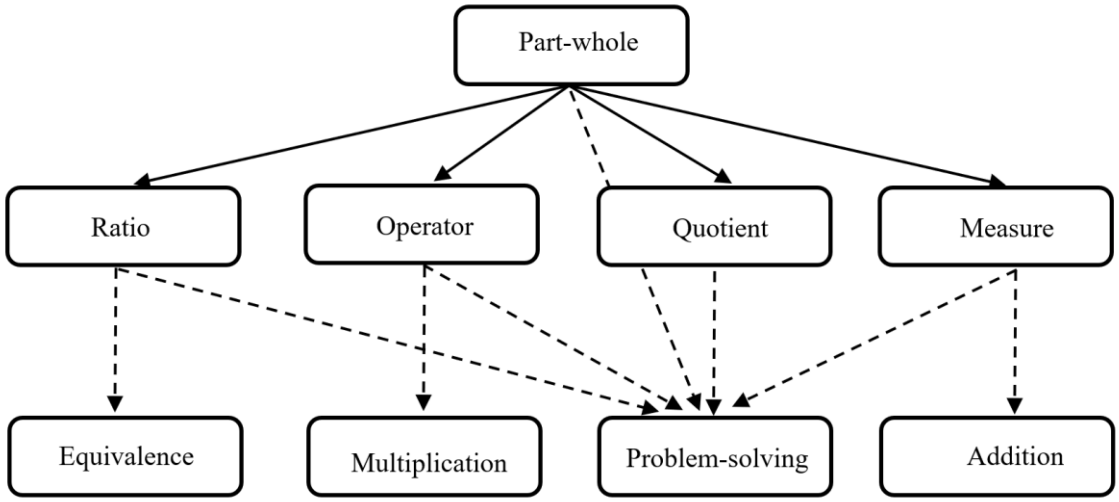


Figure 1. The Kieren-Behr Model (Behr et al. 1983).

Site and Participants

The respondents of the study were 61 pre-service teachers enrolled at a public university in central Luzon, Philippines, during the second semester of the academic year 2020-2021. This study used a purposive sampling design to select the respondents. Purposive sampling design is a sampling method in which the researcher uses his discretion to determine the respondents who best fulfill the study's objectives. The study purposefully chose the students enrolled in the Bachelor of Elementary Education program, as these pre-service teachers will soon be in-service teachers in the different municipalities or cities in Nueva Ecija and nearby provinces where elementary pupils' low mathematics achievement in the 2016-2017 National Achievement Tests is prevalent (Albano 2020). In addition, the sampling method was brought about by the restrictions of the Coronavirus (COVID-19) pandemic, in which the university was forced to go on fully online mode (asynchronous) classes, and random sampling would not be a practical option since only a limited number of students would have a reliable internet connection.

Data Collection

The researchers secured the necessary permission from the dean of the College of Education. Letters of courtesy and permission addressed to the above office have been circulated. The questionnaire distribution commenced after securing permission from the dean and the head of the elementary education department. The instrument was administered online through Google Forms on the dates set by the dean. The respondents were allowed to work independently for a time duration of 1 hour and 30 min.

Addressing the ethical issues in testing (Cohen et al. 2018), none of the respondents were forced to participate. The respondents answered the questionnaire with a complete understanding that the data collected would not be reflected in their academic records. Furthermore, the problem-posing tasks compelled them to work independently; unlike problem-solving, problem-posing does not have a single correct response. Thus, the researchers could easily discern if they had cheated. They scanned the students' responses and found that no two respondents had the same responses on the same item. The data's confidentiality and the respondents' anonymity were also assured, as the data is stored in a secured account, and no respondents' names were mentioned in the entire paper. Thus, no potentially delicate data will be traced back to each respondent.

Instrumentation

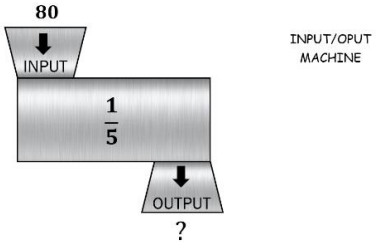
The content validity of the Fraction Subconstruct Test (FST) and Problem-Posing Task (PPT) has been established by the two mathematics experts. A table of specifications was provided to help the experts examine the test instrument for the study. Several revisions have been made to the instruments to capture the overall purpose of the study.

Two test questionnaires were used in the study. The first test was the FST. The study excerpted and modified some test items used in Baker et al. (2012) and Charalambous and Pitta-Pantazi (2007) to measure the respondents' proficiency in FST. The FST is subdivided into four major parts that measure respondents' proficiency in each fraction subconstruct. The test for the part-whole subconstruct (7 items) contained three components: translating a picture to a symbolic fraction, translating symbolic fractions to the

equivalent picture, and reconstructing the whole given a part. The test for the measure subconstruct (11 items) consists of identifying fractions as numbers and locating numbers on number lines, finding a number close to a certain number, comparing magnitudes of fractions, and finding a number between two numbers. The operator subconstruct test (5 items) consists of three components: representing mathematical statements into fractions, finding the output quantity given by the input and fraction operators, and finding the input quantity provided by the output and fraction operators. The test for the quotient subconstruct (6 items) consists of linking a fraction to the division of two numbers and solving partitive and quotative division situations. The second test is the PPT, which was divided into three sub-parts. Each sub-part was dedicated to each classification of problem-posing tasks (translating, comprehending, and selecting) described by Christou et al. (2005). Each of the three sub-parts consisted of four items, constituting the four operations on fractions (addition, subtraction, multiplication, and division). The decision to use the classification of Christou et al. (2005) is because the tasks are more structured (or at least semi-structured) in nature compared to the classifications proposed by Silver (1994) and Stoyanova and Ellerton (1996), which are "unstructured" or open-ended, which would be harder to score objectively and are more prone to bias.

A split-half method was utilized to test for the internal consistency of the FST. A Spearman-Brown coefficient of 0.825 has been computed, implying that the test is reliable. Tables 1 and 2 present the sample questions of the FST and PPT, respectively.

Table 1. Sample items of the Fraction Subconstruct Test.

Subconstruct	Sample Items
Part-whole	If these marbles  represent 2/3 of the whole set of marbles, draw the whole set of marbles.
Measure	Which of the following fractions is nearest to 1? a.) 1/2 b.) 2/3 c.) 4/5 d.) 5/6
Operator	The following diagram represents a machine that outputs 1/5 of the input number. What will be the output number if the input number is 80? 
Quotient	A 7-meter rope is to be cut into smaller pieces measuring 1/3 each. How many pieces can we cut from the rope?

The reliability of the scoring procedure was tested by asking two mathematics teachers to score 10% of the total problem-posing responses (cf. Tong et al. 2020). The inter-rater reliability coefficient was calculated using the formula described by Miles and Huberman (1994):

$$Inter-rater\ reliability = \frac{number\ of\ agreements}{number\ of\ agreements + number\ of\ disagreements}$$

As a result of applying the formula, a confidence percentage of 93% was obtained. The present study used a dichotomous scoring scheme for assigning values based on the respondents' response to the Fraction Subconstruct Test. Thus, the answers were given a numerical value of zero (0) if the response was incorrect and a numerical value of one (1) if the response was correct. The FST has a total score of 29 points. The allocation of items for each subconstruct was determined based on the K–12 Curriculum Guide for Mathematics.

For PPT, the study adopted and modified the scoring rubric from Cankoy and Özder (2017) to assess the respondent's performance in structured and semi-structured problem-posing tasks (Table 3). The rubric was originally intended to assess the problem-

Table 2. Sample items of Problem-Posing Test.

<table>
<tr><th>Type of PPT</th><th>Sample Item</th></tr>
<tr><td>Comprehending</td><td>Write an appropriate word problem based on the equation $\frac{1}{2}+\frac{1}{3}=n$.</td></tr>
<tr><td>Translating</td><td>Write a subtraction problem based on the table below.
<table>
<tr><th>Day</th><th>Cooked Rice</th></tr>
<tr><td>1</td><td>1/2 cavan of rice</td></tr>
<tr><td>2</td><td>1/3 cavan of rice</td></tr>
<tr><td>3</td><td>2/3 cavan of rice</td></tr>
<tr><td>4</td><td>1/3 cavan of rice</td></tr>
</table></td></tr>
<tr><td>Selecting</td><td>Write a question about the following story so that the answer to the problem is 5/6. Use the space provided after the story.
“Don Rafael ate 1/6 of a bibingka for a snack and 2/3 of the same bibingka for lunch. _____?</td></tr>
</table>

Table 3. The Problem-Posing Task Scoring Rubric. [a] For comprehending tasks only; [b] For translating tasks only; [c] For selecting tasks only.

CATEGORY	SUB-CATEGORY	EXPLANATION	SCORE
Solvability	Solvable	The information given in the problem is sufficient to solve the problem and find the solution.	1
	Unsolvable	The information given in the problem is not sufficient to solve the problem and find the solution.	0
Reasonability	Reasonable	The problem and the solution are reasonable and applicable in real life.	1
	Unreasonable	The problem and the solution are not reasonable and applicable in real life.	0
Language	Correct Mathematical Terms	The mathematical terms are correctly used in the problem	1
		The mathematical terms are not appropriately used in the problem	0
	Obeying grammar rules	The problem obeyed the grammar rules at all to express the question.	1
		The problem partly obeyed or did not obey grammar rules at all when expressing the question.	0
Restrictions	Appropriate to the given equation[a]	The solution to the problem fits the given equation	1
		The solution to the problem does not fit the given equation	0
	Appropriate to the given table[b]	The quantitative information on the table was used properly	1
		The quantitative information on the table was used properly	0
	Appropriate to the given situation and expected solution[c]	The problem satisfies the given situation, and the needed answer	1
		The problem satisfies the given situation, and the needed answer	0

posing performance of students in a free situation (PPT). The rubric was modified by removing two original categories that do not seem appropriate to assess structured and semi-structured PPTs (cf. Cankoy and Özder 2017). One category is also added to assess their problem-posing performance in specific problem-posing processes described by Christou et al. (2005). The PPT has a total score of 60 points. Each of the operations is given a maximum score of 15 points.

RESULTS

Pre-service Teachers' Proficiency in Fraction Subconstructs

The pre-service teachers performed unsatisfactorily in the FST (Overall MPS $= 51.76$) (Table 4), suggesting they have about 52% mastery of the expected competencies. Furthermore, the computed average standard deviations (SD = 25.98) of scores indicate that the Elementary Pre-service Teachers' scores range from beginning to proficient levels (51.76 ± 25.98).

Elementary Pre-service Teachers' Problem-Posing Performance in Fraction Arithmetic

They performed unsatisfactorily in the PPT (Overall mean = 2.00), suggesting that their conceptual understanding of fraction arithmetic is not fully developed (Table 5). The computed overall SD indicates that student performance has a wide variability, ranging from poor to excellent (2.00 ± 3.25).

Table 4. Pre-service teachers' proficiency in fraction subconstructs. Note: Unsatisfactory/Beginning = 0.00-59.99; Fairly Satisfactory/Developing = 60.00-67.99; Satisfactory/Approaching Proficiency = 68.00-75.99; Very Satisfactory/Proficient = 76.00-83.99; Outstanding/Advanced = 84.00-100.00. MPS – mean percentage score_; SD – standard deviation.

FRACTION SUBCONSTRUCTS	MPS	SD	DESCRIPTION
Part-whole subconstruct	**64.87**	**25.09**	**Fairly Satisfactory / Developing**
1. Translating the picture to a symbolic fraction	75.41	26.18	Satisfactory / Approaching Proficiency
2. Translating symbolic fractions to picture	34.43	47.91	Unsatisfactory / Beginning
3. Reconstructing the whole given a part of it	42.62	49.86	Unsatisfactory / Beginning
Measure subconstruct	**39.49**	**20.25**	**Unsatisfactory / Beginning**
1. Identifying fractions as numbers	65.57	47.91	Fairly Satisfactory / Approaching Proficiency
2. Locating numbers on number lines	36.07	24.72	Unsatisfactory / Beginning
3. Comparison of magnitudes of fractions	50	37.64	Unsatisfactory / Beginning
4. Finding a number between two fractions	24.59	43.42	Unsatisfactory / Beginning
5. Finding a number closer to one	31.98	39.83	Unsatisfactory / Beginning
Operator subconstruct	**47.21**	**27.58**	**Unsatisfactory / Beginning**
1. Representing mathematical statements into fractions	63.93	29.01	Fairly Satisfactory / Approaching Proficiency
2. Finding output quantity given input and fraction operator	41.8	44.89	Unsatisfactory / Beginning
3. Finding input quantity given output and fraction operator	24.59	43.42	Unsatisfactory / Beginning
Quotient subconstruct	**55.46**	**23.91**	**Unsatisfactory / Beginning**
1. Linking a fraction to the division of two numbers	75.41	43.42	Satisfactory / Beginning
2. Partitive division	47.54	30.10	Unsatisfactory / Beginning
3. Quotative division	57.38	40.66	Unsatisfactory / Beginning
Overall MPS	**51.76**	**25.98**	**Unsatisfactory / Beginning**

Table 5. The respondents' problem-posing performance in operations with fractions. Note: Poor = 0-1.25; Unsatisfactory = 1.26-2.50; Satisfactory – 2.51-3.75; Excellent = 3.76-5.00.

OPERATION	$\bar{x}$	SD	DESCRIPTION
Addition	**2.44**	**3.69**	**Unsatisfactory**
Comprehending	2.41	1.99	Unsatisfactory
Translating	3.02	1.88	Satisfactory
Selecting	1.89	1.46	Unsatisfactory
Subtraction	**1.95**	**3.58**	**Unsatisfactory**
Comprehending	1.95	1.91	Unsatisfactory
Translating	1.33	1.63	Unsatisfactory
Selecting	2.56	173	Satisfactory
Multiplication	**1.70**	**3.82**	**Unsatisfactory**
Comprehending	1.08	1.49	Poor
Translating	1.69	1.77	Unsatisfactory
Selecting	2.33	1.74	Unsatisfactory
Division	**1.90**	**4.13**	**Unsatisfactory**
Comprehending	1.61	1.88	Unsatisfactory
Translating	2.26	1.68	Unsatisfactory
Selecting	1.82	1.91	Unsatisfactory
Overall Performance	**2.00**	**3.25**	**Unsatisfactory**

Predictors of Conceptual Understanding of Arithmetic Operations on Fractions

When examining the predictors of conceptual understanding of arithmetic operations on fractions, multiple linear regression analyses were conducted. The Variance Inflation Factor (VIF) of the independent variables ($\text{part} - \text{whole} = 1.66, \text{measure} = 1.30, \text{operator} = 1.04, \text{and quotient } 1.49$) was less than 2 in all models, indicating no severe multi–collinearity among the independent variables. Furthermore, the tests for normality of the residuals using the Shapiro-Wilk test and the Durbin-Watson Test for autocorrelation were not significant ($P > 0.05$).

The results revealed that EPTs' proficiency in the measure subconstruct significantly predicts their conceptual understanding of adding fractions (Table 6). Additionally, their proficiency in the quotient subconstruct predicts their conceptual understanding of subtracting fractions (Table 7). Moreover, their proficiency in operator and quotient subconstruct predicts a conceptual understanding of multiplying fractions (Table 8), while their proficiency in the part-whole subconstruct predicts their conceptual understanding of dividing fractions (Table 9).

Table 6. Predictors of conceptual understanding of adding fractions. Note: * Test is significant at the 0.05 level (2-tailed); ***Test is significant at the 0.001 level (2-tailed).

Predictor	Coefficient	Standard Error	*t*-value	*p*-value
Part-Whole Subconstruct	0.182	0.305	0.596	0.554
Measure Subconstruct	0.445	0.213	2.089	0.041*
Operator Subconstruct	0.394	0.308	1.277	0.207
Quotient Subconstruct	0.649	0.345	1.831	0.072
Constant	1.465	1.360	1.077	0.286
R-square = 0.286	Multiple R = 0.535	F (4,56) = 5.62***		

Table 7. Predictors of conceptual understanding of subtracting fractions. Note: * Test is significant at the 0.05 level (2-tailed); ***Test is significant at the 0.001 level (2-tailed).

Predictor	Coefficient	Standard Error	*t*-value	*p*-value
Part-Whole Subconstruct	0.442	0.305	1.474	0.146
Measure Subconstruct	-0.095	0.210	-0.453	0.652
Operator Subconstruct	0.465	0.304	1.531	0.131
Quotient Subconstruct	0.792	0.349	2.269	0.027*
Constant	0.508	1.339	0.379	0.706
R-square = 0.266	Multiple R = 0.516	F (4,56) = 5.08***		

Table 8. Predictors of conceptual understanding of multiplying fractions. Note: * Test is significant at the 0.05 level (2-tailed); **Test is significant at the 0.01 level (2-tailed).

Predictor	Coefficient	Standard Error	*t*-value	*p*-value
Part-Whole Subconstruct	0.171	0.326	0.524	0.602
Measure Subconstruct	0.004	0.227	0.019	0.985
Operator Subconstruct	0.820	0.329	2.489	0.016*
Quotient Subconstruct	0.767	0.378	2.028	0.047*
Constant	-0.183	1.452	-0.126	0.900
R-square = 0.243	Multiple R = 0.492	F (4,56) = 4.48**		

Table 9. Predictors of conceptual understanding of dividing fractions. Note: * Test is significant at the 0.05 level (2-tailed); **Test is significant at the 0.01 level (2-tailed).

Predictor	Coefficient	Standard Error	*t*-value	*p*-value
Part-Whole Subconstruct	0.797	0.350	2.278	0.027*
Measure Subconstruct	-0.249	0.244	-1.018	0.313
Operator Subconstruct	0.268	0.354	0.756	0.453
Quotient Subconstruct	0.725	0.407	1.781	0.080
Constant	0.105	1.562	0.067	0.947
R-square = 0.249	Multiple R = 0.499	F (4,56) = 4.64**		

DISCUSSION

Proficiency in Fraction Subconstructs

The results of the descriptive analysis demonstrate that most pre-service teachers were proficient in the part-whole subconstruct. This suggests that understanding the part-whole interpretation of fractions is easier for pre-service teachers compared to other aspects of fractions. This finding supports the Kieren-Behr model and implies that the part-whole interpretation is fundamental to learning fractions. The results also indicate that pre-service teachers are comfortable interpreting fractions from visual representations. This verifies the popular notion that it is easier to learn with visual aids, similar to what Mendiburo et al. (2014) found in learning part-whole through visual aids. The students must first understand the part-whole concept of the fraction before moving on to understanding the other four subconstructs. Nevertheless, this is also aligned with the conclusion of the study concluded by Baker et al. (2009) and Charalambous and Pitta-Pantazi (2007). The part-whole subconstruct being the most straightforward interpretation to acquire is not surprising since it is the most common representation of fractions starting from primary school (Alajmi 2012; Kolar et al. 2018; Jiang 2021).

To develop a robust understanding of the measure subconstruct, an understanding of portioning and the density property of rational numbers is required, as the number of fractions between any two fractions is infinite (Charalambous and Pitta-Panttazi 2007). The overall low proficiency in the measure subconstruct can be attributed to pre-service teachers' difficulties dealing with number lines, especially when asked to locate a point on a number line (Widjaja et al. 2011; Ergene and Ergene 2020; Jiang 2021). Furthermore, Tunc-Pekkan (2015) found that students performed poorly on problems with number lines compared to other graphical representations.

For the operator subconstruct, pre-service teachers also demonstrated unsatisfactory performance. This aligns with the notion that understanding fractions as operators, involving multiplication and division operations is challenging due to their multiplicative nature (Kieren 1976). Similar findings were reported by Buforn et al. (2017), highlighting pre-service teachers' difficulties in recognizing students' reasoning with inverse fraction operators.

The pre-service teachers also performed poorly in the quotient subconstruct, indicating a lack of recognition that any fraction can be seen as the result of a division. Specifically, they struggled with discerning that the fraction *x/y* denotes the numerical value obtained when *x* is divided by *y*. This deficiency can be attributed to their unsatisfactory performance in quotative and partitive divisions. The result suggests that the pre-service teachers are not yet proficient in the "repetitive subtraction" and the "fair-sharing" concept of division. On some note, the results contradict the study conducted by Clarke and Roche (2009), who concluded that pre-service teachers were more successful in solving partitive division than quotative division. However, they partially support the findings of Lee (2017), who found that most pre-service instructors could perform procedural fraction division calculations but had limited understanding of the quantitative meaning of quotative division.

