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ABOUT THE COVER

Neurigona. susanrocesae sp. nov., the first species of the genus *Neurigona* found in the Philippines, is named after the late Susan Roces, the "Queen of Philippine Movies". Photos by Custer C. Deocaris and co-authors

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EDITORIAL

Predatory journals, high-quality science, research ethics, artificial intelligence: how confusing could digital academic publishing be?

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Navigating the publishing process could be exhausting and puzzling for early career researchers. Having published in a predatory journal and from low-medium-to high-quality journals, with a Web of Science Impact Factor of <0.5 to a metric of 13.6, opens a broad perspective in scientific publishing. I, too, started my scientific publishing career, unknown to its depths. Excited for research, I gathered the data for six months, collated and interpreted the results for ~4 months, and wrote, edited, reviewed, and rewrote the paper for over six months. For the sake of publication at the state universities and colleges, for institutional evaluation purposes, and deadlines, but mainly due to the lack of awareness of the publication and scientific publishing, these efforts became rubbish: the fact of getting published in a low-quality, unknown journal, potentially predatory, without proper technical, scientific scrutiny—where no one reads and recognizes.

Acknowledging predatory publishing as a global problem is a way to combat bad science. Unfortunately, good science is challenging to define, and in this digital era, how can an amateur researcher navigate the labyrinth of scientific publishing? Four significant issues and challenges in science are presented herein. First is (1) how predatory journals and publishers generally operate, 2) what high-quality science is, 3) how research ethics uplift standards, and 4) how to utilize and limit artificial intelligence as a tool in science. Luckily, a group of scientists published in "Nature" came up with the definition (Grudniewicz et al. 2019) of predatory journals:

> "*Predatory journals and publishers are entities that prioritize self-interest at the expense of scholarship and are characterized by false or misleading information, deviation from best editorial and publication practices, a lack of transparency, and/or the use of aggressive and indiscriminate solicitation practices.*" Nature, 576: 210-212.

However, without experience, it is still problematic to evaluate which journal is predatory, even when it is free. These journals are very persistent: they send emails, praise your mediocre work, demand excessive open access fees, provide little to no editorial services, and offer rapid publication-often within days to weeks. These journals are mostly multidisciplinary and publish almost anything for money. To ensure quality publications, the simplest solution is to stick with the established and trusted indexing list, such as the Web of Science (WoS). The most impactful journals are covered under the WoS Core Collection Indexes: Science Citation Index (Expanded) (SCI & SCIE) and Social Science Citation Index (SSCI). Other core collections include the Arts and Humanities Citation Index (AHCI) and the Emerging Sources Citation Index (ESCI), good options for new researchers. Web of Science is an independent database and unassociated from any journal publisher. Still, some journals can be categorized

as predatory within these indexes and difficult to spot. Overall, you can choose journals published for free by independent, recognized national or international organizations and established universities and are mainly indexed in high-quality indexes like the WoS SCIE.

High-quality science requires a broad definition in all aspects of the scientific process—from conceptualization, undertaking, and analysis to publication. The easiest, common way of evaluating scientific publications is based on journal metrics. The Declaration on Research Assessment (DORA) recommends assessing the scientific substance of a particular article using article-level metrics or context-specific metrics such as five-year impact factor, EigenFactor, SCImago, h-index, and editorial or publication times (DORA 2024). However, to evaluate the worth of research contributions, most universities employ citation counts, accepted lists of prestigious journals, or other criteria (Lindgreen et al. 2021). In transdisciplinary science, quality can be based on relevance, credibility, legitimacy, and effectiveness, the four basic tenets. These are grounded in social significance, integration, reflexivity, equitable representation of stakeholder interests, and real or potential contributions to social change and problem-solving (Belcher et al. 2016). However, "the concept of research excellence is ubiquitous, but its meaning depends on context" (Campbell 2018). It cannot be only based on metrics but on its impacts on society.

Research ethics is gaining more attention in the Philippines as malpractices gather social media attention (Facebook). One viral case was using a student's thesis published solely by a Professor from the University of Southern Mindanao (posted May 6, 2024). Another was the allegedly plagiarized news article originally written by a student at Ateneo de Manila University (posted August 31, 2024), and for sure, many more. Research ethics should be made the foundation of research. High-quality journals always require research ethics approval and permits, accordingly, and using the norms and highest ethical standards uplifts one's research quality. Developing research ethical practices as a culture rather than a requirement and incorporating them in all research curricula paves the way for our acceptance and awareness of these norms. Adding to the jargon in scientific publishing is artificial intelligence (AI). Inevitably, AI is a promising advance in scientific inquiry and offers a diverse use in all aspects of research i.e., planning-to-publication. Artificial Intelligence is used in science to improve experimental design, data gathering, interpretation, and hypothesis creation. This allows for the provision of insights that may not be possible with traditional approaches (Wang et al. 2023). However, using AI in manuscript writing poses issues with scientific integrity when carelessly done. Nowadays, many might use ChatGPT and the like to generate entire write-ups and then humanize them with another AI tool. However, this is unacceptable in science and additionally stunts someone's scientific growth, critical thinking, and sense of responsibility. To uphold scientific integrity while utilizing powerful AI tools, AI in manuscript writing should only aid the authors by correcting grammar and clarifying sentence structures. One best example of these functions can be found, e.g., in Quilbott and Grammarly.

Where is the Palawan Scientist journal positioned in the Philippine academic publishing? To date, there are 17 Philippines journals indexed in the Web of Science Core Collection Indexes: SCI, SSCI, AHCI, and ESCI, which was included in the new Journal Citation Reports (JCR) 2023 (Clarivate 2023). JCR does not include journals in the Philippines indexed in Additional WoS Indexes, e.g., Biological Abstracts, BIOSIS Previews, Zoological Records, etc. The Palawan Scientist having its new Impact Factor (IF) and being included in the JCR this year creates a new avenue for quality metrics and journal ranking (IF: 0.1, Biology Category, Q4) (Clarivate 2023). The growth of the Palawan Scientist journal contributes to the development of Philippine science. Having 2 issues per year, getting an impact factor, this current issue's discovery of a new species of long-legged fly *Neurigona susanrocesae*

(Deocaris et al.), and papers authored throughout the Philippine archipelago, Indonesia, and Malaysia further marks the increasing international journal reputation. As a multidisciplinary journal, a variety of fields can be published, from biodiversity by Deocaris et al. and Mecha, fish genomics by Guia et al., fisheries management and society by Juan et al., Chelliah et al., and Labayo and Preña. The current issue also features chemical engineering technology by Junco et al. and educational management by Casinillo and Pentang et al. The Palawan Scientist offers a great avenue for quality research publication and guidance for young and expert scientists. Editors and reviewers are experts and mentors with high-quality publication track records.

Everything is easier to navigate with a helping hand. The Palawan Scientist is here to guide your career to high-quality science for free! We welcome your submission to the Palawan Scientist journal.

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CONTENTS

Original Article

Neurigona susanrocesae, the first *Neurigona* species from the Philippines

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ABSTRACT

The first species of the genus *Neurigona* is described from the Philippines. The diagnosis, description and molecular data based on the partial DNA sequence of mitochondrial cytochrome oxidase subunit I gene were documented. The *Neurigona* species exhibits distinct characteristics, including a sub-apical dorsal stylus resembling an arista, a peduncle on the seventh abdominal segment, a flat dorsal postcranium, elongated legs devoid of prominent setae or bristles, and a distinctive rectangular bend in wing vein M. Based on the DNA sequence analysis, the unknown species is 90.06% similar to *Cyrtona* sp. and *Neurigona zhejiangensis*. However, 10% of its DNA sequences are significantly variable making it a totally different species. The specimen was verified by a dipterist as a species belonging to Genus *Neurigona* under Family Dolichopodidae. These flies are recognized for their lengthy legs and sizable yellow bodies. The species is named as *N. susanrocesae* as a tribute to the late Susan Roces, the "Queen of Philippine Movies".

Keywords: Bohol Island, DNA barcoding, new species, phylogenetic analysis, taxonomy

INTRODUCTION

Although taxonomists have estimated one to 1.7 million species in the order Diptera, they have only just scratched the surface in terms of documenting and describing its immense diversity, as the dipterans are believed to represent some 10-15% of the world's biodiversity (Stork 1996; Brown 2005). Dolichopodidae, or the long-legged flies are the largest dipteran family with about 7,500 species described globally (Bickel 2009). These flies are cosmopolitan and inhabit diverse ecosystems including freshwater and marine environments, forests, grasslands, and wetlands. Notably, they constitute the most prevalent true fly group, with adult members typically measuring between a mere 1.8 and 10 millimeters in size. (Grootaert and Meuffels 2004). Despite their small size, the adults and larvae are both known to be avid feeders. They mostly consume chironomid, ceratopogonid, and culicid larvae. Adults take out prey larvae from their burrows and secure them between their fleshy labellae throughout the feeding process. The prey is then punctured via the concealed hypopharynx, which mimics a dagger as bodily fluids are sucked up (Coulibaly 1993).

A high diversity of dolichopodids is normally thought to indicate an undisturbed ecological system, whereas a low diversity of these insects is linked with some kind of ecological disruption. Grichanov et al. (2021) noted that diversity of Dolichopodidae in East Asia is much higher compared to other parts of the world. In Malaysia, for instance, there was a lack of

knowledge of dolichopdid pointing to the single study done even prior to World War II despite the country being recognized as a biodiversity hotspot (Parent 1935). The team of Grootaert and Meuffels (2004) surveyed for only three days in Endau-Rompin Park in Malaysia and revealed the presence of 83 species. Their paper highlights the need for more studies to understand the biogeography and evolutionary history of Dolichopodidae in biodiverse regions of the world.

The Philippines is in the "center of the center for biodiversity" and is likewise considered a hotspot for the discovery of new species of Dolichopodidae due to its unique geography (Ramos et al. 2018). Apart from colonization, the high species richness and endemism of insects in the country is believed to be explained by speciation and phylogenesis. Their limited dispersal abilities and small size prevent these insects from traveling long distances, leading to high levels of isolation and speciation in islands with diverse habitats and oceanic barriers (Heaney 2000). Several species of Dolichopodidae have been recently reported in various habitats in the Philippines, including mangroves, freshwater streams, and forests (Ramos et al. 2018; Ramos and Grootaert 2018; Jose et al. 2022; Wang et al. 2022; Grichanov 2023). The continued exploration and documentation of Dolichopodidae diversity in the Philippines are crucial in understanding the biogeography and evolutionary history of this diverse family.

In this paper, a new species belonging to the *Neurigona* genus of Dolichopolididae from Bohol Island, Philippines is reported. The recently discovered species bears a striking resemblance to N. squamifera, previously documented in Singapore (Parent 1935; Grootaert and Foo 2019). This finding marks the first record of its kind within the Philippines, enriching our comprehension of Dolichopolididae biodiversity in the country. The *Neurigona* genus is widely distributed globally, with only 25 known oriental species out of the 150 identified species worldwide (Yang et al. 2006), making this finding particularly significant.

METHODS

Sampling Area, Species Collection and Sorting

With permission to sample and later an issuance of a gratuitous permit from Department of Environment and Natural Resources – Region VII (Wildlife GP 2019-11, series of 2019), collections were made from June to August 2016 at Magsaysay Park, Rajah Sikatuna Protected Landscape (RSPL), Bilar, Bohol Island, Philippines. The vegetation of the habitat where the species was collected are predominantly planted natural regenerants of big-leaf mahogany and several species of *Ficus*. Malaise traps deployed in areas with minimum disturbance: Trap 1 (9.70431°N, 13 24.1239 E) and Trap 2 (9.70359°N, 124.1252°E) from June to August 2016. The traps were allowed to remain open during the entire sampling period and the bottles containing 70% unmethylated ethanol alcohol were changed every week. Collected specimens were sorted into various families and placed in separate vials with screw caps and labels/codes for molecular work. Sorting of specimens was based on "The Families of Diptera of the Malay Archipelago" (Oosterbroek 1998) and verified by taxon-specific experts from the National University of Singapore (NUS).

Digital Referencing and Morphological Characterization of Specimen

Images of the unidentified specimen were acquired at National University of Singapore using a Dun Inc. Passport II microphotography system, fitted with a Canon 65mm 5X MPE lens. The images were compiled using Zerene Stacker and digitally processed using Photoshop CS5. To confirm new species identification, taxonomic experts compared the undetermined specimens with specimens from a digital reference collection, a physical reference collection of specimens used for taxa identification that needs to be identified routinely by taxonomists from different backgrounds and updated identification tools for dipterans (Ang et al. 2012).

Molecular Identification using CO1 Gene Marker for DNA Barcoding

To further confirm the identification of the unknown dolichopod, DNA barcoding was conducted using mitochondrial CO1 as the gene marker. A partial sequence of 313 bp from the CO1 region was amplified and compared to other dipteran DNA sequences. Two DNA-sequence based approaches were conducted for species discrimination and identification namely, the "best match" approach where the DNA sequence is directly compared to all the barcodes in the database and the tree-based identification using phylogenetic analysis (Meier et al. 2016; Barrett and Hebert 2005; Blaxter et al. 2005)

DNA Extraction and Sequencing

DNA extraction from the leg portion of the sample were subscribed from the methods of Wong et al. (2014). Primer pairs (Macrogen) designed to target the mitochondrial cytochrome c oxidase I (COI) gene were used for polymerase chain reaction (PCR) amplification. Conditions for the PCR were set at the following: initial denaturation at 95°C (3 m); 1 cycle of 94°C (1 m), annealing 47°C (1 m), and 72°C (1 m), followed by 40 cycles with final extension set at 72°C (5 m). Amplicons were then purified using Sure Clean (Bioline), quantified in equimolar ratios using Nanodrop (Quiagen), and pooled prior to library preparation and Next-Generation Sequencing with Illumina MiSeq and HiSeq 2500 sequencing platforms. Sequencing libraries were prepared by AIT biotech

using the TruSeq Nano DNA Library Preparation Kit (Illumina), according to the manufacturer's protocol. Illumina MiSeq runs were provided by AITbiotech with the use of MiSeq Reagent Kit v3 (2 X 300 bp read lengths) while HiSeq runs were provided by Singapore Centre for Environmental Life Sciences Engineering (SCELSE) with HiSeq 2500 System and Rapid SBS Kit v2 (2 X 250 bp read lengths). The respective COI mitochondrial DNA sequence has been submitted to National Center for Biotechnology Information (NCBI) with accession number ON023659 for data referencing.

Phylogenetic Analysis

The DNA analysis pipeline was based on the method of Meier et al. (2016). Paired-end reads were merged using PEAR 0.9.6 (Zhang et al. 2014). Reads from each PCR product were assigned to their corresponding specimen using uniquely labeled primer pair, and the dominant read was identified as the specimen barcode using a Python script (Srivathsan and Meier 2012). To sort the data, the reads in each sample were counted, grouped identical reads into sets, identified the most common set, and merged it with similar-length variants. These were also compared to the number of reads in the biggest set and the second-largest set (Meier et al 2016).

For purposes of quality control, barcoding of a particular sample was only considered successful if (i) the total read count was > 50x, (ii) the total barcode count was > 10x, and (iii) and the most dominant read was at least five times that of the second most dominant read (Meier et al. 2016). These sequences were then used for NCBI-BLAST (Basic Local Alignment Search Tool) to search for sequences that matches (> 97% identity) the taxa. The top twenty specimens with the highest percentage match (86-88%) were retrieved for phylogenetic analyses.

All retrieved sequences were aligned using Multiple Alignment using Fast Fourier Transform (MAFFT) v7. Aligned sequences in fasta format were further analyzed for phylogenetic inference using Molecular Evolutionary Genetics Analysis (MEGA X) (Kumar et al. 2018). Evolutionary relationships of each taxon were inferred using the Neighbor-Joining method (Saitou and Nei 1987) with 1000 bootstrap support. Evolutionary distances were computed using the Maximum Composite Likelihood method (Tamura et al. 2004). In addition, a time tree was generated using the strict-clock method and the Tamura-Nei model (Tamura and Nei 1993) with an estimated log likelihood value of -5435.14 at a global rate of 0.001. The tree is drawn to scale with branch lengths measured in the relative number of substitutions per site.

RESULTS

***Neurigona susanrocesae* sp. nov.**

Type material. Philippines, island of Bohol, province of Bilar, Magsaysay Park, 08.30.2006, ♀ holotype, 1 (Figure 1), leg. RP Jose, Entomology Laboratory, National University of Singapore (after the photo was taken, the specimen was desiccated and securely archived within a collection).

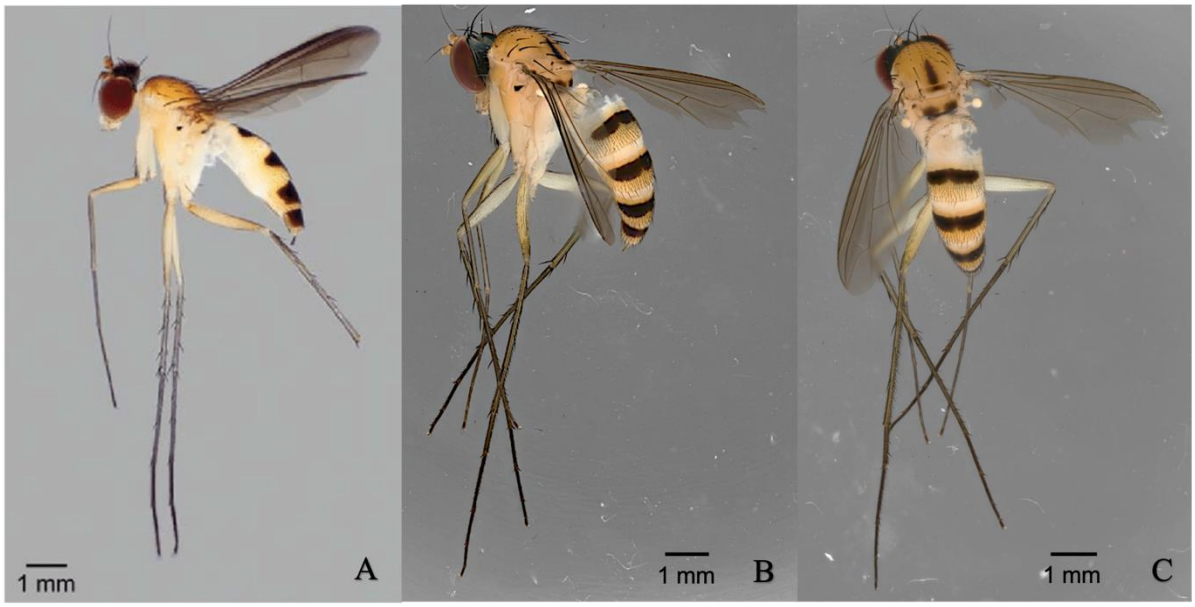

Figure 1. Gross morphological comparison between a parent *Neurigona squamifera* **(A)** from ZRCBDP0007646 (Photograph: K.Q. Chin) and the unidentified dolichopod discovered from Bohol Island. Holotype, female (P1F32R20) showing the **(B)** dorsal and **(C)** lateral habitus of the specimen. Scale bar =1 mm.

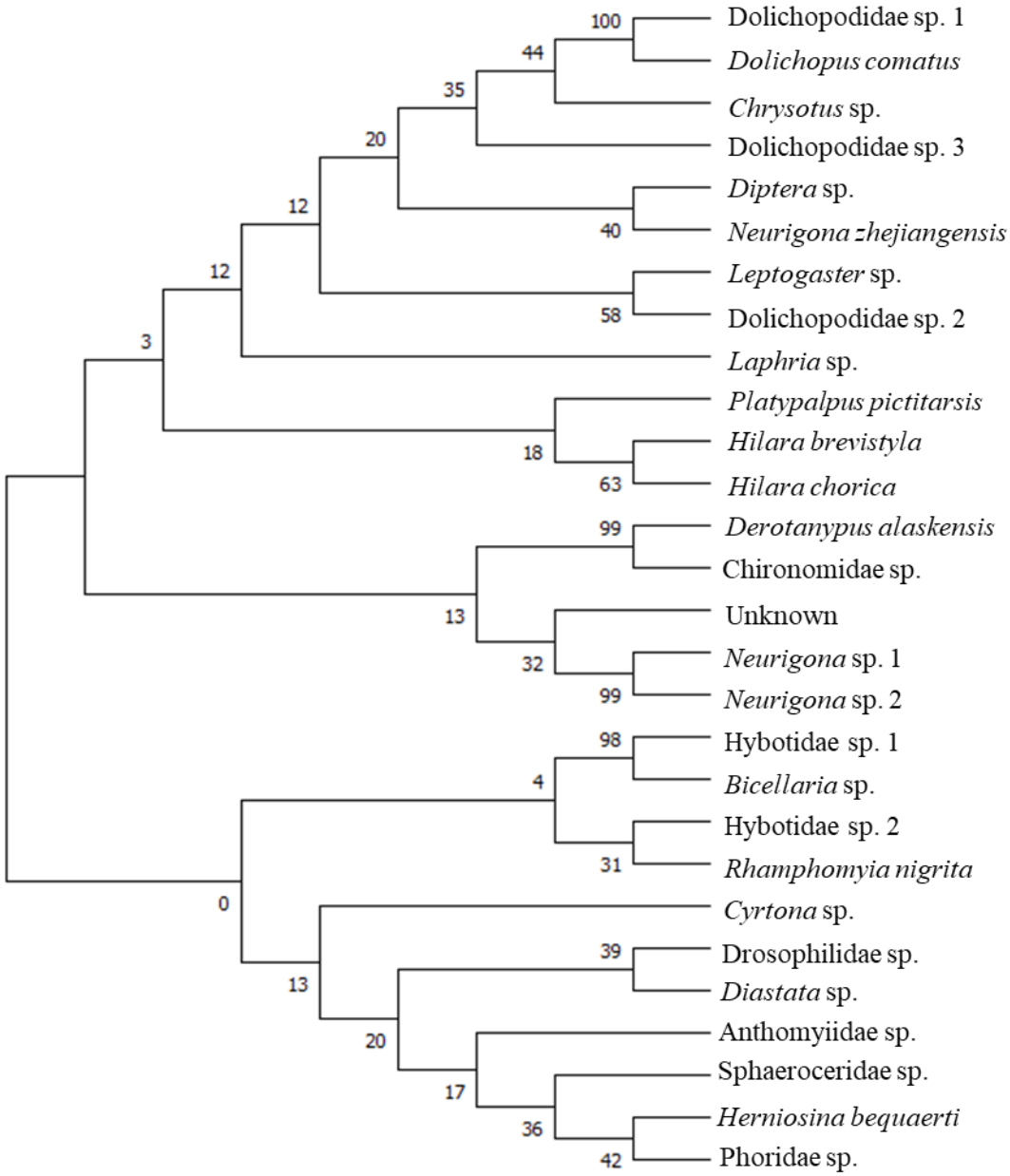

Figure 2. Phylogenetic analysis using MEGA X. The top thirty species sharing the highest similarity to the unknown DNA sequence were inferred for phylogenetic analysis using the Neighbor-Joining method with 1000 bootstrap support. The unknown sample clustered together with two conspecific *Neurigona* species with 32% bootstrap support. Numbers next to branches indicate percentage of replicate trees where associated taxa clustered together in the bootstrap test.

Dimensions. L: 6 mm, H: 3 mm, W: 5 mm.

Description. Female body length: 6 mm, wings: 5 mm, antenna: yellowish. Arista with basal segment yellowish, base of apical aristal segment pale becoming black towards the tip. Palpus light brown elongate with bristling. Thorax: light brown with a brown prescutellar patch. Acrostichals biseriate. Scutellum brown, border yellow. Ventral border of postnotum is brown. Legs: yellow, tarsomeres entirely black, hind femur ventrally yellow. Fore coxa with minute yellowish white anterior bristles on basal half. Tibia with black bristles-like structures. Wings transparent brownish tinged; anterior third darker brown than the posterior part. Haltere with knob anteriorly dusky yellow, otherwise almost entirely white. Abdomen: first tergite yellow with long black marginal bristles. Base, tip, and sides of tergite two and three yellow, the rest is brown to black. Tergite four with only a narrow yellow band at the base and tip, side brown. Tergite five dorsally yellowish white, a small brown patch at the side, cercus yellowish white.

The DNA sequence analysis of the unknown species showed a 90.06% similarity to *Cyrtona* sp. and *Neurigona zhejiangensis*, with 10% of its DNA sequences being significantly variable, indicating it is a distinct species. Figure 2 illustrates the evolutionary relationships between 30 closely related species with 88-90% similarities, using the Neighbor-Joining (N-J) method with 1000 bootstrap support. The unidentified species was found to be closely related to two different species of *Neurigona*, with 32% bootstrap support, and clustered as one group with them, suggesting it is highly likely to belong to the *Neurigona* genus. The percentage of replicate trees where associated taxa clustered together in the bootstrap test is indicated next to the branches.

DISCUSSION

The unidentified species shares key characteristics with other *Neurigona* species within the Dolichopodidae family found in Asia. These distinctive features include a flat dorsal postcranium, a sub-apical dorsal stylus resembling an arista, a face covered in dense pruninosity, proepisterum adorned with setae, a mesonotum with a flat posterior slope, noticeably elongated legs without major setae, ventral modifications on abdominal segments four or five, a well-defined peduncle on abdominal segment seven, and a spherical hypopygium (Bickel and Lian-Meng 1996; Bickel 2009).

This recently discovered species closely resembles *N. squamifera* in several aspects. Its antenna is distinctly yellow, with a notably wide third antennal segment. The palpus exhibits a vibrant yellow coloration adorned with yellow bristles. The thorax displays a uniform yellow hue, while the prescutellar depression, although subject to slight variability in intensity, generally appears as a faint brown shade, never dark brown. The scutellum features brown coloring, bordered by a striking yellow outline. The ventral border of the postnotum is also brown in appearance.

The arrangement of acrostichals is consistently biseriate throughout, adding to its distinctive characteristics. In the basal half, the dorsocentrals are short and multiseriate, followed by a row of six uniseriate dorsocentrals, which gradually lengthen toward the scutellum.

The legs of this species are primarily yellow, with a notable exception: the fore tarsus possesses entirely black apical three tarsomeres, while the hind femur exhibits a darkened ventral surface. The fore coxa bears pale hairs on its basal half and transitions to black hairs on the apical half. Additionally, there are three prominent black bristles on the side and six at the tip of the fore coxa. Tarsomeres four and five display a dorsal comb of black squamiform bristles, with the longest ones situated at the base of tarsomere four and decreasing in length toward the tip of tarsomere five.

The wings of this species are tinged with a brownish hue, with the anterior third appearing darker brown than the posterior portion. A distinctive feature is the strong rectangular bend in vein M. Finally, the squama is yellow with a brown border, adorned with long yellow setae, completing the unique characteristics of this species.

The haltere exhibits an anteriorly positioned dusky yellow knob, while the remainder of the structure appears almost entirely white. Moving to the abdomen, the first segment has a complete yellow coloring. On tergite two and three, the base, tip, and lateral aspects are characterized by a yellow hue, contrasting with the brown to black shading along the remaining portions. Tergite four presents a slender yellow band solely at its base and tip, while the sides adopt a brown shade. The fifth tergite displays a dorsal coloring that appears yellowish white, featuring a minor brown patch along its lateral region. Notably, the cercus displays a distinct white hue (Figure 1A). However, this newfound species exhibits notable morphological distinctions, particularly evident in the palpus. The palpus showcases an elongated structure with a light brown coloration, accompanied by bristling. Furthermore, the thorax displays a light brown hue, punctuated by a distinctive brown prescutellar patch. The ventral surface of the hind femur is adorned with a yellow coloring, while the wings uniformly exhibit a transparent brownish tinge.

The molecular analysis of the DNA sequence from the unknown species provided valuable insights into its genetic relationships. The species demonstrated a 90.06% similarity to *Cyrtona* sp. and *Neurigona zhejiangensis*, with a notable 10% variability in its DNA sequences, confirming its distinctiveness. Through the Neighbor-Joining (N-J) method and phylogenetic analysis, the species was shown to be closely affiliated with two distinct *Neurigona* species, clustering as a unified group. This clustering further strengthens the hypothesis that the unknown species falls within the *Neurigona* genus.

To establish the identity of the unknown dolichopod, DNA barcoding techniques using mitochondrial CO1 as the gene marker were applied. Both the "best match" approach and tree-based identification methods were employed. Although no exact matches were found using the "best match" approach, the species exhibited a striking 90.06% similarity to *Cyrtona* sp. and *Neurigona zhejiangensis*. The tree-based identification, using the N-J method, yielded a cluster of closely related species sharing 88-90% similarities, among which the unknown species aligned itself most closely with two *Neurigona* species. These combined results conclusively support the placement of the unknown species within the *Neurigona* genus. Thus, amalgamating the tenets of traditional taxonomy with insights gleaned from

molecular investigations, has unveiled this species as a distinct and hitherto unrecorded member of the *Neurigona* genus.

Through a meticulous scrutiny of its morphological attributes and a robust molecular analysis, the recently uncovered species from Bohol Island as *Neurigona susanrocesae* sp. nov is confidently designated. This chosen appellation serves as a tribute to the illustrious legacy of Jesusa Sonora Poe, affectionately known as Susan Roces, the revered "Queen of Philippine Movies". Roces, who adorned the silver screen with her presence in more than 130 films during her seven-decade career, garnered numerous accolades, including the prestigious "Lifetime Achievement Award" from the Film Academy of the Philippines. Beyond her status as a celebrity, Roces exemplified modest living and philanthropy through her support of various charitable endeavors, including the Rivers of Living Water Catholic community, Carmelite Sisters, and the Movie Workers Welfare Foundation (Mowelfund). As the widow of presidential candidate Fernando Poe Jr. and the mother of Senator Grace Poe (19th Congress), Roces left an indelible mark on Philippine society. Her passing on 20 May 2022 at the age of 80 adds a poignant context to the naming of this new species in her honor.