Overall, the pre-service teachers' proficiency in fraction subconstructs fell short of the 50% mastery expected. This result is consistent with previous studies that revealed limited and unsatisfactory knowledge of fractions among pre-service teachers (Van Steenbrugge et al. 2013; Avcu 2019). Similarly, Lee et al. (2015) suggested that many pre-service teachers have limited understanding of fraction subconstructs, particularly in the measure and operator subconstructs.

Problem-Posing Performance in Fraction Arithmetic

Generally, the pre-service teachers performed unsatisfactorily on the problem-posing task. This indicates that they posed problems that captured only limited aspects of the different semantic structures of the operation. Akay and Boz (2009) commented that pre-service teachers who did not have the opportunity to pose problems during their university years would encounter difficulties in preparing and posing practical problems for their students. They would likely rely mostly on textbook problems, giving assessments that are not sensitive to the student's level of understanding.

The unsatisfactory performance of the pre-service teachers in posing addition problems in the comprehending-type PPT suggests that they face difficulties in making sense of the given equation by translating mathematical expressions into verbal expressions. Similarly, they performed unsatisfactorily on the selecting–type of PPT when adding fractions. This also shows that pre-service teachers need help with the operational and semantic structure of adding fractions. On the other hand, the pre-service teachers performed satisfactorily on translating-type PPT by adding fractions, indicating that they could translate quantitative information embedded on a table into a verbal mathematics problem. Overall, the data revealed the deficiency of the pre-service teachers in problem-posing performance in adding fractions. This supports the study of Dogan-Coskun (2019), who further asserted that although the pre-service elementary teachers were able to pose problems focusing on the "part-part-whole" or "joining" meanings of the addition operation, most of them posed problems with at least one error.

The unsatisfactory performance of the pre-service teachers in posing subtraction problems in the comprehending-type PPT suggests that they need help in formulating verbal mathematics problems as they could not grasp the overall meaning of the equation. Similarly, they performed unsatisfactorily on the translating type of PPT in subtracting fractions. This also shows that pre-service teachers have problems translating quantitative information into tabular form. In contrast, the pre-service teachers performed satisfactorily in the selecting-type of PPT in subtracting fractions. This indicates that they can translate quantitative information into a verbal problem in subtracting fractions. Similar results were articulated by the study conducted by Dixon et al. (2014), where they found that most pre-service teachers could not pose a problem with subtraction problems appropriately. Furthermore, they found that pre-service teachers, when asked to pose a problem presenting the expression $a - b$, tend to pose problems representing $a - (ab)$, especially in the domain of fractions because of incorrect redefinition of the whole. Similar errors were noticed in the problems posed by the pre-service teachers in the present study.

The results suggest that the pre-service teachers have difficulty posing a multiplication problem in all three types of PPT, especially in the comprehending-type of task. This further suggests that they could not wholly translate equations, situations, tables, and figures into verbal mathematics problems when multiplying fractions. In total, this result was

comparable to the analysis of Luo (2009), where their analysis suggests that a significant percentage of the pre-service teachers in the study could not construct an entirely appropriate fraction multiplication word problem, and their known semantic structures are limited. Based on these results, Luo (2009) asserted that pre-service teachers should at least possess both mathematical content knowledge and problem-posing skills.

From the results, it can also be concluded that they performed worse in posing multiplication problems compared to the other operations. This contradicts the common knowledge that division is more complicated to grasp due to its more complex structure (Tirosh 2000). Moreover, this contradicts the findings of Xie and Masingila (2017), who concluded that division was the most challenging operation for posing story problems among the four operations. This further indicates that pre-service teachers were not familiar with or comfortable with the semantic structures of multiplication problems (e.g., part-of-a-whole and area). It can also be noted from the results of the present study that the pre-service teachers performed poorly on the comprehending-type of PPT. These difficulties in the transformation of symbolic expressions into verbal expressions are noticeable at the international level (Kar and Işık 2014). These alarming results suggest that formal training and frequent exposure to problem-posing tasks, especially in the multiplication-comprehending-type, need attention from teacher educators and authorities.

The unsatisfactory performance of the pre-service teachers in posing division problems conforms with the study conducted by Leung and Carbone (2013). Their analysis showed that only one-third of pre-service teachers could pose reasonable division problems that require a fraction divisor. Thus, in conjunction with their analysis, this depicts that many pre-service teachers do not have a rigorous understanding of the meaning of "dividing by a fraction." They could potentially skip explanations of these concepts with their future students or just focus on computation procedures.

Predictors of Conceptual Understanding of Arithmetic Operations on Fractions

To recall, the study aimed to argue that the fraction subconstruct must be able to predict not only procedural fluency in fraction arithmetic but also conceptual understanding. For comparison, Figure 1 presents the Kieren-Behr model, and Figure 2 summarizes the results of the series of regression analyses**.** We can notice that the analyses partially concurred with the hypothesis of the Kieren-Behr model except for the quotient subconstruct.

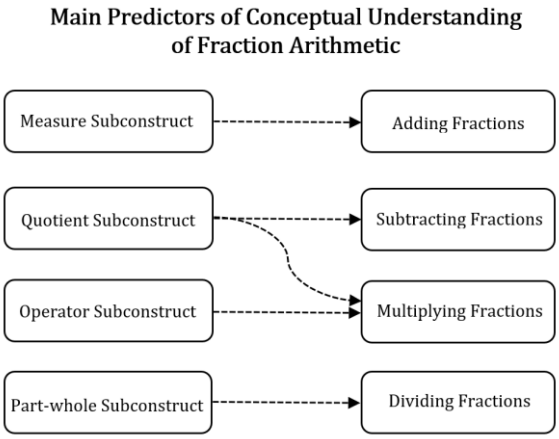


Figure 2. Summary of the regression analysis.

For predicting of the conceptual understanding of adding fractions, it was found that proficiency in the measure subconstruct is the most critical predictor. Pre-service teachers with a firm grasp of the measure subconstruct are likely adept at recognizing and manipulating fractions in various contexts, enabling them to better conceptualize the addition of fractions. The measure subconstruct, encompassing numerical relationships and magnitude comprehension, provides a foundation for pre-service teachers to accurately assess and perform operations related to the quantitative aspects of fractions. The result is consistent with the hypothetical pathways of the Kieren-Behr model. Furthermore, it supports the analysis of Baker et al. (2009) on adult learners, in which they found that understanding the measure subconstruct implies proficiency in adding fractions. The result suggests that teacher educators should pay attention to and plan intervention on pre-service teachers' proficiency in determining magnitudes of fractions, locating numbers on number lines, finding a number between two fractions, and finding a number closer to one, as they showed a lack of understanding in these areas. It has been shown that this lack of understanding may contribute to their development of concepts in adding fractions.

The quotient subconstruct appeared to be the primary predictor of the conceptual understanding of subtracting fractions. The result disagreed with the analysis of Charalambous and Pitta-Pantazi (2007) and Baker et al. (2009), who suggested that the measure subconstruct must also have a significant relationship with solving subtraction problems. However, the result of the present study showed that when it comes to posing subtraction problems, the relationship between the measure subconstruct and the operation of subtraction does not hold. A plausible reason for the relationship found between the quotient

subconstruct and the conceptual understanding of subtracting fractions is that pre-service teachers may be using their proficiency in "repeated subtraction" (quotative division) as a strategy for building relationships between the given quantitative information on each problem in subtraction. Nevertheless, the result of the analysis implies that the proficiency of the pre-service teachers in solving quotative and partitive division problems must be emphasized in the curriculum to help them be better problem-solvers when it comes to subtracting fractions.

For the conceptual understanding of multiplying fractions, the operator and quotient subconstruct appear to be the main predictors. The result is consistent with the hypothesis of the Kieren-Behr model, which suggests that knowledge of the operator subconstruct implies procedural knowledge of multiplying fractions. It is important to note that the quotient subconstruct was also found to be a significant predictor, which is comparable with the study of Charalambous and Pitta-Pantazi (2007) and Baker et al. (2009) where they found that knowledge of the quotient subconstruct is more important than the operator subconstruct in predicting fluency in multiplying fractions both young and adult learners. A plausible explanation for their relationship is that pre-service teachers may be using their proficiency in the "invert-multiply strategy" (a strategy commonly used to solve division problems) to establish relationships between the quantitative information needed to pose multiplication problems involving fractions. The results suggest that teacher educators should pay attention to and plan interventions for pre-service teachers' knowledge of partitive and quotative divisions as these help understand problem-posing tasks related to fraction multiplication.

Surprisingly, the quotient subconstruct did not significantly predict the concept of dividing fractions. Results showed that proficiency in the part-whole subconstruct is the main predictor of the conceptual understanding of dividing fractions. This result supports the relationship between part-whole and division found by Bicknell and Loveridge (2015). This further implies that pre-service teachers might be using the part-whole concept, in which the parts are considered components of the whole, to help identify which quantitative information serves as the dividend (part) and which one serves as the divisor (whole).

Recommendation for Instruction and Future Researchers

The significant regression model suggests that fractions subconstructs should be introduced first before the concepts of adding, subtracting, multiplying, and dividing fractions. These subconstructs will serve as a stepping stone in successful assimilating and accommodating the semantic structures of the corresponding fraction operations.

Due to low performance in both FST and PPT, we encourage curriculum writers and educators of pre-service teachers to revisit the mathematics curriculum offered to them and consider providing an adequate learning episode for fraction subconstructs.

A separate study dedicated solely to the detailed description of the mental activities and misconceptions of pre-service teachers on operations with fractions manifested through problem-posing tasks and a follow-up interview is highly recommended for future researchers. Furthermore, the analysis of the creativity of the problem-posers may be given a spot light to provide a more explicit role for proficiency in fraction subconstructs.

FUNDING

This study was funded by the Department of Science and Technology-Science Education Institute (DOST-SEI).

ETHICAL CONSIDERATIONS

The dean approved the letter to conduct the study inside the College of Education, Central Luzon State University. Consent from each respondent was also considered. No traceable data was collected from the respondents; thus, the confidentiality of the responses is secured.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests from any authors.

ACKNOWLEDGMENTS

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REFERENCES

Akay H and Boz N. 2009. Prospective teachers' views about problem-posing activities. Procedia – Social and Behavioral Sciences, 1(1): 1192–1198. https://doi.org/10.1016/j.sbspro.2009.01.215

Alajmi AH. 2012. How do elementary textbooks address fractions? A review of mathematics textbooks in the USA, Japan, and Kuwait. Educational Studies in Mathematics, 79: 239–261. https://doi.org/10.1007/s10649-011-9342-1

Albano E. 2020. CAR, Other Top Regions Nearly Lost Nat Standings Due to PSA Ineptness. https://www.zigzagweekly.net/car-other-top-regions-nearly-lost-nat-standings-due-to-psa-ineptness/?fbclid=IwAR3iqkKxLKf2ugY9xvNqC-905js2GBCJJZ-YE46GxpgorUBKkjPpH1u3c8Y. Accessed on 14 March 2023.

Avcu R. 2019. Turkish Pre-service Middle-Level Mathematics Teachers' Knowledge for Teaching Fractions. Research in Middle Level Education, 42(9): 1–20. https://doi.org/10.1080/19404476.2019.1681624

Baker W, Czarnocha, B, Dias O, Doyle KM and Prabhu V. 2009. On Adult Students Learning Fractions at a Community College. Annales of the Polish Mathematical Society 5th Series: Didactica Matimaticae, 31.

Baker W, Czarnocha B, Dias O, Doyle K and Kennis JR. 2012. Procedural and Conceptual Knowledge: Adults Reviewing Fractions. Adults Learning Mathematics International Journal, 7(2), 39–65.

Behr M, Lesh R, Post T and Silver E. 1983. Rational Number Concepts. In Lesh R and Landau M (eds.). Acquisition of Mathematics Concepts and Processes. Academic Press, New York, pp. 91–125.

Bicknell B and Young-Loveridge J. 2015. Using multiplication and division contexts with young children to develop part-whole thinking. Set: Research information for teachers, (2): 53–59.

Buforn À, Fernández C, Llinares S and Sánchez-Matamoros G. 2017. Characteristics of pre-service primary teachers' noticing of students' thinking related to fraction concept sub-constructs. Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education. https://hal.science/hal-01949061v1/document. Accessed on 14 March 2023.

Cai J and Hwang S. 2023. Making Mathematics Challenging Through Problem Posing in the Classroom. In: Leikin R. (eds). Mathematical Challenges For All. Research in Mathematics Education. Springer. https://doi.org/10.1007/978-3-031-18868-8_7

Cankoy O and Özder H. 2017. Generalizability theory research on developing a scoring rubric to assess primary school students' problem-posing skills. Eurasia Journal of Mathematics, Science and Technology Education, 13(6): 2423–2439. https://doi.org/10.12973/eurasia.2017.01233a

Charalambous CY and Pitta-Pantazi D. 2005. Revisiting a theoretical model on fractions: implications for teaching and research. Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education, 2: 233–239.

Charalambous CY and Pitta-Pantazi D. 2007. Drawing on a theoretical model to study students' understanding of fractions. Educational Studies in Mathematics, 64(3): 293–316. https://doi.org/10.1007/s10649-006-9036-2

Christou C, Mousoulides N, Pittalis M, Pitta-Pantazi D and Sriraman B. 2005. An empirical taxonomy of problem-posing processes. Zentralblatt füur Didaktik der Mathematik – International Journal on Mathematics Education, 37(3): 149–158. https://doi.org/10.1007/s11858-005-0004-6

Clarke DM and Roche A. 2009. Making sense of partitive and 93uotative division: a snapshot of teachers' pedagogical content knowledge. In Hunter R, Bicknell B and Burgess T (eds). Crossing Divides: Proceedings of the 32nd Annual Conference of the Mathematics Education Research Group of Australasia. Palmerston Nth, New Zealand, pp. 467–474.

Cohen L, Manion L and Morrison K. 2018. Research Methods in Education (8th ed.). Routledge, London, England. 585pp.

Copur-Gencturk Y. 2021. Teachers' conceptual understanding of fraction operations: results from a national sample of elementary school teachers. Educational Studies in Mathematics, 107: 525–545. https://doi.org/10.1007/s10649-021-10033-4

Dixon JK, Andreasen JB, Avila CL, Bawatneh Z, Deichert DL, Howse TD and Mercedes T. 2014. Redefining the Whole: Common Errors in Elementary Pre-service Teachers' Self-Authored Word Problems for Fraction Subtraction. Investigations in Mathematics Learning, 7(1): 1–22. https://doi.org/10.1080/24727466.2014.11790336

Dogan-Coskun S. 2019. The analysis of the problems posed by pre-service elementary teachers for the addition of fractions. International Journal of Instruction, 12(1): 1517–1532. https://doi.org/10.29333/iji.2019.12197a

Donovan MS and Bransford JD. 2005. How students learn: Mathematics in the classroom. Washington, DC: National Academies Press.

Ergene BC and Ergene O. 2020. Repeating decimals and irrational numbers on the number line: through the lens of pre-service and in-service mathematics teachers. Acta Didactica Napocensia, 13(2): 215–232. https://doi.org/10.24193/adn.13.2.15

Jiang Z, Mok IAC and Li J. 2021. Chinese students' hierarchical understanding of part-whole and measure subconstructs. International Journal of Science and Mathematics Education, 19(7): 1441–1461. https://doi.org/10.1007/s10763-020-10118-1

Kar T and Işık C. 2014. Analysis of problems posed by pre-service primary teachers about adding fractions in terms of semantic structures. International Electronic Journal of Mathematics Education, 9(2): 135–146. https://doi.org/10.29333/iejme/286

Kieren TE. 1976. On the mathematical, cognitive and instructional foundations of rational numbers. Number and Measurement: Papers from a Research Workshop. Education Resources Information Center Information Analysis Center for Science, Mathematics, and Environmental Education and Georgia University, pp. 108–151.

Kieren TE. 1980. The Rational Number Construct: its Elements and Mechanisms. In: Kieren TE (eds). Recent Research on Number Learning, ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, pp. 125–149. https://eric.ed.gov/?id=ED212463

Kilic C. 2015. Analyzing pre-service primary teachers' fraction knowledge structures through problem-posing. Eurasia Journal of Mathematics, Science and Technology Education, 11(6): 1603–1619. https://doi.org/10.12973/eurasia.2015.1425a

Kolar VM, Čadež TH and Vula E. 2018. Primary teacher students' understanding of fraction representational knowledge in Slovenia and Kosovo. CEPS Journal: Center for Educational Policy Studies Journal, 8(2): 71–96. https://doi.org/10.26529/cepsj.342

Lee JE and Lee MY. 2023. How elementary prospective teachers use three fraction models: their perceptions and difficulties. Journal of Mathematics Teacher Education, 26: 455–480. https://doi.org/10.1007/s10857-022-09537-4

Lee MY, Son JW and Arabeyyat T. 2015. Pre-service teachers' fractional concepts in solving advanced fraction problems. Proceedings of the 37th annual meeting of the North

American Chapter of the International Group for the Psychology of Mathematics Education, 724–731. https://www.pmena.org/pmenaproceedings/PMENA%2037%202015%20Proceedings.pdf

Lee MY. 2017. Pre-service teachers' flexibility with referent units in solving a fraction division problem. Educational Studies in Mathematics, 96: 327–348. https://doi.org/10.1007/s10649-017-9771-6

Leung IKC and Carbone RE. 2013. Pre-service Teachers' Knowledge about Fraction Division Reflected through Problem-posing. In The Mathematics Educator, 14(2): 80-92.

Luo F. 2009. Evaluating the Effectiveness and Insights of Pre-Service Elementary Teachers' Abilities to Construct Word Problems for Fraction Multiplication. Journal of Mathematics Education, 2(1): 83–98. https://www.researchgate.net/publication/237781989

Matsko VJ and Thomas J. 2015. Beyond Routine: Fostering Creativity in Mathematics Classrooms. In: Singer FF, Ellerton N and Cai J. (eds) Mathematical Problem Posing. Research in Mathematics Education. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-6258-3_6

Mendiburo M, Hasselbring T and Biswas G. 2014. Teaching fractions with technology: what type of support do students need as they learn to build and interpret visual models of fractions ordering problems? Journal of Cognitive Education and Psychology, 13(1): 76–87. https://doi.org/10.1891/1945-8959.13.1.76

Miles MB and Huberman MA. 1994. Qualitative data analysis: An expanded sourcebook, 2nd ed. In Qualitative data analysis: An expanded sourcebook, 2nd ed. Sage Publications, Inc. California.

Nillas LA. 2003. Division of fractions: Pre-service teachers' understanding and use of problem-solving strategies. The Mathematics Educator, 7(2): 96–113.

Osana H and Royea D. 2011. Obstacles and challenges in pre-service teachers' explorations with fractions: A view from a small-scale intervention study. The Journal of Mathematical Behavior, 30(4): 333–352. https://doi.org/10.1016/j.jmathb.2011.07.001

Perry CJ. 2023. Elementary pre-service mathematics teachers fraction knowledge: an integrative review of research. Educational Considerations, 49(1): 6. https://doi.org/10.4148/0146-9282.2346

Rosli R, Goldsby D, Onwuegbuzie A, Capraro MM, Capraro R and Gonzalez E. 2020. Elementary pre-service teachers' knowledge, perceptions and attitudes towards fractions: A mixed-analysis. Journal on Mathematics Education, 11(1): 59-76. https://doi.org/10.22342/jme.11.1.9482.59-76

Tichá M and Hošpesová A. 2013. Developing teachers' subject didactic competence through problem posing. Educational Studies in Mathematics, 83: 133–143. https://doi.org/10.1007/s10649-012-9455-1

Tirosh D. 2000. Enhancing Prospective Teachers' Knowledge of Children's Conceptions: The Case of Division of Fractions. Journal for Research in Mathematics Education, 31(1): 5–25. https://doi.org/10.2307/749817

Tong F, Tang S, Irby B J, Lara-Alecio R and Guerrero C. 2020. Inter-rater reliability data of classroom observation: Fidelity in large-scale randomized research in education. Data in Brief, 29: 105303. https://doi.org/10.1016/j.dib.2020.105303

Tossavainen A and Johansson M. 2023. An insight into prospective elementary teachers' mathematical knowledge for teaching: An example of fraction division. In Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13) (No. 19). Alfréd Rényi Institute of Mathematics; ERME. https://hal.science/hal-04421423/

Tunc-Pekkan Z. 2015. An analysis of elementary school children's fractional knowledge depicted with circle, rectangle, and number line representations. Educational Studies in Mathematics, 89: 419–441. https://doi.org/10.1007/s10649-015-9606-2

Van Steenbrugge H, Lesage E, Valcke M and Desoete A. 2013. Pre-service elementary school teachers' knowledge of fractions: a mirror of students' knowledge? Journal of Curriculum Studies, 46(1): 138–161. https://doi.org/10.1080/00220272.2013.839003

Widjaja W, Stacey K and Steinle V. 2011. Locating negative decimals on the number line: insights into the thinking of pre-service primary teachers. The Journal of Mathematical Behavior, 30(1): 80–91. https://doi.org/10.1016/j.jmathb.2010.11.004

Xie J and Masingila JO. 2017. Examining Interactions between Problem-posing and Problem-solving with Prospective Primary Teachers: A Case of Using Fractions. Educational Studies in Mathematics, 96(1): 101–118. https://doi.org/10.1007/s10649-017-9760-9

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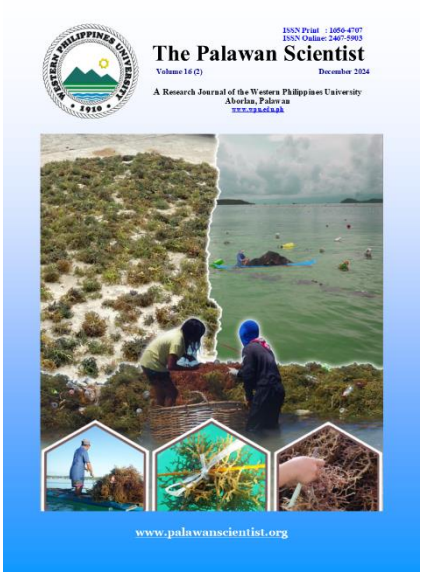

Morphological variation among cowries (Gastropoda: Cypraeidae) using geometric morphometrics and correlation analysis based on distances

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ABSTRACT

Cowries (Cypraeidae) are popular among shell collectors because of their beauty and relative availability. Some species of cowry have high collection values among shell markets, however this has led to an increase number of species and unnecessary proliferation of taxonomic names with little information on their morphology. Thus, this study was conducted to describe morphological variations among cowry shells obtained along Sindangan Bay, Philippines. The shell morphological attributes (e.g. shell shape, color, bands, banding pattern), morphometric characters (e.g. shell length, width, height, number of teeth, etc.), and shape were characterized using the relative warp scores generated from the outline and landmark-based geometric morphometric analysis (GM) and correlation analysis based on distances (CORIANDIS). Sixteen (16) morphological and ten (10) meristic characters of 113 samples from the seven Cypraeidae species were examined and analyzed. The variations on color, banding pattern, lateral margins, dorsal/transverse line, spire, teeth, size and shape of the shell were mainly observed. Relative warp analysis showed significant shell shape variation among Cypraeidae species. Correlation analysis based on distances showed morphological, size, and shape differences among Cypraeidae species. As revealed in correlation analysis, the observed variation in size was significantly correlated with shape. The observed differences could be due to many factors including genetic, biotic and abiotic factors; developmental processes and physiology in responses of the organisms to a unique environment. Thus, geometric morphometrics and CORIANDIS helped us understand the nature of diversity in the family Cypraeidae species. Further studies on environmental heterogeneity, species position within the population's distribution, and the genetic basis of the observed phenotypic diversity are necessary. Such emphasis can lead to additional information in the systematic studies on species of family Cypraeidae.

Keywords: cowry, cluster, dendrogram, disparity, Sindangan, variation

INTRODUCTION

Cowries, marine gastropods in the family Cypraeidae, are popular among shell collectors due to their glossy shells with varied colors and patterns. Cowries are collected for its aesthetic value, consumed as food, and used in shell crafts industry. Cowries play important roles as herbivores, predators and

decomposers in maintaining healthy balanced marine ecosystems (Poutiers 1998). Generally, they are widely distributed in reef-building corals (Malay and Paulay 2010). The presence of a beautiful shell in some cowry species have high collection values among shell markets (Ma et al 2023). However, commercial factors have led to an increase in the species number of cowries, which has resulted in an unnecessary proliferation of taxonomic names (Passamonti 2015). Cowries are currently classified into 55 genera and 9 subfamilies (MolluscaBase 2022) and approximately 217 species and numerous subspecies. Species level taxonomies are very subjective in contrast to stable taxonomies in higher levels. Despite well-defined shell-based genera, they have received limited attention from biologists and malacologists, resulting in few scientific studies available (Passamonti 2015).

Morphological studies rely on defining characters for species identification that may support the taxonomic validity of the species (Moneva 2012). In gastropod species-level taxonomy (Ackerly 1989), the external form of the shell is crucial for species discrimination (Kohler and Glaubrecht 2003). Cowry shells possess numerous characteristics, requiring multiple traits to describe their variability (Heiman 2011). Despite the relative disparity of shell morphologies, several conserved anatomical features and the rigid nature of their shells make gastropods well suited subjects of morphometric analysis (Smith and Hendricks 2013).

Geometric morphometrics is a tool used to quantify, interpret and analyze the size and shape of biological structures (Rohlf and Slice 1990), transforms continuous morphological data in the form of coordinate points into discrete characteristics represented by principal components of shape (Zelditch et al. 2012), integrates multivariate statistics and geometric principals to convey shape variation between specimens. This approach may add to understanding of morphological evolution, biogeography, and trait plasticity. In order to describe variability in the species, it is necessary to use a range of characters since cowry shells can be distinguished by more than one character.

Thus, this study aimed to characterized the phenotypic variations in Cypraiedae species using qualitative and quantitative morphological characters such as shell shape, color, bands, banding pattern, length, width, height, and teeth, respectively. Landmark and outline-based geometric morphometrics and correlation analysis based on distances were used to detect size and shape variation and analyze similarities and differences among species collected in Sindangan Bay, Philippines. This study is important in advancing the knowledge in the nature of variations in populations of organisms living in different ecological environments.

METHODS

Sampling Area

Sampling occurred in marine sanctuaries in Guisukan, Doña Josefa; Languyon, La Concepcion; and Dinukot, RG Macias in Sindangan Bay, (8°13'37"N; 122°54'55"E), Zamboanga del Norte, Philippines (Figure 1).

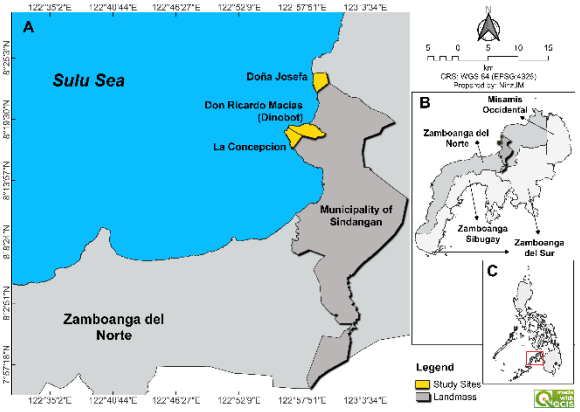

Figure 1. (A) The three study areas in Sindangan Bay, Sindangan, Zamboanga Del Norte.and (B) Zamboanga peninsula, and (C) inlet maps of the Philippines.

Sample Collection, Identification and Digital Images

Sampling was conducted during the lowest tide mark. A total of 113 specimens (Figure 2) which comprise of seven (7) *Cypraeidae* species namely; *Cypraea. caputserpentis* Linn 1758 (a), *Cypraea annulus* Linn 1758 (b), *Cypraea felina* Gmelin 1791, *Cypraea tigris* Linn 1758 (d), *Cypraea caurica* Linn 1758 (e), *Cypraea moneta* Linn 1758 (f) and *Cypraea arabica* Linn 1758 (g), were collected from reef flat shorelines up to 3 meters deep. The cowries were identified based on literature and locally available references (Poutiers 1998; Froese and Pauly 2022). Each shell was photographed where the columella is at 90° of the x-axis in aperture and dorsal views. These images were subjected to geometric morphometric analysis (e.g. TPS file, Relative Warp Analysis).

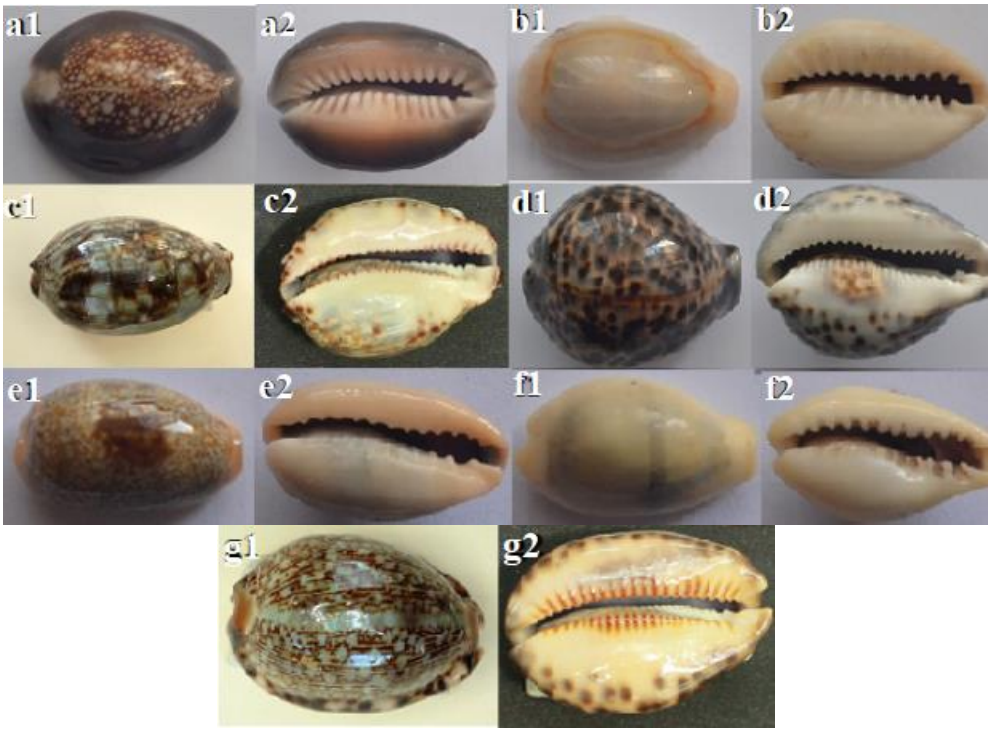

Figure 2. An illustration showing the dorsal (a1-g1) and ventral (a2-g2) shell of the Cypraeidae species. Legend: *Cypraea cataputserpentis* (a), *Cypraea. annulus* (b), *Cypraea felina* (c), C*ypraea tigris* (d), *Cypraea caurica* (e), *Cypraea moneta* (f) and *Cypraea arabica* (g).

Morphological (Qualitative) and Morphometric (Quantitative) Characterization

A matrix summarizing 26 characters (16 qualitative and ten quantitative) was created for data analysis (Table 1). Morphometric measurements, including shell dimensions, aperture size, and weight, were obtained using a digital Vernier caliper and weighing scale, respectively (Figure 3A, 3B and 3C). Columellar and labial teeth (CTR and LTR) (Figure 3D) were normalized using the formula, where total length or TL (in mm) of the shells served as the primary input variable (Heiman 2011):

$$LTR = 7 + (LT - 7) \times \left(\frac{25}{L} \times \frac{1}{2}\right)$$

$$CTR = 7 + (CT - 7) \times \left(\frac{25}{L} \times \frac{1}{2}\right)$$

Table 1. List of shell characters used in the analyses of the morphology and morphometrics characterization.

Characters	Scoring
1. Shape-dorsal	(0) ovate; (1) deltoidal-ovate; (2) elongated/cyclindrical
2. Shape-ventrall	(0) broad, flat, slightly concave; (1) flat-convex; (2) concave
3. Color- dorsal part	(0) creamy- white; (1) light fawn; (2) dark brown; (3) yellowish-green; (4) grey
4. Color- ventral part	(0) creamy grey/purplish pink; (1) creamy-light fawn/brown; (2) cream white/whitish
5. Color- lateral margins	(0) grayish-white; (1) creamy-light fawn; (2) dark brown; (3) cream-white/white
6. Color-columellar and labial teeth	(0) reddish-brown; (1) light fawn/brown; (2) cream-white/whitish
7. Axial bands- line situated along the axis	(0) none; (1) 1; (2) dissolve; (3) 3; (4) 4
8. Banding patterns- irregular arrangement of lines and space on the dorsal portion of the shell	(0) numerous; (1) few; (2) no white rounded spaces; (3) numerous white spots; (4) numerous smaller brown spots; (5) transverse bands; (6) yellow ring; (7) black/brown spot; (8) regular brown flecking crossed by four darker bands that run along at the dorsal surface

Characters	Scoring
9. Dorsal line- line around the shell body	(0) indistinct; (1) visible; (2) partially visible
10. Spire	(0) partially covered by a callus; (1) visible, slightly protruding; (2) depressed
11. Lateral margins	(0) distinctly calloused at proximity; (1) flat and smooth;(2) rounded; (3) wide angulate
12. Lateral spots	(0) absent; (1) present
13. Basal spots	(0) absent; (1) present
14. Terminal spots	(0) absent; (1) present
16. Outer lip	(0) declivous; (1) constricted
17. No. of Labial teeth	(0) 8-12; (1) 13-17; (2) 18-22; (3) 23-27
18.No of Columellar teeth	(0) 8-12; (1) 13-17; (2) 18-22; (3) 23-27
19. LTR	(0) 8-12; (1) 13-17; (2) 18-22; (3) 23-27
20. CTR	(0) 8-12; (1) 13-17; (2) 18-22; (3) 23-27
21. Shell Length (mm)	(0) 15-26; (1) 27-38; (2) 39-50; (3) 51-62; (4) 63-74; (5) ≥75
22. Shell Width (mm)	(0) 9-19; (1) 30-30; (2) 31-41; (3)42-52; (4) ≥53
23. Shell Height (mm)	(0) 7-17; (1) 18-28; (2) 29-39; (3) 40-50
24. Aperture length (mm)	(0) 13-23; (1) 24-34; (2) 35-45; (3) ≥46
25. Aperture width (mm)	(0) 1-2; (1) 3-4; (2) 5-6
26. Ave. weight (g)	(0) < 10; (1) 11-21; (2) 22-32; (3) ≥33

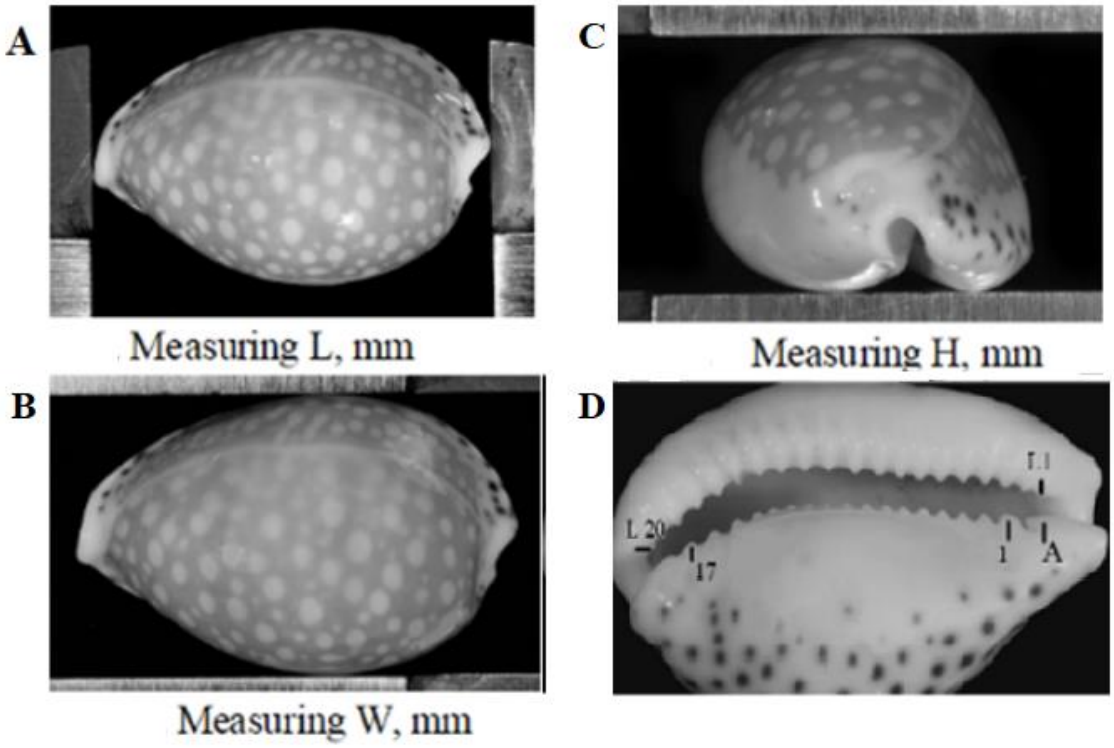

Figure 3. Morphometric and meristic measurements of *Cypraea* species shell size (in mm) such as length (A), width (B), height (C), and (D) - counting of teeth designations: A - a terminal ridge; L1 - the first labial tooth; 20-the last labial tooth; 1 the first columellar tooth; 17 - the last columellar tooth.

Landmark and Outline-based Geometric Morphometric Analysis

Shell shape analysis was done using a landmark and outline-based methodology to eliminate variations in location, orientation, and scale. One hundred anatomical landmarks along the dorsal portion (Figure 4A) and 17 along the ventral or apertural outline (Figure 4B, Table 2) were defined. The TpsDig freeware 2.12 (Rholf 2008a,) and Tps Util program 1.4 (Rholf 2009) facilitated the data

collection and statistical analysis of landmark data in morphometrics. The landmark coordinates were transferred to Microsoft Excel application for data organization into groups. Then the generalized orthogonal least squares Procrustes average configuration of landmarks was computed using the generalized Procustes Analysis (GPA) superimposition method. GPA was performed using the software tpsRelw, ver. 1.46 (Rholf 2008b). Histograms were generated using Paleontological Statistics [PAST] software (Hammer et al. 2009). The pairwise comparisons (Demayo et al. 2011), Kruskal-Wallis tests, and Canonical Variance Analysis (CVA) were used to analyze differences in shell shape among species and population variations.

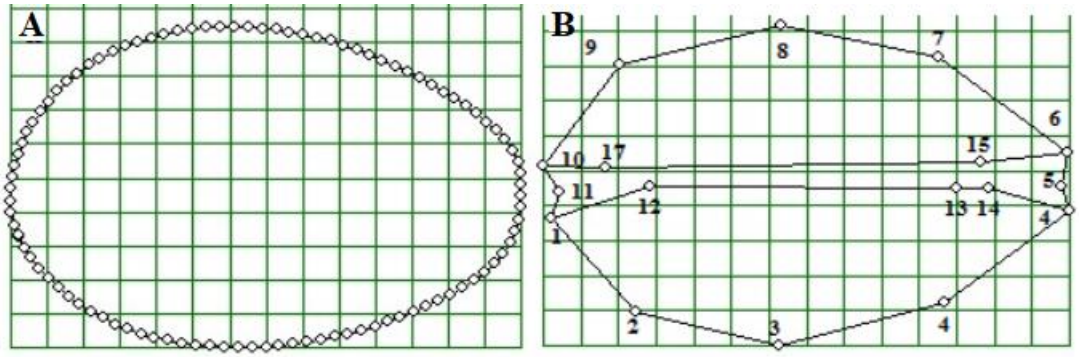

Figure 4. Landmarks used to describe the shape of the (A) dorsal and (B) ventral/apertural view of the shell of seven *Cypraea* species collected from Sindangan, Philippines.

Table 2. Descriptions of the anatomical landmark (LM) points in seven *Cypraea* species.