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This research did not receive any funding.

ETHICAL CONSIDERATIONS

Field collection was approved and later granted permit through the issuance of a gratuitous permit from DENR – Region VII (Wildlife GP 2019-11, series of 2019).

DECLARATION OF COMPETING INTEREST

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

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Genotyping of red tilapia strains in Central Luzon Philippines targeting ESR1 gene

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ABSTRACT

Tilapia is an economically important commodity worldwide. Marker-assisted selection (MAS) has been practiced in livestock culture to ensure the selection of a specific trait that will benefit the culture system. This study assessed the allelic variation in six red tilapia strains in Central Luzon, Philippines. Polymerase Chain Reaction-Restriction Fragment Length Polymorphism (PCR-RFLP) was done to evaluate the genotypes of six strains of red tilapia using intron one portion of the chromosome one of the estrogen receptor 1 (ESR1) gene. The target gene was amplified using primers designed in previous study and then subjected to RFLP using PvuII restriction enzyme. Single Nucleotide Polymorphisms (SNPs) were also evaluated in six DNA sequences. Results showed that 18 red tilapia samples were found to be of the AA genotype. Aligned sequences of the 122 bp ESR1 gene revealed that among six red tilapia strains, there are 117 identical pairs, three transversional pairs, and three transitional pairs. The SNPs observed can be used to identify restriction enzymes that discriminate different genotypes in the target gene. Association studies can be done to determine the genotypes that are linked to specific traits in cultured animals.

Keywords: marker-assisted selection; PCR-RFLP, PvuII; single nucleotide polymorphisms, tilapia

INTRODUCTION

Growing demands for food production and consumer demand for tilapia necessitate the search for alternate production methods for tilapia growth (Balcazar et al. 2004). Nile tilapia (*Oreochromis niloticus*) is perhaps Thailand's most essential cultured fish (Belton et al. 2006). Tilapia production accounted for 98,300 t, equivalent to 30% of recorded freshwater fish production (DOF 2005). In Malaysia, red tilapia has dominated the total tilapia production. Ninety percent of the total tilapia produced is accounted for red tilapia. National production increased by 26% between 2004 and 2007 (from 25,000 to 32,000 t) (Hamzah et al. 2009).

Among the genetically improved strains is the red tilapia. Red tilapia in the Philippines was introduced from Singapore in 1978 and subsequently

crossed with *O. niloticus* from Taiwan, Japan, and Singapore (Galman et al. 1988). The original red tilapias were genetic mutants. A hybrid between a mutant reddish-orange female Mozambique tilapia and a regular male Nile tilapia produced the first red tilapia, known as Taiwanese red tilapia. In Florida, a red-gold Mozambique tilapia was generated by combining a normal-colored female Zanzibar tilapia with a red-gold Zanzibar tilapia. A hybrid between a mutant pink Nile tilapia and wild blue tilapia produced the third red tilapia strain discovered in Israel. All three original strains have been mated with unidentified red tilapia or wild *Oreochromis* species (Popma and Masser 1999).

Due to their fast growth, excellent salinity tolerance, appealing skin color, likeness to some marine species, and high price, red tilapias have acquired favor among aquaculturists (Watanabe et al. 1990). They are also suitable for both intensive and extensive settings, and their likeness to premium marine species has helped them gain consumer acceptability in various Asian countries (Gupta and Acosta 2004). Red tilapia could be a good choice for improvement because they can survive high salt and be raised in seawater (Vadhel et al. 2016). On the other hand, the development of diverse strains of red tilapia highlights the necessity to assess its genetic variability. Despite their widespread use and economic importance in tropical aquaculture, little is known about the genetic variation of red tilapia strains, particularly on other color variants (McAndrew et al. 1988).

According to Eknath et al. (1991), genetic improvement programs are beginning to be applied in aquatic species but far more left behind when compared to livestock and crops. For example, a genetic marker has been developed by Rothschild et al. (1991) that determines which sow will produce more offspring. A specific attribute required for successful breeding could be improved using molecular marker-assisted selection (Soller and Beckmann 1983). But before applying for marker-assisted selection programs, candidate genes or anonymous genetic markers associated with the target traits must be identified first.

Genotyping is the scientific method of differentiating an individual's genetic makeup (genotype) by examining its DNA arrangement. This method can identify minor genetic differences, which lead to significant variations in phenotype, comprising physical differences that make us unique and pathological changes underlying disease. This is traditionally used in breeding to find individuals with favorable alleles (Toyama et al. 2017). Estrogen receptor 1 (ESR1) is a gene known to control reproduction and development in most mammalian and non-mammalian vertebrates (Toyama et al. 2017).

This study assessed the intron of ESR1 with the use of PvuII restriction enzyme on six red tilapia strains in the Philippines. This method was developed by Rothschild et al. (1991) and was used to select pigs' (*Sus scrofa*) litter size. Evaluation of the same genotypic patterns was done for possible application of broodstock selection of different red tilapia strains. Single Nucleotide Polymorphisms (SNPs) were also identified for future use.

METHODS

Sample Collection

Muscle and fin tissues were taken from genetically modified farmed red tilapia in Central Luzon, Philippines. The red tilapia strains Muñoz and FAC Selected Tilapia (FaST) were obtained at the Freshwater Aquaculture Center (FAC) facilities. Batangas, Laguna, and Zambales strain were obtained from the College of Fisheries, Central Luzon State University (CF-CLSU). BFAR-Red strain was obtained from the Bureau of Freshwater and Aquaculture Center (BFAR). Both stations are located in the Science City of Muñoz, Nueva Ecija. Eighteen samples (triplicates in every strain) were used in this study (Table 1).

Table 1. Basic information of the red tilapia samples.

Strain	No. of Samples	Source	Genotype
Muñoz	3	FAC-CLSU	N/A
FaST	3	FAC-CLSU	N/A
Batangas	3	CF-CLSU	N/A
Laguna	3	CF-CLSU	N/A
Zambales	3	CF-CLSU	N/A
BFAR	3	BFAR	N/A

DNA Extraction

Promega Wizard® Genomic DNA Purification Kit (USA) was used to extract fish genomic DNA according to the manufacturer's instructions. In a 15 ml centrifuge tube, 600 µl Nuclei Lysis Solution was added and cooled on ice. Then, using a tiny homogenizer, about 20 mg of tissue samples were added to each tube with Nuclei Lysis Solution and homogenized for 10 s. In a 1.5 ml microcentrifuge tube, the lysate was transferred. The

tissue was pulverized in liquid nitrogen using a pre-chilled liquid nitrogen mortar and pestle. After the liquid nitrogen had evaporated, 10-20 mg of the powdered tissue was transferred to 600 µl of Nuclei Lysis Solution in a 1.5 ml microcentrifuge tube. The lysate was incubated for 15–30 min at 65°C.

The sample was mixed by inverting the tube 2–5 times after adding 3 µl of RNase Solution to the nuclear lysate. At 37°C, the mixture was incubated for 15–30 min. Before starting, the sample was cooled down to room temperature for 5 min. Afterward, 200 µl of Protein Precipitation Solution was added to the sample and vortexed vigorously for 20 s at high speed. After cooling for 5 min on ice, the sample was centrifuged at 13,000–16,000 × g for 4 min. The protein pellet was transferred to a clean 1.5 ml microcentrifuge tube containing 600 µl of room temperature isopropanol after removing the supernatant containing the DNA. The solution was gently stirred by inversion until the white thread-like DNA strands formed a visible mass. This was centrifuged for 1 min at an ambient temperature at 13,000–16,000 × g. The supernatant was discarded, leaving the DNA as a pellet. Six hundred (600) µl of 70% ethanol was added, and the tube was inverted several times to wash and remove contaminants. This was centrifuged for 1 min at an ambient temperature at 13,000–16,000 × g. After placing the tube on clean absorbent paper, the pellet was air-dried for 10–15 min. The DNA was rehydrated with 100 µl of Tris-EDTA (TE) buffer and incubated at 65°C for 1 h. The DNA was stored at 2–8°C.

Polymerase Chain Reaction (PCR) Assay

The ESR1 gene was amplified using ESR1 F: 5'-CCT GTT TTT ACA GTG ACT TTT ACA GAG-3' and ESR1 R: 5'-CAC TTC GAG GGT CAG TCC AAT TAG-3' (Rothschild et al. 1991). The cocktail mix consisted of 3.0 µl 1X PCR buffer, 0.5 µl 2.5 mM MgCl2, 0.5 µl 2.0 mM dNTPs, 0.3 µl 10 pmol of each primer, 1.2 µl DNA sample, 1 unit of Taq DNA polymerase and 4.2 µl NFH2O.

Optimized PCR profile conditions for the ESR1 gene consist of 95°C for 5 min for the initial denaturation step, 35 cycles of: (95°C for 30 s) for denaturation, (62°C 30 s) for annealing, and (72°C 30 s) for extension and 72°C for the final extension for 7 min. The PCR product was loaded to agarose gel for the result.

Restriction Fragment Length Polymorphism (RFLP)

Amplified ESR1 genes were digested using the PvuII restriction enzyme to identify the genotypes of each sample. A master mix composed of 1.7 µl nucleas-free H_2O, 1.0 µl reaction buffer, 0.3 µl restriction enzyme, and 2.0 µl was used in the reaction. In a heat block, the mixture was incubated for 4 h at 37°C. Gel electrophoresis was used to confirm the result.

Gene Sequencing and Phylogenetic Analysis

Six DNA samples were sent to 1st Base (Malaysia) for sequencing with one for each red tilapia strain. MEGA 7.1 software was used to align and compare sequences. MN586879-MN586884 are the accession numbers for the nucleotide sequences submitted to GenBank. Single Nucleotide Polymorphisms (SNPs) in the six samples were observed. As to phylogenetic analysis, there were six sequences aligned using the CLUSTAL W alignment tool under Molecular Evolutionary Genetics Analysis (MEGA) 7 software. Then, the evolutionary history was inferred using Neighbor-Joining method, whereas the evolutionary distances were computed using the Jukes-Cantor model with 1,000 bootstrap replications.

RESULTS

PCR

The ESR1 gene was amplified from all the samples with an amplicon size of 122 base pairs, as shown in Figure 1. The PCR products were used for the RFLP analysis using the PvuII restriction enzyme.

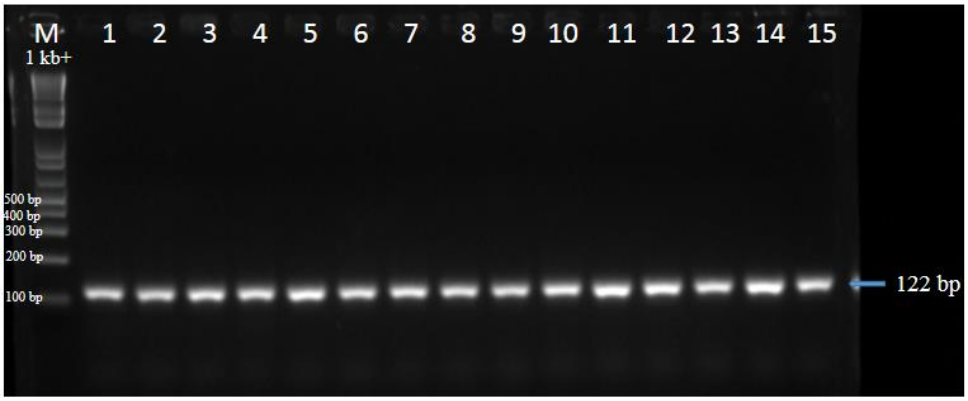

Figure 1. Agarose gel image of amplified product of ESR1 gene from red tilapia.

Restriction Fragment Length Polymorphism (RFLP)

Restriction Fragment Length Polymorphism (RFLP) analysis of the ESR1 gene using PvuII showed only one band pattern among all samples (Figure 2). Results showed that all samples are of the AA genotype (one band at 122 bp). Figure 3 shows the single band pattern that can be observed.

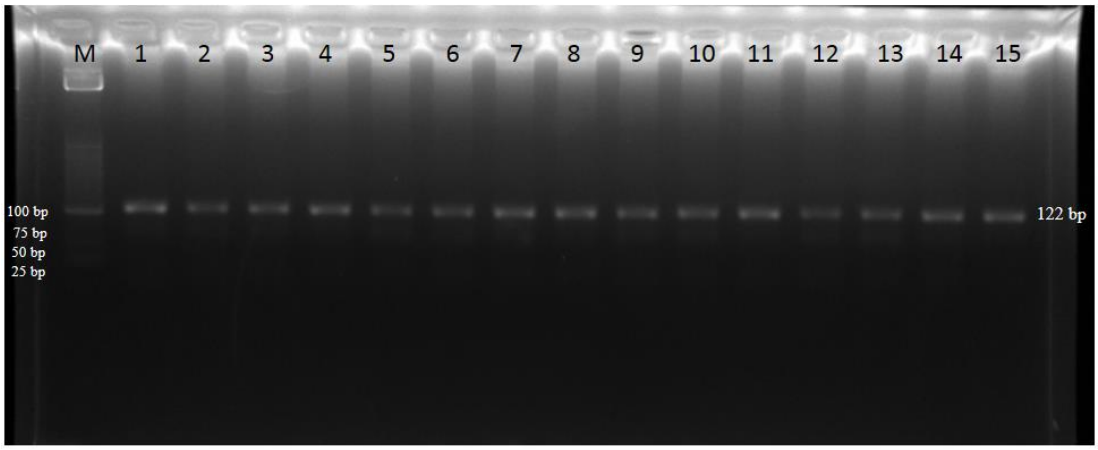

Figure 2. Agarose gel image of PvuII digested PCR product of ESR1 gene from red tilapia.

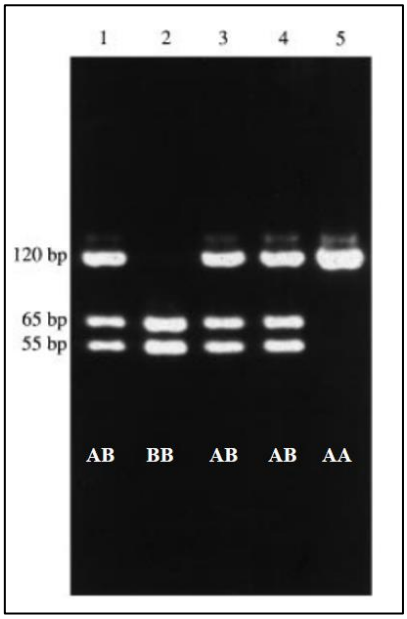

Figure 3. Three types of alleles observed in intronic ESR1 region of *Sus scrofa* cut using PvuII (Short et al. 1997).

Sequence and Phylogenetic Analysis of ESR1

A total of six sequences (one representative per strain) of ESR1 from red tilapia were generated. The amplified ESR1 gene produced a 122 bp sequence (Figure 3). Comparing all six sequences, there were 117 identical pairs, three transitional pairs, and three transversional pairs with a ratio of 1.9 (Figure 4). Phylogenetic analysis (Figure 5) did not consist of an outgroup since no ESR1 gene from other fish were deposited in National Center for Biotechnology Information. Meanwhile, the same fragment isolated from pigs were deposited in NCBI. However, the genetic distance from both species could be questionable. The phylogenetic tree showed 3 clades between the 6 red tilapia strains putting Laguna and Batangas strain together while BFAR, FAC and Zambales in different clade and Muñoz strain was isolated from the 2 groups.

```
#MN586879_O._niloticus_ESR1_gene_Batangas_strain    CCTGTTTTTA CAGTGACTTT TACAGAGTAT ATCTAAAGAT GCAGAATCAA GTTTTATGAG ACCAACTTTC TTGTCAAGTC  [ 80]
#MN586880_O._niloticus_ESR1_gene_BFAR_strain       ..........  ..........  ..........  ..........  ..........  .......G-T C......-..  [ 80]
#MN586881_O._niloticus_ESR1_gene_FaST              ..........  ..........  ..........  ..........  ..........  .......G-T C.........  [ 80]
#MN586882_O._niloticus_ESR1_gene_Munoz             ..........  ..........  ..........  ..........  ..........  ........-T C.........  [ 80]
#MN586883_O._niloticus_ESR1_gene_Laguna            ..........  ..........  ..........  ..........  ..........  ........-. ..........  [ 80]
#MN586884_O._niloticus_ESR1_gene_intron_Zambales   ..........  ..........  ..........  ..........  ..........  .......G-T C......-..  [ 80]

#MN586879_O._niloticus_ESR1_gene_Batangas_strain    CCC-C-TATT CCACCCTATT CTAATTGGAC TGACCCTCGA AGTG [124]
#MN586880_O._niloticus_ESR1_gene_BFAR_strain       ...ATGC... ..........  ..........  ..........  .... [124]
#MN586881_O._niloticus_ESR1_gene_FaST              .A.ATG-... ..........  ..........  ..........  .... [124]
#MN586882_O._niloticus_ESR1_gene_Munoz             ...T.--... ..........  ..........  ..........  .... [124]
#MN586883_O._niloticus_ESR1_gene_Laguna            ...-.A.... ..........  ..........  ..........  .... [124]
#MN586884_O._niloticus_ESR1_gene_intron_Zambales   ...ATGC... ..........  ..........  ..........  .... [124]
```

Figure 4. Aligned sequences of six ESR1 gene from red tilapia strains in the Philippines.

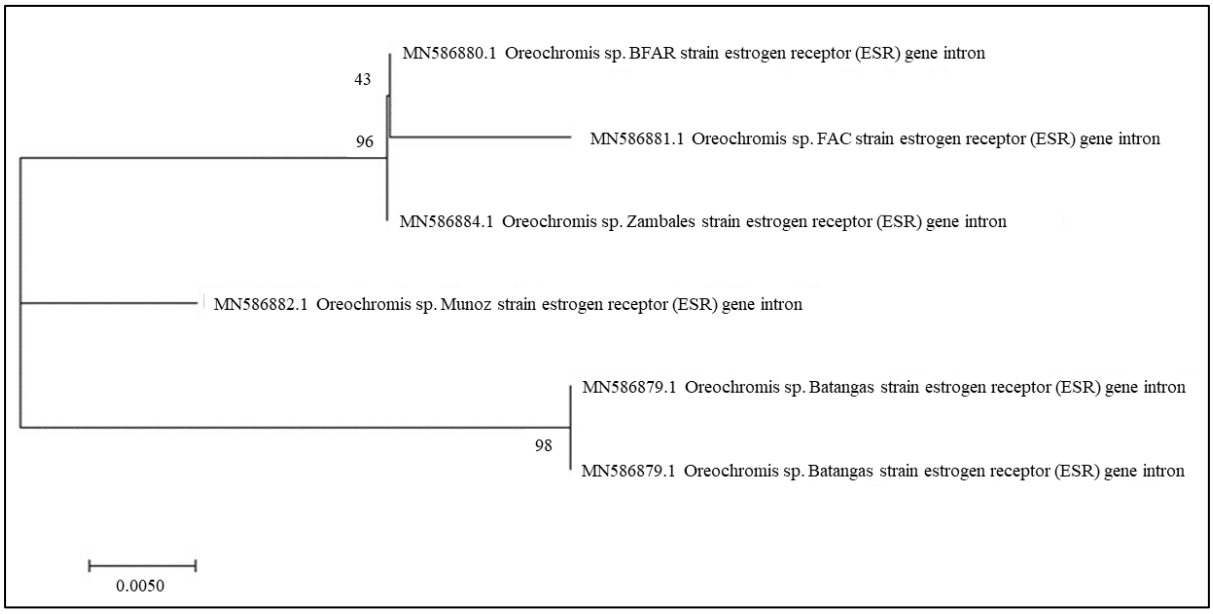

Figure 5. Phylogenetic analysis of the 6 red tilapia strains in the Philippines.

DISCUSSION

Estrogens are crucial for females and males in terms of fertility and reproductive capacity in vertebrates, and their signal is controlled by ESRs (Yan et al. 2019). This study determined the allelic variation in the ESR1 gene of 6 red tilapia strains.

The ESR1 gene was successfully amplified in the 18 individual red tilapia samples. However, only one band pattern was observed during RFLP analysis: the AA genotype (single band at 122 bp). It can be justified by the sequences, which show that the cutting site (5'-CAGCTG-3') for PvuII is not present in the same region in the red tilapia ESR1 gene. Studies on pigs showed that genotype AA is the most common genotype. The genotype BB (favorable genotype) has low rate of heritability in pigs, which can be true in the case of Tilapia, hence the result of this study revealed genotype AA in 18 samples. One of the limitations is the availability of related studies using ESR1 gene as marker in Tilapia which only indicates that this study serves as a baseline study. Moreover, repository sequences found in NCBI are limited to ESR1 reference sequences in pigs and sequences obtained from the result of this study in Tilapia. In the study conducted by Yan et al. (2019), they found out that the ESR1 gene in Nile tilapia has no phenotypes of reproductive development and function in both females and males. It can be the reason why genotypes AB (banding patterns at 120, 65, and 55 bp) and BB (banding patterns at 55 and 65 bp) (Figure 3) were not observed in the result of the RFLP analysis. In quail, the study showed that the polymorphism in the ESR1 gene related to egg numbers was found in exon 8 (Wu et al. 2015). While in Chinese dagu chicken, C/T transition located within exon 4 of the ESR1 gene was found to have an association with egg production. The presence of this allelic variation differs in each species. Association studies must be conducted to locate these SNPs associated with specific traits (i.e., high fecundity in tilapia).

Though the cutting site for PvuII was not present in the sequences, the presence of some

polymorphisms was observed in the amplified ESR1 intronic region. Out of 122 nucleotides, only 116 bp have identical pairs among the samples. Transversional pairs were observed in loci numbers 68, 83, and 86, while transitional pairs occurred in loci 71, 72, and 88. Insertion-deletion (Indels) were observed in loci number 69, 70, 79 and 85-88. These polymorphisms can somehow be the subject of future studies in finding other suitable restriction enzyme/s for the genotyping of this gene. Furthermore, data on polymorphism in this gene can be used in association studies.

Additionally, the sequences generated in this study were analyzed for SNPs. These SNPs can help find another restriction enzyme/s that can show different alleles in the six different strains of red tilapia. Phylogenetic analysis revealed 3 different clades from the 6 strains of red tilapia. However, these genetic variations did not contribute to their genotypic characteristics.

The observed genotypes can be associated with favorable traits, such as high fecundity and a high fry survival rate. However, this requires extensive analysis. According to Vicencio et al. (2017), litter size is one of the factors which is essential in measuring reproductive success of a sow in swine operations. On the other hand, fecundity is the measure of reproductive success in Tilapia. Hence this study was conducted to evaluate ESR1 gene as candidate marker of fecundity in Tilapia. Therefore, it can be attributed as the most important economic trait in aquaculture production and brings more economic profit for the fisheries industry. The development of such technology will directly benefit the aquaculture industry as it will be easier for the farmers to look for the best broodstocks to be used in breeding in the future.

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ETHICAL CONSIDERATIONS

This study followed all institutional and national ethical guidelines for the care and use of tilapia for the sample collection.

DECLARATION OF COMPETING INTEREST

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

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Experiences and aspirations of seaweed farmers in Palawan, Philippines

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ABSTRACT

Many coastal dwellers engage in seaweed farming despite of various challenges because of its simple farming technology, low capital investment, and short cultivation period. This paper explored the attitudes of seaweed farmers (n = 187) from nine coastal communities of Aborlan, Puerto Princesa, Roxas, and Taytay, Palawan towards the difficulties and challenges they experienced. The farmers' experiences in seaweed farming, mid-term aspirations, and factors affecting their positive attitudes towards seaweed farming were gathered using a Likert-scale questionnaire in KoBoToolbox. Focused group discussion (FGD) sessions were also conducted to obtain more data about their optimistic attitudes. Participants are 55% male and 45% female. Results revealed that farmers had a high level of optimism toward seaweed farming. The majority (75%) 'will continue to engage in planning the next cropping cycle', most (89%) 'are expecting to have a good harvest', and almost all (96%) 'are planning to generate raw dried seaweeds from their harvest.' Many (59%) of the respondents obtained high earnings from seaweed farming, but most (93%) experienced economic losses. As recovery options, 92% aspired to culture other organisms such as sea cucumber and abalone. Further, most of them wanted to seek assistance from government offices (91%), participate in seaweed product development (86.5%), and join a cooperative (87.5%). This study could serve as baseline information in designing relevant training and educational activities to assist seaweed farmers in managing their farms sustainably. Subsequently, this could aid in formulating effective policies to address similar problems of seaweed farmers in other municipalities of Palawan.

Keywords: attitude, cooperative, cropping cycle, diseases, diversity, farming technology

INTRODUCTION

Seaweeds have been utilized for wide applications such as food for human consumption and as an important hydrocolloid (alginate and carrageenan) that are used in food processing, pharmaceutical, and cosmetic industries (Hurtado et al. 2015). It is also an important livelihood among coastal communities (Mundo et al. 2002). Aside from its economic value and food for human consumption, seaweeds also provide other ecological services and have been included as one of the priority commodities under the World Bank-assisted Philippine Rural Development Project (PRDP) (BFAR 2022). Recently,

its potential as a carbon sequester to mitigate ocean acidification (Xiao et al. 2021) and prevent eutrophic algal bloom (Narvarte et al. 2022), has been considered ecosystem services that seaweed farming may offer. Seaweed (Eucheumatid) farming was established in the Philippines in 1969 in Tawi-Tawi (Trono 1990), utilizing the indigenous cultivars of *Kappaphycus* ('cottonii') (Hurtado et al. 2015) and later named *Kappaphycus alvarezii* in honor of Vicente Alvarez, the General Manager of Marine Colloids Philippines, Inc. (MCPI) (Neish et al. 2017). Initial experimental farming sites included Panagatan Island, Caluya, Antique, and Ilin Island, Occidental Mindoro. However, these farming sites were later abandoned due to frequent typhoons and management problems. In Sulu, better growth was obtained in 1971 and had driven the cultivation in other areas (Hurtado et al. 2015). In Palawan, Eucheumatid seaweed farming started in Quinloban Island, Agutaya as part of the satellite cultivation conducted by MCPI in 1973. The first commercial seaweed farming was set up in Green Island, Roxas, in 1978 with the initiatives of MCPI. However, the take-off of Eucheumatid seaweed farming in the province started utilizing the Tawi-tawi seaweed culture technology in Balabac. Since then, farming has been replicated in other areas, resulting in widespread cultivation through out the province and about 138,950 t annual production from the 20 seaweed-producing municipalities, Palawan is the second largest producer of seaweeds in the country; it contributes significantly to the export market as an aquaculture product. In 2020, Palawan produced 317,830 mt of seaweed, contributing 22% to national seaweed production (BFAR 2022). Overall, this industry contributes about 60-70% to the country's total aquaculture production and improves the socioeconomic status of millions of Filipinos (BFAR 2022; Pedrosa 2017).

On a global scenario, the Philippines ranked fourth (1.49 million metric ton or Mmt) in the major seaweed-producing countries, with China as ranked number one (20.1 Mmt), followed by Indonesia (9.9 Mmt), and South Korea (1.8 Mmt) (FAO 2021). The Philippines has been a leader in seaweed production for three decades until 2007, when Indonesia surpassed production in 2008 (Hurtado et al. 2015). In 2009, Indonesia produced 85,000 mt of dry seaweed, while the country only produced 61,000 mt (Valderrama 2012). Farm production was centered on two genera, *Kappahycus* and *Eucheuma*. The reduction in the country's production was attributed to the 'ice-ice' disease outbreak brought about by unfavorable weather conditions and political instability in farming areas (Valderrama 2012; Valderrama et al. 2015). The highest production was recorded at 1.84 mt in 2011, but production started to follow a downward trend and has not recovered since then (BFAR 2022).

Seaweed farming significantly contributes to the improvement of the socioeconomic status of coastal communities (Hayashi et al. 2010). An estimated 200,000 families in the country rely on seaweed farming as their primary source of income (SIAP 2017), mainly due to relatively simple technology, low investment capital, and a short culture period of 45-60 days (Valderrama 2012). A varying profit margin of 22-82% can be realized in seaweed farming (Hurtado 2013). Hurtado et al. (2015) also stated that properly managed seaweed farming could earn more than US$ 800 yr^{-1}. Over the years, seaweed farming served as an important livelihood in coastal areas (Trono and Ganzon-Fortes 1989; Ask et al. 2003). It has generated employment for many coastal families in the country (Hurtado 2013), and positively impacted the coastal villages' socioeconomic aspect (Hayashi et al. 2010; Msuya 1998). Aside from providing a stable annual income, it improves household economic status, thus, resulting in a sustainable way of life (Zamroni and Yamao 2011), and promoting community well-being (Rimmer et al. 2021). Moreover, employment opportunities provided by seaweed farming during the initial stages helped empower women in coastal communities (Cooke 2004), where extra labor during the planting process is necessary (Zamroni and Yamao 2011).

In Palawan, there is an estimated aggregate farming area of 13,774 ha in the province but only 5,567 ha are being utilized by 7,604 farmers with an average farming size of 0.73 ha per farmer (BFAR (2022). There are 11 Eucheumatid cultivars being cultivated with 'spinosum*'* (*Eucheuma denticulatum*) as the most widely grown. In addition, the cultivars 'cottonii', 'tambalang' and 'giant' for *K. alvarezii* while 'sacol' and 'vanguard' for *Kappaphycus striatus* are utilized for farming (Dumilag et al. 2022). The culture methods employed are fixed-off bottom and hanging long lines. However, due to the expansion of the culture areas, the use of multiple long line methods has been widely adopted in deep (>5 m) waters (Hurtado et al. 2015).