Landmark (LM) No.	Description of landmarks
1	last columellar tooth
2	first columellar tooth
3	terminal ridge
4	fore top of the inner lip
5	medial point between points 4 and 6 at the left shell margins
6	most prominent point of the left shell margins
7	medial point between points 6 and 8
8	hind top of the inner lip
9	junction point of the posterior canal
10	hind top of the outer lip
11	last labial tooth
12	first labial tooth
13	junction point of the anterior canal
14	fore top of the outer lip
15	medial point between points 14 and 16
16	most prominent point of the right shell margins
17	medial point between points 16 and 10

Correlation Analysis Based on Distances

Morphological and morphometric datasets that include landmarks for shell shape were analyzed using the Correlation analysis based on distances (CORIANDIS) 1.1 beta (Marquez and Knowles 2007). Associations among cowry shells were determined using multivariate datasets, compromise space projections, trait variance, unity, and multivariate covariance measures. The option "Projections on compromise space" was selected; this was done to plot all specimens/groups and traits/sets in the same space, obtained by projecting each dataset plus their weight average ('compromise') onto the compromise space. The stacked bar graphs visualized differences among the species (Tabugo et al. 2010 and Gutierrez et al. 2011). Cluster analysis was performed using the obtained scores. Correlation analysis examined the relationship between shell shape (dorsal and ventral) and size (length, thickness, aperture length).

RESULTS

Morphological (Qualitative) and Morphometric (Quantitative) Analysis of Shell Morphology

Morphological and morphometric analyses identified three clusters based on 16 morphological characteristics (Figure 5A). Clusters 1 and 2 differed in shell shape, axial bands, banding patterns, color, and lateral margins while cluster 3 consisted of four species subgroups with axial bands and banding pattern variations. Each species exhibited unique morphological traits. However, the morphometric analysis identified six clusters (Figure 5B), each representing different species based on labial and columellar teeth, shell dimensions, apertural length, and average weight. Clusters identified include Cluster 1 (two closely-related species 7), Cluster 2 (species 2, 4, 5, and 6), Clusters 3, 4, and 5 (species 1 and 3), and Cluster 6 (sole species 1). The seven Cypraeidae species exhibit distinct variations in labial and columellar teeth, shell dimensions, and average weight within each cluster.

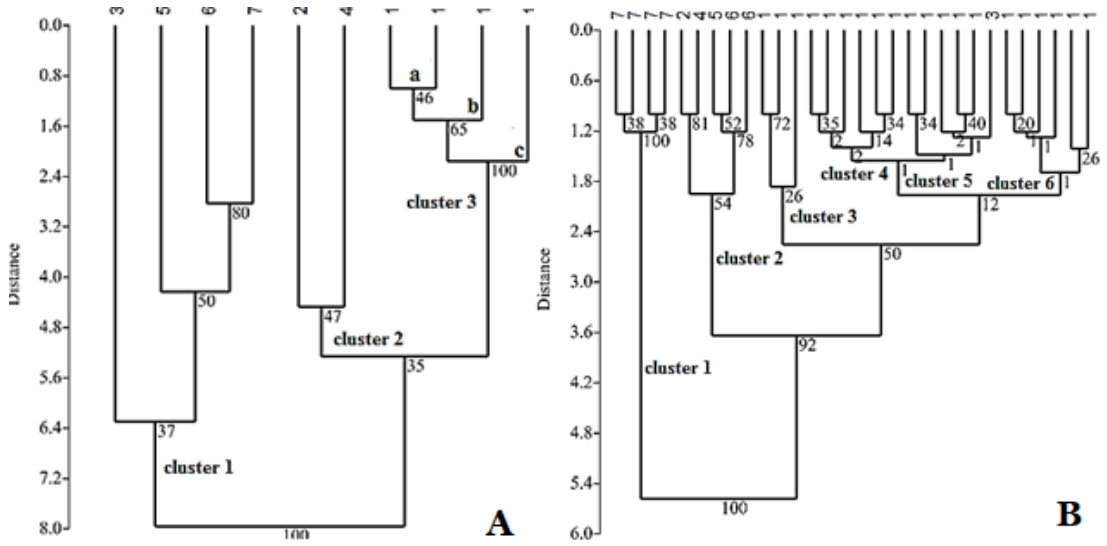

Figure 5. Hierarchical clusters of individuals of various qualitatively described (A) morphological (B) morphometric characters of *Cypraea arabica* (1), *Cypraea caputserpentis* (2), *Cypraea felina* (3) *Cypraea caurica* (4), *Cypraea moneta* (5), *Cypraea annulus* (6) and *Cypraea tigris* (7) collected in Sindangan Bay, Philippines.

Cypraea tigris had the highest shell weight and size measurements, such as length, width, thickness, apertural length, and apertural width (Table 3). *Cypraea felina* had multiple labial and columellar teeth. *Cypraea moneta* had the most petite average shell weight and size measurements except apertural width. *Cypraea annulus* had the least apertural width (1.08 mm). *Cypraea annulus*, *Cypraea moneta*, *Cypraea caputserpentis*, had measurement values very close to each other while *Cypraea arabica* had values more comparable to *Cypraea felina* and *Cypraea tigris* had the highest size measurements among the group.

Landmark and Outline-based Geometric Morphometric Analysis

Figure 6 presents the geometric morphometric analysis summary of 113 shells, showing consensus morphology (ventral/apertural and dorsal portion) based on relative warps (RW) from Table 4. Two significant RWs described the dorsal shape (Figure 6A), and four described the ventral shape (Figure 6B). Histogram projections display negative and positive deviations from the mean shape. The mean shape of the shell is shown in the topmost image. Negative RW1 and RW2 show depressed right lateral margins on the dorsal side, while positive RW1 and RW2 show depressed left and right lateral margins. On the ventral side, negative RW1-4 scores indicate a slightly depressed anterior extremity, while positive scores show heavily depressed anterior and posterior extremities. Kruskal-Wallis test confirmed differences in dorsal and ventral shell shapes among the seven species (Table 5).

Significant differences in shell shapes of the seven species were observed, such as the number of landmarks used, species differentiation based on the distribution of the samples along the first canonical variate axes of RW scores of the dorsal and

ventral/apertural view of the shell (Table 6). The distribution of individual cowries in the CVA scatterplot of the dorsal and ventral shell is shown in Figure 7A and Figure 7B, respectively. While overlaps were observed, the differences could also be observed on those variant forms that are outside the overlaps.

Table 3. Average measurements in shell size such as shell length (SL), shell width (SW), shell thickness (ST), shell aperture length (SAL), shell aperture with (SAW); shell weight (SWt) and number of normalized labial (LTR) and columellar (CTR) teeth of the seven *Cypraea* species.

Species	SL (mm)	SW (mm)	ST (mm)	SAL (mm)	SAW (mm)	SWt (g)	LTR (no.)	CTR (no.)
Cypraea arabica	43.05	27.78	22.66	40.51	3.35	14.88	19.16	18.49
Cypraea caputserpentis	27.67	21.28	13.92	26.40	1.68	5.94	15.00	11.00
Cypraea felina	39.80	25.20	21.13	38.63	2.88	7.64	22.00	20.00
Cypraea caurica	20.99	11.57	9.65	20.19	1.18	0.94	14.00	13.00
Cypraea moneta	16.48	9.58	7.66	14.97	1.23	0.49	13.00	11.00
Cypraea annulus	19.67	13.80	10.04	18.59	1.08	1.84	13.00	10.00
Cypraea tigris	73.39	51.93	39.10	68.82	5.84	64.46	17.00	16.00

Table 4. Percentage variance and overall shape variation in the dorsal and ventral shell of Cypraeidae as explained by significant relative warps.

RW	% Variation	Dorsal shell	% Variation	Ventral shell
1	73.13	High (+) RW scores show heavily depressed left and right lateral margins near the anterior and posterior parts of the right shell margins. Low (-) RW1 scores indicate heavily depressed right lateral margins near the anterior part of the shells.	52.08	High (+) RW scores: Heavily depressed anterior and posterior extremities. Low (-) RW scores: Slightly depressed anterior extremity of the shell.
2	17.66	High (+) RW scores: Heavily depressed left and right lateral margins near the anterior part, slightly depressed posterior part of right shell margins. Low (-) RW1 scores: Heavily depressed right lateral margins near the anterior part of shells.	16.77	High (+) RW scores: Heavily depressed anterior and posterior extremity. Low (-) RW scores: Slightly depressed anterior extremity of the shell.
3			10.11	High (+) RW scores: Heavily depressed anterior and posterior extremity. Low (-) RW scores: Slightly depressed anterior extremity of the shell.
4			7.27	High (+) RW scores: Heavily depressed anterior and posterior extremity. Low (-) RW scores: Slightly depressed anterior extremity of shell.

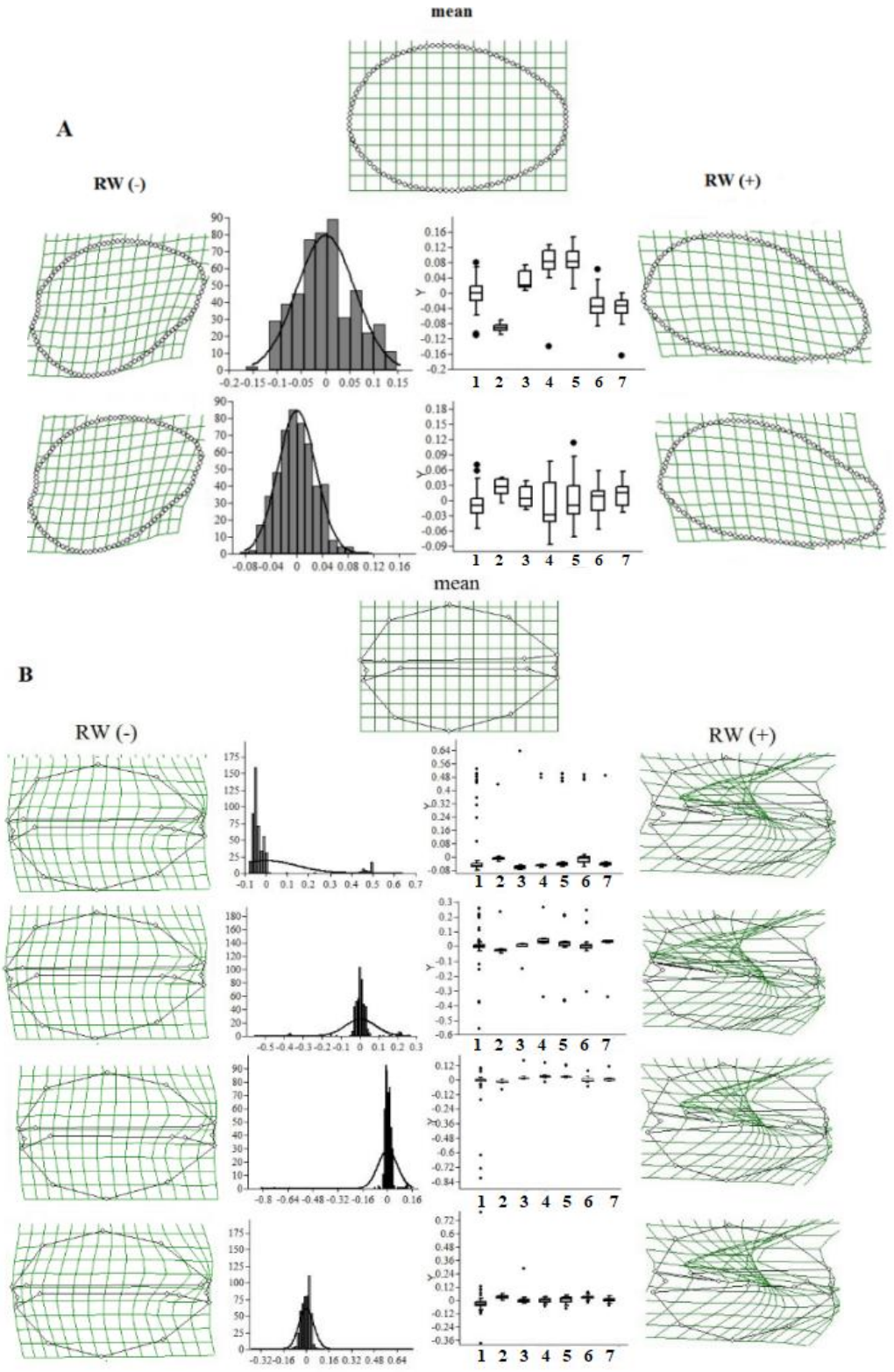

Figure 6. Relative warp (RW), box plot and histogram showing variations in the (A) dorsal and (B) ventral/aperture shell shape of seven *Cypraea* species. Legend: (1) *Cypraea arabica*, (2) *Cypraea caputserpentis*, (3) *Cypraea felina*, (4) *Cypraea caurica*, (5) *Cypraea moneta*, (6) *Cypraea annulus* and (7) *Cypraea tigris*.

Table 5. Pairwise comparison of the mean shapes of the dorsal and ventral side of the shell of the seven *Cypraea* species from Kruskal-Wallis Test.

RW	Sp.	**Dorsal**						
		1	2	3	4	5	6	7
1	1		4.365E-30	2.908E-08	1.766E-15	1.585E-31	1.569E-14	7.551E-13
	2	9.168E-29		1.371E-14	6.698E-13	1.072E-22	5.75E-24	2.02E-15
	3	6.107E-07	2.88E-13		4.113E-07	1.398E-10	1.97E-12	1.121E-2
	4	3.709E-14	1.407E-11	8.637E-06		0.6957	5.248E-14	2.893E-11
	5	3.328E-30	2.251E-21	2.937E-09	1		8.06E-26	3.436E-18
	6	3.295E-13	1.208E-22	4.138E-11	1.102E-12	1.693E-24		0.8937
	7	1.586E-11	4.242E-14	2.354E-11	6.076E-10	7.215E-17	1	
2	1		6.174E-21	0.0001107	0.2131	0.2954	5.375E-05	1.317E-07
	2	1.297E-19		1.428E-05	5.856E-05	3.608E-06	7.91E-08	0.01201
	3	0.002325	0.0002999		0.02236	0.07839	0.7623	0.3131
	4	1	0.00123	0.4696		0.1734	0.08118	0.005793
	5	1	7.576E-05	1	1		0.2599	0.01551
	6	0.001129	1.661E-06	1	1	1		0.05106
	7	2.765E-06	0.2522	1	0.1217	0.3257	1	
RW	Sp	Ventral/Apertural						
		1	2	3	4	5	6	7
1	1		1.776E-21	1.749E-07	0.9235	3.521E-07	3.656E-19	0.00127
	2	3.729E-20		6.698E-13	20525E-11	2.121E-08	0.2912	1.079E-15
	3	3.673E-06	1.407E-11		6.067E-06	6.539E-12	3.473-13	1.357-08
	4	1	5.303E-10	0.0001274		0.0001309	2.087E-09	0.0003621
	5	7.394E-06	4.454E-07	1.373E-10	0.002748		1.709E-05	0.4282
	6	7.678E-18	1	7.294E-12	4.383-08	0.0003589		2.603E-10
	7	0.02667	2.266E-14	2.849E-07	0.007604	1	5.467E-09	
2	1		1.913E-23	0.001159	2.48E-12	3.252E-10	0.8862	1.051E-15
	2	4.018E-22		3.998E-12	3.763E-12	5.479E-16	4.411E-16	9.703E-15
	3	0.02434	8.397E-11		5.573E-10	0.01113	0.02106	1.392E-11
	4	5.207E-11	7.903E-11	1.17E-08		8.897E-05	3.634E-11	0.9244
	5	6.83E-09	1.151E-14	0.2337	0.001868		2.885E-07	1.586E-06
	6	1	9.264E-15	0.4423	7.631E-10	6.059E-06		5.996E-15
	7	2.208E-14	2.038E-13	2.924E-10	1	3.331E-05	1.259E-13	
3	1		1.913E-23	0.001159	2.48E-12	3.252E-10	0.8862	1.051E-15
	2	4.018E-22		3.998E-12	3.763E-12	5.479E-16	4.411E-16	9.703E-15
	3	0.02434	8.397E-11		5.573E-10	0.01113	0.02106	1.392E-11
	4	5.207E-11	7.903E-11	1.17E-08		8.897E-05	3.634E-11	0.9244
	5	6.83E-09	1.151E-14	0.2337	0.001868		2.885E-07	1.586E-06
	6	1	9.264E-15	0.4423	7.631E-10	6.059E-06		5.996-15
	7	2.208E-14	2.038E-13	2.924E-10	1	3.331E-05	1.259E-13	
4	1		5.146E-27	1.402E-09	3.283E-09	3.485E-17	3.668E-33	8.855E-14
	2	1.081E-25		8.188E-10	2.634E-09	4.078E-08	0.8696	5.206E-10
	3	2.943E-08	1.72E-08		0.4553	0.05558	5.881E-10	0.1596
	4	6.894E-08	5.531E-08	1		0.1445	1.746E-09	0.5689
	5	7.321E-16	8.565E-07	1	1		4.727E-09	0.2755
	6	7.702E-32	1	1.235E-08	3.666-08	9.926E-08		2.742E-10
	7	1.859E-12	1.093E-08	1	1	1	5.758E-09	

Table 6. Canonical variance analysis (CVA) of relative warp scores among seven *Cypraea* species.

	DORSAL	**VENTRAL**
Wilks Lambda	0.1556	0.6977
df1	12	24
df2	984	1711
F	125.8	7.748
P(same)	3.721E-189	2.061E-25

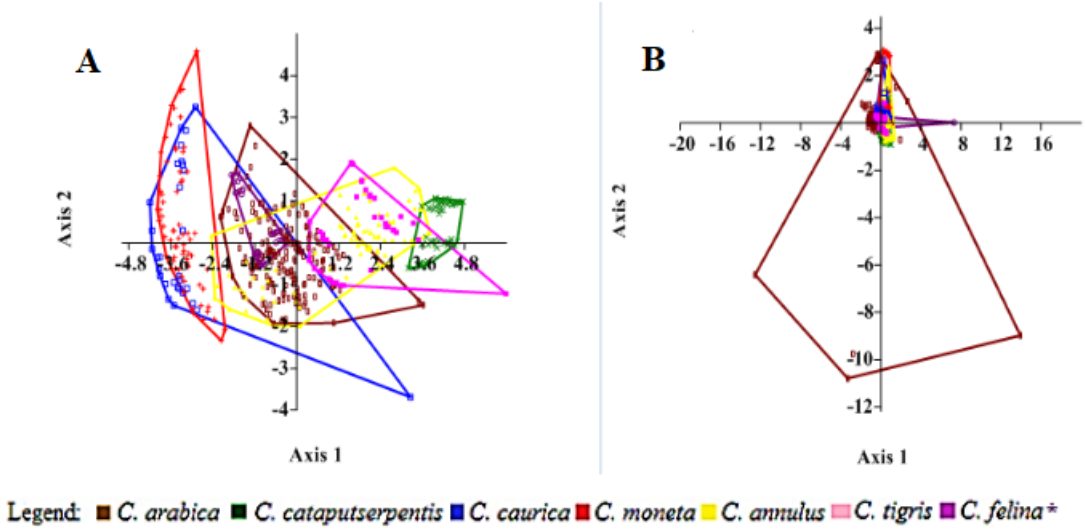

Figure 7. Canonical variance analysis (CVA) scatter plot of the (A) dorsal and (B) ventral shell of the seven *Cypraea* species.

Correlation Analysis Based on Distances (CORIANDIS)

The heights of the stacked bar graphs (Figure 8) and the interspecific locations of traits/characteristics (represented as colored points) in compromise space (Figure 9) indicate morphological and meristic differences among Cypraeidae species. The result shows low congruence and high disparity in the species' average shapes (dorsal and ventral/apertural) morphology and size measurements. As shown in the figure, species 2, 4, 5, and 6 had higher tendencies to cluster together, followed by species 1 and 3 in terms of their morphological and meristic similarities, except species 7, which inferred great differences in the characters between clusters.

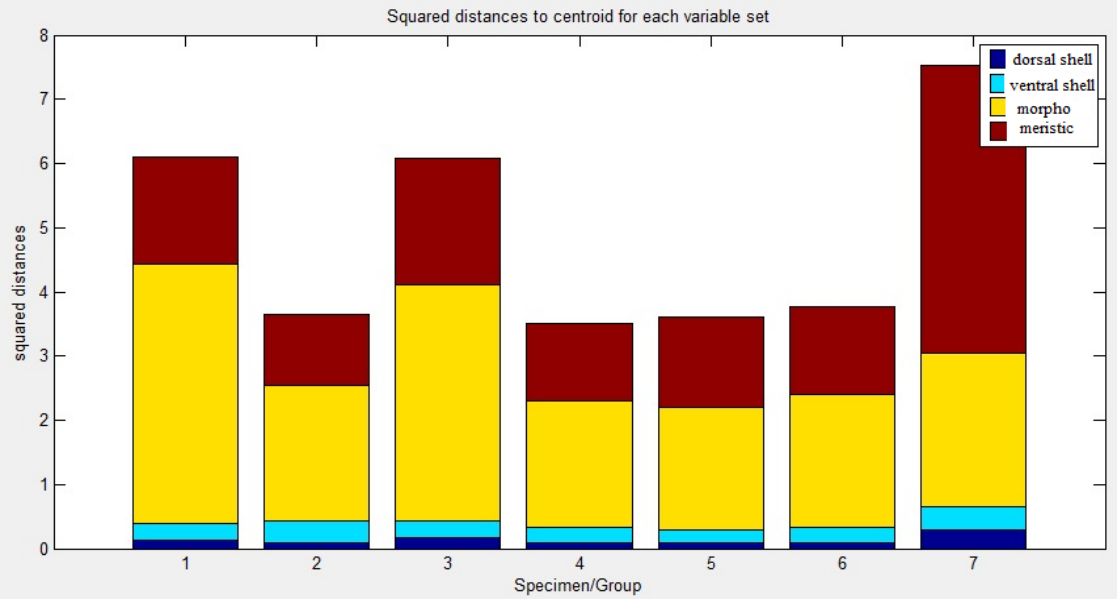

Figure 8. Stacked bar graphs showing disparity among the seven *Cypraea species* with regards to the shape (dorsal and ventral), morphological and morphometrics characters. Legend: (1) *Cypraea arabica*, (2) *Cypraea caputserpentis*, (3) *Cypraea felina*, (4) *Cypraea caurica*, (5) *Cypraea moneta*, (6) *Cypraea annulus* and (7) *Cypraea tigris*.

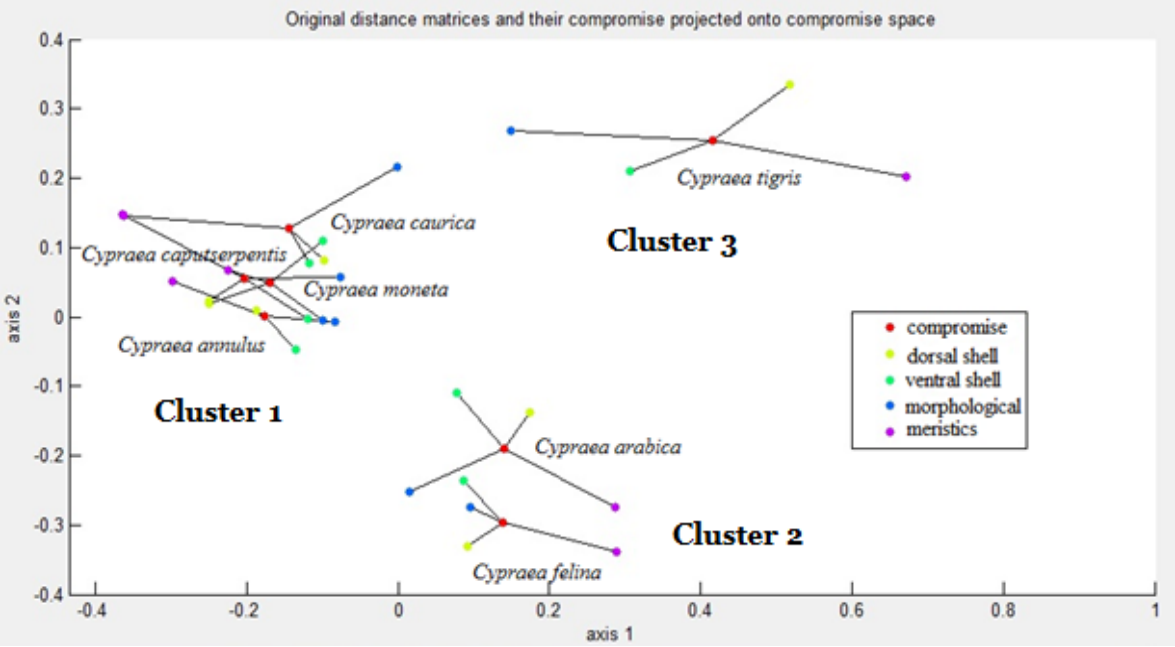

Figure 9. Plot of the principal components of "compromise" space axis of the seven *Cypraea* species.

Figure 10 displays a dendrogram of the overall relationship among the seven Cypraeidae shells in compromise space. The results revealed three clusters based on the shell characters examined. Cluster 1, comprised of *C. annulus* was 71% similar to *C. caurica*, while *C. moneta* was 29% identical to *C. caputserpentis*, and 38% similar to *C. caurica*. The size, color, dorsal and ventral shape, and depressed spire were the main points of similarity. Cluster 2 C. *arabica* and *C. felina* were 34% similar in the visible spire, dorsal line, rounded lateral margins, and present lateral spots. Clusters 1 and 2 are 65% identical while species *C. tigris* solely clustered at 100% with the rest of Cypraeidae species because of its apparent large size and numerous black spots.

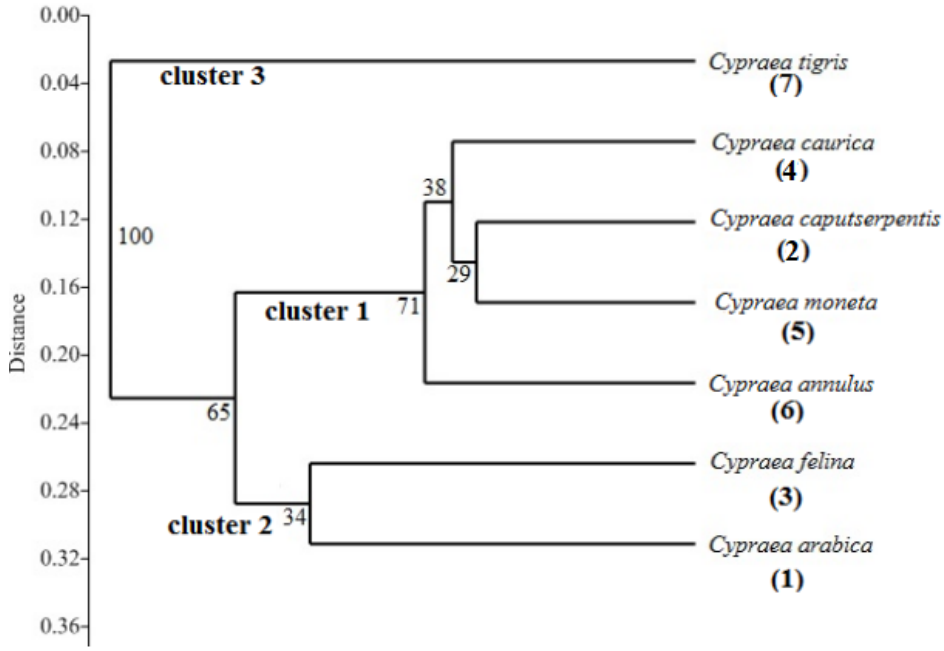

Figure 10. Plot showing the degree of similarity of characters among the seven *Cypraea* species.

A correlation analysis was performed to determine the observed shell shape (Figure 11B) and size (Figure 11A) differences between groups based on the computed centroid size. Results show that shell length (Figures 12 and 13A), width (Figures 12B and Figure 13C), aperture length (Figures 12 and 13D) and width (Figures 12 and 13E) were significantly correlated with shell shape ($P < 0.05$) except for the average weight (Figures 12 and 13F; Table 7).

DISCUSSION

Morphological (Qualitative) and Morphometric (Quantitative) Analysis of Shell Morphology

Morphological differences observed among cowries (such as color, shape, banding pattern, lateral margins, dorsal/transverse line, spire, and teeth) are likely influenced by phenotypic plasticity, developmental plasticity, genetic composition, and environmental conditions (Miner et al. 2005). Phenotypic plasticity is an adaptive process that allows organisms to adjust their traits in response to environmental pressures (Moneva 2012). However, it is difficult to identify specific environmental factors responsible for shell morphology differences (Patiluna and Demayo 2015). Several studies revealed that plasticity in shell morphology has implications for its adaptation to different environments and evolutionary processes (Trussell and Etter 2001). The morphological differences of the snail, *A. fulica* in size, shape and color can be attributed to environmental conditions (Mead 1961), variability in shape was due to genetic anomalies (Bequaert 1950). In addition, the morphological expression of characteristics (phenotypic) in other *Cypraea* species (i.e. *Cypraea annulus)* varies from juvenile to post-adult development of shells (Laimeheriwa 2017). According to Irie and Iwasa (2003), the variety of phenotype characters are strongly influenced by genetic material or genotype and environment or ecotype. Furthermore, the environmental factors such as climate, humidity and temperature may cause physiological changes which could affect snail's development (Vinic et al. 1988), especially the shell length-width relationship (Albuquerque et al. 2009) and influence the phenotypic character of a cowry shell (Oliver 2004).

Growth rate and population density may also influence shell variations, indicating the presence of either phenotypic plasticity or genetic differentiation (Dela Rosa et al. 2010). While genetics is commonly associated with ecology-to-evolution effects, evidence is inconsistent (Hendry 2013). Understanding the specific mechanisms and other potential factors involved is crucial (Trussell and Etter 2001). A recent study in the reconstruction of the Cypraeidae's mitogenomic phylogeny showed the usefulness of pairwise genetic distance analysis in the identification of species (Ma et al. 2023), especially in cases of phenotypic plasticity or convergence (Abalde et al. 2017a, b; Yang et al. 2018). Despite the progress made in genetic analysis, the conventional classification of Cypraeidae, which mostly relied on shell and anatomical traits, remains relevant.

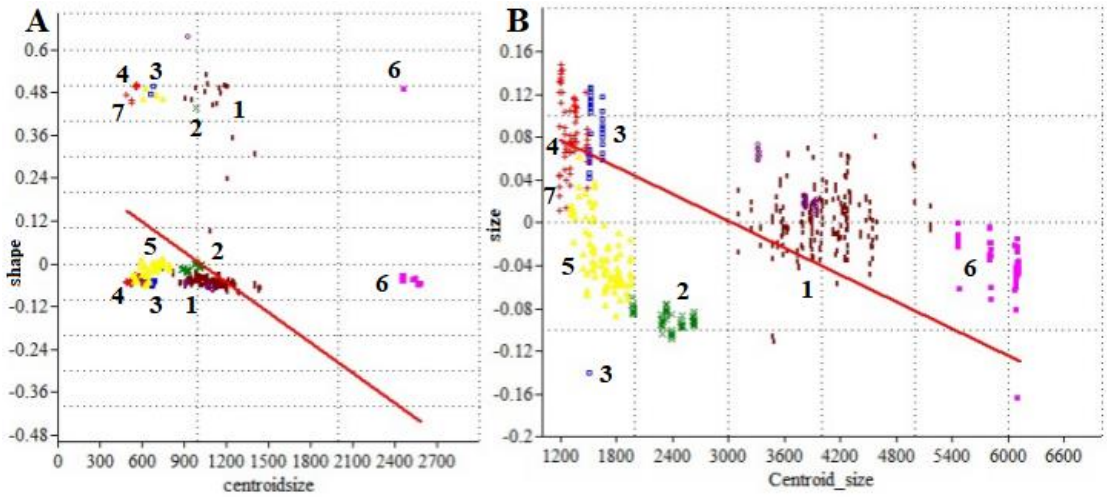

Figure 11. Centroid size (A) vs shape correlation (B) of the shell of the seven *Cypraea* species. Legend: (1) *Cypraea arabica;* (2) *Cypraea caputserpentis,* (3) *Cypraea caurica;* (4) *Cypraea moneta; (5) Cypraea annulus;* (6) *Cypraea felina* and (7) *Cypraea tigris*.

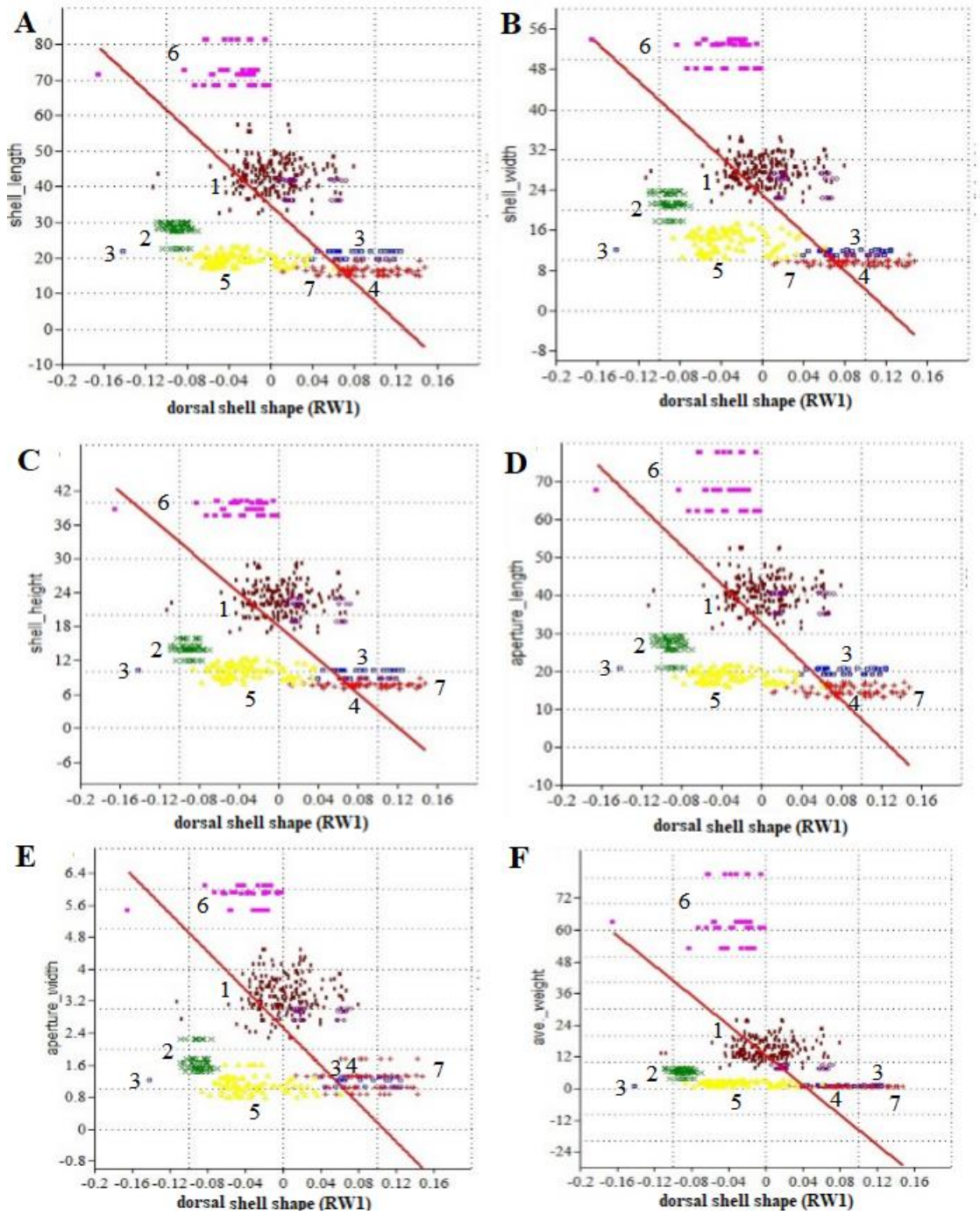

Figure 12. Correlation of shell dorsal shape with different morphological measurements such as (A) shell length, (B) shell width, (C) shell height, (D) shell aperture length, (E) width and (F) average weight of the seven *Cypraea* species. Legend: (1) *Cypraea arabica;* (2) *Cypraea caputserpentis*, (3) *Cypraea caurica;* (4) *Cypraea moneta; (5) Cypraea annulus;* (6) *Cypraea felina* and (7) *Cypraea tigris*.

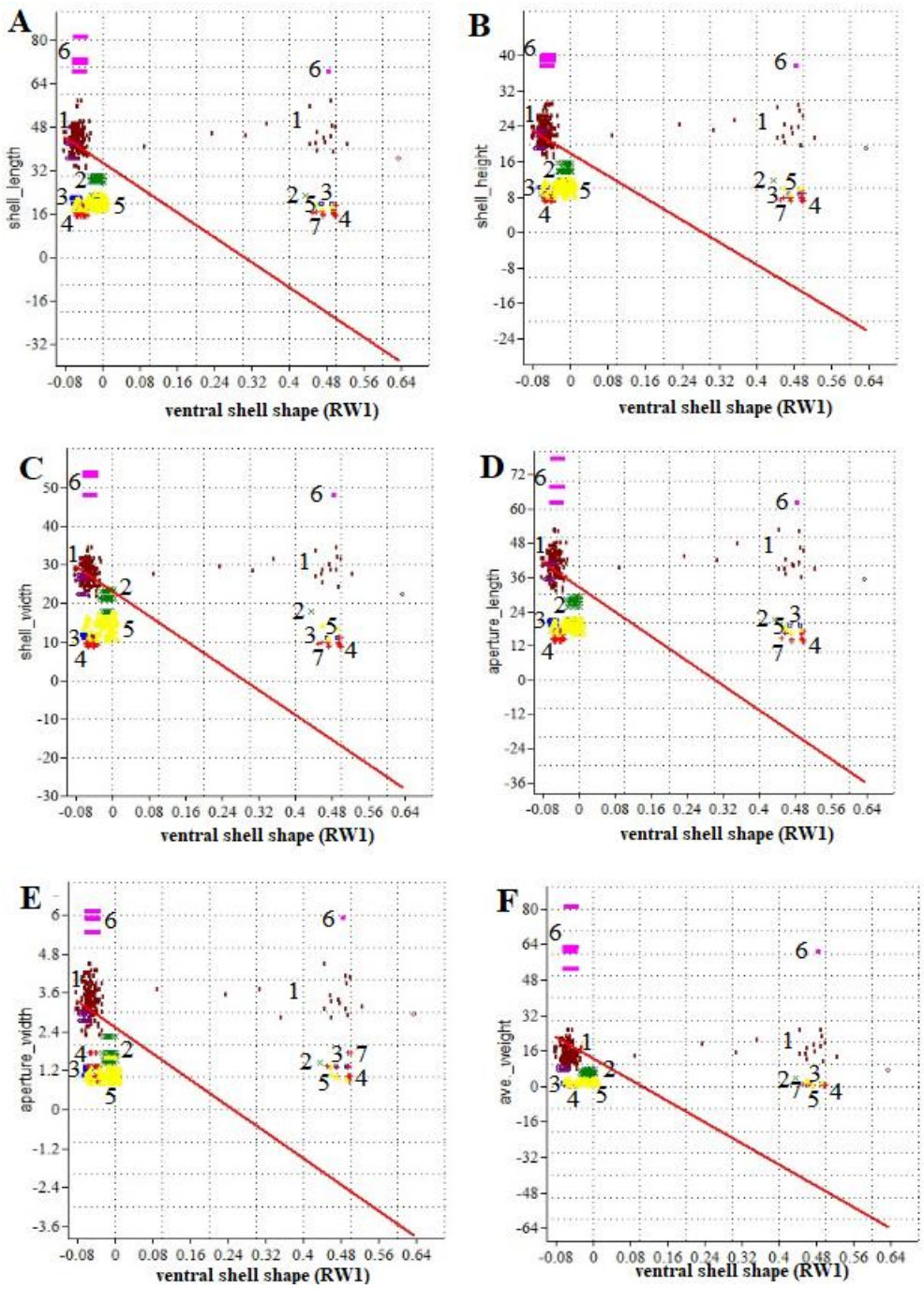

Figure 13. Correlation of shell ventral shape with different morphological measurements, such as (A) shell length, (B) shell height, (C) shell width, (D) shell aperture length, (E) width and (F) average weight of the seven *Cypraea* species. Legend: (1) *Cypraea arabica;* (2) *Cypraea caputserpentis,* (3) *Cypraea caurica;* (4) *Cypraea moneta; (5) Cypraea annulus;* (6) *Cypraea felina* and (7) *Cypraea tigris*.

Table 7. Correlation analysis of shape (significant relative warp, RW1) with centroid size and other morphological measurements, such as shell length, shell height, shell width, shell aperture length and average weight of the seven *Cypraea* species.