From 2020 to 2021, many Eucheumatid farmers in Palawan experienced economic loss presumably due to the "ice-ice" disease (IID) of seaweed, which is associated with climate change (Largo et al. 2017). IID and epiphyte infestations caused an estimated 15% reduction in total seaweed production in 2018 and can therefore affect the sustainability of seaweed farming in the country (BFAR 2022). Over the years, several strategies (such as submerging the longlines down to 0.5 m below the sea surface and transferring the long lines into deeper locations) to cope with these problems have been employed by farmers, but not much is known about how they react and interact with the situations. Thus, this study sought to explore the farmer's demographics, recent experiences in seaweed farming, medium-term aspirations, and potential factors affecting their

positive attitudes toward problems encountered in seaweed farming.

METHODS

Study Area

Coastal barangays from four municipalities that have known Eucheumatid farming activities were selected. These municipalities were Aborlan, Roxas, Taytay, and Puerto Princesa City (Figure 1). The nine barangays: Isaub (9.5106° N, 118.5932°E) and San Juan (9.4341° N, 118.5594° E) in Aborlan, Rizal (10.2386° N, 119.2437° E) in Roxas, Pamantolon (10.9019° N, 119.4528° E), Pularaquen (10.9803° N, 119.4760° E) and Calawag (10.6367° N, 119.5804° E) in Taytay, and Tagburos (9.8352° N, 118.7273° E), Babuyan (9.9908° N, 118.9119° E), and San Rafael (10.0471° N, 118.9412° E) in Puerto Princesa City were chosen as study sites (Figure 1). All these coastal barangays have Eucheumatid farming and fisheries-related activities as their main living sources.

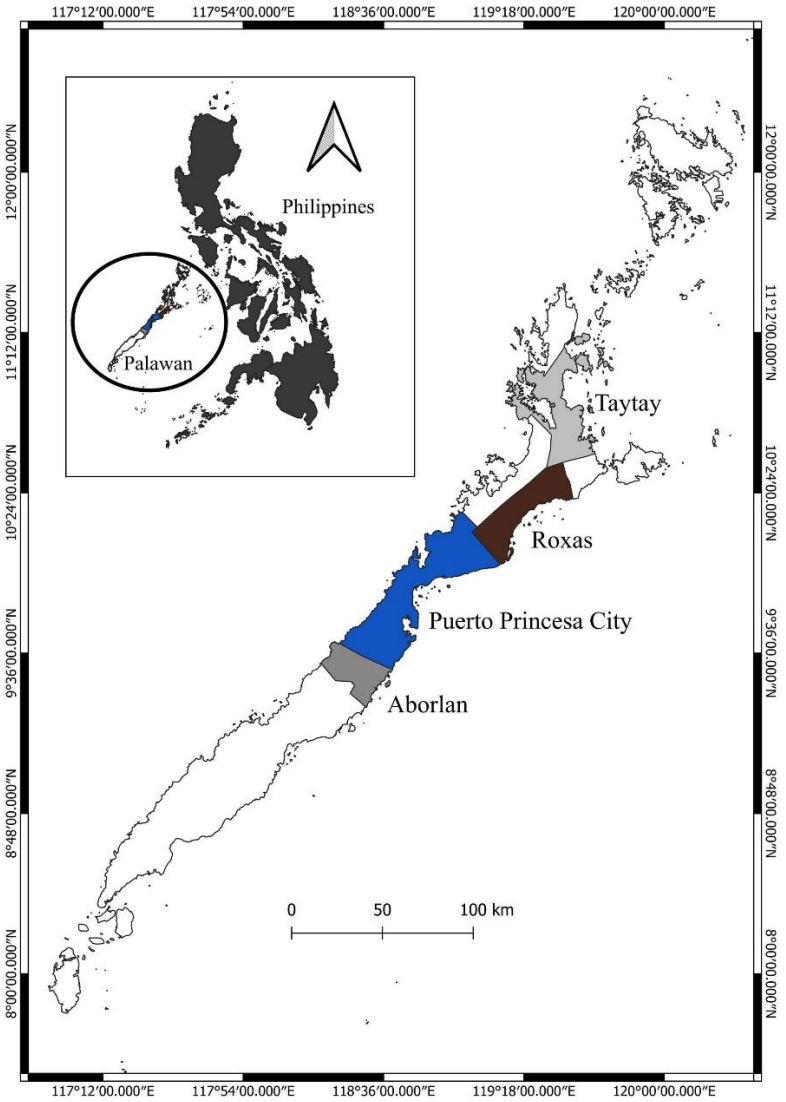

Figure 1. Map of Palawan, showing municipalities where the interview was conducted.

Survey Participants

The participants were taken from a collective survey of preselected fisherfolks from each coastal barangay. Out of the 935 fisherfolks, only 187 were seaweed (Eucheumatid) farmers aged 18 and above. All the respondents were seaweed farmers who lived in the coastal areas of the municipalities surveyed. Aside from seaweed farming, most of them were engaged in fishing as a supplemental livelihood.

Data Collection

This study was conducted from 23 November to 10 December 2021. Approval was sought from each municipal and barangay government before the conduct of study. The participants from Aborlan,

Roxas, Taytay and Puerto Princesa were organized through their respective Barangay Fisheries and Aquatic Resources Management Council (BFARMC) representatives and gathered in an open venue in their barangay where health protocols were observed. A face-to-face interview was conducted using a Computer Assisted Personal Interviewing (CAPI) tool on a tablet computer with recorded interview responses under a KoboTool box program. Due to literacy and technology concerns, the interviewers assisted the participants in answering the survey; however, those knowledgeable in the operation of tablet computers were allowed to answer the questions in English alone while an interviewer was on standby for clarifications or further explanation about the questions. The participants were asked using a structured survey questionnaire. The survey was divided into four sections. The first section was about (1) the demographics, followed by (2) their recent experiences in seaweed farming by answering the causes of losses in seaweed farming and how they feel about several activities on seaweed farms, and (3) their medium-term plans for the next 12 months. Their responses to the questions under sections 2-3 were in a Likert-scale questionnaire with five anchor points ("1" - extremely dislike/poor, "2" - poor/dislike, "3" - moderate/neutral, "4" - high/like, and "5" - extremely high/like). All answers were recorded and saved on tablet computers.

A focus group discussion (FGD) was conducted involving 8-10 seaweed farmers (Key Informants) in each study site for section 4 of the survey questionnaire. During the FGD, an open-ended questionnaire was used to identify factors affecting their attitudes toward seaweed farming. Similar answers were grouped and tabulated according to the frequency of answers received, and the summary was presented in a table.

Statistical Treatment

The data from the tablet computers were exported into an Excel file and cleaned before the analysis. Data from the survey were analyzed using SPSS 25, while data collected from FGD were qualitatively analyzed to understand factors affecting their attitude toward seaweed farming.

RESULTS

Profile of the Respondents (Demographics)

The distribution of the participants was: Taytay-116 (62%), Puerto Princesa City-53 (28.4%), Aborlan-16 (8.5%), and Roxas-2 (1.0%). There were 104 (55%) male and 83 (45%) female participants (Figure 2A). Most (86.4%) of the participants were married, while a small portion was widowed (7.4%) and single (6.2%) (Figure 2B). The highest age bracket of participants was 41-50 years old (28.3%), followed by 31-40 years old (26.1%) (Figure 2C). In terms of educational attainment, half (50%) of the participants were able to reach high school (high school level, (25.3%) and high school graduate (24.7%)), while 28.7% were elementary (elementary graduate (19.7%) and elementary level (9.0%)) (Figure 2D).

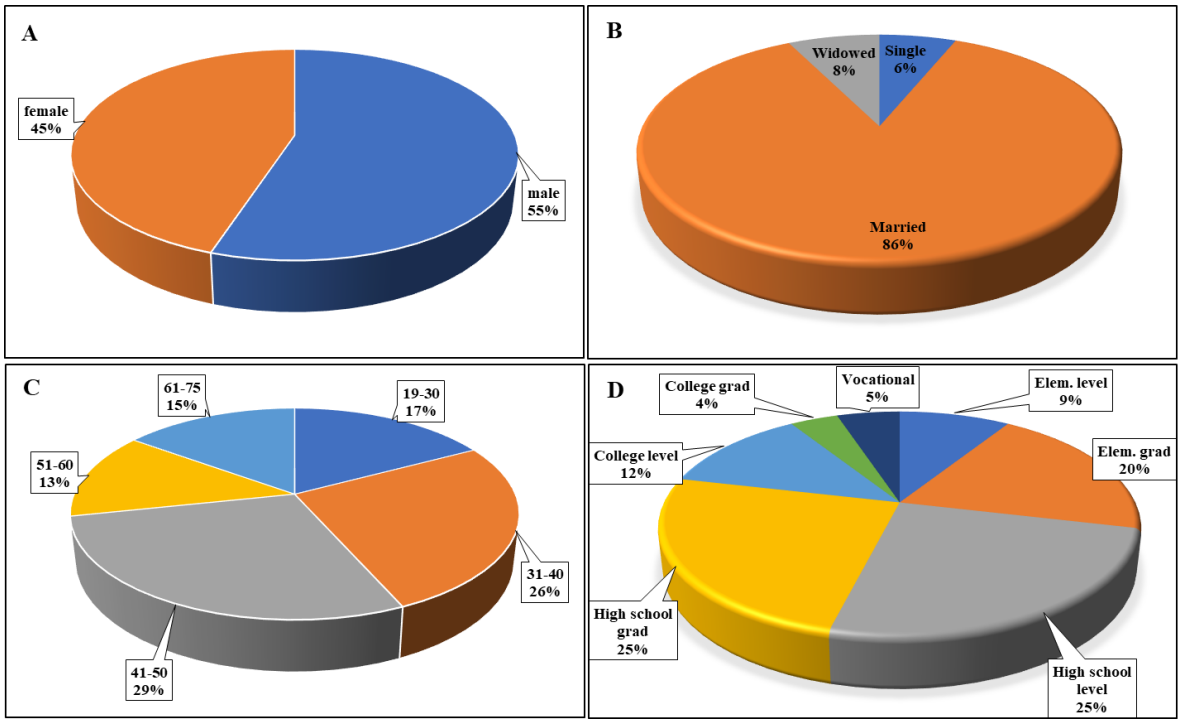

Figure 2. Demographics of the participants across survey sites, sex (2A), civil status (2B), age (years) brackets (2C), and educational attainment (2D) of participants.

The methods of farming largely used were multiple-hanging long lines, single lone lines, triangle ("tumbo-tumbo"), and few utilized fixed-off bottom and multiple rafts (Figure 3A). The triangle and fixed-off bottom were noted in the barangays of Puerto Princesa. Further, 30.5% of the participants were practically new to Eucheumatid farming (1-5 years), 33.1% farmers were moderately old (11-20 years) and 18.7% were old (>21 years) (Figure 3B). The three major cultivars being cultured were 'spinosum' (*E. denticulatum*) and 'sacol' (*K. striatus*) and 'giant' (*K. alvarezii*) (Figure 3C).

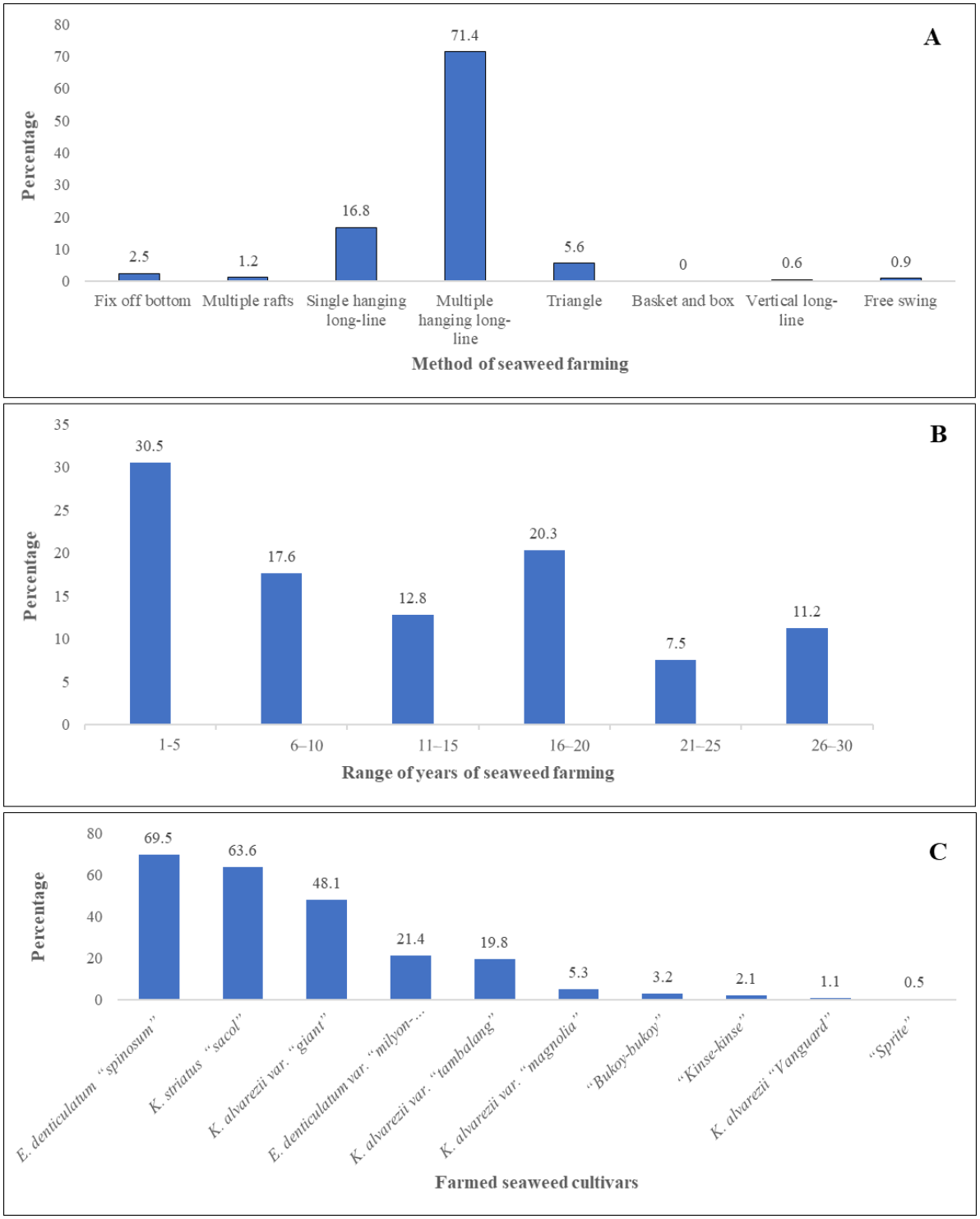

Figure 3. The farming methods practiced by seaweed farmers (3A), years of engagement in seaweed farming (3B), and the seaweed cultivars being farmed in their areas (3C).

Recent Experiences in Seaweed Farming

The recent experience of seaweed farmers, which incurred major economic losses, was primarily due to IID (99.5%), followed by losses from typhoons (82.1%) and epiphyte infestation (64.7%) (Table 1). According to the respondents, upon the onset of IID, it only took a week for the whole plot to get infected and the cultivars to disintegrate and get lost from long lines. The participants also mentioned the presence of epiphytes "buhok-buhok" or filamentous red algae believed to be *Polysiphonia* sp., which worsens the losses. However, several other factors affect productivity in Eucheumatid farming, which includes price fluctuations, poor or insufficient cultivars, drastic weather conditions, typhoons, and farm management. These factors could be the cause for a few respondents (23.5%) who experienced losses even before the onset of the disease. Despite these incidences, most respondents (75.3%) liked to continue to engage in seaweed farming when asked if they were planning for the succeeding cropping. Most of them had anticipated harvesting (89.1%) and getting income from their dried seaweed product (93.3%). Harvesting and drying, for them, were the highlights of seaweed farming. At least 59% of the respondents answered that they earned from seaweed farming before the onset of the disease, while the majority of them (93.5%) had indicated economic loss after its occurrence. More than 50% of them also revealed receiving technical assistance (such as seminars) from government agencies, specifically from the Office of the Municipal Agriculturist (OMA) / Office of Provincial Agriculturist (OPA) (67%), Bureau of Fisheries and Aquatic Resources (BFAR) and other line agencies of the national government (65.9%), and the academe Western Philippines University (WPU)/Palawan State University (PSU) (59.0%). However, it is interesting to note that a small number of responses (21.5- 29.5%) were neutral or perceived to receive poor support from government agencies (Table 2).

Table 1. Diseases/losses of farmed seaweeds observed by farmers in the coastal areas of Taytay, Roxas, Puerto Princesa and Aborlan, Palawan.

Diseases/losses	Number of responses	Percent (%)
a. 'Ice-ice' disease	183	99.5
b. Epiphyte infestation	124	64.7
c. Grazing by turtle	88	47.8
d. Grazing by fish	103	56.0
e. Lost during typhoon	151	82.1

Table 2. Participants' perception about seaweed farming activities, earnings from farming, and technical assistance received during the past 6-12 months (n = 187).

Perceptions	Responses %				
Activities done	**Extremely dislike**	**Dislike**	**Neither dislike nor like**	**Like**	**Extremely like**
a. Planning for next seaweed farming	1.1	2.7	21.0	53.8	21.5
b. Harvesting seaweed from longlines	0	1.1	9.8	53.8	35.3
c. Drying and selling harvested seaweeds	0	1.1	2.7	44.9	51.4
Earning from seaweed farming	**Extremely poor**	**Poor**	**Neutral**	**High**	**Extremely high**
a. Before occurrence of seaweed disease	6.0	17.5	17.5	46.4	12.6
b. After occurrence of seaweed disease	58.7	34.8	6.5	0	0
Technical assistance received	**Extremely poor**	**Poor**	**Neither poor nor satisfactory**	**Satisfactory**	**Highly satisfactory**
a. From LGUs OMA/OPA	2.2	9.7	21.1	55.1	11.9
b. From BFAR and other line agencies	1.1	9.7	23.2	53.5	12.4
c. From WPU/PSU	3.3	8.2	29.5	43.7	15.3

Medium-term Aspirations

Most respondents (92.4%) wanted to restart seaweed farming after the IID incidence that occurred throughout the year, but predominantly after sweltering weather followed by heavy rain. Due to the economic loss from the previous cropping, the same number of farmers (92.4%) wanted to culture other organisms aside from seaweeds to recover from their losses. They also wanted to participate in various activities that would help them become resilient in the advent of unexpected events that might happen at the farms. These include taking part in citizen science activities with WPU/PSU (91.3%), the development of value-added products from seaweeds (86.4%), and actively participating in cooperative/association activities for the marketing of products (87.5%) (Table 3).

Factors Affecting Positive Attitude

The factors identified by seaweed farmers influencing their positive outlook on seaweed farming despite the challenges that beset the industry during the past few months are presented in Table 4. Most of them were optimistic about seaweed farming because of the huge profit that could be derived from this activity, and this served as their primary source of livelihood. Further, the simple technology involved and the fast turnover of cycles enable them to continue to engage in this activity. Besides, this livelihood has been passed over from generation to generation, wherein families were familiar with the various activities involved in seaweed farming. They also considered seaweed farming as a legal livelihood that requires minimum inputs and has the advantage of having a support group.

Table 3. Participants' perception about their plans and aspirations as seaweed farmers for the next 6-12 months (n = 187).

Plan and aspirations for aquafarming activities for the next 12 months	Perceptions (%)				
	Extremely dislike	Dislike	Neutral	Like	Extremely like
a. Restart a seaweed farm	0	2.7	4.9	60.9	31.5
b. Culture other organism aside from seaweeds	0.5	2.2	4.9	58.5	33.9
c. Report observations in the farm to WPU/PSU project and seek technical assistance	0	0.5	8.2	58.7	32.6
d. Participate in developing value-added products from seaweeds	0	1.1	12.5	50.5	35.9
e. Actively participate in cooperative/association activities for marketing of products	0	2.2	10.3	52.7	34.8

Table 4. Factors affecting the positive attitudes of farmers in the surveyed municipalities in Palawan.

Factors	Score
Big profit	49
The primary source of livelihood	38
Simple technology	21
Fast turn-over	17
Familiar livelihood	14
Legal livelihood	13
Coop as a support group	10
High market demand	7
Supplemental livelihood	3
Additional capital	1

DISCUSSION

Profile of the Respondents (Demographics)

The respondents were dominated by male (55%), likely due to the off-shore farming practice that is labor-intensive and physical in nature. This finding was corroborated by the results of Mateo et al. (2021), where Palawan farmers use offshore shallow (5-6 m deep) farming techniques and require skills to set up their long lines. However, it was noted during the interview that females helped prepare planting materials and dry harvested seaweeds which also conforms to the study of Mateo et al. (2021). Almost half (43.3%) of the surveyed farmers aged 19-40 years old and engaged in farming for 1-10 years (48.1%), which also conforms to the studies of Tahiluddin et al. (2023) and Mateo (2021). Further, the involvement in this activity at a young age suggests that the knowledge

of seaweed farming was passed down from generation to generation (Mateo et al. 2021). Family members obtain first-hand information on seaweed farming early on by helping with rudimentary tasks such as tying cultivars on long lines and drying harvested seaweeds. Further, this also indicates that Eucheumatid seaweed farming (ESF) is a family enterprise (Tahiluddin et al. 2023).

The three popular seaweed cultivars being cultured in the area surveyed were 'spinosum' (69.5%) (*E. denticulatum*), 'sacol' (63.9%) (*K. striatus*) and 'giant' (48.1%) (*K. alvarezii*). According to the farmers, since the onset of IID, they have been cultivating 'spinosum' and 'sacol' as these two were resilient against the disease and can withstand drastic changes in seawater temperature

Recent Experiences in Seaweed Farming

Diseases, pests, and unpredicted weather conditions were disturbances that impacted seaweed production (Suyo et al. 2020). The outbreak of IID and epiphytic algae resulted in a major loss in seaweed farming in the areas surveyed. The disease is characterized by the gradual depigmentation of the seaweed thallus, softening of infected tissues, and eventually, detachment of the infected thalli, resulting in biomass loss (Hurtado et al. 2021; Faisan et al. 2021). The occurrence of diseases such as "ice-ice" and epiphytic algae rendered losses (93.5%) to the seaweed farmers across the survey areas. On the other hand, a small number (23.5%) of participants experienced losses even before the occurrence of diseases, which could probably be due to other factors such as insufficient/poor supply of cultivars, price fluctuations, poor carrageenan content, and weather disruptions. Farmers claimed that a drastic change in weather conditions (rains after very hot mornings) and an elevated water temperature initiated the onset of these diseases. Largo et al. (2017) stated that stressful abiotic conditions are conducive to the emergence of IID and epiphytes in seaweed farms. Epiphyte infestation was observed by the presence of hair-like growth on the thallus that penetrated the outer and inner layers of the host seaweed, exposing the thallus tissues to microbial infection (Hurtado et al. 2021; Hayashi et al. 2010). Initially, tiny black spots become visible on the cortex of the host seaweed, as the epiphyte matures, the appearance of "goosebumps" results in dark pits on the cortical surface making the host susceptible to opportunistic bacteria (Faisan et al. 2021; Ward et al. 2019). Several opportunistic bacteria and other microorganisms have been found to induce IID, such as *Cytophaga-flavobacterium* (Largo et al. 1995), *Alteromonas* and *Pseudoalteromonas* (Syafitri et al. 2017), and marine fungi (*Aspergillus ochraceus, Aspergillus terrius* and *Phoma* sp.) (Solis et al. 2010). Moreover, Hayashi et al. (2010) stated that *Ceramium* and *Neosiphonia-Polysiphonia* were the most harmful epiphytes. *Polysiphonia* caused massive losses in *K. alvarezii* production in the Philippines and Malaysia (Hurtado and Critchley 2006). Extreme surface seawater temperature changes increase seaweed susceptibility to pathogens (Largo et al. 2017) and reduce seaweed productivity and quality by lowering iota levels, yield, gel strength, and viscosity (Mendoza et al. 2002). According to Zabala and Gonzales-Plasus (2020), IID and epiphytic filamentous algae were observed in March-December and February-May in Palawan, respectively.

The continuous spread and outbreaks of these diseases can further be attributed to the lack of biosecurity measures across the survey areas. Although farmers cut out the infected parts of the seaweeds during the vegetative selection of cultivars, proper disposal was never practiced. In Malaysia, the use of healthy and uninfected propagules, regular simple cleaning of seaweed thallus and farm ropes to remove biofouling and early identification of infected stocks were proven to be effective simple biosecurity measures (Cottier-Cook et al. 2022). Hurtado et al. (2021) and Mateo et al. (2021) further corroborated the lack of biosecurity measures in the country's seaweed industry. The only existing policies in seaweed aquaculture are the Good Aquaculture Practices for seaweeds (GAqP, PNS/BAFS 208:2021 and Dried Raw Seaweeds (RDS, PNS/BAFS85:2021). However, enhancing biosecurity measures will require strict monitoring and implementation of guidelines and the participation of all players in seaweed farming (Hurtado et al. 2021; Mateo et al. 2021; Cottier-Cook et al. 2022). Moreover, simple management strategies such as the implementation of regular cleaning of long lines and manual removal of epiphytes as quickly as possible (Ask and Azanza 2002) and proper disposal can decrease its impact on seaweeds (Ward et al. 2019).

Typhoons are also natural calamities that critically affect Eucheumatid seaweed which the participants also considered as the second (82.1%) reason for their losses. Harvesting the seaweed before the typhoon is one of their management strategies, but sometimes this reduces the price due to low carrageenan content. Another strategy they reported, is to submerge the seaweed lines to 0.5-1 m below the water surface.

The repetitive harvests and utilization from the same mother plant resulted in low-quality or inferior lines of propagules (Hurtado et al. 2015). The use of low-quality cultivars may have aggravated the effects of these factors, such as diseases, climate change, and natural calamities (Largo et al. 2017), preventing farmers from optimizing their production (Ginigaddara and Lankapura 2018), which eventually affected the yield and income of seaweed farmers (Dangan-Galon 2019). According to Largo et al. (2017), a strong genetic foundation determines the resilience of seaweed species to changing environmental conditions. Repetitive monoclonal

propagations weaken resistance, affecting metabolic functions and reproductive processes, eventually resulting in loss of seedling quality. Hurtado et al. (2021) stated that to maintain genetic robustness, propagation from naturally occurring stocks or wild populations should be done.

Although there was technical assistance received from government offices, seaweed farmers were left vulnerable to the effects of various production disturbances that were aggravated during COVID-19, which prevented most of the farmers from going out freely and effectively managing their farms. Further, a small number of participants (21.1%-29.5%), divulged that the technical assistance received was not fully utilized to their advantage as reflected by the number of farmers (23.5%) that experienced losses before the onset of IID. The paper of Hurtado et al. (2015) pointed to weak linkages between the academe-scientist-expert group and the seaweed farmers as one of the major technical problems in seaweed farming in the country. Closer interactions pave the way to better education and technology transfer, shared experiences and information, and confirmation of technologies. Subsequently, a more open interaction involving all stakeholders in seaweed farming would provide better answers to exploring various problems (Zamroni and Yamao 2011). Moreover, not all seaweed farmers (10.8-11.9%) could benefit from the assistance/programs provided by the government, and the lack of effective implementation, monitoring, and evaluation further challenged the effectiveness of these programs and projects (Suyo et al. 2020). Grassroot seaweed farmers can provide valuable information on various aspects of seaweed farming that may aid the government in providing appropriate solutions to existing problems (Nor et al. 2017). According to Suyo et al. (2020), the collaboration between various actors in seaweed farming has been seen as a crucial aspect of lessening the risks in seaweed farming. Seaweed farmers may be able to solve minor problems in their farms, but severe problems need interventions from other organizations such as the government and research institutions.

Medium-term Aspirations

Seaweed farming has been the primary livelihood of participants in the study sites and continues to support coastal families over the years, especially those with limited alternative livelihood options (Rimmer et al. 2021) but due to the incurred losses that seaweed farmers experienced after the onset of diseases, they wanted to recover from their losses. They also wanted to culture other organisms that complement seaweeds. Examples of these organisms they wanted to culture were sea cucumber and abalone. Some farmers in Taytay with the highest number of participants have experienced the abalone culture (ADB 2014; Creencia et al. 2018).

Despite the mentioned incidences, seaweed farmers wanted to continue to engage in seaweed farming because this activity is a significant source of their livelihood. This finding was corroborated by the study of Rimmer et al. (2021) and Sudarwati et al. (2020) that seaweed farming is an important livelihood in coastal communities. Further, the continuing global demand for carrageenan (Dumilag et al. 2022; Suyo et al. 2020) will create further expansion in farming. Subsequently, this industry will continue to provide employment opportunities to coastal families (Krishnan and Narayanakumar 2010). Various studies have corroborated this finding to have positive impacts on coastal families' socioeconomic status (Valderrama 2012; Hurtado 2013; Rimmer et al. 2021). Further, seaweed farming has been considered a family business passed down from generation to generation, where almost all the family members participate in all activities to reduce the overall labor cost. The husband usually performs the heavy tasks while the wife and the children assist in the initial preparations, such as tying seaweed cultivars on lines and harvesting and drying harvested seaweeds. These labor contributions performed by other family members were important factors in the success of seaweed farming (Cooke 2004). The low operational cost and simple management after planting allow farmers to engage in other income-generating activities, such as fishing (Ginigaddara and Lankapura 2018), which also help generate additional income. In Indonesia, seaweed farming has been considered a complementary and compatible livelihood with other village activities such as fishing and agriculture. Families highly dependent on seaweeds lacked economic resilience and were vulnerable to ever-changing production cycles. Income diversification is an important coping option to achieve sustainable income (Rimmer et al. 2021). Thus, the development of other income-generating or alternative livelihoods, such as participation in the development of value-added products and joining a cooperative, are some of the strategies that seaweed farmers may engage in. In Indonesia, seaweed farmers and their families engage in a variety of livelihoods including agriculture, fishing, aquaculture, and small business (Zamroni and Yamao 2011; Rimmer et al. 2021).