DORSAL			
Correlation	**Slope**	***r***	**P(uncorr)**
Shape (RW1) vs centroid size	-4.1999E-05	-0.24215	**4.1851E-08**
Shape (RW1) vs SL	-269.22	-0.24218	**4.165E-08**
Shape (RW1) vs ST	-148.53	-0.24941	**1.5805E-08**
Shape (RW1) vs SW	-188.56	-0.34053	**4.8501E-15**
Shape (RW1) vs SAL	-254.19	-0.24821	**1.8616E-08**
Shape (RW1) vs SAW	-23.763	-0.16363	**0.0002384**
Shape (RW1) vs SAve.Wt.	-281.98	-0.23462	**1.1123-07**
VENTRAL			
Shape (RW1) vs centroid size	-0.0002824	-0.12477	**0.0052096**
Shape (RW1) vs SL	-114.3	-0.1307	**0.0034148**
Shape (RW1) vs ST	-63.06	-0.13176	**0.00316**
Shape (RW1) vs SW	-80.053	-0.13417	**0.0026445**
Shape (RW1) vs SAL	-107.92	-0.13625	**0.0022636**
Shape (RW1) vs SAW	-10.089	-0.11072	**0.013244**
Shape (RW1) vs SAve.Wt.	-119.72	-0.086341	0.053679

Landmark and Outline-based geometric morphometric analysis

The observed variations in shell shape among cowries can be determined by the shell ontogenetic process, where new shell material is gradually deposited onto the existing aperture through accretionary growth. This allows the shell to expand and develop as the organism matures, maintaining its structural integrity (Liew and Schilthuizen 2016). Differences in shell shape amongst closely related species may therefore represent variations in shared developmental trajectories (Cruz et al. 2012), genetic architecture, and the influence of environmental factors (Cazzaniga 2006) such as shore exposure and zonation (Doyle et al. 2018). However, there are advantages to quantifying these shape differences that had been carried out in this study. Quantification allows for the recognition of intermediate forms; judging degrees of proximity or similarity; and extrapolation or prediction of hypothetical and experimental extremes (Cruz et al. 2012).

As a result of this study, the landmark-based method has the greatest advantage than the outline-based method because aperture shape is highly variable depending on the environmental factors where greater shell girth acts as defense against crushing predators (Doyle et al. 2018). Whereas the outline-based method can capture shells callus thickness since individuals of *Cypraea annulus* and *Littorina* species displayed larger and broader shell in lower shore and sheltered shores and with higher temperature (Irie 2005). Thus, geometric morphometrics offers a more effective approach than traditional methods for studying gastropod shell morphology. It provides a more detailed assessment of shape, identifying subtle differences and patterns missed by traditional measurements (Carvajal-Rodríguez et al. 2005).

Correlation Analysis Based on Distances (CORIANDIS)

The morphometric characters observed in this study are positively correlated with shell shape, except for weight and number of teeth (Irie 2005). Cowries exhibit explicit determinate growth, with shell size not increasing after the juvenile stage (Irie and Morimoto 2008). The shell form among cowries has, over time, varied greatly in the morphometrics selected to represent shell form (Bridges and Lorenz 2013). The observed variations can be the result from the interaction between an individual's genetic architecture and the environment. Environmental conditions are essential for understanding the differences observed in cowry shells shape (Cazzaniga 2006; Torres et al. 2011).

Several studies have pointed out that there is no reaction norm by which of these environmental cues induces could increase or decrease body size in cowries (Irie 2005). One should not discount the influence of environmental conditions in bringing about differences in shell shapes. It was reported that latitudinal difference in juvenile shell size can be explained by phenotypic plasticity based on environmental heterogeneity (Irie 2005). It is also plausible that a cue from predators affects callus thickness, because predation pressures vary at different latitudes (Irie 2005; Vermeij 1972).

This study highlights the use of GM and CORIANDIS in assessing morphological, size, and shape variations in Cypraeidae species. These variations result from the interaction between genetic architecture and the environment, indicating phenotypic diversity. Autoregulatory developmental processes may differ among species in buffering against environmental and genetic influences. Further exploration of variables like environmental heterogeneity and species distribution is needed. Understanding the genetic basis of phenotypic diversity is crucial. Consideration of juvenile size and shape as well as the genetic analysis can provide additional insights for systematic studies of Cypraeidae species.

Geometric morphometric analysis revealed significant variations in gastropod shell morphology influenced by phenotypic plasticity and environment. Geometric morphometrics outperformed traditional measurements. Future research should explore genetic and environmental mechanisms, expand the analysis to more taxa, and integrate genomics for a comprehensive understanding of shell morphology and its evolutionary implications in response to environmental changes.

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ETHICAL CONSIDERATIONS

There are no human subjects in this article and informed consent is not applicable. However, the collection procedures of shell samples were conducted in accordance with local government guidelines and approved by the office of municipal Mayor.

DECLARATION OF COMPETING INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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REFERENCES

Abalde S, Tenorio MJ, Afonso CM, Uribe JE, Echeverry AM and Zardoya R. 2017a. Phylogenetic relationships of cone snails endemic to Cabo Verde based on mitochondrial genomes. BMC Evolutionary Biology, 17: 231. https://doi.org/10.1186/s12862-017-1069-x

Abalde S, Tenorio MJ, Afonso CM and Zardoya R. 2017b. Mitogenomic phylogeny of cone snails endemic to Senegal. Molecular Phylogenetic Evolution, 112: 79–87. https://doi.org/10.1016/j.ympev.2017.04.020

Ackerly SC. 1989. Kinematics of accretionary shell growth, with examples from brachiopods and mollusks. Paleobiology, 15(2): 147-164. https://doi.org/10.1017/S0094837300009337

Albuquerque FS, Peso-Aguiar MC, Assunção-Albuquerque MJT and Gálvez L. 2009. Do climate variables and human density affect *Achatina fulica* (Bowditch) (Gastropoda: Pulmonata) shell length, total weight and condition factor? Brazil Journal Biology; 69(3): 879-885. https://doi.org/10.1590/S1519-69842009000400016

Bequaert JC. 1950. Studies on the achatinidae, a group of African Land Snail. Bulletin of the Museum of Comparative Zoology, 105: 1-216.

Bridges RJ and Lorenz FE. 2013. A revised morphometric formula for the characterization of cowries (Gastropoda: Cypraeidae). Conchylia, 43(1-4): 27-40.

Carvajal-Rodríguez A, Conde-Padin P and Rolan-Alvarez E. 2005. Decomposing shell form into size and shape by geometric morphometric methods in two sympatric ecotypes of *Littorina saxatilis*. Journal of Molluscan Studies, 71(4): 313-318. https://doi.org/10.1093/mollus/eyi037

Cazzaniga NJ. 2006. *Pomacea canaliculata*: Harmless and useless in its natural realm (Argentina). In: Joshi RC, Sebastian LS (eds). Global advances in ecology and management of golden apple snails. Science City of Muñoz, Nueva Ecija: Philippine Rice Research Institute, pp. 37-60.

Cruz RA, Pante M and Rohlf F. 2012. Geometric Morphometric analysis of shell shape variation in *Conus* (Gastropoda: Conidae). Zoological Journal of the Linnean Society, 165(2): 296-310. https://doi.org/10.1111/j.1096-3642.2011.00806.x

Dela Rosa VG, Torres MAJ and Demayo CG. 2010. Geometric morphometric tools in the analysis of shell shape of twelve local populations of the invasive snail *Achatina fulica* Bowdich from the Philippines. 2010 International Conference on Environmental Engineering and Applications. Singapore. https://doi.org/10.1109/ICEEA.2010.5596101

Demayo G, Harun SA and Torres MAJ. 2011. Procrustes analysis of wing shape divergence among sibling species of *Neurothemis dragonies*. Australian Journal of Basic and Applied Sciences, 5(6): 748-759.

Doyle D, Gammell MP and Nash R. 2018. Morphometric methods for the analysis and classification of gastropods: a comparison using Littorina littorea. Journal of Molluscan Studies, 84(20): 190–197. https://doi.org/10.1093/mollus/eyy010

Froese R and Pauly D (eds). 2022. FishBase. www.fishbase.org. Accessed on 07 March 2022.

Gutierrez PM, Torres MA and Demayo CG. 2011. Thin-plate spline (TPS) and correlational based on distances (CORIANDIS) analyses as tools for the analysis of morphological differences in dragonfly wings. 2011 2nd International Conference on Environmental Science and Technology (ICEST 2011). Bangkok, Thailand.

Hammer O, Harper DAT and Ryan PD. 2009. PAST: Paleontological statistical software package for education and data analysis. Paleontologia Electronica, 4(1): 1-9.

Heiman EL. 2011. A conchological method of diagnosing mollusc taxa in reference to recent Cypraiedae. Part 1. TRITON, 24-30.

Hendry AP. 2013. Key questions in the genetics and genomics of eco-evolutionary dynamics. Heredity, 111(6): 456–466. https://doi.org/10.1038%2Fhdy.2013.75

Irie T. 2005. Geographical variation of shell morphology in *Cypraea annulus* (Gastropoda: Cypraeidae). Journal of Molluscan Studies, 72(1):31-38. https://doi.org/10.1093/mollus/eyi043

Irie T and Iwasa Y. 2003. Optimal growth model for the latitudinal cline of shell morphology in cowries (genus *Cypraea*). Evolutionary Ecology Research, 5: 1133-1149.

Irie T and Morimoto N. 2008. Phenotypic plasticity and sexual dimorphism in size at post-juvenile metamorphosis: common-garden rearing of an intertidal gastropod with determinate growth. Biology Bulletin, 215(2): 126-134. https://doi.org/10.2307/25470693

Kohler F and Glaubrecht M. 2003. Morphology, reproductive biology and molecular genetics of ovoviviparous freshwater gastropods (Cerithioi, Pachychilidae) from the 192 Philippines with description of a new genus Jagora. Zoologica Scripta, 32(1): 35-39. https://doi.org/10.1046/j.1463-6409.2003.00100

Laimeheriwa MB. 2017. Phenetic Relationship Study of Gold Ring Cowry, *Cypraea annulus* (Gastropods: Cypraeidae) in Mollucas Islands Based on Shell Morphological. Fisheries and Aquaculture Journal, 8(3): 1000215. https://doi.org/10.4172/2150-3508.1000215

Liew TS and Schilthuizen M. 2016. A method for quantifying, visualising, and analysing gastropod shell form. PLOS ONE, 11(6): e0157069. https://doi.org/10.1371/journal.pone.0157069

Ma Q, Li F, Zheng J, Liu C, Wang A, Yang Y and Gu Z. 2023. Mitogenomic phylogeny of Cypraeidae (Gastropoda: Mesogastropoda). Frontiers in Ecology and Evolution, 11: 1138297. https://doi.org/10.3389/fevo.2023.1138297

Malay MC and Paulay G. 2010. Peripatric speciation drives diversification and distributional pattern of reef hermit crabs (Decapoda: Diogenidae: Calcinus). Evolution 64(1), 634–662. https://doi.org/10.1111/j.1558-5646.2009.00848.x

Marquez J and Knowles LL. 2007. Correlated evolution of multivariate traits: detecting co-divergence across multiple dimensions. Journal of Evolutionary Biology, 20(6): 2334-2348. https://doi.org/10.1111/j.1420-9101.2007.01415.x

Mead AR. 1961. The giant African snail: a problem in economic malacology. Chicago, U.S.A.: The University Chicago Press.

Miner BG, Sultan SE, Morgan SG, Padilla DK and Relyea RA. 2005. Ecological consequences of phenotypic plasticity. Trends Ecological Evolution, 20(12): 685–692. https://doi.org/10.1016/j.tree.2005.08.002

MolluscaBase. 2022. "Cypraeidae Rafinesque, 1815." in: World Register of Marine Species. https://www.marinespecies.org/aphia.php?p=taxdetails&id=23022. Accessed on 15 March 2023

Moneva CSO. 2012. Applications of geometric morphometric analysis in the shell shape patterns of the freshwater snails (Family: Ampullaridae, Thiaridae, Viviparidae). International Journal of the Bioflux Society, 4(1): 14-19.

Oliver A. 2004. Guide to seashells of the world. Octopus publishing group Ltd London. 320pp.

Passamonti M. 2015. The family Cypraeidae (Gastropoda Cypraeoidea) an unexpected case of neglected animals. Monograph: Biodiversity Journal, 6(1): 449-466.

Patiluna ML and Demayo CG. 2015. Describing shell shape and its correlation with size in the Arabian cowry *Cypraea arabica* using landmark and outline-based geometric morphometrics. Asia Pacific Journal of Science, Mathematics and Engineering (APJSME), 3: 32-40.

Poutiers J. 1998. Gastropods. In: Carpenter KE and Niem VH (eds). FAO Species identification guide for fishery purposes. The living marine resources of the Western Central Pacific Seaweeds, Corals, Bivalves and Gastropods. Food and Aquaculture Organization of United Nations, Rome, Italy, pp. 364-686.

Rholf JF and Slice D. 1990. Extension of the Procrustes method for the optimal superimposition of landmarks. Systematic Zoology, 39(1): 40-59. https://doi.org/10.2307/2992207

Rholf JF. 2008a. TpsDig Version 1.4. Department of Ecology and Evolution. State University of New York at Stony Brook, New York. http://life.bio.sunysb.edu/morph/index.html Accessed on April 2 2014

Rholf JF. 2008b. Relative Warps version 1.46. Department of Ecology and Evolution. State University of New York at Stony Brook, New York. http://life.bio.sunysb.edu/morph/index.html Accessed on April 2 2014

Rholf JF. 2009. Tps Utility program version 1.44. Department of Ecology and Evolution. State University of New York at Stony Brook, New York. http://life.bio.sunysb.edu/morph/index.html Accessed on April 2 2014

Smith UE and Hendricks JR. 2013. Geometric Morphometric Character Suites as Phylogenetic Data: Extracting Phylogenetic Signal from Gastropod Shells, Systematic Biology, 62(3): 366–385, https://doi.org/10.1093/sysbio/syt002

Tabugo SRM, Torres MAJ and Demayo CG. 2010. Relative warps and correlation analysis based on distances of the morphological shape of the shell of the Golden Apple Snail *Pomacea canaliculata* from Iligan City, Philippines. International Conference on Environmental Engineering and Applications (ICEEA). Singapore. https://doi.org/10.1109/ICEEA.2010.5596099

Torres MAJ, Joshi RC, Sebastian LS and Demayo CG. 2011. Geographic phenetic variation in the golden apple snail *Pomacea canaliculata* (Ampullariidae) based on geometric approaches to morphometrics. Advances in Environmental Sciences - International Journal of the Bioflux Society, 3(3): 243-258.

Trussell GC and Etter RJ. 2001. Integrating genetic and environmental forces that shape the evolution of geographic variation in a marine snail. Genetica, 112: 321–337. https://doi.org/10.1023/A:1013364527698

Vermeij GJ. 1972. Intraspecific shore-level size gradients in intertidal molluscs. Ecology, 53: 693-699. https://doi.org/10.2307/1934785

Vinic GK, Unnithan VK and Sugunan VV. 1988. Farming of the giant African snail, *Achatina fulica*. Central Inland Capture Fisheries Research Institute. Indian Council of Agricultural Research. Barrackpore, West Bengal, India. 24pp.

Yang Y, Li Q, Kong L and Yu H. 2018. Comparative mitogenomic analysis reveals cryptic species in Reticunassa festiva (Neogastropoda: Nassariidae). Gene 662: 88–96. https://doi.org/10.1016/j.gene.2018.04.001

Zelditch ML, Swiderski DL, Sheets HD and Fink WL. 2012. Geometric morphometrics for biologists (2nd Edition) Elsevier, Academic Press, San Diego and London. 81pp.

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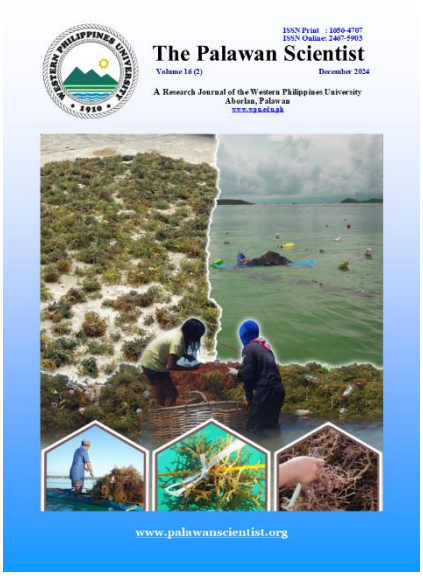
Review Paper



The ecological status and fisheries of Malampaya Sound, northwestern Palawan, Philippines

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ABSTRACT

A review of the state of the marine ecosystem and fisheries of Malampaya Sound, Palawan was undertaken. A total of 30 papers relevant to the topic were selected and reviewed. The results showed that the rich and diverse coastal waters of Malampaya Sound harbor 8 species of seagrasses, 9 species of mangroves, 262 species of fish, and various species of corals and macroinvertebrates including the rare giant clams *Tridacna* spp. The Sound plays a vital role in the local economy because the local community uses it for subsistence fishing and as a source of livelihood. It is so productive that it was termed the "fishbowl of the country" because it provides a substantial contribution to the country's fishery sector and economy. However, degradation continuously threatens it, most of which are interrelated anthropogenic issues. The declining environmental condition of the area prompted the government to close it for commercial fishing in the 1970s. Several conservation measures have been undertaken since then to preserve its remaining resources, including its declaration as a protected landscape and seascape in 2000. Despite this, if not for a slight improvement, the condition has worsened. So far, only the mangrove ecosystem has dramatically improved. Seagrass and coral reefs are still in poor to fair condition. A collective effort by the community and government agencies, with the support of the academe and non-government organizations, coupled with strict enforcement of existing laws, income diversification for the locals, monitoring of environmental parameters, and implementation of sustainable fishing practices, is necessary to achieve sustainable use of the area.

Keywords: conservation, ecoregion, fishing ground, last frontier

INTRODUCTION

Malampaya Sound is part of the larger Malampaya Sound Protected Land and Seascape. It is located at 10.8464° N, 119.3654° E, on the northwestern side of Palawan Province, Philippines (Figure 1). This rich marine area covers 24,000 ha and includes 10 barangays from the municipalities of San Vicente and Taytay. It is a protected inlet consisting of complex sheltered bays, coves, and islands, with a

marine area of approximately 240 km^2. It is an estuary system that receives water from 30 river systems. It is divided into two sections, the Inner and the Outer Sound, which are home to diverse ecosystems of seagrasses, mangroves, and corals (DENR 2001).

During the 1960s, Malampaya Sound was a significant and thriving traditional fishing ground in the Philippines. Located at the northwestern tip of Palawan Island, on the western part of the archipelago, the Sound is a popular tourist destination for diving and Irrawaddy dolphin watching. At the same time, it serves as an area for subsistence fishing for local fisherfolk. It has a rich and diverse ecosystem and was considered a fishbowl in the 1970s. However, the increasing demand for marine fish food did not spare the Sound from overexploitation. Ecological stress is brought about by degrading human activities has caused damage to corals and other marine life (McNeely et al. 1990; Deocadez and Aliño 2005). This can permanently impact ecological timelines when combined with changing climate conditions due to rising atmospheric carbon dioxide (Bindoff et al. 2005; Doney et al. 2012; Doney et al. 2016).

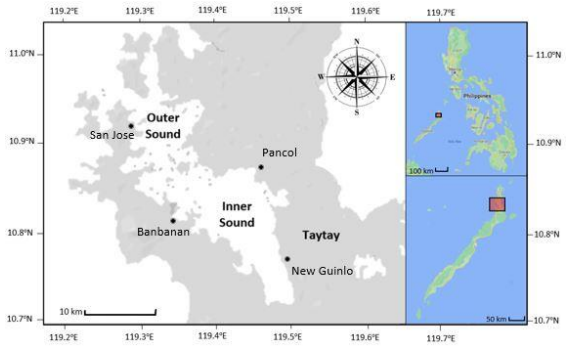

Figure 1. The Malampaya Sound Protected Landscape and Seascape, Taytay, Palawan is located in the northwestern sector of Palawan province, Philippines.