Joining a cooperative and participating in its marketing activities would pave for a stronger position to negotiate with traders that would positively impact farm gate prices, especially for consolidated volumes of seaweeds. Access to government assistance can be easily achieved through an organized group such as a cooperative (Nor et al. 2017).

Factors Affecting Positive Attitude

Seaweed farming is perceived as an important livelihood of the participants surveyed and is considered a family business that was handed down for generations. According to them, they would rather

engage in a livelihood they are familiar with than do a job that needs higher skills and education. Most (78.7%) of the participants were in elementary and high school levels of education. This is supported by the study of Mateo et al. (2021) that the majority of farmers in Palawan were in primary and secondary levels of education. The promise of high economic returns is one factor that makes farmers positive and reliant on seaweed farming. This conforms to the studies of Valderrama (2012) and FAO (2018) that the socioeconomic impacts of seaweed farming have been positive and very significant in coastal communities. Moreover, the study by Zacharia et al. (2015) stated that seaweed farming plays an important role in the livelihood improvement of coastal families. Various studies corroborated that seaweed farming is an important livelihood that brings sustainable income to the coastal villages (Trono and Ganzon-Fortes 1989; Ask et al. 2003; Ginigaddara and Lankapura 2018). In cases where family labor is insufficient during the initial preparations for seaweed farming, additional labor was employed to support the labor force. This is viewed as an opportunity to create employment in the seaweed industry. These economic impacts were corroborated in various studies (Msuya 2006; Bindu and Levine 2011; Zamroni and Yamao 2011). According to the participants, they lack capital investment, which renders them not fully benefiting from the economies of scale (Hurtado 2013). Further, they claimed that seaweed farming is a legal livelihood, and it utilizes low investment, simple technology, and a short culture period of 45-60 days. The thought of investment being monetized in a short period is necessary for them to support the family's needs. Further, this enables them to continue to rely on seaweed farming and engage in other livelihoods, such as fishing for additional income (Mateo et al. 2021).

Villanueva et al. (2011) reported that *Kappaphycus* seaweeds exhibit fast growth during the first few weeks of culture, which conforms with the harvest period of 45-60 days, allowing rapid turnover of investment in a short cycle. However, to attain sustainable seaweed production, various factors should be considered. A greater understanding of pathogenic and physiological diseases that will lead to early detection and possible outbreaks, an understanding of environmental conditions, the adaptation of farming management, and the use of genetically diverse and resistant cultivars are factors that can impact production and yield (Ward et al. 2019). Developing advanced and cost-efficient cultivation technologies is also important (Kim et al. 2017). The use of inorganic nutrient enrichment by farmers in Sibutu, Tawi-Tawi, in southern Philippines has proven to improve growth and mitigate IID (Tahiluddin et al. 2022). Subsequently, Echem (2017) noted that using nitrates and phosphates increased macroalgae biomass *(Gracilaria arcuata, K. alvarezii, and E. denticulatum*) in laboratory experiments. These techniques were innovations that farmers employed in the hope of increasing production which is absent in the areas surveyed, although seaweed farmers in Palawan have a fair knowledge of Eucheumatid seaweed farming and practices (Mateo et al. 2021). Further, Suyo et al. (2021) stated that seaweed farmers' perceptions and understanding were influenced by their experiences and roles in seaweed farming.

Seaweed farmers in Palawan will continue to engage in seaweed farming primarily because of its high economic returns, low investment requirement, short culture period, and practically simple technology. Moreover, this legal livelihood has been handed over for generations and is perceived as an important source of income. Being a major income-generating activity, seaweed farming will continue to play an important role in providing livelihood in coastal communities despite various challenges. These factors will continue to serve as drivers of the positive attitude of the farmers toward seaweed farming. However, various factors should be considered to adapt to the changing environmental conditions that would lead to sustainable seaweed farming. The use of resistant and diverse cultivars, advanced farming technologies, and a greater understanding of the physiological processes involving the occurrence of diseases and pathogenic agents would impact production and yield.

The development of other alternative livelihoods will enable seaweed farmers to become more resilient to the risks of engaging in one livelihood. Diversification and employing integrated farming systems would help in becoming resilient in the advent of environmental and anthropogenic hazards. Joining a cooperative could boost the morale of seaweed farmers by looking at the organization as a support group and a venue to access assistance from the government. Subsequently, cooperatives can serve as a group that provides support in times of difficulties and serve as a channel for working together for the spirit of "bayanihan" or community cooperation. Further, the organization's sense of belonging will also help foster a positive attitude among seaweed farmers. Subsequently, strong collaboration with various stakeholders in seaweed farming would pave the way for a concerted effort to address industry problems.

Moreover, Palawan is an island province with vast coastal areas, wild stocks of seaweeds, and clear waters that have the potential to expand Eucheumatid farming. Thus, this livelihood will continue to persist and expand in areas free from pollution and other anthropogenic disturbances. Strengthening collaboration and linkages between stakeholders, research institutions, and government units should be enhanced to address problems to sustain the industry.

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ETHICAL CONSIDERATIONS

The survey protocol of this study was submitted for ethics approval to the National Ethics Committee (2021-023-Creencia-Palawan) of the Department of Science and Technology, Philippines. Revisions as per NEC recommendations were implemented before the conduct of this study.

DECLARATION OF COMPETING INTEREST

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

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Incidence of ghost nets in the Tioman Island Marine Park of Malaysia

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ABSTRACT

Ghost nets are major contributor to ocean pollution with extensive social, economic and environmental impacts. Ghost nets trap marine life, build up sediment, and smother and damage sensitive bottom habitats such as coral reefs and seagrass beds. Data on ghost nets are widely available for many coastal locations but there has been very limited information from Malaysia specifically Tioman Island. In 2015, Reef Check Malaysia started training local islanders to locate and remove ghost nets from reefs and beaches around Tioman Island. A reporting hotline was set up to gather information on ghost nets. Once vital information was gathered, the local islanders retrieved them and recorded the ghost nets and sent them for proper disposal. A total of 145 ghost nets weighing over 21 t were retrieved from Tioman Island from 2016 to 2022. The volume of ghost nets retrieved showed an increasing trend and were often found in March, April and September. The ghost nets originated from fishermen operating illegally inside the marine protected area (MPA) and legal fishermen operating outside the MPA. Ghost nets find their way to Tioman Island with strong currents and monsoonal winds. Most of the ghost nets retrieved were inside the MPA and on the western side of Tioman Island. Higher human population, shallower waters, shoreline morphology, dominant coral growth design and reef rugosity on the western side of Tioman Island are reasons for higher ghost nets sightings, thus retrieval and management efforts should focus on this side.

Keywords: coral reefs, fishing, protected area

INTRODUCTION

The abandoned, discarded and lost nets, commonly called ghost nets, have been causing injuries and death of marine animals, cause navigational hazards and environmental damage (Macfadyen et al. 2009; Butler et al. 2013; Richardson et al. 2022). Ghost nets are major contributor to ocean pollution, with extensive social, economic, and environmental impacts causing damage to coral reefs, mangroves and seagrass beds (Richardson et al. 2022). Ghost nets break corals, damages vegetation, build up sediment, and smother and damage sensitive bottom habitats such as coral reefs and seagrass beds

(Macfadyen et al. 2009; Balderson and Martin 2015; Laura et al. 2018).

Ghost nets have been reported to cause injury and death of fish, crustaceans, seabirds, marine mammals and reptiles due to entanglement, suffocation and ingestion (Macfadyen et al. 2009; Stelfox et al. 2016). Globally, an estimate of more than 136,000 marine organisms have been caught, injured and killed yearly by ghost nets (WSPA 2014). For instance, in Australia, it is estimated that 1,500 Australian sea lions *Neophoca cinerea* die yearly from entanglement with ghost nets (WWF 2020). In 2018, about 300 turtles were found dead in a single ghost net incident in Mexico (Green Peace 2019). More recently, in January 2023, nine bamboo sharks were found entangled of which four were dead in a single ghost net incident in Tioman Island, Malaysia.

Annually it is estimated that 2,963 km^2 of gillnets, 75,049 km^2 of purse seine nets and 218 km^2 of trawl nets are lost to the ocean (Richardson et al. 2022). A study of the Great Pacific Garbage Patch, an area of marine debris accumulation in the subtropical waters between California and Hawaii, estimated that it contained over 36,000 t of fishing nets (Lebreton et al. 2018). In the Black Sea coasts of Turkey, the number of nets lost yearly was 1,627 panels (Dagtekin et al. 2019). Nearer to this region in the coastal waters of South Korea, it is estimated that 38,535 t of gillnets entered the ocean every year (Kim et al. 2014). A recent study in 2020 in the Gulf of Carpentaria, Australia, recorded over 1,400 pieces of ghost nets (Hardesty et al. 2021). Nearer to Malaysian waters in Sadeng, Indonesia, it is estimated around 40,000 pieces of gillnets are lost annually (FAO 2017).

While many studies have been done about the incidence of ghost nets in North America, Europe, Atlantic and Indian Oceans, little to none has been reported from Africa, Asia and South America (Richardson et al. 2019). Very limited information on the incidence of ghost nets in Malaysia exist, while there is none for Tioman Island, Malaysia.

Tioman Island hosts three marine ecosystems – coral reefs, seagrass beds, and mangrove forests – that create important connectivity in the life cycle of many marine species, including green and hawksbill turtle, blacktip reef shark, sea snake, snapper and other fish which migrate between these ecosystems during the different stages of their life. Tioman Island serves as nurseries to numerous fish and prawns, nesting site and staging ground for green and hawksbill turtle, and also part of the wider and extensive migratory routes for whale sharks and marine mammals such as the false killer whale and Indo-Pacific bottlenose dolphin, which are sighted periodically. Many pods of dolphins are resident around Tioman Island (Chelliah et al. 2022).

In 1994, the waters extending 3.7 km around the island were gazetted by the Department of Fisheries Malaysia as a marine park under the Fisheries Act 1985 where all forms of fishing were prohibited (Lau et al. 2019; PLANMalaysia 2019) in order to protect fish breeding grounds and ensure that fisherman could sustainably reap the benefits from the spillover effect. Today, Tioman Island has a small local population of around 3,500 people, of which more than 75% depend on tourism as their main source of income (PLANMalaysia 2019) and with less than 30 individuals registered as fishers with the Department of Fisheries Malaysia. Over 250,000 tourists visit the island yearly (Tourism Pahang 2019) for its beautiful sandy beaches, crystal clear water and healthy coral reefs. Though only a handful of locals still remain as fishermen, commercial fishing fleets from coastal towns on the peninsular actively fish the waters surrounding the island while international fishing fleets fish the Exclusive Economic Zone boundary less than 75 km away from the shores of Tioman Island. Fishermen in the surrounding waters often use gillnets, trawl nets and purse seine nets. The abandoned, lost and discarded nets from these activities are drifting towards Tioman Island Marine Park causing reef damage and wildlife mortalities. Information about the presence of ghost nets is thus essential in understanding the extent of its threat to the marine life within the Tioman Island Marine Park. This study documented the number, volume and location of ghost nets found and retrieved from Tioman Island Marine Park between 2016 to 2022.

METHODS

Study Site

Tioman Island Marine Park is situated in the South China Sea at 2º48'N and 104º10E (Figure 1), about 50 km from the jetty in Mersing, Johor and 57 km from the jetty in Kuala Rompin, Pahang and is located within the implementation boundary of the Coral Triangle Initiative. The island is approximately 20 km long and about 12 km wide, with a total area of 133 km^2 (PLANMalaysia 2019), a coastline of about 69 km (DMPM 2012) and surrounded by 5.46 km^2 of fringing reefs (Lau et al. 2019) with most of the reefs located on the western side of the island (PLANMalaysia 2019). The eastern side of the island is facing the South China Sea while the western side is facing mainland Peninsular Malaysia. The nearest fish landing sites – Mersing, Endau and Penyabong – are approximately 43 to 55 km away in the Mersing District with fish landings concentrated at Endau (JICA 1993).

In 2014, Reef Check Malaysia, an NGO working towards sustainable management of coral reefs in Malaysia, started a program called "Cintai Tioman" (Love Tioman) on the island. The program is the first long-term community-based project in

Malaysia. The program aims to protect coral reefs around Tioman Island and to improve the livelihoods of the local community. The end goal is to ensure sustainable use of the island's natural resources for the benefit of all stakeholders.

Data Gathering

In the past, ghost net retrieval efforts within the marine protected area were mainly done during annual clean-up events organized by park managers or by dive operators. In 2015, Reef Check Malaysia started training local islanders known as the Tioman Marine Conservation Group (TMCG) to locate and remove ghost nets from reefs and beaches around Tioman Island. A reporting hotline was set up to gather information on ghost nets from dive centers, snorkel guides and tourists. Reports also came in from social media platforms. Once vital information such as the location, size, type and depth of the ghost nets is gathered, the TMCG would retrieve the ghost nets and send them for proper disposal. Weight of nets were recorded using top loading scale at the incinerator, hand held scale or estimation. The documentation started in 2016 until 2022.

Data Analysis

The incidence of ghost nets was determined using descriptive data analysis by summing the number and weight of retrieved ghost nets from 2016 until 2022. The data were graphically presented using Microsoft Excel.

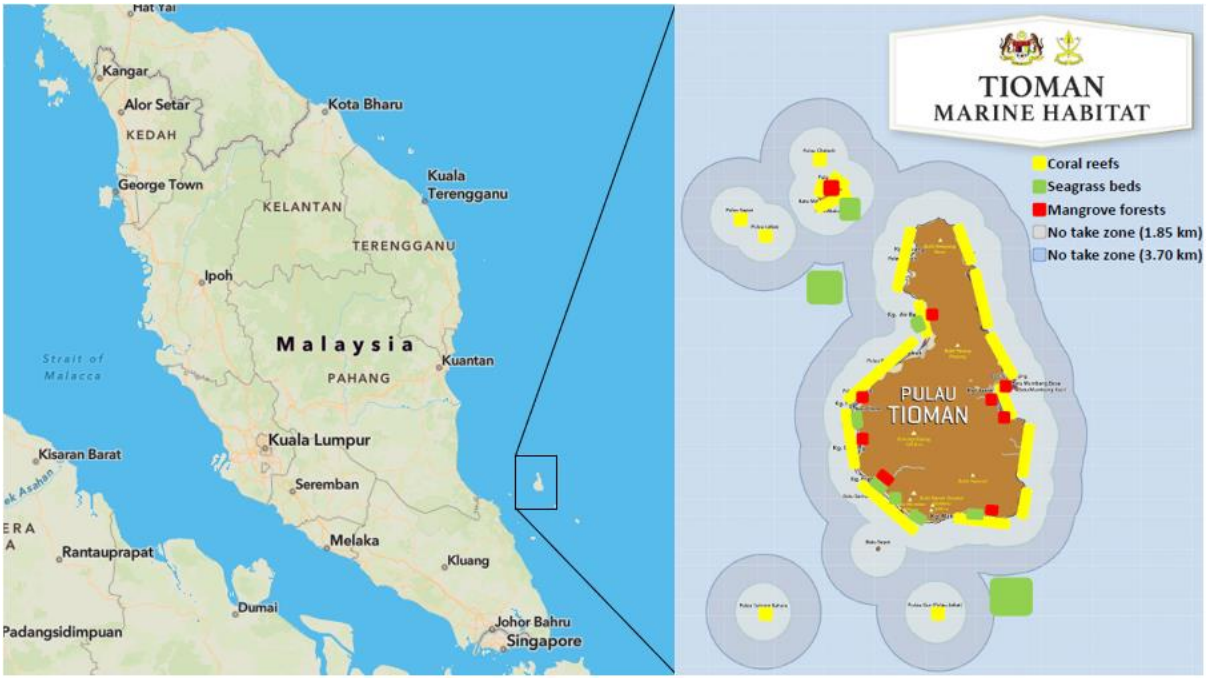

Figure 1: Geographical location of Tioman Island Marine Park, Malaysia.

RESULTS

Volume and Number of Ghost Nets

The volume of ghost nets showed an increasing trend with a drop in 2019, the year before Malaysia was hit by COVID-19 pandemic. From a total of 11 ghost nets in 2016, numbers rose to 39 in 2022. The total weight per year ranged from 1.3 t to 7.3 t (Figure 2). Based on data over the years, ghost nets were often found in March and April as well as in September (Figure 3).

Location and Volume of Retrieved Ghost Nets

Figure 4 shows the locations of ghost nets retrieved around Tioman Island for 2016, 2017, 2018, 2019, 2020, 2021 and 2022, respectively. Most of the ghost nets retrieved were inside the marine protected area no-take zone where coral reefs, seagrass beds and mangrove forests can be found. Though ghost nets were found on reefs and coastlines around the island, some hot spots were identified. Highest numbers and volume of ghost nets were recorded along the western coast of the island including around P. Tulai Candang (Figures 5 and 6).

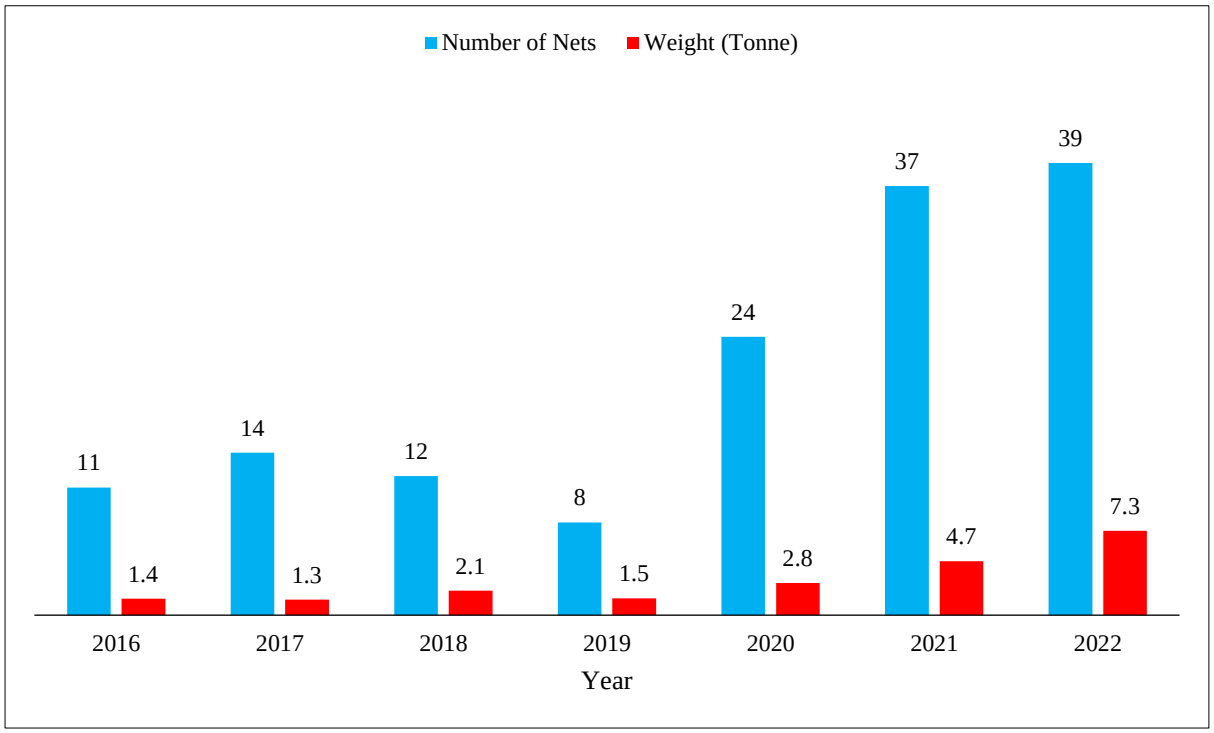

Figure 2. Numbers and total weights (tons) of ghost nets retrieved around Tioman Island Marine Park from 2016 to 2022.

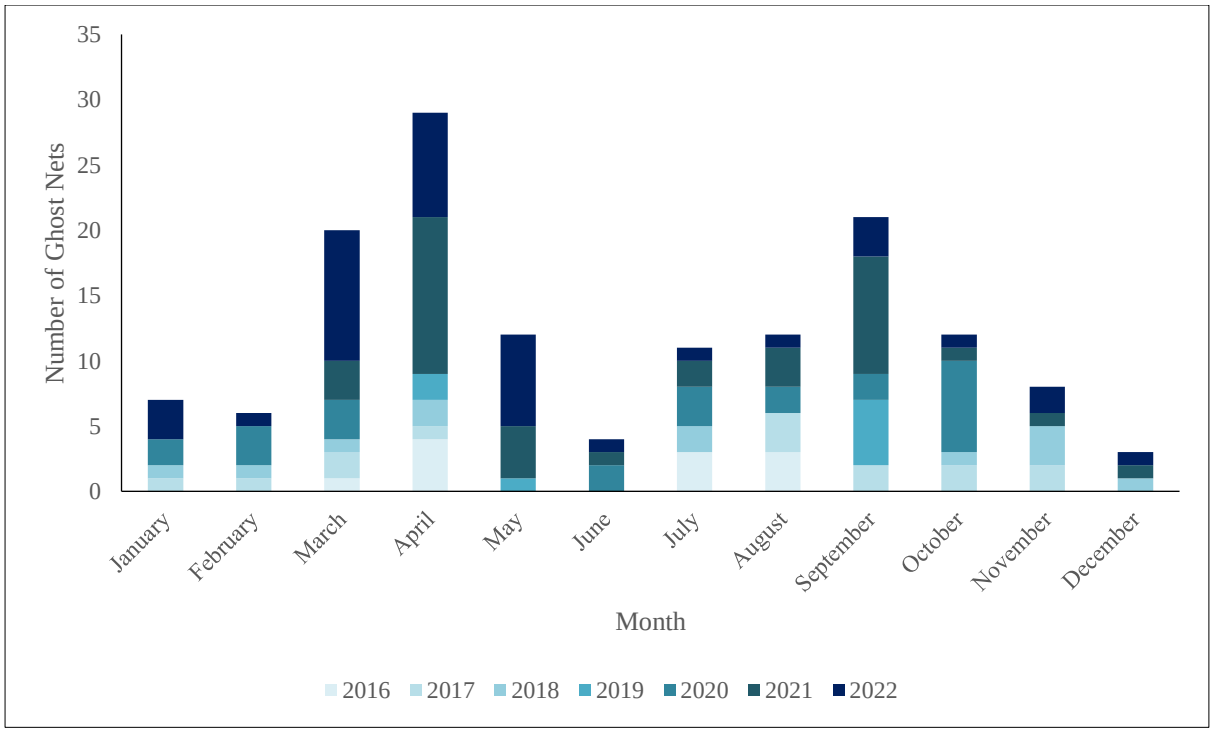

Figure 3. Monthly number of ghost nets retrieved around Tioman Island Marine Park between 2016 to 2022.

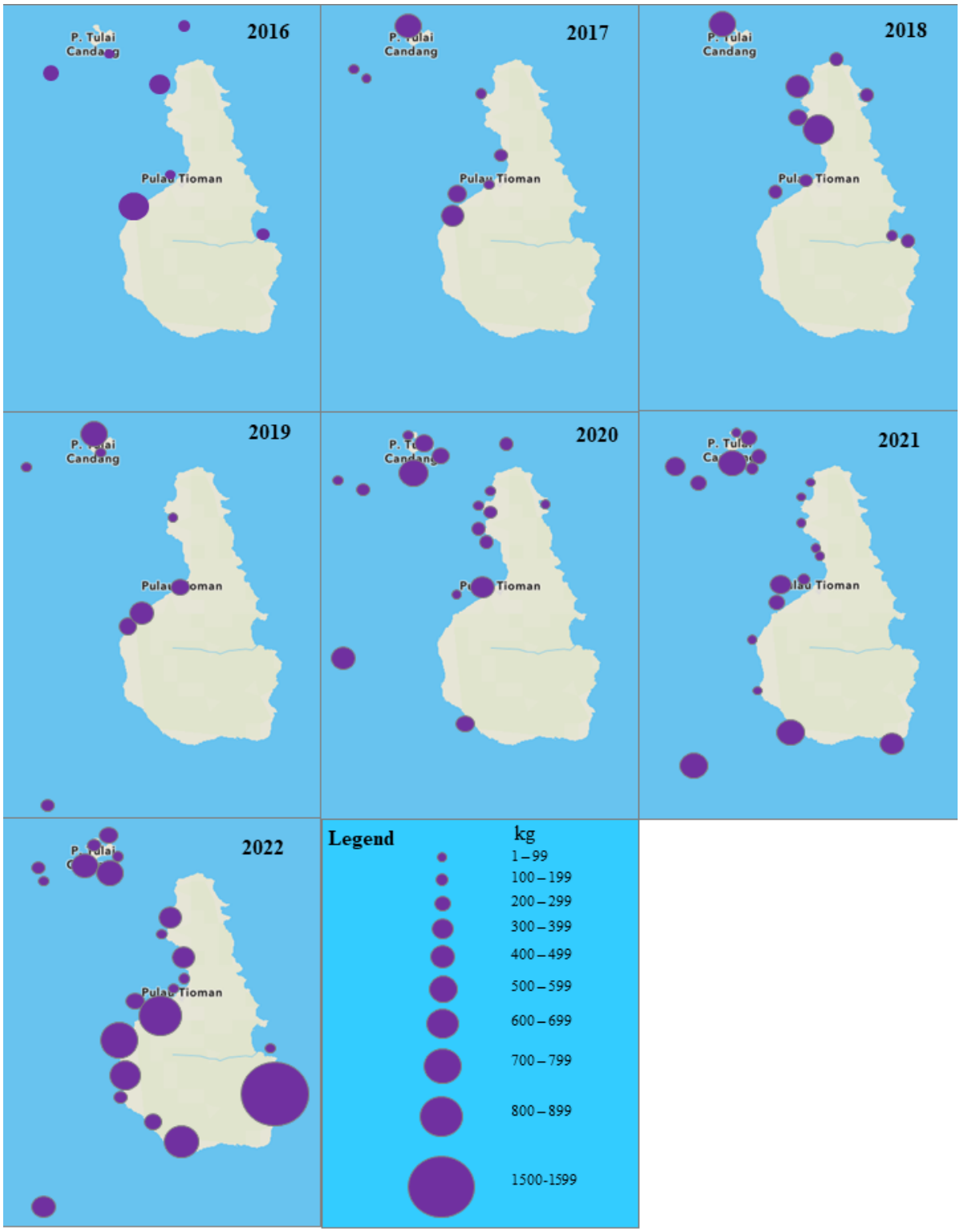

Figure 4.Weight (kg) of ghost nets retrieved around Tioman Island between 2016 and 2022.

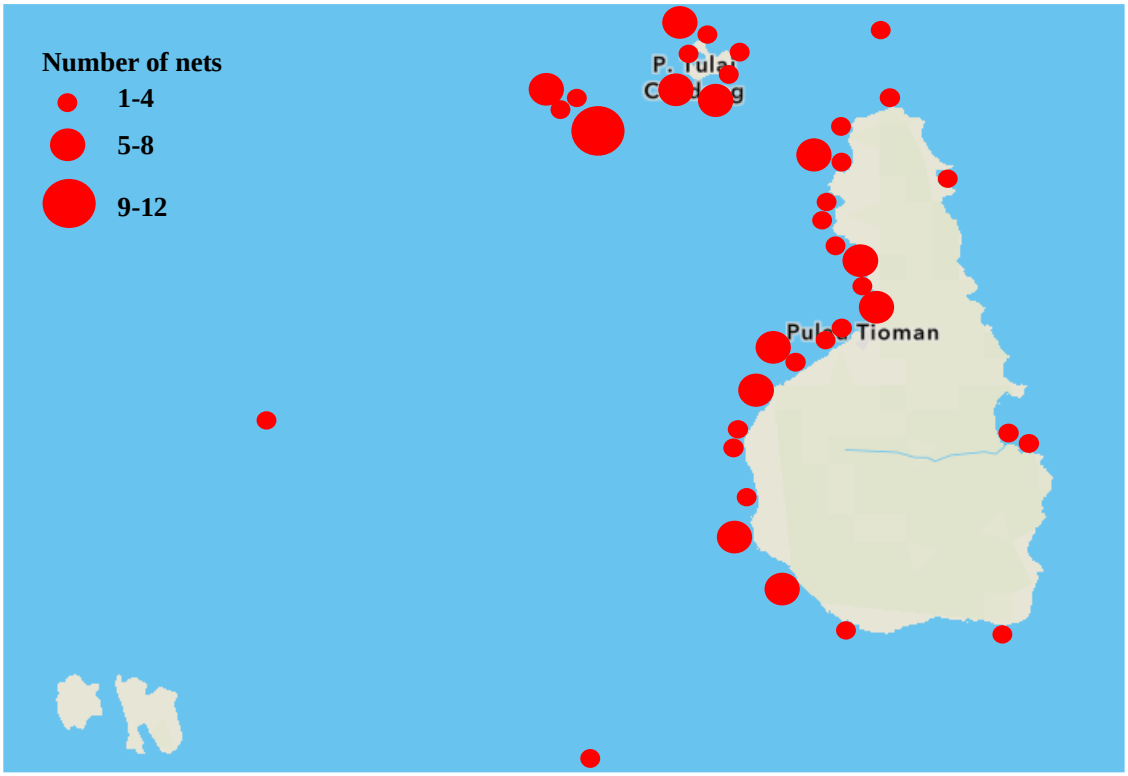

Figure 5. Number of ghost nets retrieved within the period of 2016 and 2022 around Tioman Island.

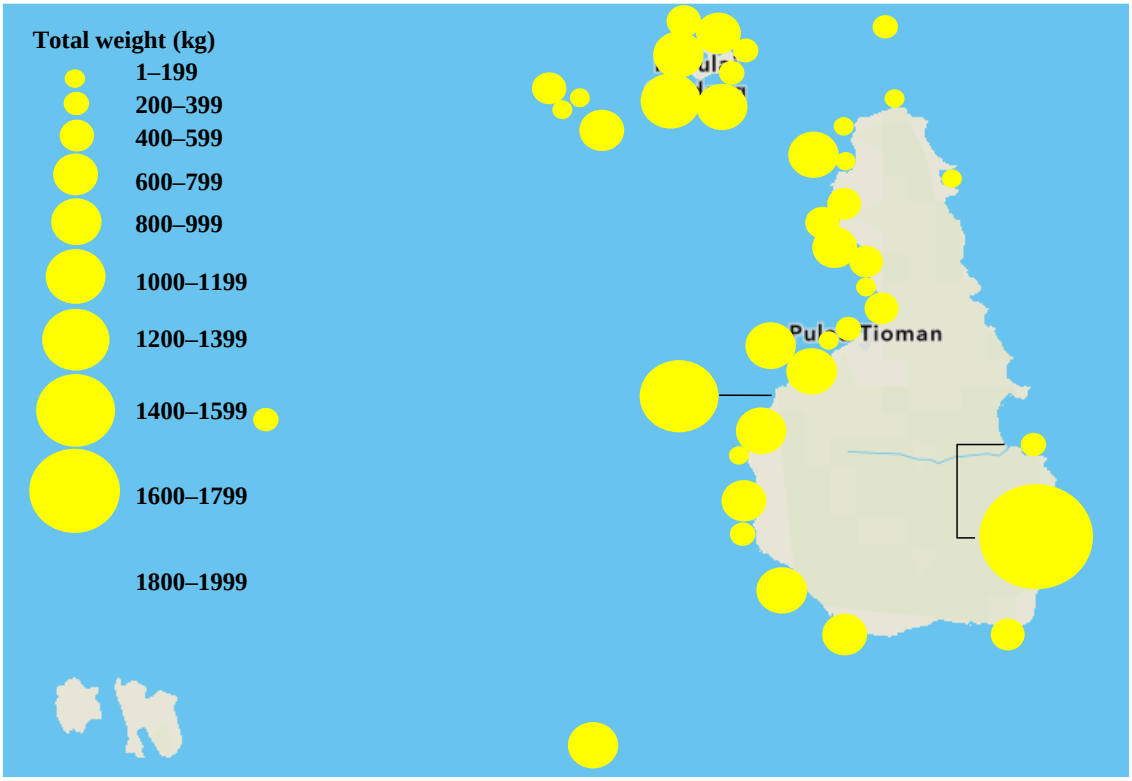

Figure 6. Weight (kg) of ghost nets retrieved within the period of 2016 and 2022 around Tioman Island.

DISCUSSION

Volume and Number of Ghost Nets

Though the Tioman Island Marine Park is set up to safeguard the fishing industry, the industry continues to threaten marine life in the form of ghost nets. Fishing nets are lost from vessels for a variety of reasons including adverse weather, when it is improperly stored and washed overboard, when vessels are inadequately maintained, and when crew are incompetently trained and inexperienced (Macfadyen et al. 2009; Richardson et al. 2018; Richardson et al. 2019). Fishing nets are often abandoned when it is inadequately marked and the cost of gear retrieval is high (Macfadyen et al. 2009; Richardson et al. 2018). Enforcement pressure can also cause illegal fisherfolk to abandon gear in an attempt to flee from authorities (Macfadyen et al. 2009). High disposal costs and availability of shoreside collection facilities are other contributing factors to fishers dumping used nets in the sea (Macfadyen et al. 2009; Richardson et al. 2018).

Ghost nets found around Tioman Island originate from fishers operating illegally inside the marine protected area as well as legal fishers operating outside the marine protected area. With strong currents and monsoonal winds, ghost nets that are abandoned, lost or discarded in the sea, outside the marine protected area, can find their way to Tioman Island ending up entangled on coral reefs and mangroves or washed up on shore. The presence of biofouling organisms such as algae and barnacles on the ghost nets are good indicators that the nets have been in the water for some periods of time. Ghost nets that are abandoned, lost or discarded by illegal fishers inside the marine protected area are usually clean and absent of biofouling organisms.

For most parts of 2020 and 2021, the island was closed to tourism following the Movement Control Order (MCO) to curb the spread of COVID-19. The MCO was first implemented on 18 March 2020 and was converted to conditional MCO (CMCO) from 04 May 2020 onwards. The CMCO continued until 09 June 2020, after which the recovery MCO (RMCO) was activated from 10 June 2020. During RMCO, tourism sector was reopened, however the international borders remained closed except for approved travel (Hashim et al. 2021). In January 2021, MCO was reintroduced and interstate travel was banned. The interstate travel ban was only lifted on 11 October 2021 for fully vaccinated individuals (Kuok 2021), while international borders for travelers from all countries were only reopened on 01 April 2022 (KKM 2022). During this period a spike in ghost nets was recorded. This was mainly due to an increase in fishing activities, including illegal fishing activities within the marine protected area. During MCO, those working in fisheries were considered essential services, and activities related to fishing were allowed to operate (MITI 2020). This means fishers could cross borders and go out to sea and fish. Many who had lost income due to the MCO, turned to fishing during this period but lacked the skills and knowledge regarding the sea, fishing grounds or how to properly use fishing nets. Although the MCO was lifted and tourism resumed in 2022, the number of ghost nets retrieved remained high.

Fish and seafood is the prime animal protein source in the Malaysian diet (Goh et al. 2021) and fish tends to dominate over other animal protein sources (Nik Mustapha and Ahmad Zubaidi 1999; Ibrahim et al. 2014). During the height of COVID-19 pandemic in 2020 and 2021, control measures imposed by many countries had restricted international trade; causing disruptions of supply from the imported fish and fish-related products due to closure of some country borders, forcing local consumers to depend on local fishery resources (Menhat et al. 2021). This probably increased the demand for local fish and fish-related products from local consumers (Menhat et al. 2021) and hence fishing activities.

Although with the increase in volume and number of ghost nets per year during and after the height of COVID-19 pandemic, the number of ghost nets around Tioman Island is considered very low in comparison to other places such as the Black Sea coasts of Turkey – 1,627 panels per year (Dagtekin et al. 2019), South Korea – 38,535 t of gillnets per year (Kim et al. 2014), Sadeng, Indonesia – 40,000 pieces of gillnets per year (FAO 2017) and the Gulf of Carpentaria, Australia – over 1,400 pieces ghost nets in 2020 (Hardesty et al. 2021). Even at Andrott Island Lakshadweep, India which recorded 38 ghost nets in 2020, the number was documented over a 3-week survey period (Sahab et al. 2021) and is considered high compared to Tioman Island.

The Northeast monsoon season in Tioman Island is between November and March (DMPM 2012). The monsoon winds and currents bring ghost nets into the island. However, heavy rainfall and strong winds during this time make the surrounding seas rough, thus hindering ghost net retrieval efforts and causing a backlog of ghost nets to be retrieved. Water activities on the island resume in March and April. As a result, during this period a spike in ghost nets was recorded. High number of ghost nets recorded in September can be attributed to the inter-monsoon phase, the transition period between Southwest monsoon and Northeast monsoon (Mohd Fadzil et al. 2014). During the inter-monsoon phase, heavy rain and strong winds bring ghost nets into the island.

The variation in the number of ghost nets compared to total weight was due to the type and size of ghost nets collected. The type of ghost nets found around Tioman Island were gillnets, trawl nets and purse seine nets with the majority being gillnets. An

average gillnet weighs 20 to 30 kg while a trawl net weighs over 500 kg.

Location of Ghost Nets

The western side of Tioman Island has a larger population and more villages along the coast (Lechner et al. 2020). The reefs are frequently visited by divers and snorkelers (Lau et al. 2019), making the chances of ghost nets sighting higher. The remoteness of the eastern coastline that only has one village and not many diving or snorkeling locations added with the deeper waters along the east coast (Cob et al. 2002) is probably the reason for lower sightings of ghost nets. The shoreline morphology, dominant coral growth design and reef rugosity differ between the east coast and west coast (Lee et al. 2006; Kharina et al. 2016; Shahbudin et al. 2017) and this too might be a reason for lower sightings of ghost nets along the east coast.

Although fishing activities happen all around Tioman Island, the coastal waters between western side of Tioman Island and mainland Peninsular Malaysia are commonly fished by fishers from mainland (JICA 1993) because the western side of Tioman Island is more sheltered from waves and winds compared to the eastern side that is open to and facing the South China Sea (Lechner et al. 2020). The coastal waters are fishing ground for a large fleet of commercial fishing boats especially from Endau and Mersing (JICA 1993). During the southwest monsoon, winds and currents flows toward the western side of Tioman Island (Zuraini and Mohd Fadzil 2016), thus bringing ghost nets into the island. Fishers often rest, take shelter from storms, refill supplies and visit the mosque on the western side of Tioman Island. When anchored, they have been seen mending broken fishing nets and discarding fragments of damaged fishing nets into the water during nets mending.

Proposed Management Efforts

Ghost nets are threat to marine life and can cause severe damage to marine ecosystems. Local government agencies along with marine park managers must work together to overcome this issue to minimize loss of biodiversity and income to both the fishermen as well as tourism operators that depend on healthy marine ecosystems. The reasons for ghost nets ending up in the environment are varied, hence solutions to this problem must be multipronged and transboundary.

Management efforts should look into the prevention of ghost nets. Awareness campaign with fishing communities should be conducted to help them to understand the impacts of ghost nets. Collection bins should be provided at all fish landing ports and incentives could be provided to fishers to encourage them to dispose used or damaged nets responsibly. The sale of fishing nets should be regulated by the Department of Fisheries Malaysia and only registered fishermen should be allowed to purchase fishing nets and old nets must be returned before new ones are allowed to be purchased. Ghost nets are a transboundary issue hence the Malaysian governments must work with neighboring countries to overcome this problem. The use of modern technologies to track and retrieve fishing gears should be explored. On Tioman Island, frequent reef surveys and monitoring should be conducted on the west coast of the island where most ghost nets have been recorded to ensure nets are retrieved quickly and minimal damage is caused to marine life.

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ETHICAL CONSIDERATIONS

This study did not involve the use of any living organisms.

DECLARATION OF COMPETING INTEREST

There are no competing interests to any authors.

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Selection of optimal draw solution recovery technology for forward osmosis desalination system using analytical hierarchy process

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ABSTRACT

Water scarcity poses a significant threat to global food and water security, prompting a need for practical solutions. With 97% of Earth's water situated in oceans, desalination emerges as a viable option. Among desalination technologies, forward osmosis (FO) using membrane-based technology stands out for its potential to reduce costs and energy requirements. The focus on energy consumption in FO has prompted an exploration of optimal technology selection through the Analytical Hierarchy Process (AHP), a multi-criteria decision-making method. Value judgments were collected through a questionnaire in consultation with two experts. Environmental aspects emerged as the most critical factor, weighted at 0.3963. The AHP analysis revealed nanofiltration (NF) as the optimal system, attaining a total weight of 0.2612. The NF scored highest in terms of environmental impact (C3), operating and maintenance costs (S6), and energy requirements (S4). Conversely, membrane distillation ranked as the least preferred alternative, with a total score of 0.1335, mainly due to lower maturity of technology (S3), higher capital costs (S5), and negative environmental impact (C3). Sensitivity analysis was conducted to investigate how changing weights for sub-criteria might affect the preferred technology. Notably, Reverse Osmosis became the most favored technology when efficiency (S1) and S3 weights were set at 0.3 and 0.2, respectively. Conversely, thermal separation gained preference when the weights for resistance to scaling and fouling (S2) and S5 were set at 0.3. Changes in S4, S6, and C3 have showed the most minor sensitivity.

Keywords: membrane, nanofiltration, thermal separation, water scarcity

INTRODUCTION

Water scarcity is an emerging global issue. It is characterized by an insufficient water supply to meet demand (Tzanakakis et al. 2020). This issue results either from unfavorable environmental conditions or inadequate technology (United Nations – Water n.d.). Approximately 2.3 billion people inhabit water-stressed environments, with contaminated water causing 3.4 million annual fatalities. Only 2.5% of Earth's water is freshwater, with a mere 1% accessible to humanity. The United

Nations is dedicated to ensuring universal access to water and sanitation, integral components of its sustainable development goals.

Desalination, the process of extracting salts and pollutants from seawater, brackish water, or wastewater, presents as a promising solution (Feria-Diaz et al. 2021). Progress in membrane technology has made membrane filtration processes, driven by pressure or concentration gradients, more cost-effective and environmentally friendly compared to thermal desalination using steam (Chaoui et al. 2019).

Among membrane technologies, reverse osmosis (RO) has been considered the optimal choice for seawater desalination. However, RO membranes face durability and efficiency challenges related to scaling (Feria-Diaz et al. 2021). Conversely, forward osmosis (FO) attracted attention due to its lower energy requirements and reduced membrane fouling compared to RO, making it a promising option in desalination.

Overall, membrane filtration technologies offer improved cost efficiency compared to traditional thermal desalination technologies, driving their increased adoption in the field (Chaoui et al. 2019). In forward osmosis, water from the feed of low concentration flows through the semipermeable membrane alongside the draw solution (DS) of high concentration. The disparity in osmotic pressure between the two solutions leads to the separation of water from unwanted solutes while diluting the draw solution. The solution containing unwanted solutes is discharged as wastewater, which can be treated later. Meanwhile, the diluted draw solution undergoes further treatment in a recovery system to obtain the desired clean water. Most energy consumed in forward osmosis desalination is expended in the draw solution recovery phase. Therefore, selecting the appropriate technology is imperative as it profoundly affects the efficiency and economic viability of the desalination system.

Various draw solution recovery technologies, including thermal separation for volatile compounds, are employed but with high energy costs. Membrane-based methods such as reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and membrane distillation (MD) are widely used. High-temperature RO is effective for thermo-responsive draw solutions, while FO-NF hybrid systems achieve high water recovery. The NF is more cost-effective than RO, and UF filters small molecules. Membrane distillation offers high water recovery and low investment costs but may encounter scaling and maintenance issues. Considerations for selecting a desalination technology include energy demand, economic viability, and water quality.

The Analytical Hierarchy Process (AHP), developed by Thomas L. Saaty in 1970, organizes information. Saaty and Ozdemir (2014) underscore the importance of carefully considering the expertise needed for a decision and highlight that, in many cases, a single expert judge may suffice. The problem in this study concerns the selection of the optimal draw solution recovery technology for forward osmosis desalination. Expert consultations and literature review revealed four potential solutions: RO, UF, NF, and MD. Criteria under consideration encompass economic viability, energy requirements, water quality, and system efficiency.

Water scarcity threatens 50% of the world's population by 2050, with 97% of water being salt water. Desalination systems often a promising solution; however, they often rely on high energy consumption and economically inefficient methods. Technologies include thermal separation, electrodialysis, and membrane-based methods like RO, FO, and MD. The majority of the energy consumed in FO is allocated to draw solution recovery. Selecting the best draw solution recovery technology will maximize FO desalination systems.

The study aims to identify the optimal draw solution recovery technology for forward osmosis in desalination systems using the AHP methodology. Specifically, the study employs pairwise comparisons to determine the weight of each criterion and sub-criterion, considering technical, economic, and environmental aspects. The ranking of alternatives is based on the global weights of the criteria and subcriteria. In addition, sensitivity analysis was conducted to determine the most influential factors and how the weights affect the ranking of alternatives.

The study employed the Analytical Hierarchy Process (AHP) to compare TS, RO, MD, NF, and ED. These technologies were analyzed comprehensively considering technical aspects, economic viability, and environmental impact. Each criterion and technology were compaired in a pairwise manner through consultations with experts with at lease ten years of of experience in the relevant field. These experts have not only accumulated substantial experience but have also produced significant studies in the fields of forward osmosis, membrane systems, and desalination. Their contributions to these areas validate their expertise and justify their inclusion in the study. For this research, two experts were interviewed to enrich the depth of analysis further.

The study did not seek to specify the characteristics of the forward osmosis membrane, including the membrane type, operating conditions (pressure and temperature), and reaction time. Moreover, the specifics of the technologies considered, such as the kind of membrane, were not specified. Achilli et al. (2010) noted that NaCl is commonly used due to its solubility, low toxicity, and scaling prevention but found it one of the least effective draw solutes. They observed that $MgCl_2$ performed better with a high recovery rate, suggesting it may be the best

draw solute for water and wastewater treatment. Arcanjo et al. (2020) used $MgCl_2$ and NaCl in an FO-MD hybrid system, finding that $MgCl_2$ reduced FO reverse salt flux and was completely rejected by the membrane distillation process. With literature review and conversation with the experts, this study was limited to considering $MgCl_2$, as the draw solution for the forward osmosis process.

METHODS

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a multi-criteria decision analysis method utilized for comparing the weights of each criterion relative to each other in determining the best alternatives. Developed by Thomas Saaty in 1970, Analytic Hierarchy Process (AHP) is most effectively applied in selecting the optimal alternative. The process is summarized in Figure 1.

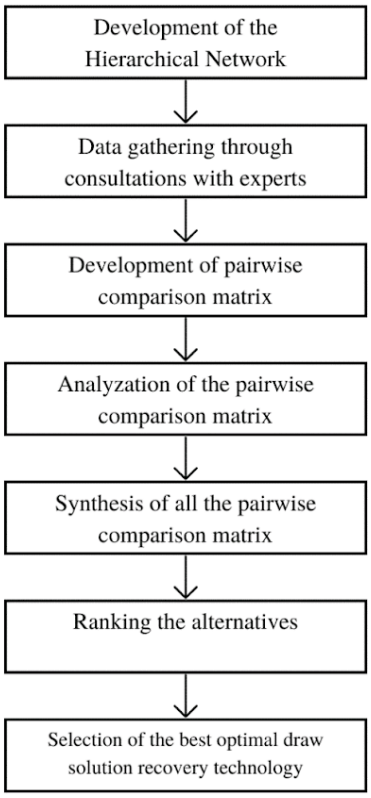

Figure 1. Overview of the analytical hierarchy process (AHP).

The preliminary step in AHP involves the construction of a hierarchical network with three levels (Figure 2). The first level represents the goal. In this study, the goal is defined as selecting the optimal draw solution recovery technology. The second level consists of the criteria and sub-criteria, while the third level comprises the alternatives. Following a review and expert consultation, the identified criteria include Technical Aspect (C1), Economic Aspect (C2), and Environmental Aspect (C3). Six sub-criteria were determined: efficiency (S1), resistance to scaling and fouling (S2), maturity of technology (S3), energy requirement (S4), capital costs (S5), and maintenance and operating costs (S6). C3 does not have sub-criteria.

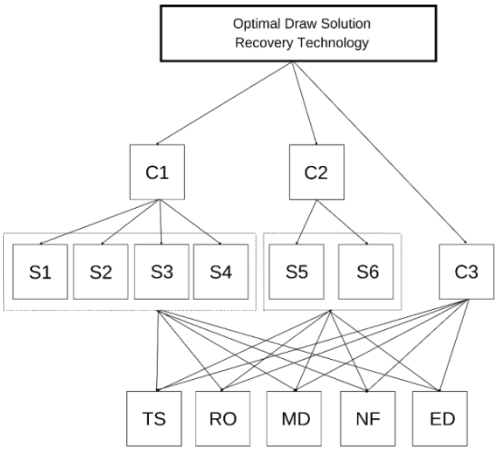

Figure 2. Hierarchical network for analytical hierarchy process (AHP). C1 – Technical Aspect; C2 – Economic Aspect; C3 – Environmental Aspect; S1 – Efficiency; S2 – Resistance to Scaling and Fouling; S3 – Maturity of Technology; S4 – Energy Requirement; S5 – Capital Costs; S6 - Operating and maintenance costs; TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane Distillation; NF – Nanofiltration; ED – Electrodialysis.

Pairwise Comparison

Value judgments for pairwise comparison were gathered from the experts. A questionnaire was formulated describing the study's objectives, criteria, sub-criteria, and alternatives. Experts rated each criterion/sub-criterion and alternatives relative to each other using Saaty's scale of relative importance (1980), as shown in Table 1. Pairwise comparison matrices were constructed based on the collected expert value judgments with an example shown in Table 2. The geometric mean of the value judgments was used in the matrices due to multiple experts' involvement.

Table 1. Saaty's scale of relative importance.

Definition	Equivalent
Equal Importance	1
Equal to moderate Importance	3
Strong importance	5
Very strong importance	7
Extreme importance	9
Intermediate values	2, 4, 6, 8, 10

Determination of Criteria, Sub Criteria, and Alternatives

Upon conducting a literature review and expert consultation, the environmental impact of the draw solute recovery system was identified as primarily concerning CO_2. Thus, the environmental aspect focuses only on greenhouse gas emissions in carbon dioxide equivalents, as shown in Table 3. The alternatives were determined through literature review and expert consultation. Initially, ultrafiltration was considered. However, the pore size was the only significant difference between ultrafiltration (UF) and nanofiltration (NF). Moreover, NF showed more promising results with $MgCl_2$ as the draw solute, UF was omitted as an alternative. The final alternatives selected were thermal separation (TS), reverse osmosis (RO), membrane distillation (MD), nanofiltration (NF), and electrodialysis (ED). The hierarchical network is shown in Figure 2. Definitions of factors are summarized in Table 3.

Table 2. Example of a pairwise comparison matrix. C1 to C5 – example criteria; a_{12} – value judgments comparing C1 and C2; a_{13} – value judgment comparing C1 and C3; a_{14} – value judgment comparing C1 and C4; a_{15} – value judgment comparing C1 and C5; a_{23} – value judgment comparing C2 and C3; a_{24} – value judgment comparing C2 and C4; a_{25} – value judgment comparing C2 and C5; a_{34} – value judgement comparing C3 and C4; a_{25} – value judgement comparing C3 and C5; a_{45} – value judgement comparing C4 and C5; w_1 – calculated weight of C1; w_2 – calculated weight of C2; w_3 – calculated weight of C3; w_4 – calculated weight of C4; w_5 – calculated weight of C5.

Criteria	C1	C2	C3	C4	C5	Priority Weight
C1	1	a_{12}	a_{13}	a_{14}	a_{15}	w_1
C2	$1/a_{12}$	1	a_{23}	a_{24}	a_{25}	w_2
C3	$1/a_{13}$	$1/a_{23}$	1	a_{34}	a_{35}	w_3
C4	$1/a_{14}$	$1/a_{24}$	$1/a_{34}$	1	a_{45}	w_4
C5	$1/a_{15}$	$1/a_{25}$	$1/a_{35}$	$1/a_{45}$	1	w_5

Table 3. Criteria and sub criteria used in analytical hierarchy process (AHP).

Criterion	Sub Criterion	Definition
Technical aspect (C_1)	Efficiency (S_1)	Effectivity of the technology in separating water from the draw solute
	Resistance to Scaling and fouling (S_2)	Frequency of occurrence of scaling and fouling in the membrane
	Maturity of technology (S_3)	Degree of how long the technology has been established and continually improved.
	Energy requirement (S_4)	The amount of energy it takes to separate the water from the draw solute
Economic aspect (C_2)	Capital Costs (S_5)	Initial costs for the equipment
	Operating and maintenance costs (S_6)	Costs for the personnel who will operate and maintain the technology.
Environmental aspect (C_3)		Impact to the environment through GHG emission in carbon dioxide equivalents (kg, CO_2-eq).

RESULTS

Selection of Optimal Recovery Technology

Two questionnaires were administered to the experts. The first focused on their judgment regarding preselected criteria and alternatives, while the second aimed to gather value judgments through performing pairwise comparisons. The results of the first questionnaire were discussed in the methods section since it is essential in creating the hierarchical network. The second questionnaire was administered after the results of the first questionnaire were completed.

Table 2 shows the local and global weights of each criterion and sub-criterion. It can be observed from Table 4 that among the criteria, the environmental aspect (C3) has the most weight at 0.3963, followed by the technical aspect at 0.3963 and the economic aspect at 0.2810. Local weights refer to the weight of each sub-criteria relative to the other sub-criteria within that criterion. Within the technical aspect (C1), efficiency (S1) has the highest local weight (0.4180), while the maturity of technology (S3)

has the least weight (0.0494). The economic aspect sees operating and maintenance costs (S6) with a higher weight of 0.8173 than capital costs (S5) at 0.1827. Global weight refers to the weight of the sub-criteria in comparison to the other sub-criteria, regardless of the criteria they are under. With C1 having the second highest score and S1 having the highest score in C1, S1 gained the highest global weight among the sub-criteria. The maturity of technology (S3) has the least global weight. Having no sub-criteria and the highest weight among the criteria, C3 has the highest global weight.

Table 5 shows the different grades for each alternative in every sub-criterion. The higher the grade, the more the technology is preferred in that sub-criteria. Regarding S1, reverse osmosis (RO) has the highest grade of 0.5923. Meanwhile, thermal separation (TS) has the lowest grade of 0.0643. Regarding resistance to scaling and fouling (S2), TS has the highest grade of 0.4428, and RO has the lowest grade of 0.0932. In S3, RO has the highest grade of 0.5276, and membrane distillation (MD) has the lowest grade of 0.0573. Regarding energy requirements (S4), nanofiltration (NF) has the highest grade of 0.3621, and RO has the lowest grade of 0.0670. In S5, TS has the highest grade of 0.5062, and MD has the lowest grade of 0.0389. In S6, NF and electrodialysis (ED) have the highest grade of 0.2854, with MD having the lowest grade of 0.0886. Lastly, in C3, NF has the highest grade of 0.3122, and MD has the lowest grade of 0.1443.

Table 6 shows the overall grade of each technology, along with their ranks. The technology with the highest grade most preferred, the one with the lowest is the least preferred. The NF has the highest overall grade of 0.2621 and ranking highest grade in S4, S6, and C3.

Table 4. Local and global weight of criteria and sub-criteria used in determining the optimal technology.

Criteria	Weight	Sub Criteria	Local Weight	Global Weight
Technical Aspect (C1)	0.32273	Efficiency (S1)	0.4180	0.1349
		Resistance to Scaling and Fouling (S2)	0.2433	0.0785
		Maturity of Technology (S3)	0.0494	0.0159
		Energy Requirement (S4)	0.2893	0.0934
Economic Aspect (C2)	0.28097	Capital Costs (S5)	0.1827	0.0513
		Operating and Maintenance Costs (S6)	0.8173	0.2296
Environmental Aspect (C3)	0.39630			0.3963

Table 5. Summary of grade of each alternative for each criterion and sub criterion.

	Sub-criteria and Criteria						
Alternative	S1	S2	S3	S4	S5	S6	C3
Thermal Separation (TS)	0.0643	0.4428	0.2422	0.0837	0.5062	0.2244	0.1639
Reverse Osmosis (RO)	0.5923	0.0932	0.5276	0.0670	0.0560	0.1161	0.1487
Membrane Distillation (MD)	0.1763	0.2155	0.0573	0.1323	0.0389	0.0886	0.1443
Nanofiltration (NF)	0.0943	0.1130	0.1117	0.3621	0.2877	0.2854	0.3122
Electrodialysis (ED)	0.0728	0.1355	0.0612	0.3549	0.1112	0.2854	0.2310

Table 6. Overall grade and rank of each technology.

Alternative	**Grade**	**Rank**
Thermal Separation (TS)	0.1976	3
Reverse Osmosis (RO)	0.1904	4
Membrane Distillation (MD)	0.1335	5
Nanofiltration (NF)	0.2612	1
Electrodialysis (ED)	0.2173	2

Sensitivity Analysis

The study conducted sensitivity analysis to observe rankings change by adjusting the global weight of specific sub-criteria while keeping the other sub-criteria and criteria adjusted with a constant preference ratio. The global weight of the target sub-criteria varied from 0 to 1 in intervals of 0.1. Figures 3 to 9 display the results of this analysis.

Regarding S1, nanofiltration (NF) remained the preferred technology when the grade is 0.2 and

below, as shown in Figure 3. However, reverse osmosis (RO) became the preferred technology when the grade of S1 reached 0.3. The behavior of the ranking regarding change in the grade of S1 can be graphically observed in Figure 3.

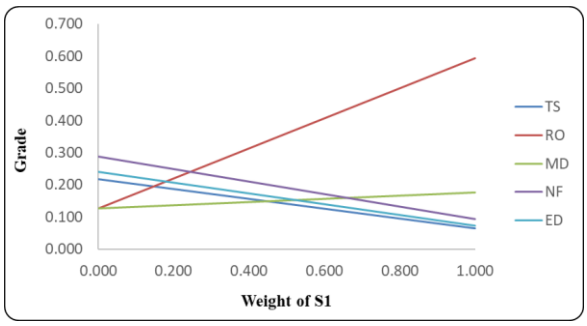

Figure 3. Sensitivity analysis for efficiency (S1). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane Distillation; NF – Nanofiltration; ED – Electrodialysis.

Nanofiltration (NF) remained the most preferred technology at a low global weight of S2, as shown in Figure 4. It was observed that thermal separation (TS) would become the most preferred technology when the weight of S2 was increased to 0.3. Thermal separation had the highest grade in terms of resistance to scaling and fouling, making it the optimal choice for this aspect. The behavior of the ranking regarding change in the grade of S2 can be graphically observed in Figure 4.

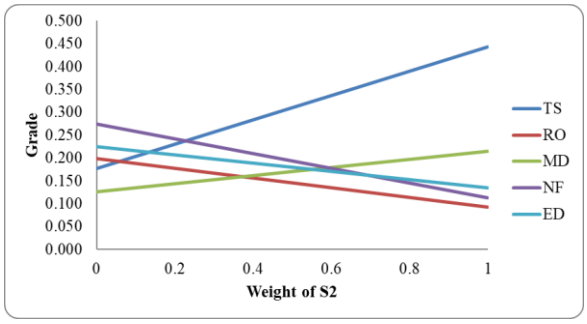

Figure 4. Sensitivity analysis for scaling and fouling (S2). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane Distillation; NF – Nanofiltration; ED – Electrodialysis.