Fish stocks cannot sustain their population due to the compounding effects of natural and anthropogenic causes, resulting in the depletion of marine species (Pauly et al. 2002, 2005). The area was closed for commercial fishing activities in 1973 because it was already heavily overfished (Ronquillo and Llana 1987). In 1986, stricter conservation measures were implemented, allowing only municipal fishing boats (3 GT or less) to use handline, spear, crab hook, cover pot, fish trap, fish pot, pole and line, gill net for fish, and shrimps, fish corral, and beach seine for fishing in the area. To further conserve the remaining marine resources, ensure continuity and sustainability of species, replenish fish stocks, and increase the biodiversity of flora and fauna in the area, it was declared a protected landscape and seascape in 2000.

This paper does not generate new field data; instead, it uses existing literature to answer the research question, "What are the current ecological conditions and trends in Malampaya Sound?" This research question focuses on the environment and fisheries within the context of Malampaya Sound. It investigates the status of the ecosystem including aspects of biodiversity, and habitat health. Moreover, described the fishery resources and activities. The degrading ecological conditions of Malampaya Sound, mainly due to anthropogenic activities, lead to a decline in biodiversity and habitat quality. As a result, it negatively impacts the productivity and sustainability of its fishery resources by reducing fish stocks and altering species composition. In effect, it decreases economic opportunities for local fishing communities. The implementation of applicable conservation measures and restoration activities is vital to achieving ecological resilience and sustainable fisheries.

THE REVIEW PROCESS

This study describes the current conditions of major coastal ecosystems in Malampaya Sound, including seagrass, mangroves, and coral reefs. It also presents information on area utilization and fisheries. It also identified the factors affecting the area and ascertained the threats, problems, and resource issues.

A review was undertaken on the state of the marine environment of Malampaya Sound, Palawan. A thorough search was done on Google Scholar for literature in April 2024. The probe revealed that there have been very few studies conducted on Malampaya Sound. From the year 2000, only an average of 2 articles every year were published in scientific journals. These are mainly related to biodiversity, coastal resource management, geology, and aquaculture. Due to the scarcity of information from the published papers in journals, government reports, and other technical papers were also considered in the review.

The initial output of the search revealed a total of 452 literature (Table 1). They were screened and selected based on their titles and the relevance to the study. A total of 30 papers relevant to the topic were selected for review. Data were gathered from each article, paper, or report and were categorized and grouped into seagrass, mangroves, coral reefs, and fisheries.

CURRENT STATE OF MAJOR COASTAL ECOSYSTEMS

The Sound has a diverse coastal environment with various ecosystems, such as seagrass meadows, mangrove forests, and coral reefs that are extremely rich in biodiversity and productivity.

Seagrass

Seagrass beds serve a variety of ecological functions. They cover sandy areas of the ocean floor and serve as nursery and breeding grounds for small fish and invertebrates, not just food and shelter. In Malampaya Sound, they cover an area of about 21 km^2 (PNSS 2004), mainly in Barangay Banban, Bucal, Liminangcong, San Jose, and Tumbod (PCSD 2006; dela Peña et al. 2015b) (Table 2). There are 13 species found in the Philippines, but only eight are thriving in the Sound. These species are: *Enhalus acoroides* Royle, 1839; *Cymodocea rotundata* Asch. and Schweinf.; *Cymodocea serrulata* Ascherson and Magnus, 1870; *Halodule pinifolia* Hartog; *Halodule uninervis* Ascherson; *Halophila ovalis* Hooker, 1858; *Syringodium isoetifolium* Dandy; and *Thalassia hemprichii* Ascherson, 1871. In 2004, a baseline survey found that the outside of the Sound had a percentage cover of these species ranging from very poor to poor (8 –30%). However, the monospecific stands of *E. acoroides* thickly cover the inner Sound (PCSD 2006; dela Peña et al. 2015b).

Table 1. The search string used and the resulting literature reviewed.

Search String	("Malampaya Sound" OR "Northwestern Palawan") AND ("Coastal ecosystems" OR "Marine biodiversity" OR "Ecological status" OR "Fisheries" OR "Aquatic Biodiversity" OR "Biodiversity" OR "Habitat health" OR "Water quality" OR "Ecosystem degradation" OR "Sustainable fisheries" OR "Fish population dynamics" OR "Anthropogenic impacts" OR "Fishing communities" OR "Conservation measures" OR "Resource management" OR "Management strategies" OR "Marine protected areas" OR "Marine conservation" OR "Resource management" OR "Environmental monitoring" OR "Environmental impact")
Initial Search	452
Titles that Qualified	46
Papers Relevant to the Review	30

Table 2. The seagrasses of the Malampaya Sound, Palawan, and the Philippines. Note: Asterisks indicate sources of the literature.

Location	**Area Covered (**km^2)	**Number of Species Present**	**Status**	**Author**
Malampaya Sound	21 *	8**	8-30% in Outer Malampaya Sound, 100% in Inner Sound***	*PNSS 2004 **PCSD 2006 ***CHE-UPLB 2015
Palawan	187* (excluding Tubbataha Reefs and Spratlys)	10**		*Fortes 2004 **PCSD 2015
Philippines	978	16		World Bank 2005

Mangroves

Another critical ecosystem found in Malampaya Sound is the mangroves. These plants serve various ecological and economic functions that line the intertidal zones of the area. It was estimated to cover an area of 2500 ha in 1985 (Figure 2). A decline occurred in 1998 when excessive harvesting for charcoal and housing materials reduced the cover by half (Pilien and Walpole 2003; dela Peña et al. 2015b). However, according to a recent report, the mangrove population has dramatically improved, covering 3342 ha in 2017 (Table 3) (PSA 2020).

Based on the study conducted in 2004, there are nine mangrove species commonly found in the Sound, namely: *Rhizophora apiculata* Blume, *Rhizophora mucronata* Poir, *Xylocarpus granatum* J. Koenig, *Bruguiera cylindrica* Blume, *Ceriops tagal* C.B. Robinson, *Bruguiera gymnorrhiza* Lam,

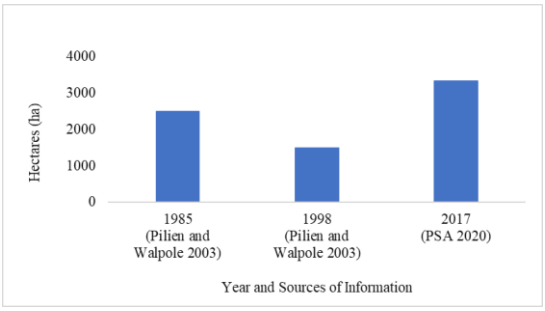

Figure 2. Temporal changes of mangrove cover in Malampaya Sound, Palawan.

Excoecaria agallocha L, *Scyphiphora hydrophyllacea* C.F.Gaertn, and *Lumnitzera littorea* Voigt (Table 4) (PCSD 2006). The percentage cover was assessed as "moderate" to "high" in several barangays, including Old and New Guinlo, Alacalian, Abongan, Banbanan,

Liminangcong, and Pancol. All areas, except San Jose, were subjected to extensive mangrove-cutting activities. It has an average density of 525 trees per hectare. However, a recent study conducted by dela Peña et al. (2015b) found that only about 46% of the area is in a healthy condition, and only Banbanan has good mangrove forest cover.

Table 3. Estimates of mangrove cover of the Malampaya Sound, Palawan, and the Philippines. Note: Asterisks indicate sources of the literature.

Location	Area Covered (hectares)	Number of Species Present	Author
Malampaya Sound	3,342 *	9**	*PSA 2020 **PCSD 2006
Palawan	59,421*	23**	*FMB 2019 **PCSD 2004
Philippines	256,185*	65**	*Long and Giri 2011 **Garcia et al. 2013

Table 4. Estimates of mangroves around Malampaya Sound (PCSD 2006). Ra = *Rhizophora apiculata*, Rm = *Rhizophora mucronata*, Xg = *Xylocarpus granatum* Campostenum, Bc = *Bruguiera cylindrica*, Ct = *Ceriops tagal*, Bg = *Bruguiera gymnorrhiza*, Ea = *Excoecaria agallocha*, Sh = *Scyphiphora hydrophyllacea*, Ll = *Lumnitzera littorea*.

Barangay	Trees ha.$^{-1}$	Stand Volume (m3 ha^{-1})	SV Class	Species Present
Old Guinlo	1037	361.44	High	Ct, Bc
New Guinlo	696	127.15	Moderate	Ct, Ra, Rm
Alacalian	702	367.8	High	Ct, Ra, Rm, Xg, Bg, Bc, Ll, Sh
Abongan	429	388.18	High	Bs, Ra, Ct, Xg, Bg, Ea
Banbanan	329	274.41	High	Bg, Ra
San Jose	116	120.59	Logged-over to High	Bg, Ra, Rm
Liminangcong	322	278.38	Moderate to High	Ct, Ra, Rm
Pancol	566	184.56	Moderate to High	Ct, Ra, Rm
Mean	524.63	262.81	High	

Coral reefs

Coral reefs are built by a hermatypic group of anthozoan corals belonging to the Order Scleractinia (Alcala 2001). They are important sources of food, valuable pharmaceuticals, and chemicals of importance to industry. They regulate global climate, serve as research and recreation areas, and help prevent land erosion. Unfortunately, the reefs that remain in excellent condition in the Philippines make up only 1.9% in the 1990s (Wilkinson 2000). In the Sound, the fringing reefs are found in the outer portion, in Barangays Liminangcong, Tumbod, San Jose, and Bambanan. There has been no published report on how many species of corals are present in the area; however, it was reported in 2004 that coral cover ranges from 30 to 75% (CHE-UPLB 2015). A similar report was published by the PCSD (2004, 2006), accounting for the coral reefs from fair to good condition. However, the latest published surveys revealed that the condition in the Sound worsened from poor to fair (Matillano et al. 2014; dela Peña et al. 2015a), except in areas on the Outer Sound like Liminancong where corals remained in excellent condition (Matillano et al. 2014).

Associated reef fish are also found to be abundant in the Sound. There are 262 species of fish recorded (Balisco et al. 2014; Dolorosa and Matillano 2014), of which 101 were target species, 97 were indicator species, and 64 were major species. Pomacentrids and chaetodontids mostly dominate the fish population. Comparatively, the Sound harbors more fish species than the reefs found in the adjacent Taytay, Turtle, Binunsalian, and Bacuit Bays. It is estimated that the reefs have a high productivity that can yield fish biomass of 59.94 t.km^2.

Macroinvertebrates also inhabit the area, with 10 species recorded, including the rare *Tridacna* spp. Bruguière, 1797, and *Conus* spp. Linnaeus, 1758 (Dolorosa and Matillano 2014). Sightings of the destructive *Acanthaster plancii* Linnaeus, 1758, were also noted.

Over the years, deterioration has been observed among the reefs around the Sound. This can mainly be attributed to siltation and destructive fishing practices such as dynamite and cyanide fishing (dela Peña et al. 2015b). The rampant use of inappropriate fishing gear, such as beach seine and Danish seine, makes recovery challenging as well. In 2015, the remaining corals were in either poor or fair condition (PCSD 2006; Matillano et al. 2014; dela Peña et al. 2015b).

FISHERIES

Malampaya is considered the "fishbowl" of the Philippines. It provided a substantial contribution to the fisheries sector before its closure in 1973. The Sound contributed 19% to the total national 'municipal' landings (Pido et al. 1996). It was also among the top ten producers of anchovies during this time (DA-BFAR 1977). Experts estimated that the standing stock density and potential fisheries productivity of Malampaya Sound are 6.5–9.7 t.km^{-2} (Ronquillo and Llana 1987) and 2,750 mt annually (dela Peña et al. 2015a). These values are three to six times higher than other fishing grounds like Manila Bay, Bacuit Bay, and Imuran Bay (Ronquillo and Llana 1987). The mean catch rate by trawl is 1073 kg hr^{-1}, mostly demersal fish. The major species caught are *Sardinella* spp., Indo-Pacific mackerel, Spanish mackerel, and anchovies (DA-BFAR 1977). These results were further verified by Estudillo et al. (1987) through the plankton study they did in the area. They further found out that the Sound harbors a significant population of ichthyoplankton, including fish eggs, which makes it a critical breeding and nursery area.

A recent study revealed that there are 17–23fishermen per km^{-2} that rely on fishing as a source of livelihood (dela Peña et al. 2015a, 2015b). They mainly use hook and line, bottom set gillnet, and drift net (dela Peña et al. 2015b; Gonzales 2018), catching 69 commercial species of fish, shrimp, and crabs (Gonzales et al. 2017) that can reach up to 100 kg trip^{-1} (Table 5).

Table 5. Catch per unit effort using major fishing gears used in Malampaya Sound, Calamianes, and Apo Island, Philippines.

Fishing Ground/ Type of Gear	Year of Study	Hook and line	Drift Net	Gill net	Author
Malampaya Sound	April to August 2016	0.84-2.2 kg hr^{-1}	-	0.06-3.35 kg hr^{-1}	Gonzales 2013; Gonzales et al. 2017
Malampaya Sound	2010-2012	10-100 kg trip^{-1}	30-80 kg trip^{-1}	10-40 kg trip^{-1}	dela Peña et al. 2015a
Calamianes Islands	2008	5.6-12.5 kg trip^{-1}	21.5 kg trip^{-1}	9.0 kg trip^{-1}	Tupper et al. 2015
Apo Island Marine Reserve	1980-2001	1-2 kg hr^{-1}	-	-	Maypa et al. 2002

THE SOUND AT A GLANCE: THREATS, PROBLEMS AND RESOURCE ISSUES

The deteriorating state of the environment, not just in Malampaya but throughout the country, highlights the need for the government to take measures to protect the remaining resources of the Sound. Natural causes and anthropogenic activities have already impacted the fragile state of the Sound. A series of conservation measures must be implemented to achieve this, such as the periodic closure of the area for commercial fishing and the use of selected fishing gear.

Table 6 lists the issues and challenges faced by Malampaya Sound, as identified by various authors. It is worth noting that some problems arose as a result of the preceding issues. For example, the high demand for fish in the export market and the growing population led to the use of illegal and harmful fishing techniques, which caused habitat destruction and overfishing.

Several issues contribute to the problem, some of which originate on land. Poor waste disposal and agricultural run-off are two examples of activities that add to the stress. The sedimentation rate, as measured by Sombrito et al. in 2004, ranges from 0.2 to 4 cm per year. David et al. (2009) also found that the silt in the Sound is mainly siliciclastics, indicating a terrestrial-dominated source. They further emphasized that the slight increase in organic content in younger sediments reflects the rise in various anthropogenic inputs into the coastal region. Additionally, the high total coliform concentration in the Sound could be attributed to household waste/ sewage and/ or effluent run-off, making it unsuitable for recreational purposes.

An indication of eutrophication is already visible in the area due to the frequent occurrence of algal blooms (Sellner et al. 2003). According to Borja et al. (2000) and Sombrito et al. (2004), the cysts of *Pyrodinium* are responsible for causing harmful algal blooms. Such events can result in massive fish kills and even mortality in humans due to the depletion of oxygen in the water and the toxins they release (McGowan, 2016).

Anthropogenic activities reduce the ability of the Sound to recover from natural pressures like typhoons and diseases. This is evident in the current coverage of seagrass and coral, as described above. The declining fish catch and biodiversity in the area are causes for concern among the marginal fisherfolk. Immediate action is needed to address this issue and safeguard the livelihoods of the people who depend on fishing for their income and sustenance. Fishermen continue to experience a 60-80% reduction in catch (dela Peña et al. 2015b). As such, a comprehensive approach is recommended to address the identified threats and issues.

Table 6. Threats and problems observed in Malampaya Sound.

Threats and Problems	Pido 1995	Sandalo 1996	Pilien and Walpole 2003	David et al. 2009	Avillanosa et al. 2006	CHE-UPLB 2015	dela Peña et al. 2015a	Gonzales et al. 2017
Terrestrial development								+
Population increase								+
Overexploitation					+	+		
Resource conflict (use and access)			+				+	+
Habitat Destruction		+					+	
Pollution	+			+			+	
Cyanide and dynamite fishing		+					+	
Illegal fishing	+							
Organic matter and nutrient loading	+			+				
Poor waste disposal and management						+		
High export of fish supply						+		
Climate change						+		

IMPLICATION AND SOLUTION TO THE CURRENT CONDITION

It has been several decades since the government initiated the conservation of the remaining resources of the Sound. The decadal effort was already noticeable in the mangrove forests of the area. Figure 2 shows that it has already surpassed the initial coverage of the survey conducted in 1985. This suggests that environmental policies can coexist with rapid economic growth and competition for resources (Thomas and Belt, 1997). However, with the current global economic crisis and other internal problems that every nation is experiencing today, the delivery of services to the masses takes time. Given the limited capacities of the government to respond to the needs of the citizenry at the community level, non-government organizations (NGOs) are seen as vital links between the government and the people for the delivery of services (Balagot 1992). Involving and fostering partnerships with these stakeholders, including academic institutions and local communities, in conservation activities and decision-making, are encouraged to develop and implement a holistic fishery resource-based management approach.

Community involvement and empowerment are highly recommended. Javan (1999) stated that it is one of the keys to achieving sustainable development objectives. Interventions must be designed to enhance development at the community level. Environmental information and awareness are advocated to increase community participation (Thomas and Belt 1997). Promoting environmental literacy and capacity-building programs will empower local stakeholders to actively engage in conservation efforts that will further bolster long-term sustainability.

Aside from all of this, strict enforcement of the existing laws is still one of the keys to saving the remaining resources of the Sound. Monitoring of environmental resources and water quality should be regularly done too. Moreover, more scientific studies must be done to understand the ecological processes in the area. Stock assessments must be conducted, and the extent of exploitation must be determined to provide information for evaluating species vulnerability and devising management options suited for the area. Encouraging sustainable fishing practices, such as setting up catch restrictions, size limits, and closed seasons for fish species would be pivotal in mitigating overexploitation of fish stocks and safeguarding critical habitats. Moreover, exploring eco-tourism initiatives could provide alternative income sources for local communities while heightening awareness about the significance of conserving Malampaya Sound's ecosystems.

CONCLUSION

The Malampaya Sound boasts a rich and diverse ecosystem. It used to be the “fishbowl” of the Philippines during the 1970s. Its rich environment supports fisheries which is important in the livelihoods of the inhabitants. However, it is threatened by

destruction due to human-made disturbances such as poor waste disposal, high sedimentation rate, high Coliform concentration, terrestrial development, habitat destruction, pollution, illegal fishing, and overexploitation. While protective measures have been in place since the 1970s, more work is needed to achieve sustainable use of the area. The seagrass and coral cover in the area is still in poor to fair condition, indicating the need for urgent action to protect them. The mangrove population is the only one that has significantly improved. The preservation of Malampaya Sound, a vital natural resource, is only achievable through the collaboration and cooperation of the academic community, government agencies, non-government organizations, and the local community. The protection of this ecosystem requires a joint effort from all stakeholders to ensure a sustainable future for the Sound and the surrounding environment. Community involvement and empowerment, income diversification of the locals, strict enforcement of existing laws, monitoring of environmental parameters, and implementation of sustainable fishing practices will ensure long-term sustainability of marine resources.

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ETHICAL CONSIDERATION

The author declares that this work is free of plagiarism or research misconduct.

DECLARATION OF COMPETING INTEREST

The author declares no competing interests.

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REFERENCES

Alcala AC. 2001. Marine Reserves In The Philippines: Historical Development, Effects And Influence In Marine Conservation. Bookmark, Makati City, Philippines. 115pp.

Avillanosa AP, Avillanosa AL and Matillano MD. 2006. Catch composition of skimming net in Malampaya Inner Sound, Taytay, Palawan, Philippines. Journal of Aquatic Science, 3:22–30.

Balagot BP. 1992. Implications of environmental legislations to development sectors. The Philippine Journal of Public Administration, 36:328–366.

Balisco RAT, Dieron N, Gacita L and Cacho D. 2014. Reef Fish Communities and Assemblage in Malampaya Outer Sound, Taytay, Palawan. In: Gonzales BJ (eds). Sustainable coral reef ecosystem management in Bacuit Bay, El Nido and Outer Malampaya Sound, Taytay, Palawan. Western Philippines University- College of Fisheries and Aquatic Sciences, Puerto Princesa City, Philippines, pp. 15–22.

Bindoff NL, Willebrand J, Artale V, Cazenave A, Gregory JM, Gulev S, Hanawa K, Le Quere C, Levitus S and Nojiri Y. 2005. Observations: oceanic climate change and sea level. Notes, 17.