Changes in S3 were observed to cause RO to become the optimal technology more quickly than S1, as shown in Figure 5. When the grade reached 0.2, RO became the optimal technology due to its highest score in terms of maturity. The behavior of the ranking regarding change in the grade of S3 can be graphically observed in Figure 5.

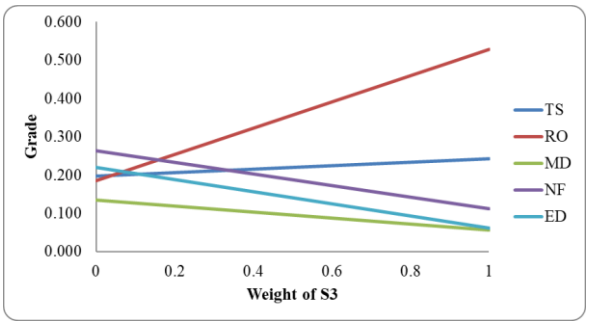

Figure 5. Sensitivity analysis for maturity of mechnology (S3). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane Distillation; NF – Nanofiltration; ED – Electrodialysis.

The optimal technology remains NF at all values of S4. However, it can be noted that membrane distillation (MD) ended up as the third technology when the global weight of S4 is set to 0.7. It occurred because the grades of TS and RO significantly decreased as S4 approached 1. The behavior of the ranking regarding change in the grade of S3 can be graphically observed in Figure 6.

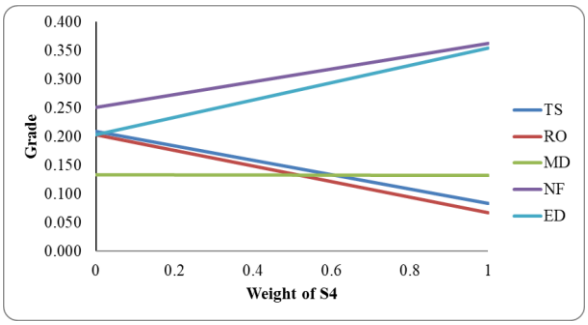

Figure 6. Sensitivity analysis for energy requirement (S4). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane distillation; NF – Nanofiltration; ED – Electrodialysis.

Thermal separation went up from the fourth position to the second when the global weight of S5 was 0.1. Eventually, it became the preferred technology when the global weight reached 0.3. It is also evident that this technology is susceptible to capital costs. This sensitivity can be explained by the significant difference in scores regarding S5. Thermal separation achieved a grade of 0.5062, whereas NF lagged with a score of 0.2877. Among the technologies, only TS exhibited a drastic change in ranking. The behavior of the ranking regarding change in the grade of S5 can be graphically observed in Figure 7.

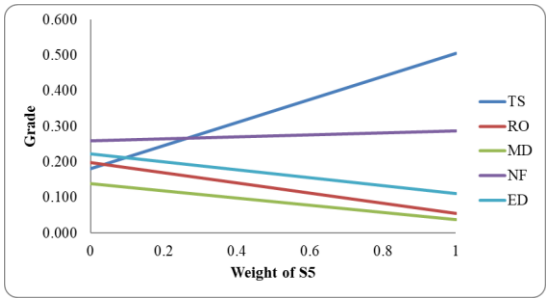

Figure 7. Sensitivity analysis for capital costs (S5). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane distillation; NF – Nanofiltration; ED - Electrodialysis.

The rankings were least sensitive to changes in S6 and C3. At all values of S6 and C3, NF remains the most preferred technology, and MD is the least preferred. It can be attributed to the grades of the technology in S6 and C3. Nanofiltration has the highest grades, with MD having the least. The behavior of the ranking regarding change in the grade of S6 and C3 can be graphically observed in Figure 8 and Figure 9, respectively.

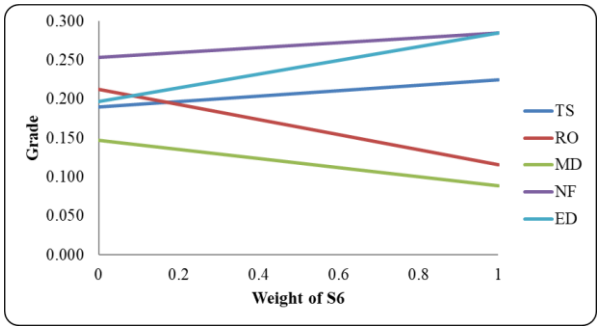

Figure 8. Sensitivity analysis for operating and maintenance cost (S6). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane distillation; NF – Nanofiltration; ED – Electrodialysis.

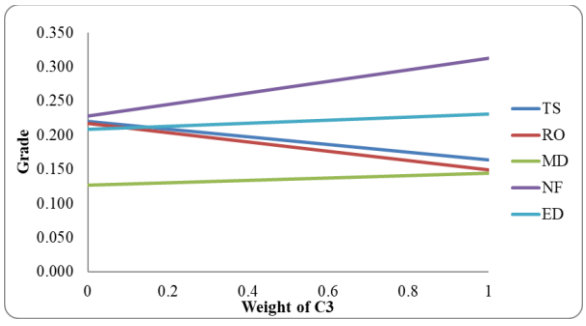

Figure 9. Sensitivity analysis for environmental aspect (C3). TS – Thermal Separation; RO – Reverse Osmosis; MD – Membrane distillation; NF – Nanofiltration; ED – Electrodialysis.

DISCUSSION

Selection of Optimal Recovery Technology

Nanofiltration achieved the highest grades in terms of energy requirement (S4), capital costs (S5), operating and maintenance cost (S6), and environmental impact (C3). Studies have supported the economic viability and environmental impact of NF. Kim et al. (2017) compared Forward Osmosis-Reverse Osmosis (FO-RO) and Forward Osmosis-Nanofiltration (FO-NF) systems, assessing the differences in their environmental and economic performances in hybrid systems. Four draw solutes were considered, namely, MgCl2, NaCl, Na2SO4, and MgSO4. It was determined that FO-RO systems are more efficient, having a consistent 99% rejection rate across all the draw solutes, unlike FO-NF systems, which have a rejection rate of 46% to 94%. However, in terms of energy requirements, the FO-RO system consumes more energy (2.75 kWh/m3) than the FO-NF system (approximately 2.25 kWh/m3) when using MgCl2 as the draw solution. Additionally, the FO-NF system showed a promising result in its global warming impact, with 2.25 kg CO2 – eq compared to FO-RO 2.75 kg CO2 – ep. Bordbar et al. (2022) used life cycle assessment (LCA) in an NF-RO process. This study compared five cases of desalination systems: recirculation multi-stage flash (R-MSF), hybrid RO/R-MSF, NF/R-MSF, single pass RO, and NF/RO system, respectively. It can be observed that nanofiltration is integrated into cases two and four to develop cases three and five. It was found that integrating NF into these processes resulted in a decrease in kg CO2 eq emissions. Integrating NF to case two resulted in a reduction from 7.39 kg CO2 eq to 6.38 kg CO2 eq. In case four, the reduction was 2.16 kg CO2 eq to 1.74 kg CO2 eq despite the addition of equipment. The decrease in these emissions can be attributed to the decrease in the use of thermal energy. Using nanofiltration causes a decrease in the reduction of pressure required in RO.

It was also noted that most of the cost in an FO-NF process can be attributed to the chemical costs. However, Corzo et al. (2018) compared FO-NF with UF-RO and noted that FO-NF costs less in terms of chemical use. FO process can cut costs since it does not require chemical cleaning. The losses in draw solute incur a significant contributor to chemical costs for an NF membrane. However, it was noted that $MgCl_2$ has a fertilizing property, which can further compensate for the costs. It was found that magnesium chloride as the draw solute would reduce operational costs. According to Dutta et al. (2019), NF can also reduce the maintenance cost.

Membrane Distillation (MD) has been ranked last, with a grade of 0.1135. MD received the lowest scores in terms of maturity (S3), capital costs (S5), and the environmental aspect (C3). Roy et al. (2018) noted

that MD is an emerging technology that can potentially replace thermal distillation processes. They mentioned ongoing studies exploring possibilities for improving the recovery rate of MD processes, which may include advancements in membrane fabrication to optimize performance. Chaoui et al. (2019) also highlighted that MD is relatively new compared to other membrane-based technologies. Using fuzzy AHP and Grey Relational Analysis, Eusebio et al. (2016) found that FO-MD scored lowest in maturity.

Cabrera-Castillo et al. (2021) conducted a comparison between Forward Osmosis-Membrane Distillation (FO-MD) and Forward Osmosis-Reverse Osmosis (FO-RO) as well as single RO systems. Their findings align with the results of this study. FO-MD was found to have higher capital costs compared to FO-RO and single-RO systems. The need for boilers influences the capital costs in FO-MD systems operating on steam, while FO-MD systems operating on thermal fluid face increased costs due to the heaters. Site development for an FO-MD system is also slightly higher compared to FO-RO.

Additionally, FO-MD membranes are estimated to be costlier due to their lesser commercialization and relative immaturity compared to FO-RO. In contrast to RO systems that rely on pressure, operation and maintenance costs in FO-MD systems were noted to be mainly associated with using steam to produce high-quality water. Although FO-RO systems require a pumping system, the cost is significantly lower than the heating used in FO-MD systems.

Given that MD is relatively new, the membrane replacement cost is significantly higher than that of other membrane systems like FO-RO. Nevertheless, this may be a temporary scenario, as the commercialization of FO-MD could reduce membrane costs. Such scenarios are not addressed in the study but offer opportunities for further exploration.

Glover et al. (2022) conducted a life cycle assessment (LCA) to compare the carbon footprint of a membrane bioreactor-membrane distillation (MBR-MD) wastewater treatment system. They compared it with a baseline system that integrated RO and UF systems. They assessed environmental impacts using the ReCiPe Midpoint (E) impact assessment method. The study found that most of the impact from the baseline and MBR-MD systems is attributable to air emissions. In the MBR-MD system, most of the impact results from the integrated MD system, although this impact has been reduced through the MBR system. The MBR-MD system exhibited a 218-1400% higher environmental impact than the baseline. However, when waste heat is used in MD, the environmental impact of the MBR-MD system is 53.7% lower than that of the baseline system, which integrates RO and UF systems. Elshafei et al. (2022) examined various AHP techniques that could be applied to optimize the establishment of green buildings. The study mentioned that they combined Life Cycle Assessment (LCA) with AHP to account for the environmental impact of each alternative.

Given that environmental impact is one of the criteria (C3) used in this study, future research could explore using AHP with LCA to select the optimal recovery technology. MD has the lowest score in terms of MD. However, there are opportunities to reduce these costs. FO-MD can operate on low-grade heat sources, such as waste heat, due to its ability to function in small temperature gradients. Industrial heat sources from nearby plants or smelters could be potential alternatives, although these need to be specified in this study. The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis could also be paired with AHP. Eusebio et al. (2016) employed Fuzzy AHP and Grey Relational Analysis (GRA). Fuzzy AHP was used to determine the weights of criteria and sub-criteria, while GRA was employed to establish the grades of the alternatives. Exploring the application of these methods in combination with AHP for future studies is worth considering, especially in determining other factors that may influence the results. It may allow the consideration of factors such as potential for improvement for technologies such as MD.

Reverse Osmosis has the highest grade in terms of efficiency and maturity. It was previously discussed that RO can function with 99% efficiency across different draw solutes, including $MgCl_2$ (Kim et al. 2017). In the study by Do Thi et al. (2021), it was highlighted that RO has the capability to produce water of high purity, removing toxic substances present in brackish water. Unlike in thermal separation, which has the lowest efficiency score, toxic materials were present, as noted by Deiling (2015). Kim et al. (2013) examined a Forward Osmosis-Thermal Separation (FO-TS) hybrid system using various draw solutes. They found that in all the draw solutes used, traces of toxic materials were found and thus resulted in undrinkable water. RO has the lowest grade regarding resistance to scaling and fouling (S2) and energy requirement; both scores can be attributed to RO operating under high pressure. Roy et al. (2018) mentioned that the pressure in the Forward Osmosis-Reverse Osmosis (FO-RO) system results in unwanted pollutants, causing scaling and fouling. Im et al. (2019) also mentioned that scaling and fouling are still problematic in RO.

Regarding S2, Im et al. (2019). also mentioned that the FO-RO system has a relatively higher energy requirement than a two-stage RO system. It agrees with the finding of Kim et al. (2017) when Forward Osmosis-Nanofiltration (FO-NF) was compared to FO-RO, noting that FO-RO consumed more energy than FO-NF. Moreover, Othman et al. (2022) mentioned that a typical RO functions at up to

1000 psi in high pressure. This condition results in high energy requirements and fouling in the membranes. Deiling (2015) mentioned that RO tends to have the most fouling (among all membrane technologies) because the hydrodynamic pressure will carry the unwanted materials on the membrane's surface. It was also noted that RO consumes energy as it functions under high pressure. Unlike in MD, the energy required in an RO system is high-grade to provide the needed pressure.

Considering its heavy reliance on expert judgment, Paulson and Zahir (1994) explored into the uncertainties that can arise in AHP. They pointed out that these uncertainties stem from both external and internal sources. External sources pertain to how value judgments were obtained, while internal sources are related to the expert's limited knowledge of the topic despite their years of experience. Recognizing these uncertainties, Finan and Hurley (1999) suggested a method known as transitive calibration. In this method, experts are asked how they would define the scale initially established by Saaty in terms of percentages. This value is then used to calibrate the rest of the expert's responses. While the method is complex and demands substantial statistical analysis, it can be used when there is no time constraint to yield results with minimal uncertainties.

Sensitivity Analysis

Sensitivity analysis was conducted to assess how rankings could shift by adjusting the overall weight of a particular sub-criteria while maintaining a consistent preference ratio for the other sub-criteria and criteria. Reverse Osmosis emerges as the preferred technology when S1 reaches 0.3 and S3 becomes 0.2. Once S2 and S5 reach 0.3, TS becomes the preferred technology. According to the results of the AHP, RO achieved the highest grade in terms of efficiency, gradually surpassing NF, which dropped to third position. Studies by Kim et al. (2017) and Bordbar et al. (2022) have noted that although NF offers advantages in environmental impact and maintenance cost, RO remains the most efficient technology.

Furthermore, RO holds a considerable advantage over other technologies in terms of efficiency. Efficiency is crucial factor in producing high-quality water. As mentioned by Do Thi et al. (2021), RO operates efficiently, even in the removal of other toxins. Reverse osmosis has established itself as the most mature technology for desalination. Chaoui et al. (2019) and Roy et al. (2018) mentioned that the RO system attracted interest due to the potential for commercializing its products. This is an example of how maturity of technology can influence its global weight, as shown by the adjustment, it only needed to reach 0.2. The preferred technology remained unchange when S4, S3, and C3 were varied, showing minimal sensitivity, with NF retaining its status as the preferred technology. As the weights of S4, S3, and C3 increased from 0 to 1, the grades of NF and ED significantly increased, allowing them to maintain their ranks. In contrast to S4, an increase in the weight of S6 led to a positive change in the grade of TS. However, this change was insufficient to surpass the increasing grades of NF and ED. When the global weight of S6 reached 1, NF and ED jointly claimed the top position both with grade of 0.2854 in maintenance and operating costs. The ranking exhibited minimal changes in response to changes in the grade of C3. It can be observed that when C3 is 0, ED ranks as the fourth technology. Eventually, it became the second preferred technology when the global weight of C3 was set to 0.2. Despite the positive changes in the grade of MD, it remained the least preferred technology. Negative changes were only observed for TS and RO. Although MD scored the lowest in C3, it demonstrated a positive change, attributed to its low scores in other criteria. As C3 approached 1, other sub-criteria approached a value of 0, including those for which MD had relatively lower scores, causing a positive change in MD.

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ETHICAL CONSIDERATIONS

No human or animals were involved or harmed in the conduct of this study.

DECLARATION OF COMPETING INTEREST

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

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Quantile regression model on how logical and rewarding is learning mathematics in the new normal

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ABSTRACT

Learning mathematics through distance education can be challenging, with the "logical" and "rewarding" nature proving difficult to measure. This article aimed to articulate an argument explaining the "logical" and "rewarding" nature of online mathematics learning, elucidating their causal factors. Existing data from the literature that involving students at Visayas State University, Philippines, were utilized in this study. The study used statistical measures to capture descriptions from the data, and quantile regression analysis was employed to forecast the predictors of the logicality and rewarding nature of learning mathematics at a distance. Results indicate that learning mathematics in the new normal is perceived as "logical" and moderately "rewarding". The regression and correlation analyses revealed a significant positive association between the perceived "logical" nature and the rewarding experience of learning mathematics. The constructed statistical models depicted that the determinants of logicality in learning mathematics include family income, money spent on the internet, learning environment, household size, social status, and health. Moreover, causal factors such as family income, money spent on the internet, learning environment, leisure activities, social status, and health significantly determine the rewarding nature of learning mathematics online. Conclusively, institution must support college students with their online learning needs. Furthermore, mathematics instructors should create lively and exciting online discussions that boost their logical thinking. Providing problem-solving task that are intrinsically rewarding can contribute to a more fulfilling learning experience.

Keywords: college students, mathematics online, statistical model, state university

INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic has adversely impacted the educational scheme, resulting to an unprecedented shift in teaching-learning methods. The abrupt transition from face-to-face learning to an online setup has posed challenges for students in comprehending their mathematics lessons (Dratva et al. 2020; El Firdoussi et al. 2020; Casinillo et al. 2022). It is worth noting that mathematics, being complex and abstract, requires excellent and clear discussions from teachers. Casinillo (2022) observed that learning mathematics during the pandemic is quite difficult because students

struggle to remember lessons and comprehend mathematical facts, formulas, and concepts due to distractions from the unprecedented events. Irfan et al. (2020) and Valenzona et al. (2022) assert that students face challenges penetrating the core of mathematics lessons, resulting in low innovativeness and misuse of technologies. In that case, cognitive thinking during online classes is negatively affected (Irawan et al. 2020). Cassibba et al. (2021) and Ní Fhloinn and Fitzmaurice (2021) depicted the numerous challenges faced by teachers in imparting knowledge to students, as they struggle to interact with and monitor students effectively. This situation leads to uninteresting class discussions, proving tedious for both mathematics teachers and their students. Hence, logicality in learning mathematics does not prevail in the process, making it an unsatisfying or unrewarding experience for students.

A logical mind is imperative for mathematics problem-solving. Being a logical student involves critical thinking to analyze mathematical problems and formulate judgments (Darmayanti et al. 2022). The development of a logical mind requires formal training in the mathematics education process and continuous interaction and assessment by mathematics instructors. However, proper guidance and constant monitoring of students' academic progress become nearly impossible due to the barriers, high complexity, and uncertainty brought about by the world health crisis (Mendoza et al. 2021; Casinillo 2023). According to Kertiyani and Sarjana (2022), it is essential to maintain the critical learning process of students despite the challenges in distance learning, allowing students to develop reasoning related to the core ideas of mathematics. Progressing in the critical thinking process enables students in online learning to enhance their problem-solving skills (Braund 2021; Festiawan et al. 2021; Keener et al. 2021; Matthews et al. 2021). Once students improve and maintain their analytical and creative perspective in learning mathematics, they can find satisfaction and enjoyment in knowledge acquisition at a distance during the pandemic (Casinillo 2022). On the face of it, students with logical experience are more likely to experience a rewarding and stimulating feeling in learning mathematics online. Valenzona et al. (2022) stated that several factors are affecting the students' innovative thinking that weakens their logical and creative ideas during the pandemic. Additionally, the enjoyment and satisfaction of students are influenced by predictive determinants during this period (Casinillo 2022). Henceforth, the conceptual scheme of this article presumes that some determinants influence the "logical" and "rewarding" nature of learning mathematics in the new normal.

Although various articles in the literature explore learning experiences in online education during the pandemic, there is a relative scarcity of focus on mathematics students in higher institutions in rural areas. Additionally, the examination of the "logical" and "rewarding" experiences of students learning mathematics online remains unexplored in the literature. Moreover, employing a statistical model in determining the determinants of the "logical" and "rewarding" experiences of mathematics students has not been studied. Hence, this article aims to fill these gaps by elucidating students' logicality and the rewarding experience of learning mathematics in the new normal. Specifically, the article seeks to achieve the following objectives: (i) present a descriptive analysis of the profiles of students and their learning experiences; and (ii) determine the statistical predictors of the "logical" and "rewarding" experiences of students using a regression model. The study aims to underscore the significance of the "logical" and "rewarding" nature of learning mathematics, which is crucial to students' cognitive behavior and well-being. Furthermore, the results may serve as benchmarks and guides for mathematics educators and students to improve their teaching and learning activities, respectively. Finally, the study's findings may contribute to global baseline information for researchers.

METHODS

Research Design

This research article employed with a correlational design to articulate an argument that depicts the students' perception of how logical and rewarding learning mathematics online is during the pandemic. A correlational design is a method of research focusing on exploring association between variables (Seeram 2019). To address the study's objectives, the article used secondary data from ongoing research in the literature, specifically, a cross-sectional survey. Additionally, this study used standard statistical measures and employed quantile regression modeling as tools to extract valuable information.

Participants and Data

This study utilized secondary data from a recent research work by Casinillo et al. (2022) titled "How challenging it is to learn mathematics online." The study focus on Mathematics in the Modern World (MMW) students at Visayas State University (VSU) during the pandemic. As VSU fully implemented online (distance) learning during this period, the survey was conducted using Google Forms, employing availability sampling. A total of 135 MMW students actively participated in the survey, with extreme (outliers) responses excluded. Additionally, only students with low to middle family income, excluding those with a family income above PHP

65,000, were considered. In that case, the study attained more or less homogeneous participants group of 129 individuals. It is worth noting that the sample sized in this article, surpassing the minimum requirement for constructing a statistically sound multiple regression model, aligns with established guidelines (Jenkins and Quintana-Ascencio 2020).

The dependent variable Casinillo (2022) study involved a challenge questionnaire featuring 3-item questions with a 1-10 scaling, addressing the logically, reward, and difficulty of learning mathematics online during the pandemic. The questionnaire underwent validation by three experts in mathematics education each holding at least a master's degree. Furthermore, a reliability test (Cronbach's alpha) yielded a coefficient of 0.91, confirming that the questionnaire is reliable to use (Cronbach 1951). This study specifically considered two dependent variables: the logical level and rewarding level. The logical level represents the students' reasoning and creative ideas in their problem-solving activities. On the other hand, the rewarding level signifies the satisfaction derived from motivation and challenge in learning mathematics. Table 1 presents the intervals for students' perception scores along with corresponding verbal descriptions of the logical and rewarding aspect of learning mathematics in the new normal.

Moreover, the independent variables considered in this current study are the following: age of MMW students (in years), sex (0 = female, 1 = male), hometown (0 = Rural, 1 = Urban), family members (count), availability of a laptop (0 = No, 1 = Yes), monthly family income (PHP), number of hours (h) spent in studying mathematics per week, and the amount of money spent on internet load (PHP per week). The study also considered questions related on a 1-10 scale that include internet signal, coping with anxieties, the conduciveness of the learning environment at home, leisure time, social relationships, and health status. These independent variables (students' demographic and learning profiles) are assumed to influence the logicality and rewarding nature of learning mathematics online during the health crisis.

Table 1. Students' perception score and its corresponding verbal description.

Students' perception score	Logical category	Rewarding category
1.00-2.80	Not logical	Not rewarding
2.81-4.60	Slightly logical	Slightly rewarding
4.61-6.40	Moderately logical	Moderately rewarding
6.41-8.20	Logical	Rewarding
8.21-10.00	Very logical	Very rewarding

Data Analysis and Statistical Model

After formatting the selected data in Microsoft Excel to fit the STATA statistical program, descriptive measures such as mean average (M), standard deviation (SD), minimum (x_{min}) value, and maximum (x_{max}) value were employed for summarization. This article also incorporated graphical representation including regression line graphs and scatter plots to enhance data interpretation. The association between the two dependent variables (logical and rewarding) was determined using Pearson correlation (r_p) and simple regression though ordinary least squares (OLS) analysis. The simple regression model is expressed as:

$$Rewarding_i = \alpha_1 + \alpha_2 Logical_i + \varepsilon_i \qquad \text{(Eq 1)}$$

Here, $Rewarding_i$ represents the level of how rewarding learning mathematics is (1 to 10 scaling), $Logical_i$ represents the level of how logical learning mathematics is (1 to 10 scaling), $i = 1, \dots, 129$ students, α_1 and α_2 define the parameters in the model (1), and ε_i represents the random error. Quantile regression was then employed to determine causal factors affecting the logicality and rewarding nature of learning mathematics online. The quantile regression model provided vital insights into these aspects across different levels (quantiles) of distribution (Koenker and Bassett 1978). In that case, the logicality and rewarding level in learning mathematics were clustered into low, middle, and high to assess further the dynamics of student's learning experience in mathematics at a distance. Hence, the regression model is postulated in the following manner:

$$Y_i^Q = \lambda_0 + \lambda_1 P_{i1} + \lambda_2 P_{i2} + \cdots + \lambda_n P_{in} + e_i \quad \text{(Eq 2)}$$

where Y_i^Q represents the quantile division (25^{th}, 50^{th}, and 75^{th}) of how logical and rewarding learning mathematics is, $i = 1, \dots, 129$ students, λ_j ($\forall j \in \{0, 1, 2, \dots, n\}$) represents the coefficients (parameters) of the model (2), where n refers to the number of independent variables, P_{ij} ($\forall j \in \{0, 1, 2, \dots, n\}$) represents the independent variables and e_i represents the remaining random error term. The regression model is tested at 1%, 5%, and 10% levels of significance considering human subject involved in this study (Valenzona et al. 2022).

Findings from ordinary least square (OLS) regression served as a baseline comparison for the constructed quantile regression models. Post-estimation techniques including or diagnostic test for includes heteroscedastic, omitted variable bias, multicollinearity, and normality of residuals, were executed to validate the model's findings and test its significance at a 5% level or less.

RESULTS

Profile of Students

Table 2 shows the demographic and learning profiles of students. The mean average age of students is approximately 19.89 (±1.78) years, hanging from the youngest at 18 years old to the oldest at 33 years old. Gender distribution indicates that 29% of students are male, while 71% are female. Only 26% percent of the students live in urban areas, while the majority (74%) reside in rural areas. On average, these students belong to the families with nearly six members (± 2.25), ranging from a minimum of two to a maximum of 12. The monthly family income varies, averaging around 15,648.29 PHP (±15,953.91 PHP), ranging from a minimum income of 880 PHP and a maximum of 65,000 PHP. On a scale of 1-10, students rate their level of engagement in leisure activities during the pandemic at 5.79, their health status at 5.13, and their social relationship status at 6.67. Fifty-seven percent of the students used laptops, while 43% used mobile phones for their mathematics online classes. Students devote approximately 5.77 h (±7.33 h) per week to studying mathematics, and their average weekly expenditure on internet is PHP 187.85 (±PHP 179.73). Rating their internet connectivity on a scale of 1 to 10, students average 5.01 (±1.74). Students report coping with mathematics anxiety at a rating of 5.17 (±1.88), while their perception of the learning environment at home is rated at 4.26 (±1.68).

Logicality and Rewarding Level in Learning Mathematics

Table 3 reveals the nature of learning mathematics online in terms of logically and rewarding experiences. The data reveal that the learning experience online is "logical", with a mean of 6.59 (SD = 2.56). However, the degree of "rewarding" is observed to be moderately rated at 6.08 (SD = 2.51). Moreover, the Pearson correlation demonstrated a significant positive association $(r_p = 0.776, P < 0.001)$ between the "logical" and "rewarding" nature of learning mathematics online during the new normal. This implies that the relationship between how logical and how rewarding learning mathematics at a distance is directly proportional. In that case, as the logical level increases, students are more likely to feel a satisfying behavior in learning, and vice versa.

Table 2. Summary of students' demographic and learning profile. a-dummy (indicator); b-count; c-Philippine Peso (PHP); d-1 to 10 scaling.

Variables	Mean (M)	Std. dev. (SD)	x_{min}	x_{max}
Demographic profile				
Age (in years)	19.89	1.78	18	33
Sex: Male[a]	0.29	0.46	0	1
Hometown: Urban[a]	0.26	0.44	0	1
Household size[b]	6.11	2.25	2	12
Monthly Family Income[c]	15648.29	15953.91	880	65000
Leisure activities[d]	5.79	2.22	1	10
Health status[d]	5.13	2.19	1	10
Social relationship status[d]	6.67	2.11	1	10
Learning profile				
Availability of laptop for online class[a]	0.57	0.49	0	1
Number of hours (h) studying (per week)[b]	5.77	7.33	1	60
Money spent for internet load (per week)[c]	187.85	179.73	0	1000
Internet connection signal[d]	5.01	1.74	1	10
Coping strategies for anxiety[d]	5.17	1.88	1	10
Learning environment (at home)[d]	4.26	1.68	1	10

Table 3. Descriptive statistics and correlation for how logical and rewarding learning mathematics online. a-1 to 10 scaling; b-see Table 1 for details, ***$P < 0.01$.

Variables	Mean	Std. dev.	Verbal interpretaion[b]	Correlation (r_p)	*P* (Two-tailed test)
Logical[a]	6.59	2.56	Logical	0.776***	< 0.001
Rewarding[a]	6.08	2.51	Moderately rewarding		

As seen in Table 4, the simple regression model ($F = 191.7, P < 0.001$) is significant at a 1% level. In addition, the model reveals a statistically sound coefficient of determination ($R^2 = 0.602$). This implies that about 60.2% of the differences in students' "rewarding" perception scores can be attributed to the students' "logical" perception scores. The model shows that for every one-unit increase in the "logical" perception score, there is a corresponding increase of 0.759 in the "rewarding" perception score, and it is significant at a 1% level. Moreover, Figure 1 shows that the regression line has an increasing trend, indicating that the slope of the line is positive.

Table 4. Simple regression on how logical and rewarding learning mathematics is (dependent variable: rewarding[a]). a-1 to 10 scaling; ***$P < 0.01$.

Regression	**Coefficient**	**Std Error**	**T-test**	***P* (Two-tailed test)**
Logical[a]	0.759***	0.055	13.85	<0.001
Constant	1.072***	0.388	2.76	0.007
R^2	0.602			
F-test computed	191.70			
P (Two-tailed test)	< 0.001			

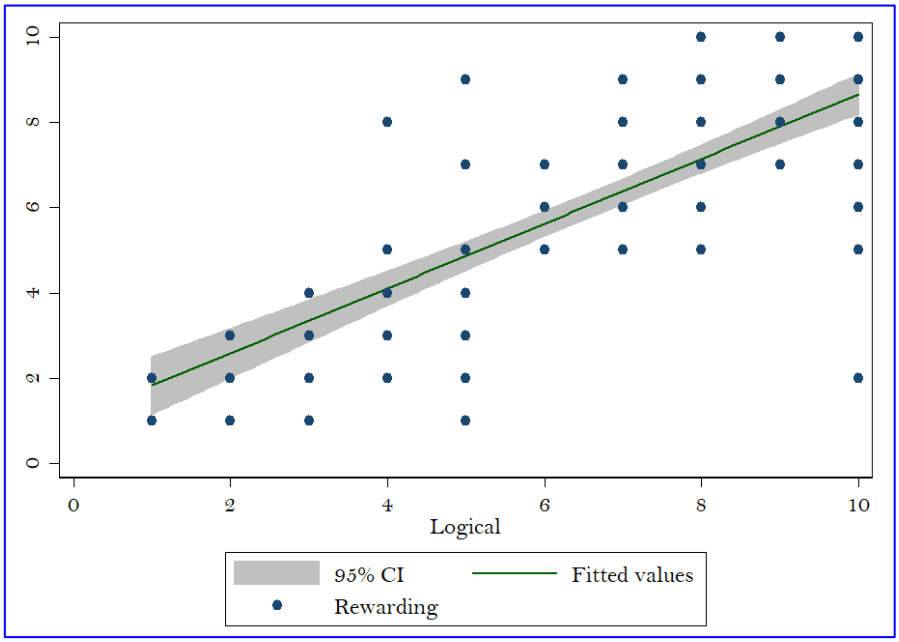

Figure 1. Regression line and scatter plot.

Regression Models for Logicality and Rewarding Level

The result of the Breusch-Pagan test reveals that the quantile and OLS models in Table 5 (dependent variable: Logical) are homoscedastic ($\chi^2 = 0.47; P = 0.494$), indicating constant variances. Additionally, no omitted variable bias ($F = 1.82; P = 0.148$) is found in quantile and OLS models based on the findings of the Ramsey RESET test. The model also does not involve multicollinearity between the independent variables, as the average variance inflation factor (VIF) is less than 10, specifically VIF = 1.56. Moreover, the residuals of the models are found to be normal ($W = 0.983; P = 0.115$) based on the result of the Shapiro-Wilk W test. Thus, the outcome in Table 5 is considered valid for interpretation and prediction, free from misleading and biased results. It is worth noting that the OLS model in Table 5 reveals a significant construct at a 1% level, indicating substantial determinants that govern the student's logicality in learning mathematics at a distance. The quantile models (25^{th} Quantile: $R^2 = 0.328$; 50^{th} Quantile: $R^2 = 0.239$; 75^{th} Quantile: $R^2 = 0.177$) and OLS model ($R^2 = 0.177$) have depicted a non-negligible coefficient of determination. The lower level (25^{th} Quantile) of logicality in learning mathematics online has the following significant determinants: family monthly income (at a 10% level), social relationship status (at a 10% level), and learning environment (at a 10% level). No significant factors

are found in the middle level (50th Quantile) of logicality. For the high level (75th Quantile) of logicality, it is depicted that the only significant determinant is the amount of money spent on internet load (at a 10% level). Moreover, the OLS model reveals that the following determinants of logicality are significant: household size (at a 5% level), health status (at a 10% level), money spent on internet load (at a 10% level), and learning environment (at a 10% level).

Table 5. Quantile and OLS regression models on how logical learning mathematics is and its predictors. a-dummy (indicator); b-count; c-Philippine Peso (PHP); d-1 to 10 scaling; Standard errors are enclosed with parenthesis; *$P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ns-not significant.

Independent Variables	Regression Models (Dependent variable: Logical)			
	25th Quantile	50th Quantile	75th Quantile	OLS
Age (in years)	-0.228ns (0.218)	-0.105ns (0.216)	0.002ns (0.245)	-0.055ns (0.123)
Sex: Male[a]	-0.081ns (0.818)	-0.068ns (0.814)	-0.915ns (0.694)	-0.248ns (0.486)
Hometown: Urban[a]	-0.106ns (0.409)	0.366ns (0.632)	1.018ns (0.886)	0.199ns (0.485)
Household size[b]	0.094ns (0.109)	0.119ns (0.183)	0.292ns (0.203)	0.217** (0.096)
log (Monthly Family Income[c] +1)	1.264* (0.731)	0.759ns (0.588)	0.308ns (0.981)	0.784ns (0.563)
Leisure activities[d]	0.079ns (0.136)	0.301ns (0.254)	0.121ns (0.196)	0.129ns (0.134)
Health status[d]	0.056ns (0.227)	0.278ns (0.231)	0.199ns (0.240)	0.206* (0.135)
Social relationship status[d]	0.396* (0.228)	0.177ns (0.299)	0.223ns (0.351)	0.227ns (0.162)
Availability of laptop for online class[a]	0.648ns (0.711)	0.381ns (0.583)	-0.503ns (0.663)	0.105ns (0.473)
Number of hours (h) studying (per week)[b]	0.017ns (0.030)	-0.003ns (0.048)	-0.028ns (0.037)	-0.008ns (0.028)
log (Money spent for internet load (per week)[c] +1)	-0.141ns (0.412)	0.101ns (0.519)	0.836* (0.537)	0.682* (0.484)
Internet connection signal[d]	0.116ns (0.223)	-0.033ns (0.147)	0.129ns (0.197)	0.104ns (0.134)
Coping strategies for anxiety[d]	0.083ns (0.149)	0.138ns (0.184)	0.053ns (0.253)	0.141ns (0.118)
Learning environment (at home)[d]	0.289* (0.149)	0.226ns (0.161)	-0.033ns (0.120)	0.192* (0.143)
Constant	-1.733ns (5.701)	-1.691ns (5.055)	-0.026ns (6.150)	-3.607ns (3.585)
Number of Participants	129	129	129	129
F-test	-	-	-	3.95***
P (Two-tailed test)	-	-	-	< 0.001
R-squared	-	-	-	0.327
Pseudo R-squared	0.328	0.239	0.177	-

The result of Breusch-Pagan test reveals that the quantile and OLS models in Table 6 (dependent variable: Rewarding) are not heteroscedastic ($\chi^2 = 3.31$; $P = 0.069$); hence, the variances are constant. In addition, no omitted variable bias ($F = 1.29$; $P = 282$) is detected for both quantile and OLS models based on the Ramsey RESET test findings. The average variance inflation factor (VIF) value indicated that the models (quantile and OLS) did not have a multicollinearity problem ($\text{VIF} = 1.56 < 10$) between the independent variables. The Shapiro-Wilk W test reveals that the residuals of the models (quantile and OLS) are normal ($W = 0.983$; $P = 0.103$). Conclusively, the results of the models in Table 6 are valid for interpretation and conclusion. The OLS model reveals a significant construct at a 1% level (Table 6), signaling significant factors affecting the students' reward level in learning mathematics online. Table 6 presents that the quantile models (25th Quantile: $R^2 = 0.345$; 50th Quantile: $R^2 = 0.270$; 75th Quantile: $R^2 = 0.126$) and OLS model ($R^2 = 0.336$) portray non-minimal goodness of fit. Hence, the lower level (25th Quantile) of rewarding level in learning mathematics online depicts the following significant determinants: family monthly income (at a 10% level), leisure activities (at a 5% level), health

status (at a 10% level), social relationship status (at a 1% level), and money spent for internet load (at a 10% level). Health status (at a 10% level) and social relationship status (at a 1% level) are the significant factors found in the middle level (50th Quantile) of the rewarding level. Furthermore, in the high level (75th Quantile), it is depicted that only social relationship status (at a 10% level) is a significant factor. The OLS model discloses that the following determinants of rewarding level, which include leisure activities (at a 10% level), social relationship status (at a 1% level), money spent for internet load (at a 10% level), and learning environment (at a 10% level) are significant factors.

Table 6. Quantile and OLS regression models on how rewarding learning mathematics is and its predictors. a-dummy (indicator); b-count; c-Philippine Peso (PHP); d-1 to 10 scaling; Standard errors are enclosed with parenthesis; $*P < 0.10$; $**P < 0.05$; $***P < 0.01$, ns-not significant.

Independent Variables	Regression Models (Dependent variable: Rewarding)			
	25th Quantile	50th Quantile	75th Quantile	OLS
Age (in years)	-0.024ns (0.235)	-0.096ns (0.287)	-0.029ns (0.199)	-0.026ns (0.119)
Sex: Male[a]	-0.351ns (0.604)	0.114ns (0.948)	0.363ns (0.966)	-0.012ns (0.473)
Hometown: Urban[a]	-0.454ns (0.500)	0.447ns (0.605)	0.457ns (0.784)	0.116ns (0.472)
Household size[b]	-0.089ns (0.139)	-0.056ns (0.109)	0.136ns (0.179)	0.022ns (0.093)
log (Monthly Family Income[c] +1)	1.079* (0.705)	0.995ns (0.781)	0.208ns (0.601)	0.642ns (0.547)
Leisure activities[d]	-0.433** (0.201)	-0.317ns (0.233)	-0.221ns (0.177)	-0.226* (0.130)
Health status[d]	0.298* (0.192)	0.238* (0.122)	0.056ns (0.187)	0.164ns (0.131)
Social relationship status[d]	0.668*** (0.241)	0.827*** (0.279)	0.545* (0.345)	0.513*** (0.158)
Availability of laptop for online class[a]	-0.107ns (0.573)	-0.397ns (0.855)	-0.445ns (1.089)	0.171ns (0.461)
Number of hours (h) studying (per week)[b]	0.024ns (0.032)	0.026ns (0.039)	-0.002ns (0.037)	0.003ns (0.027)
log (Money spent for internet load (per week)[c] +1)	1.302* (0.855)	-0.049ns (0.908)	-0.005ns (0.599)	0.756* (0.471)
Internet connection signal[d]	0.094ns (0.267)	-0.126ns (0.167)	-0.109ns (0.285)	0.072ns (0.130)
Coping strategies for anxiety[d]	0.156ns (0.134)	0.106ns (0.145)	0.218ns (0.163)	0.159ns (0.115)
Learning environment (at home)[d]	0.194ns (0.194)	0.220ns (0.188)	0.128ns (0.215)	0.261* (0.139)
Constant	-6.804ns (5.923)	-1.457ns (7.398)	2.802ns (5.197)	-3.095ns (3.488)
Number of Participants	129	129	129	129
F-test	-	-	-	4.12***
P (Two-tailed test)	-	-	-	< 0.001
R-squared	-	-	-	0.336
Pseudo R-squared	0.345	0.270	0.126	-

DISCUSSION

Profile of Students

The results indicated that the majority of MMW students are freshmen. According to Casinillo et al. (2022), MMW students are typically first-year students since the MMW course is designated to be taken in their first-year curriculum. The mean average age of first-year students was close to 20. The findings reveal that most MMW students are female. Balakrishnan and Low (2016) study suggested that addressing the shortage of female students in science and engineering careers could be achieved by increasing their enrollment in mathematical courses. Most students reside in rural areas, consistent with the study by Casinillo (2022), indicating that a number of students of VSU come from remote regions in the province of Leyte. Consequently, many of these students face challenges related to internet

connectivity, contributing to struggles in coping with mathematical anxiety. Additionally, they experience a stressful learning environment at home due to distractions and boredom. Irfan et al. (2020) and Casinillo (2023) portray that students are challenged in doing their mathematics activities due to the limitations of the learning setup during the pandemic. Most of these students struggle to acquire advanced gadgets and financial support for online learning since they come from low-income families. Adhe et al. (2020) state that COVID-19 is also an economic crisis since most of the parent's income is decreasing due to job cuts resulting from the health protocol restrictions. Furthermore, due to the lockdowns and health restrictions, students' health and social status are declining due to inactivity and fewer leisure activities. Dratva et al. (2020) portray that the pandemic causes mental health problems, depression, stress, and anxiety in students due to difficulties and obstacles in distance education.

Logicality and Rewarding Level in Learning Mathematics

Learning mathematics at a distance is considered logical and moderately rewarding. In this case, students are somehow penetrating their lessons in mathematics applying reasoning and critical thinking in their learning activities. Kertiyani and Sarjana (2022) portray that logical and critical thinking are vital components that need to be developed during the pandemic to maintain excellent student problem-solving skills. In addition, students find learning mathematics online moderately satisfying and valuable in their student's life. Hence, they are still motivated and find the subject rewarding since it is part of their curriculum. However, the moderately rewarding result is a consequence of the barriers and limitations of distance education. The result above is parallel to the findings of Gustiani (2020) and Casinillo (2023), who found that students during the new normal have experienced moderate motivation, satisfaction, and self-efficacy in learning mathematics. The findings have revealed a positive correlation between how logical and rewarding learning mathematics is. Thus, as students are involved in creating logical ideas in mathematics activities, they feel satisfied and find mathematics exciting, and the other way around. The study by Spitzer and Musslick (2021) portray that it is necessary to give engaging activities in mathematics to motivate students to create new ideas that develop their cognitive thinking.

Regression Models for Logicality and Rewarding Level

The quantile regression revealed that the lower logical and rewarding level in learning mathematics are influenced by family income. Thus, students are motivated to learn mathematics during the pandemic if they do not have financial problems. In the study of Casinillo et al. (2022), students are eager and stimulated to study mathematics if they have the materials, suitable technology, and good internet connections needed for online learning. Social relationships also influence the lower logical and rewarding levels. So, chatting and spending time with co-students and loved ones will inspire them to learn mathematics despite the challenges brought by the pandemic. According to the studies of Elmer et al. (2020) and Baber (2021), students' social interaction will help them cope with anxiety, progress in their learning process, and positively influence their well-being.

Another significant determinant of how logical and rewarding learning mathematics is the students' learning environment at home. This result is consistent with the findings of Casinillo (2022), which stated that students' learning environment is a significant factor that influences concentration in an online class. Likewise, Bahian et al. (2020) portray that a conducive learning environment will give students a relaxing learning process that can enhance their cognitive thinking and be satisfied with learning at a distance. Family income and money spent on the internet load are causal factors of logicality and reward (both low and average) levels in learning mathematics online. Thus, students with enough financial assistance and resources in their online learning tend to perform better, penetrating their lessons more effectively, and are more likely to be satisfied. Adhe et al. (2020) and Casinillo et al. (2022) depict that most students are not performing well during online learning since they have difficulty acquiring suitable technologies and other vital needs.

On average, health is a significant factor in logicality in learning mathematics. Hence, if the student is healthy both mentally and physically, students tend to have more creative and logical ideas in the learning process. Also, the health aspect of a student positively influences the reward level of learning mathematics online. Holm-Hadulla et al. (2021) portray that mental health is a strong predictor of the well-being of students and their interest in learning online. Lastly, lower levels of leisure activities can impart a coping mechanism and positively influence their satisfaction with learning because students can focus and concentrate on their lessons. So, to give more time to education and avoid distraction, students may have to diminish leisure activities, resulting in peace of mind and a gratifying occurrence in learning mathematics online (Jaskulska et al. 2022).

Conclusively, the Philippine government must support college students by providing their needs and other resources for online learning. Additionally, mathematics teachers must encourage students to

develop a good foundation of study habits and time management despite the challenges of stimulating cognitive and analytical thinking. Moreover, teachers must create a lively and motivating online class to boost their creative and logical thinking and give problem-solving tasks that are rewarding and suitable to accomplish in the required time. The study suggests that a similar study must be conducted with prominent participants in remote universities and incorporate variables in coping strategies and perceived stress as possible limitations of the current article.

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ETHICAL CONSIDERATIONS

For the students below 18 years old, a consent statement form was secured.

DECLARATION OF COMPETING INTEREST

The author declares that there is no competing interests exist.

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Problem-solving difficulties, performance, and differences among preservice teachers in Western Philippines University

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ABSTRACT

The ability to solve problems is a prerequisite in preparing mathematics preservice teachers. This study assessed preservice teachers' problem-solving difficulties and performance, particularly in worded problems on number sense, measurement, geometry, algebra, and probability. Also, academic profile differences in the preservice teacher's problem-solving performance and common errors were determined. A descriptive-comparative research design was employed with 158 random respondents. Data were gathered face-to-face during the first semester of the school year 2022-2023, and data were analyzed with the aid of *jamovi* software, ensuring ethical measures. Overall findings revealed that the preservice teachers experienced average difficulty in solving problems. The low performance of the preservice teachers on the given problems was also demonstrated. Further analysis revealed a significant difference between the preservice teachers' problem-solving performance based on their subject preference and program. Moreover, the error analysis revealed that the preservice teachers incurred comprehension errors in misrepresentation, misinterpretation, and miscalculation. These results will serve as a measure for policymakers and curriculum developers of the teacher education institution concerned to make relevant enhancements to the math courses offered in the elementary and secondary education programs.

Keywords: educational research, mathematics education, teacher education, word problems

INTRODUCTION

Problem-solving is vital in building a solid foundation for quality mathematics education. It enhances students' thinking skills to discover and formulate new things, an activity that implicates mathematics into related real-life problems and situations. Problem-solving as a mathematical task provides academic challenges for enhancing students' mathematical understanding and development (Novita et al. 2012; Pentang 2019). A crucial process necessary in teaching and learning mathematics is interpreting the problem presented as text and applying different mathematical concepts. The goal of

teaching mathematical problems is for the students to develop a generic ability to solve real-life problems and apply mathematics in real-life situations (Gurat 2018; Mariano-Dolesh et al. 2022).

Solving mathematical problems is a logical process that employs induction, deduction, and algorithm, specifying the requirements and steps to solving the problem or designing a strategy unique to the learners (Aljaberi and Gheith 2016), which is often linked to metacognition (Andres 2022). The current study focused on the preservice teachers' problem-solving abilities and deemed problem-solving models for their students. Since preservice teachers are students currently enrolled and practicing teaching preparation programs and are considered future educators, they are responsible for engaging in professional experience with dedication. Thus, exploring their problem-solving skills and performance is necessary, especially those engaging preservice teachers in problem-solving experiences that could deepen their understanding and creativity (Nielsen and Bostic 2020). Once the preservice teacher engages in more problem-solving opportunities, they become more expert in interpreting variables, symbols, and equations to illustrate mathematically the problems that eventually help them provide the appropriate solution. It is crucial for preservice teachers, who will be the knowledge facilitators in the future, to at least train them to appropriately respond to various complex problem-solving tasks and prepare them to apply the concept of mathematics correctly. Prepare them for actual teaching and enhance their critical thinking and problem-solving skills since there is a significant possibility that the students can also adopt these skills. Using real-world problems to improve students' mathematical thinking and literacy is essential (Gurat 2018; Pentang 2019; Mariano-Dolesh et al. 2022).

Preservice teachers can teach their future students cognitive problem-solving strategies such as rehearsal, elaboration, and organization, and metacognitive strategies such as critical thinking, self-regulation, planning, monitoring, and evaluating methods (Gurat 2018; Pentang 2019). Preservice preparation is the foundation for successful mathematics instruction; nevertheless, it covers only a trivial portion of what teachers will need to know and be able to do effectively during their careers. However, more focus is needed on future mathematics educators because they still lack the depth of conceptual understanding and problem-solving abilities required to effectively teach their future students (Berenger 2018; Mariano-Dolesh et al. 2022). Preservice teachers' way of facilitating mathematical learning impacts students' mathematics achievement, and solving problems may cause long-term student development issues. Mathematics' deficient performance can be traced to teachers' failure to impart students' necessary knowledge, skills, attitudes, and values. This part forms the rationale that focuses on preservice teachers who will be future math teachers. Evaluating the problem-solving performance of preservice teachers is essential to determine what, when, and how to generate action that can help them improve their skills while studying. Teachers with limited mathematics instruction indicate they will transfer the same to their students. It seems to sense that aspiring teachers who lack a solid foundation in mathematics will have students who are similarly underprepared for the classroom (Mariano-Dolesh et al. 2022).

Mathematics teachers are the key to accomplishing the goal of the K-12 mathematics curriculum to develop problem-solving skills among Filipino youths. They are expected to teach more complex concepts to diverse learners utilizing active learning methodologies geared to enhance understanding in response to the K-12 curriculum. Current changes in mathematics education also encourage teachers to create environments where students explore, discuss, and work together to solve complex problems and develop their mathematical reasoning. Thus, two primary education goals for mathematics were developed as part of the K-12 mathematics Curriculum to support the conceptual framework of mathematics education, including problem-solving and critical thinking skills. Problem-solving skills are essential for preservice teachers; however, several studies have shown that Filipino preservice teachers must develop this skill further. Pelingon (2019), Pentang (2019), Andrade and Pasia (2020), and Andres (2022) posited that preservice teachers in the Philippines exhibited low to fair performance in word problems due to poor math content knowledge and inadequate problem-solving skills. This was agreed by a comprehensive international study where Filipino preservice teachers' mathematics abilities are at par compared to other 16 countries (Tatto and Senk 2011). These alarming trends among preservice teachers hinder the country's future of credible and quality mathematics education.

Furthermore, the study was anchored on constructivist learning theory, which provides guidance and a theoretical foundation to address the study's objectives. Constructivism suggests that acquiring knowledge is a collaborative endeavor that involves interpreting and integrating new information with pre-existing cognitive structures (Tobin 1994). Transmitting knowledge from a teacher to a student is not a direct process. Instead, a teacher facilitates the construction of specific experiences by assigning activities to students. The objectives and aspirations of a constructivist approach entail fostering self-directed learning among students, promoting their autonomy, facilitating the acquisition of comprehensive comprehension of concepts, and encouraging the

formulation and pursuit of significant inquiries. In the present study, the constructivist learning approach proposes that preservice students acquire and enhance their critical thinking abilities by solving real-world problems.

The literature cited mentioned theoretical and scientific underpinning to support the need for problem-solving enhancement among preservice teachers. However, more written accounts must explore the preservice teachers' problem-solving performance regarding number sense, measurement, geometry, algebra, and statistics (Pentang 2019), particularly in the Western Philippines. Thus, this study aimed to determine the specific academic profile of the preservice teachers that possibly influence their performance in solving problems, impacting their preparedness for teaching mathematics. It is a comprehensive endeavor to study preservice teachers' academic profile (such as campus, program, type of high school attended, and subject preference) and how it relates to their problem-solving abilities. These factors collectively contribute to educational equity and access, guiding curriculum and pedagogical relevance and informing policy decisions.

Besides, the study explored their problem-solving difficulties and common errors. The teacher education institution concerned may find the study helpful in conducting similar works exploring future math teachers' preparedness at the elementary and secondary levels. The findings of this study will offer insights that will benefit teacher educators in understanding students' challenges and experiences with problem-solving; as a result, they will serve as a basis for proposing strategies that will effectively improve the preservice teachers' [(Bachelor of Elementary Education (BEEd) and Bachelor of Secondary Education (BSEd) major in Mathematics students)] problem-solving skills. Further study ramifications are deemed to address the underperformances of young Filipinos in Mathematics revealed in the National Achievement Test results and by several international studies such as Trends in International Mathematics and Science Study and Program for International Student Assessment.

The study inquired about the problem-solving performance of preservice teachers. Specifically, this aimed to answer the following questions:

1. What problem-solving content areas are difficult?
2. What are preservice teachers' problem-solving performance levels on number sense, measurement, geometry, algebra, statistics, and probability problems?
3. When grouped according to their academic profile, do significant differences exist in the preservice teachers' problem-solving performance?
4. What are the common errors in the preservice teachers' solutions to word problems?

METHODS

Research Design

A descriptive-comparative research design was employed to address the study's objectives. The descriptive phase described the preservice teachers' difficulty level and problem-solving performance in mathematics, mainly in number sense, measurement, geometry, algebra, statistics, and probability, including the common errors they encountered. Meanwhile, the comparative part investigated the statistical differences between the problem-solving performance of preservice teachers in mathematics and when grouped according to their academic profile (campus, program, type of high school attended, and subject preference).

Respondents and Sampling Procedures

The respondents were preservice teachers, specifically the second-, third-, and fourth-year teacher education (BEEd and BSEd) students taking mathematics education courses at Western Philippines University. Simple random sampling was used based on the shared traits and profiles in determining the respondents since they belong to the same sampling frame. Before obtaining the sample from a population, it is imperative to possess a sampling frame, which serves as a means of identifying and locating the sampling units within the population (Gregoire and Valentine 2008). Also, it is essential to note that using a simple random sampling technique is feasible for selecting individuals from a population that solely possesses an area sampling frame (West 2016). Thus, a sample (n) of 158 (N = 267) preservice teachers participated in the study (Table 1). While the sample size exceeds that of several related studies (Gurat 2018; Pentang 2019; Andrade and Pasia 2020; Andres 2022; Mariano-Dolesh et al. 2022) that investigated the problem-solving performance of preservice teachers in various regions of the country, the importance of a large sample size must be acknowledged in ensuring the rigor and generalizability of the findings.

It was ensured that the respondents understood the study's intent and the data collection process. The respondents were informed of what to do and had their permission or consent to answer the survey voluntarily. The researchers also ensured that the data collected would not be subjected to any data exploitation and would remain confidential to ensure their information was safe and protected. Participation or not of the preservice teachers does not affect their class standing.

Table 1. Respondents of the study. Note: *n* = sample size.

Academic Profile	Frequency (*n* = 158)	Percentage (%)
Campus		
Puerto Princesa	68	43.04
Aborlan	90	56.96
Program		
BEED	88	55.70
BSED	70	44.30
Type of High School Attended		
Public	100	63.29
Private	58	36.71
Subject Preference		
Mathematics	72	45.57
Other Subjects	86	54.43

Instrumentation

The researchers adapted the problem-solving items by Pentang (2019). The researcher modified the problem-solving questionnaire to fit the study's purpose better and make it more comprehensible among the respondents of the present study. It comprises 25 multiple-choice items subjected to item analysis after the pilot testing. Still, the preservice teachers were expected to show their complete solutions before choosing an option from the distracters provided. The instrument determined skills in the preservice teachers' mathematical problems in number sense, measurement, geometry, algebra, and statistics. The Cronbach alpha obtained was excellent: number sense ($\alpha = 0.90$), measurement ($\alpha = 0.92$), geometry ($\alpha = 0.90$), algebra ($\alpha = 0.91$), and statistics and probability ($\alpha = 0.94$), indicating the instrument is reliable (Cronbach 1951). The results suggested notable reliability and internal consistency, as demonstrated by Cronbach's alpha coefficient, ranging from 0.90 to 0.94. It is recommended to employ instruments with higher Cronbach alpha in research pursuits, as they tend to demonstrate decreased measurement error and augment statistical power in diverse research settings (Heo et al. 2015). The instrument underwent expert evaluation. Three mathematics faculty researchers, each holding a doctoral degree, were carefully selected from various academic institutions. These experts collectively possessed a decade of experience teaching mathematics at the tertiary level and a research background. They also actively participated in the evaluation of the outputs. This approach aligns with established research guidelines, emphasizing involving at least three experts in the respective field to ensure content validity (Shrotryia and Dhanda 2019). As a result of this thorough assessment, it was conclusively demonstrated that the instrument upholds its validity.

Data Collection and Analysis

Before administering the questionnaire, the respondents signed a consent form in compliance with the Data Privacy Act of 2012, emphasizing the confidentiality and anonymity of the collected data. Before administration, the respondents were given an orientation regarding the research objectives. They were then instructed to read the directions thoroughly and respond honestly to each item. Ethical factors included conflict of interest, privacy confidentiality and data protection, risk and benefit ratio, informed consent, and terms of reference. The questionnaire was administered face-to-face in the middle of the first semester (SY 2022-2023). The data were gathered over five days (from Monday to Friday) after classes so they would not experience fatigue from solving word problems.

Frequency distribution was used to organize and present the academic profile of the preservice teachers. Also, the level of difficulty in solving problems was determined. The difficulty level was reported as a proportion or percentage, ranging from 0 to 100 percent. The following verbal interpretation was used: very easy (90% to 100%), easy (70% to 89%), average (40% to 69%), difficult (20% to 39%), and very difficult (0% to 19%), which was based on Crocker and Algina (1986). In contrast, arithmetic means and standard deviation were used to determine the level of their problem-solving performance. At an alpha level of 0.05, differences in the problem-solving performance of the preservice teachers based on their academic profile were conducted using an independent samples t-test. Assumption tests for normality and homogeneity of variance were conducted using Shapiro-Wilk and Levene's, respectively, finding no violations ($P > 0.05$). The descriptive and inferential statistics and assumptions testing was conducted using *jamovi* (The jamovi project 2021).

On the other hand, error analysis was conducted to look for common mistakes in the preservice teachers' work. This was conducted to validate the problem-solving difficulties and performance of the preservice teachers. Three math instructors from several teacher education institutions

locally and abroad served in determining the errors incurred.