Borja VM, Furio EF and Rodriguez AK. 2000. Horizontal and vertical distribution of *Pyrodinium bahamense* cysts in sediments of Malampaya Sound, Palawan, Philippines. Harmful Algal Bloom 2000 Conference, Tasmania, Australia. https://www.frdc.com.au/sites/default/files/products/Conference%20Abstracts.pdf Accessed on 09 February 2022.

CHE-UPLB. 2015. Municipality of Taytay: Environmentally Critical Areas Network (ECAN) Resource Management Plan 2015-2020. College of Human Ecology, Department of Community and Environmental Resource Planning, University of the Philippines, Los Baños. 174pp.

DA-BFAR (Department of Agriculture-Bureau of Fisheries and Aquatic Resources). 1977. The country report of the Republic of the Philippines: Technical seminar on South China Sea fisheries resources. In: Proceedings of the Technical Seminar on South China Sea Fisheries Resources, Bangkok, Thailand, 21-25 May 1973. Japan International Cooperation Agency. 18pp. http://hdl.handle.net/20.500.12066/4107 Accessed on 09 February 2022.

David CPC, Maria YYS, Siringan FP, Reotita JM, Zamora PB, Villanoy CL, Sombrito EZ and Azanza RV. 2009. Coastal pollution due to increasing nutrient flux in aquaculture sites. Environmental Geology, 58:447–454. https://doi.org/10.1007/s00254-008-1516-5

dela Peña HP, Pido MD and Sespeñe JS. 2015a. Is Palawan’s Inner Malampaya Sound overfished? 2nd Palawan Research Symposium, Puerto Princesa City, Philippines, pp 60–65.

dela Peña HP, Sespeñe JS and Pido MD. 2015b. Revisiting Malampaya Sound in Palawan as the Philippines’ fishbowl: Interventions for sustainable management. The Brunei Darussalam–Indonesia–Malaysia–Philippines East ASEAN Growth Area (BIMP-EAGA) Journal for Sustainable Tourism Development, 4 (1): 68–79.

Deocadez MR and Aliño PM. 2005. Reefs Through Time: Biennial Report on the Status of Philippine Coral Reefs. Coral Reef Information Network of the Philippines. Philippines Reefs and University of the Philippines Marine Science Institute, Manila, Philippines. 248pp.

DENR (Department of Environment and Natural Resources). 2001. National Integrated Protected Areas Programme (NIPAP) - Final Report. Department of Environment and Natural Resources. 117pp. https://faspselib.denr.gov.ph/node/178 Accessed on 20 December 2020.

Dolorosa RG and Matillano JD. 2014. Abundance of reef macrobenthic invertebrates of Liminangcong and Tumbud, Taytay, Palawan: implications for conservation. In: Gonzales BJ. (eds) Sustainable coral reef ecosystem

management in Bacuit Bay, El Nido and Outer Malampaya Sound, Taytay, Palawan. Western Philippines University-College of Fisheries and Aquatic Sciences, Puerto Princesa City, Philippines, pp. 23–35

Doney SC, Fabry VJ, Feely RA and Kleypas JA. 2016. Ocean acidification: the other CO2 problem. Washington Journal of Environmental Law and Policy, 6: 213. https://doi.org/10.1146/annurev.marine.010908.163834

Doney SC, Ruckelshaus M, Duffy JE, Barry JP, Chan F, English CA, Galindo HM, Grebmeier JM, Hollowed AB, Knowlton N and et al. 2012. Climate Change Impacts on Marine Ecosystems. Annual Review of Marine Science, 4:11–37. https://doi.org/10.1146/annurev-marine-041911-111611

Estudillo RA, Gonzales CL and Ordonez JA. 1987. The seasonal variation and distribution of zooplankton, fish eggs and fish larvae in Malampaya Sound. Philippine Journal of Fisheries, 20:1–43.

FMB (Forest Management Bureau). 2019. 2019 Philippine Forestry Statistics. Department of Environment and Natural Resources. 68pp. https://forestry.denr.gov.ph/index.php/statistics/philippines-forestry-statistics Accessed on 20 December 2020.

Fortes MD. 2004. National Report on Seagrass in the South China Sea: Philippines. Reversing environmental degradation trends in the South China Sea and Gulf of Thailand. United Nations Environment Programme/Global Environment Facility (UNEP/GEF) South China Sea Project. 18pp. https://wedocs.unep.org/bitstream/handle/20.500.11822/7400/Terminal_evaluation_of_the_UNEP_GEF_project_Reversing_environmental_degradation_trends_in_the_South_China_Sea_and_Gulf_of_Thailand.pdf?sequence=1&isAllowed=y Accessed on 20 December 2020.

Garcia K, Gevaña D and Malabrigo P. 2013. Philippines' Mangrove Ecosystem: Status, Threats, and Conservation. In: Faridah-Hanum I, Hakeem ALR, Ozturk M. (eds) Mangrove Ecosystems of Asia: Status, Challenges and Management Strategies. Springer Science and Business Media New York, New York, pp 81-94. https://doi.org/10.1007/978-1-4614-8582-7_5

Gonzales BJ. 2013. Field Guide Coastal Fishes of Palawan. Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) Secretariat, Manila, Philippines. 208pp.

Gonzales BJ. 2018. Fishing gears and Methods of the Malampaya Sound Philippines: An Approach to Fisheries and Ecosystems Management. Manila, Philippines. Asian Conservation Foundation, 177pp.

Gonzales BJ, Matillano MVD, Aludia G, Miguel JA and Climatico RB. 2017. CPUE of Fishing Gears in Malampaya Sound, Western Taytay, Palawan, Philippines. World Wildlife Fund and Western Philippines University, 22pp. https://doi.org/10.13140/RG.2.2.21164.67207

Javan J. 1999. Empowerment for Community Development: A Multivariate Framework for Assessing Empowerment at the Community Level. Doctor of Philosophy, North Carolina State University, North Carolina, USA. 220pp.

Long JB and Giri C. 2011. Mapping the Philippines' Mangrove Forests Using Landsat Imagery. Sensors (Basel), 11(3):2972–2981. https://doi.org/10.3390/s110302972

Matillano JD, Dolorosa R and Matillano JA. 2014. Coral Cover of Liminangcong and Tumbud, Tatay, Palawan, Philippines: Implications to Conservation. In: Gonzales BJ. (eds) Sustainable coral reef ecosystem management in Bacuit Bay, El Nido and Outer Malampaya Sound, Taytay, Palawan. Western Philippines University- College of Fisheries and Aquatic Sciences, Puerto Princesa City, Philippines, pp. 7–14.

Maypa AP, Russ GR, Alcala AC and Calumpong HP. 2002. Long-term trends in yield and catch rates of the coral reef fishery at Apo Island, central Philippines. Marine and Freshwater Research, 53(2): 207–213. https://doi.org/10.1071/MF01134

McGowan S. 2016. Algal Blooms. Biological and Environmental Hazards, Risks, and Disasters, 5–43. https://doi.org/10.1016/B978-0-12-394847-2.00002-4

McNeely JA, Miller K, Mittermeier RA, Reid WV and Werner TB. 1990. Conserving The World's Biological Diversity. International Union for Conservation of Nature (IUCN), Gland, Switzerland, 193pp.

PCSD (Palawan Council for Sustainable Development). 2004. State of the Environment: Palawan, Philippines 2004. Puerto Princesa City, Palawan, Philippines, 186pp.

PCSD (Palawan Council for Sustainable Development). 2006. Baseline Report on Coastal Resources for Taytay Municipality. Puerto Princesa City, Palawan, Philippines, 113pp.

PCSD (Palawan Council for Sustainable Development). 2015. State of Environment Report: Palawan, Philippines 2015 Updates. Puerto Princesa City, Palawan, Philippines, 76pp.

Pauly D, Alder J, Bakun A, Eileman S, Kock KH, Mace P, Perrin W, Stergiou K, Sumaila UR, Vierros M and et al. 2005. Marine fisheries systems. In: Hassan R., Scholes R., Ash N. (eds) Ecosystems and human well-being: Current state and trends. Island Press, Washington, DC, United States of America, pp. 477–511.

Pauly D, Christensen V, Guénette S, Pitcher TJ, Sumaila UR, Walters CJ, Watson R and Zeller D. 2002. Towards sustainability in world fisheries. Nature, 418(6898):689–695. https://doi.org/10.1038/nature01017

PNSS (Philippine National Science Society). 2004. Seagrasses of the Philippines: Country Report. United Nations Environment Programme/Global Environment Facility (UNEP/GEF) South China Sea Project (SCS) Project: Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand. United Nations Environment Programme, 70pp. http://www.unepscs.org Accessed on 24 January 2021.

PSA (Philippine Statistics Authority). 2020. Compendium of Philippine Environment Statistics. Philippine Statistics Authority, Manila, Philippines, 930pp.

Pido M, Pomeroy R, Carlos M, Garces A, Agbayani R, Sandalo A, Catain V, Benavente A, Bacosa R and Matulac J. 1996. The application of the institutional analysis research framework in the evaluation of fisheries and other coastal resources management systems in Palawan, Philippines. Philippine Council for Aquatic and Marine Research and Development (PCAMRD) Book Series (Philippines), 416pp.

Pido MD. 1995. The application of Rapid Rural Appraisal techniques in coastal resources planning : experience in Malampaya Sound, Philippines. Ocean and Coastal Management, 26(1):57–72. https://doi.org/10.1016/0964-5691(95)00011-P

Pilien J and Walpole P. 2003. Moving from open access extraction to new participatory levels of accountable management Malampaya Sound, Palawan, the Philippines. In: Castro AP and Nielsen E. (eds) Natural resource conflict management case studies: an analysis of power, participation and protected areas. Food and Agriculture Organization, Rome, Italy, pp. 251–268.

Ronquillo IA and Llana MaEG. 1987. Biological effects of fishery management measures in the Philippines. Symposium on the Exploitation and Management of Marine Fishery Resources in Southeast Asia, Darwin, Australia, pp. 244–248.

Sandalo AC. 1996. Overview and Status of Fisheries and Coastal Resources. Management in Palawan, Philippines. In: The management systems of marine fisheries and other coastal resources in Palawan, Philippines: concepts, experiences and lessons. International Center for Living Aquatic and Resources Management (ICLARM) and Palawan Council for Sustainable Development (PCSD), Manila, Philippines, pp. 2–13.

Sellner KG, Doucette GJ and Kirkpatrick GJ. 2003. Harmful algal blooms: causes, impacts and detection. Journal of Industrial Microbiology and Biotechnology, 30(7):383–406. https://doi.org/10.1007/s10295-003-0074-9

Sombrito EZ, Bulos A dM, Sta Maria EJ, Honrado MCV, Azanza RV and Furio EF. 2004. Application of 210Pb-derived sedimentation rates and dinoflagellate cyst analyses in understanding *Pyrodinium bahamense* harmful algal blooms in Manila Bay and Malampaya Sound, Philippines. Journal of Environmental Radioactivity, 76(1-2): 177–194. https://doi.org/10.1016/j.jenvrad.2004.03.025

Thomas V and Belt T. 1997. Growth and the Environment: Allies and Foes? Journal of Social, Political and Economic Studies, 22:327–334.

Tupper M, Asif F, Garces LR and Pido MD. 2015. Evaluating the management effectiveness of marine protected areas at seven selected sites in the Philippines. Marine Policy, 56:33–42. https://doi.org/10.1016/j.marpol.2015.02.008

Wilkinson C. 2000. Status of Coral Reefs of the World: 2000. Australian Institute of Marine Science, Townsville, Australia, 376pp.

World Bank. 2005. Philippines Environment Monitor 2005: Coastal and Marine Resource Management, 76pp.

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   Ardines RB, Mecha NJMF and Dolorosa RG. 2020. Commonly gleaned macro-benthic invertebrates in a small offshore island of Cawili, Cagayancillo, Palawan, Philippines, The Palawan Scientist, 12: 102-125.
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   Poutiers JM. 1998. Gastropods. In: Carpenter KE and Niem VH (eds). FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific Seaweeds, Corals, Bivalves and Gastropods. Food and Agriculture Organization, Rome, Italy, pp. 364-686.
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   Froese R and Pauly D (eds). 2022. FishBase. www.fishbase.org. Accessed on 07 March 2022.
   CITES (Convention on International Trade of Endangered Species). 2014. The CITES Appendices. Convention on International Trade in Endangered Species of Wild Flora and Fauna. www.cites.org. Accessed on 07 March 2022.
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   Guion SL. 2006. Captive breeding performance of *Crocodylus porosus* (Schneider 1901) breeders at the Palawan Wildlife Rescue and Conservation Center. BS in Fisheries. Western Philippines University-Puerto Princesa Campus, Palawan, Philippines. 28pp. (include weblink, if there's any, followed by accessed date).
   Lerom RR. 2008. Biosystematics study of Palawan landraces of rice (*Oryza sativa* L.). Doctor of Philosophy, Institute of Biological Sciences, University of the Philippines-Los Baños College, Laguna, Philippines. 197pp. (include weblink, if there's any, followed by accessed date).
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   Alcantara LB and Noro T. In press. Growth of the abalone *Haliotis diversicolor* (Reeve) fed with macroalgae in floating net cage and plastic tank. Aquaculture Research.
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   Fabro KA. 2021. Surge in seizures of giant clam shells has Philippine conservationists wary. Mongabay. https://news.mongabay.com/2021/03/surge-in-seizures-of-giant-clam-shells-has-philippine-conservationists-wary/. Accessed on 07 March 2022.

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a. All organisms must be identified by their English, scientific names and local names if possible.
b. Scientific names and taxonomy authority must be cited for all organisms at first mention (e.g., *Stiphodon palawanensis* Maeda & Palla, 2015). Subsequently, only the initial of the genus should be written except when starting a sentence with a scientific name. All scientific names should be italicized. Example: *Epinephelus fuscoguttatus*; *Anadara* sp. *Musa* spp. Do not italicize the higher levels of taxonomic classification (example: family Echinometridae).
c. Local names should be in double quotes (example: locally called "saging" not 'saging'; "palay" not 'palay').
d. Research articles dealing on species list should provide the authorities for each species (example: *Conus magus* Linnaeus, 1758; *Enosteoides philippinensis* Dolorosa & Werding, 2014).

12. Punctuations, Equations, Symbols and Unit of measures

a. Unfamiliar terms, abbreviations, and symbols must be defined/spelled out at first mention even in the abstract. Acronym should only be spelled-out as it is introduced in the text, it should be written in acronym in succeeding parts of the paper.
b. Mathematical equations should be clearly presented so that they can be interpreted properly. Equations must be numbered sequentially in Arabic numerals in parentheses on the right-hand side of the equations.
c. In International System of Units of measurements must be used but separated from the value and the unit of measure (e.g. 5 mm, 25 g, 30 m^3, 100 μm, 9 ind ha^{-1}, 10 sacks ha^{-1}, 2 kg h^{-1}, 2 kg h^{-1} day^{-1}) and probability (*P*) is in upper cased and italicized (e.g. $P > 0.05$; $P < 0.05$; $P = 0.01$). To fix a single space between the value and its unit of measure, use the MS word command "CTR+SHIFT+SPACE BAR" to provide a space between the value and its unit of measure.
d. There is a single space between numbers and the following mathematical signs: ±, =, ×, -, +, ÷, (e.g. 92 ± 0.092; 5 × 6).
e. Numbers less than 10 should be spelled out (for example: eight trees, 10 fish) except when followed by a unit of measure (for example: 9 cm, not nine cm). Number mentioned at the start of the statement should be spelled-out (e.g. Nine fishermen not 9 fishermen or Six degrees Celsius not 6˚C).
f. The symbol for Degree (˚) should be inserted using the insert symbol option and not zero (0) or alphabet (o) superscript.
g. Do not separate a percent sign and degree of temperature with the number (example: 5% and 8˚C).
h. Write dates in this manner: day-month-year (example: 20 October 2012 or 20 Oct 2012).
i. Use a 24-h system for time (example: 1300 instead of 1:00 pm). To express a measured length of time, abbreviations for hour (h), minutes (min) and seconds (sec) should be used (example: 2 h and 30 min; or 2.5 h).
j. Include apostrophes in years (example: 2014's).
k. No periods in acronyms (example: UNESCO not U.N.E.S.C.O.; CITES not (C.I.T.E.S.)
l. Use a single capital letter when writing latitude and longitude (example: 9°44'27.80"N and 118°41'2.01"E). Compass points (north, south, east, west) and their derivations (northern, southern, eastern, western) are lowercase (example: north of Palawan) except when they form part of the place name (example: South Cotabato; Eastern Samar).

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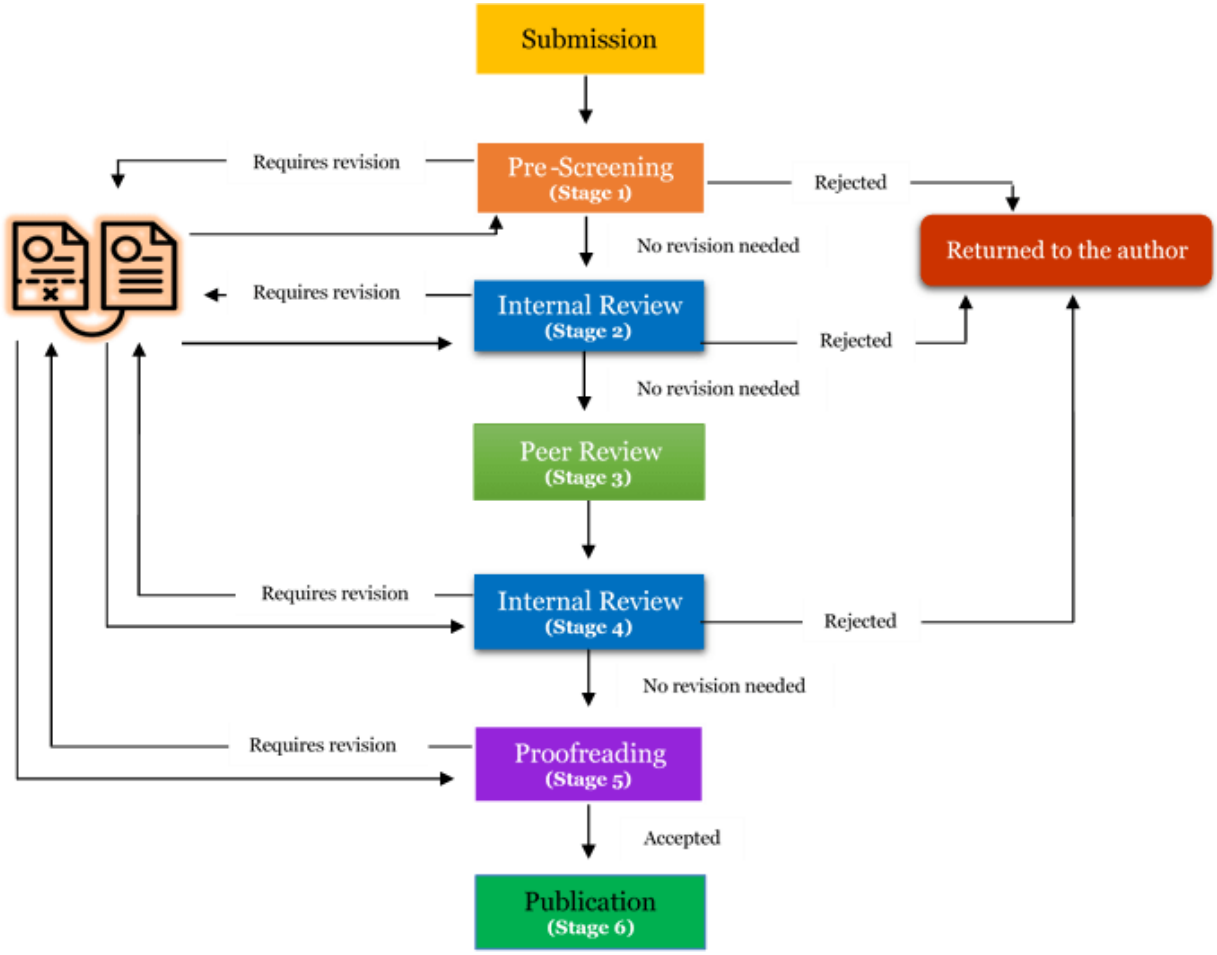

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