RESULTS

Difficulties Incurred in Problem-solving by the Preservice Teachers

The preservice teachers faced difficulty with the problem-solving items provided, with only 45 percent responding correctly (Table 2). This is far below the 90 percent or better performance. The overall result manifests that they encountered problems involving number sense, measurement, geometry, algebra, and statistics. Specifically, most of them needed help to respond correctly to difficult (6, 8, 9, 10, 12, 15, 17, 18, 19, and 20) and very difficult questions (11, 13, and 14), which fall under measurement, geometry, and algebra.

Table 2. Difficulty level of the respondents and the percentage of their correct responses. Note: 90-100 = Very Easy; 70-89 = Easy; 40-69 = Average; 20-39 = Difficult; 0-19 = Very Difficult

Item Number	Correct Responses	Difficulty Index (%)	Item Domain	Difficulty Level
1	70	88.60	Number Sense	Easy
2	62	79.48		Easy
3	37	46.83		Average
4	64	81.01		Easy
5	68	86.09		Easy
6	30	37.97	Measurement	Difficult
7	55	69.62		Average
8	20	25.32		Difficult
9	23	29.11		Difficult
10	17	21.52		Difficult
11	10	12.66	Geometry	Very Difficult
12	23	29.11		Difficult
13	15	18.99		Very Difficult
14	15	18.99		Very Difficult
15	29	36.71		Difficult
16	35	44.30	Algebra	Average
17	31	39.24		Difficult
18	20	25.32		Difficult
19	25	31.65		Difficult
20	17	21.52		Difficult
21	41	51.90	Statistics and Probability	Average
22	43	54.43		Average
23	55	69.62		Easy
24	35	44.30		Average
25	50	63.29		Average
Overall Difficulty		**45.10**		**Average**

Problem-Solving Performance of the Preservice Teachers

Findings show that the preservice teachers have poor problem-solving performance, with an overall mean of 0.45 and a standard deviation of 0.16 (Table 3). Further analysis found that the preservice teachers performed satisfactorily in the number sense ($\bar{x}$ = 0.71, *SD* = 0.43). The preservice teachers performed very satisfactorily in addition, subtraction, and whole numbers ($\bar{x}$ = 0.84, SD = 0.30) and fraction, percentage, and multiple operations ($\bar{x}$ = 0.84, *SD* = 0.27). Meanwhile, they perform poorly in multiplication, division, ratio, and proportion ($\bar{x}$ = 0.47, *SD* = 0.50).

Regarding the measurement, the preservice teachers' performance results were below expectations ($\bar{x}$ = 0.42, *SD* = 0.48), indicating their poor ability to employ measurement concepts. Specifically, the future teachers performed poorly in the perimeter of a square, conversion from inches to feet ($\bar{x}$ = 0.34, *SD* = 0.40), and in the volume of a prism, conversion from meters to liters ($\bar{x}$ = 0.23, *SD* = 0.32), except for determining the area and conversion of a rectangle ($\bar{x}$ = 0.70, *SD* = 0.46) in the context of real-world mathematics problems whose recorded performance outcome was unsatisfactory.

Concerning geometry, the preservice teachers performed unsatisfactorily ($\bar{x}$ = 0.22, *SD* = 0.44). This result reveals how a preservice teacher's low score issue in one domain can affect their overall performance in mathematics. The difficulty of the items is relatively severe; thus, while a few people

could provide the correct answer, the majority struggled. Specifically, the preservice teacher performed unsatisfactorily on the items about finding the area of a plane inscribed in solid ($\bar{x}$ = 0.28, *SD* = 0.33). Meanwhile, they performed poorly on the items relevant to the diagonal of a plane and solid figure ($\bar{x}$ = 0.13, *SD* = 0.33) and the hypotenuse of a right triangle ($\bar{x}$ = 0.24, *SD* = 0.35).

Similarly, they performed poorly in algebra ($\bar{x}$ = 0.32, *SD* = 0.32). This result indicates that their performance in algebra was below average to the desired level. Many gave incorrect answers. This implies that their understanding of mathematical ideas and the basis for approaching issues that can be employed in this context is weak. The preservice teacher performed below expectations, specifically in both presenting and solving equations in one unknown ($\bar{x}$ = 0.33, *SD* = 0.33), analyzing mathematical equations in one unknown ($\bar{x}$ = 0.32, *SD* = 0.47), and solving mathematical relationships in one unknown ($\bar{x}$ = 0.32, *SD* = 0.27) and labeled as poor performance.

Finally, in statistics and probability, the preservice teachers performed poorly ($\bar{x}$ = 0.59, *SD* = 0.50). The items divided into categories, reflected various learning situations that preservice teachers navigated. It indicates that preservice teachers need to be more competent to successfully teach statistics and probability as the topic of their instructional plan. Results revealed that the performance was poor in solving the problem intended for examining the ability of preservice teachers to use the language of chance in estimating the probabilities ($\bar{x}$ = 0.54, *SD* = 0.40), and determining probabilities by applying an empirical formula ($\bar{x}$ = 0.54, *SD* = 0.30) while making predictions and using theories of probabilities ($\bar{x}$ = 0.70, *SD* = 0.46) they performed unsatisfactory.

Table 3. Preservice teachers' problem-solving performance. Note: 0.91-1.00 = Excellent; 0.81-0.90 = Very Satisfactory; 0.71-0.80 = Satisfactory; 0.61-0.70 = Unsatisfactory; 0.00-0.60 = Poor

Content Area	Mean	SD	Description
Number Sense	0.71	0.43	Satisfactory
1. Addition, subtraction, and whole numbers.	0.84	0.30	Very Satisfactory
2. Multiplication, division, ratio, and proportion.	0.47	0.50	Poor
3. Fraction, percentage, and multiple operations.	0.84	0.27	Very Satisfactory
Measurement	0.42	0.48	Poor
4. Perimeter of a square, conversion from inches to feet.	0.34	0.40	Poor
5. Area of a rectangle,	0.70	0.46	Unsatisfactory
6. Volume of a prism, conversion from meters to liters.	0.23	0.32	Poor
Geometry	0.22	0.44	Poor
7. Area of a plane inscribed in solid.	0.28	0.33	Poor
8. Diagonal of a plane and solid figure.	0.13	0.33	Poor
9. Hypotenuse of the right triangle.	0.24	0.35	Poor
Algebra	0.32	0.32	Poor
10. Representing and solving equations in one unknown.	0.33	0.33	Poor
11. Analyzing mathematical situations in one unknown.	0.32	0.47	Poor
12. Solving mathematical relationships in one unknown.	0.32	0.27	Poor
Statistics and Probability	0.59	0.50	Poor
13. Using the language of chance in estimating probabilities.	0.54	0.40	Poor
14. Determining probabilities applying an empirical formula.	0.54	0.30	Poor
15. Making predictions and using theories of probability.	0.70	0.46	Unsatisfactory
Overall Performance	**0.45**	**0.16**	**Poor**

Academic Profile Differences in the Preservice Teachers' Problem-Solving Performance

An independent sample t-test was conducted to determine the significant differences in the problem-solving performance of the preservice teachers based on their academic profiles (Table 4). Regarding the campus attended, no significant difference was found between the problem-solving performance of the preservice teachers (t = -0.16, P > 0.05). This indicates that students from the Puerto Princesa Campus ($\bar{x}$ = 0.45, *SD* = 0.23) performed similarly to the Aborlan Campus ($\bar{x}$ = 0.44, *SD* = 0.15). It was also found that the preservice teachers that attended public ($\bar{x}$ = 0.50, *SD* = 0.56) and private ($\bar{x}$ = 0.41, *SD* = 0.20) high schools had no significant difference in problem-solving performance, t = 0.43, P > 0.05.

Besides, a significant difference was found between the problem-solving performance of the preservice teachers enrolled in the BSEd program. Preservice teachers enrolled in the BEEd program were found, t = 3.95, P < 0.05. This implies that BSEd preservice teachers ($\bar{x}$ = 0.51, *SD* = 0.17) perform significantly higher than the BEEd preservice teachers ($\bar{x}$ = 0.38, *SD* = 0.23). Regarding their subject preference, a significant difference was found between the problem-solving performance of the preservice teachers who prefer math and other subjects, t = 2.12, P < 0.05. Notably, the preservice teachers who like math ($\bar{x}$ = 0.63, *SD* = 0.77) perform significantly

higher than those who do not like math ($\bar{x}$ = 0.37, *SD* = 0.11).

Common Errors found in the Preservice Teachers' Work

Table 5 summarizes the common errors found in the solutions made by the preservice teachers in the word problems provided. In general, they incurred mathematical comprehension errors. Particularly, they made misrepresentation (situation and mathematical model errors, conceptual errors, and syntax errors), misinterpretation (unintelligent guesses, conceptual errors, and procedural errors), and miscalculation (casual errors, PEMDAS errors, procedural errors, and being complacent). These errors were evident in the sample solution by one (Figure 1). Due to misrepresentation, misinterpretation, and miscalculation, the preservice teacher obtained an incorrect answer to the multiple-choice test requiring problem-solving.

DISCUSSION

Problem-solving Difficulties of the Preservice Teachers

The preservice teachers encountered problem-solving difficulties, which is parallel with Tanisli and Kose (2013), Pentang (2019), and Yayuk and Husamah (2020), yet contrary to Andres (2022). The preservice teachers do not master or understand fundamental techniques and concepts that can help them solve mathematical problems correctly; therefore, they have many calculation errors on some parts of the test. These points out that some preservice teachers needed to prepare for teaching training opportunities to enhance their teaching skills in mathematics as requisite for this teaching course. This can be attributed to a need for more problem comprehension (Barham 2020; Yayuk and Husamah 2020) and mastery of content knowledge (Tatto and Senk 2011). In support of Bahtiyar and Can (2016) and Zuya (2017), the preservice teachers need help responding with more appropriate conceptual and procedural knowledge in measurement, geometry, and algebra.

Table 4. Academic profile differences in the preservice teachers' problem-solving performance. Note: *significant at 0.05 level

Academic Profile	Characteristic	Mean	SD	*t*	*P*
Campus	Urban	0.45	0.23	-0.16	0.872
	Rural	0.44	0.15		
Type of High School Attended	Public	0.50	0.56	0.43	0.667
	Private	0.41	0.20		
Program	BSEd	0.51	0.17	3.95	0.040*
	BEEd	0.38	0.23		
Subject Preference	Math	0.63	0.77	2.12	0.037*
	Other subjects	0.37	0.11		

Table 5. Common errors in problem-solving incurred by the preservice teachers.

Errors	Emerging Themes	General Theme
Situation model errors (no/wrong visual representation of the problem, mistranslating word problems to graphs, tables, or charts)	Misrepresentation	Comprehension Errors
Mathematical model errors (no/wrong mathematical models to represent the problem, mistranslating word problems to mathematical expressions or equations)		
Conceptual errors (misapplied concepts, formula misuse, wrong derivation)		
Syntax errors (miswritten formula, symbols, and coefficients)		
Unintelligent guesses (wrong assumptions/hypotheses)	Misinterpretation	
Conceptual errors (cannot connect the problem to other scenarios, unable to apply concepts, incomplete understanding of the problem)		
Procedural errors (misinterpreting the problem and data provided)		
Casual errors (miscopied data, miswriting formulas, shortcut solutions)	Miscalculation	
PEMDAS errors (inadequate knowledge, misconceptions, and misapplications)		
Procedural errors (poor mental and manual computation ability, unable to perform mathematical tasks entirely and accurately, lack of strategies)		
Complacent (failure to check the completeness of the solution and the accuracy of the final answer)		

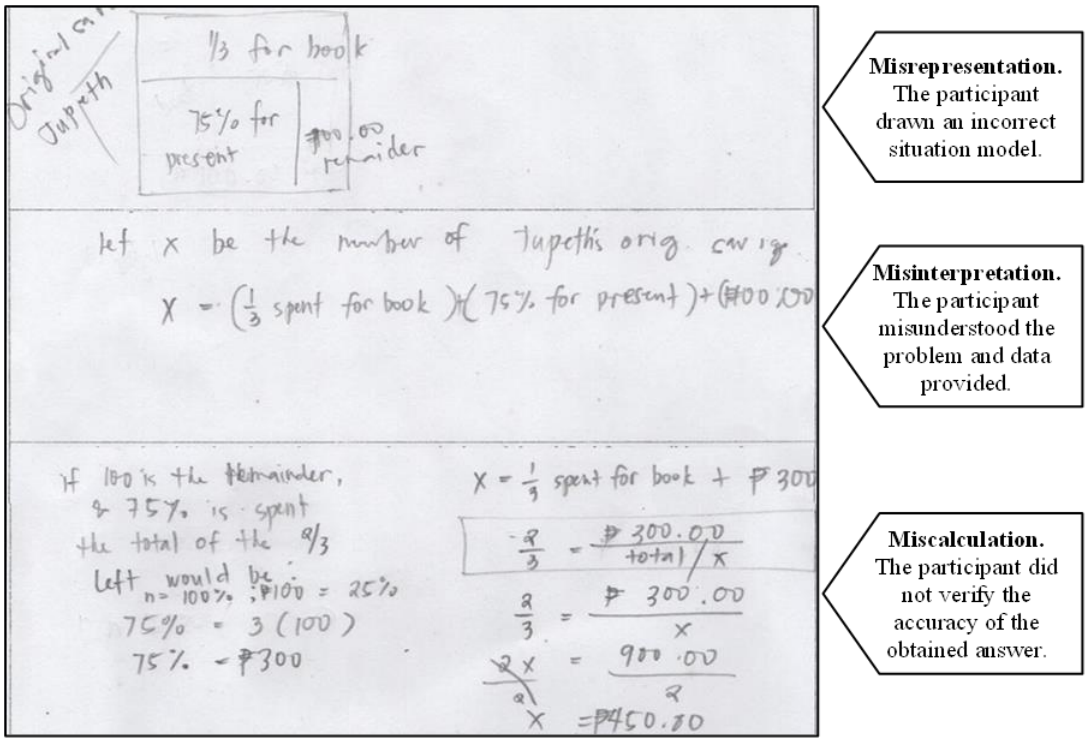

Figure 1. A sample solution of one participant showing multiple errors [Item #3 (Stem: *Jupeth used one-third of his savings to buy a book and spent 75% of the remainder to buy his mother a present. If he still has ₱100.00 left, how much was his original savings?*) Distracters: A. ₱300.00; B. ₱450.00; C. ₱600.00; D. ₱750.00). *The correct answer is C. ₱600.00.*].

One factor affecting their problem-solving performance is their willingness, interest, and attitude to answer any mathematical problem. Also, these findings indicate their deficient capacity to recall pertinent equations, apply problem-solving techniques, comprehend fundamental concepts, and exhibit mathematical proficiency (Reddy et al. 2017). Some of them may need help comprehending the context of mathematics problems and interpreting the issues; likewise, they need help to accurately identify the information given and the techniques that must be applied, which causes them to make more mistakes when attempting to solve the problems. The items mentioned earlier demonstrate that the preservice teachers cannot come up with perfect scores, which can also be attributed to their poor performance in mathematics and can describe the level of their problem-solving skills. Moreover, they need help with the questions on the five learning domains, as most of them fail to answer the items related to geometry and algebra correctly, and some of them to all subjects. Overall, the preservice teachers experienced average difficulty solving problems in number sense, measurement, geometry, algebra, statistics, and probability, foundational concepts in higher mathematics. These findings suggest that they should prioritize learning these competencies, which will be crucial in introducing them to their students.

Problem-Solving Performance of the Preservice Teachers

The preservice teachers' performance needs attention. While they consider mathematics challenging (Bacsal et al. 2022), many struggle with mathematical content knowledge and problem-solving (Aljaberi and Gheith 2016; Pelingon 2019). This may also be attributed to the methods of instruction used in the college do not encourage the preservice teachers to view mathematics as a medium for communication, reasoning, or problem-solving (Matić 2017), and problem-solving strategies have yet to be developed (Andrade and Pasia 2020). Moreover, it can be observed that students who possess high levels of self-efficacy may encounter challenges when it comes to evaluating and creating problem-solving questions, both in terms of conceptual and procedural aspects. In addition to cognitive factors and students' knowledge, inadequate attention to detail and a sense of urgency may contribute to challenges in problem-solving (Prismana et al. 2018). This result suggests that teachers should focus on deepening students' problem-solving understanding. Preservice teachers should be given constant opportunities to practice the proper procedures, concepts, and strategies to solve and comprehend mathematical problems.

The number sense performance of preservice teachers shows they need to understand this content area fully. Consistent to Santos et al. (2020), these

future teachers needed help in the components and domains of number sense. Teachers could aid in developing number sense in their students by understanding it and knowing how to teach it. When students thoroughly comprehend number concepts, they can better apply math quickly, create efficient problem-solving techniques, and improve their number sense. Agreeing with Hasanah and Yulianti (2020), the preservice teachers incurred common mathematical mistakes in measurement, particularly in formula application errors, calculational inaccuracies, failure to fully understand the problem before attempting a solution, and a lack of familiarity with the fundamental concept. They need to grasp the measurement basics to reach the expected level of proficiency in that subject. Thus, teachers and educators must focus on problem-solving concepts and revisit their teaching approaches.

The result also indicates that preservice teachers need to be more effective in teaching their future students and more capable of managing the problems they could experience while teaching geometry. This aligns with Pentang (2019), which found that preservice teachers lacked the prerequisite geometry knowledge. However, these results contradict Niyukuri et al. (2020), which reveals that student-teachers have higher competencies in geometry. Besides, these preservice teachers have difficulties answering algebra, which may affect them once they take up the licensure examination for teachers and effectively fulfill their responsibilities to harness each of their future students' abilities towards mathematics. The result agrees with Brown and Bergman (2013) and Zuya (2017), where preservice teachers performed low on items demanding knowledge of algebra procedures. Their capacity in mathematics problem solving is insufficient and weak, similar to their knowledge foundation in solving equations, interpreting through variables and equations, and their ability to give assumptions to relate and provide solutions. Hence, one additional way to improve middle students' performance in algebra is to strengthen the preservice elementary and middle school teachers' understanding of variables. Finally, they performed low in statistics. Underperformance in statistics is a common issue for preservice teachers, similar to Pentang (2019) and Bacangallo et al. (2022). This can be attributed to their poor understanding of probability, as reflected by their scores. Thus, they need adequate training and support as future statistics teachers since they will play a vital role in developing a foundation in this field for their students.

The low performance of the preservice teachers on the given problem set indicates their lack of problem-solving skills, mathematical content knowledge, and comprehension of the application of mathematics to real-world problems. This may affect their off-campus deployment, class observation, actual practice teaching as required by their course, and their licensure examination when they are finally professional teachers who should exemplify excellence in education and problem-solving, incredibly complex mathematical problems that require a solid foundation of mathematical knowledge and comprehension. Results indicate the need for remedial classes, midyear clinics, comprehensive examinations, additional tasks, and extra time for detailed review for all preservice teachers and those who struggle to solve mathematical problems. Teacher education institutions need to initiate other pedagogical strategies (i.e., Bacsal et al. 2022) and activities to improve the problem-solving performance of preservice teachers.

Academic Profile Differences in the Preservice Teachers' Problem-Solving Performance

The external environments, such as facilities and learning settings, do not affect problem-solving performance. Both rural and urban campus facilities have the same functions (the design might be different) and are efficiently used by professors and preservice teachers. On the other hand, this result contradicts the study of Tomul et al. (2021), which found that the school's location (rural, suburban, urban) contributes to significant variance in math performance. Thus, much more study is needed to clarify this phenomenon. Meanwhile, the type of high school they graduated from poses no substantial contribution to their problem-solving skills that will distinguish them from the other group. One factor that may be guided to this result is that public and private high schools follow the curriculum provided by the Department of Education, and teachers in both schools have the same competencies. Correspondingly, Pentang (2019) showed similar results.

The BSED preservice teachers are exposed to complex mathematics tasks, making them able to solve correctly and understand problem-solving exercises more quickly. At the same time, it supported the statement that BSED preservice teachers are more competent in problem-solving tasks than those taking up BEED as their program, which is also distinguished as skilled preservice teachers in general or fundamental mathematics offered in primary education. In addition, this also demonstrates that most of those who choose mathematics as their specialization have excellent scores when solving mathematics problems compared to others. Besides, the interested preservice teacher prefers mathematics over other subjects, treats mathematics positively, is willing to be teachable, and is brave enough to conquer their weaknesses. They are more likely to achieve satisfying scores in mathematics problem-solving tasks.

The program and subject preferences are attributed to their problem-solving performance and that mathematics educators should consider when introducing problem-solving in their classes. These results also may be attributed to the curriculum differences of the program between BSEd and BEEd. The BSED programs specialize in mathematical subjects, and students in these programs are more frequently exposed to complex mathematical tasks, which reveals that these students are more likely to solve mathematical problems correctly. On the other hand, BEED programs are designed to hone preservice teachers in general or fundamental mathematics offered in primary education. This demonstrates that BSED preservice teachers perform better when solving mathematics problems than BEED preservice teachers. Moreover, if the preservice teacher is interested, prefers mathematics rather than other subjects, treats mathematics in a positive perspective, is willing to be teachable, and is brave enough to conquer their weakness in the subject, there is a higher possibility that they can achieve a satisfying score in a mathematics problem-solving task. This may be because students' interests are connected to their chosen courses. Students' preferred subjects are dependent on their cognitive abilities and interests. Also, students are more likely to enjoy engaging in activities they perceive as within their competence and interest sphere. Thus, this explains why students' subject preferences impact their problem-solving performance.

Common Errors found in the Preservice Teachers' Work

Common errors among the preservice teachers (Figure 1) validated their problem-solving difficulties and underperformance. They frequently make similar comprehension errors when solving math problems, such as misinterpretation, misrepresentation, and miscalculation. These concerns among preservice teachers were also raised in Pentang (2019). Findings even reflect the specific errors made by preservice teachers, including conceptual, procedural, and casual errors. These oppose Mariano-Dolesh et al. (2022), where preservice teachers have established their conceptual understanding for solving word problems. These errors may have been aggravated by the pandemic, which limited the interaction between teacher educators and preservice teachers. Moreso, these preservice teachers lack the fundamental mathematics content knowledge taught in the primary education curriculum. Agreeing with Nielsen and Bostic (2020), these findings emphasize the importance of providing targeted training and support to preservice teachers to help them develop problem-solving skills and prepare them for their future role as mathematics educators. These errors can be prevented by facilitating the preservice teachers to master fundamental concepts and practice problem-solving drills. They encouraged the preservice teachers to present their solutions and answers to a problem. This may help identify their comprehension errors, such as misrepresentation, misinterpretation, and miscalculation.

The study's limited scope constrains the generalizability of its results. It is important to note that the sample of students involved in this study may not fully represent the broader population of all preservice teachers. Furthermore, the study focused explicitly on mathematics classes, particularly preservice teachers. The researchers intentionally selected students from a specialized program, which may have resulted in the overrepresentation in this study. Also, the potential for confounding variables that were not accounted for in the study may have influenced the results, particularly the difficulties and performance in problem-solving. It is recommended that a broader range of samples be utilized and conducted over a more extended period to yield more precise outcomes.

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ETHICAL CONSIDERATIONS

The respondents provided their consent, and the data collected was kept confidential. The researchers ensured proper credit was given for any similarities to other studies.

DECLARATION OF COMPETING INTEREST

The authors declare no competing interests.

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Livelihood assets and poverty among fishing households in Bicol Region, Philippines during the COVID-19 pandemic

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ABSTRACT

Research efforts concerning COVID-19 primarily focused on the macro-level impacts of the pandemic on multiple fronts. Less attention was paid to individuals and less still to the socio-economic condition of the poorest sectors. This research addresses this gap by utilizing the theory of change (ToC) of asset ownership to examine the effects of livelihood asset ownership on the poverty status of 200 fisherfolk households in the Bicol Region, Philippines, during the pandemic. The study employed descriptive measures and logistic regression with principal component analysis (PCA) to examine the survey data. Results revealed that ownership of productive assets increased the likelihood of households maintaining the status of nonpoor compared to households who owned less to nothing. Whereas, households with more physical assets were more likely to fall below the poverty line during the pandemic. Defining poverty in terms of livelihood asset ownership has important implications for policymakers. Addressing these evidence gaps enables a nuanced analysis of the socio-economic condition of fishing households during the pandemic. The study suggests that aid organizations and funding agencies should complement grants with efforts that promote asset ownership through capacity-building services like training, mentoring, and providing market links for fishing communities.

Keywords: binary logistic regression, fisheries sector, household poverty, principal component analysis

INTRODUCTION

The COVID-19 pandemic has significantly impacted global healthcare systems and socio-economic development. Thus, making it highly difficult for countries to achieve zero poverty set out in the 2030 Sustainable Development Goals. For the first time in over 20 years, the global extreme poverty rate rose, with around 119 to 124 million people pushed back into extreme poverty and chronic hunger (UN 2021). In lower-middle-income countries, the lockdown and physical distancing measures have

significantly impacted around 92% or 379 million of 413 million informal workers employed in agriculture, forestry, and fishing (ILO 2020).

Initially, restrictions on transport, labor mobility, and public place closures acted as supply shocks to the economy, which eventually weakened the demand for goods and services as people were sheltered in their homes (Park et al. 2020). Overall, the containment measures adopted worldwide depressed economic activities. Available data during the first half of 2020 recorded economic contractions in developing Asian economies. Some had even experienced a recession, including the Philippines (Sawada and Sumulong 2021). In August 2020, the Philippine Statistics Authority (PSA 2020a) reported the lowest recorded quarterly growth since 1981. The Philippine gross domestic product (GDP) dropped by 16.5% in the second quarter of 2020, following a 0.7% decline during the first quarter of 2020.

With the pandemic triggering a global recession, millions of people have been exposed to harsh and profound inequalities. Not surprisingly, it has affected the world's poorest and most vulnerable people residing in the rural and coastal areas, especially the fishing communities. For example, the impact of the pandemic during the first quarter of 2020 was estimated to have resulted in a 3.11% reduction in the aggregate volume of agricultural production in Southeast Asia (Gregorioa and Ancog 2020). To support small-scale fisheries, countries in Southeast Asia supplied financial help and food subsidies to address immediate food and non-food needs (Ferrer et al. 2021). Worldwide, governments have put in place around 1,600 short-term social protection measures in response to COVID-19 but still fall short of covering an estimated number of 4 billion people (UN 2021). In the Philippines, emergency support was given to households during the pandemic through the Social Amelioration Program (SAP) (Department of Finance 2020). Although it can be argued that households may also rely on financial assistance from employers, loan grants from banks, social security from the government, and remittances from relatives, these options are not equally available, especially for poorer households (Abrigo et al. 2020).

Fisherfolks, in particular, are notoriously marginalized in national statistics (PSA 2020b). Despite being recognized as the frontline in food security (DA Communication Group 2020), many fishing households live in poverty (Labayo and Preña 2021; Palanca-Tan and Bongat-Bayog 2021) and lack productive assets (WorldFish Center 2007), making them vulnerable to extreme shocks and stressors, including the COVID-19 pandemic, recurrent typhoons, and the recent recession (Preña and Labayo 2022). Needless to say, they lack the capital and resources to cope with these sudden shocks since they are often reliant on fisheries resources for food and income.

According to PSA reports on poverty incidence for the primary sectors in the country, the fisherfolks consistently posted one of the highest poverty incidences among the sectors in 2015 (36.9%) and 2018 (26.2%) (PSA 2020b). Among these poverty estimates, the incidence of poverty during the onset of COVID-19 in the Philippines in 2020 was not recorded. Consequently, there was no data to measure the poverty status of fisherfolks during the pandemic.

As the pandemic unfolds, further evidence of its impacts on socioeconomic development is also expected to grow in the academic literature. However, existing research leaves room for further investigation on at least two aspects. First, the poverty status during the pandemic lacks micro perspectives. The research papers published in academic literature were either limited in content and geographical coverage or mainly focused on macro perspectives. Second, quantitative analyses targeting fishing households within the context of the Bicol Region remain primarily unknown and insufficiently researched. The study directly provided a novel perspective that has not drawn attention in similar socio-economic studies by investigating the effects of asset ownership on poverty conditions that characterized the fisherfolks in the region during the pandemic.

In order to inform COVID-19 recovery and mitigation policy responses concerning poverty in the fisheries sector, it is critical to understand the preconditions necessary to achieve resilience and create opportunities for poor people (Kumaraswamy et al. 2020). To this end, this paper presented evidence on how ownership of livelihood assets impacted the poverty status of fishing households engaged in aquaculture and fish processing during the COVID-19 pandemic in the fishing communities along the Albay, Ragay, and Asid Gulfs in the Bicol Region, Philippines. The Department of Agriculture Bureau of Fisheries and Aquatic Resources (DA-BFAR) identified these fishing households and provided them with livelihood support as part of the Fisheries, Coastal Resources, and Livelihood (FishCORAL) Project. This project, is a joint effort between the Philippine Government and the International Fund for Agricultural Development (IFAD), spanned five years from 2016 to 2020. Specifically, this paper sought to assess the socio-economic conditions of fishing households in terms of household head characteristics, asset ownership, and poverty incidence. Finally, the paper estimated the influence of asset ownership and socio-economic factors on the poverty situation of

fishing households in the Bicol Region using a regression model.

METHODS

Study Area and Sampling Design

The study focused on eleven fisherfolk groups that were given livelihood projects (e.g. aquaculture and fish processing) under BFAR's FishCORAL Project (Table1). These groups are situated across the three provinces in the Bicol Region, namely Camarines Sur, Masbate, and Sorsogon (Figure 1). A multistage sampling technique was employed to 200 samples out of 1152 fishing households considered for the study (MOE = 0.069, z = 1.96). After purposively selecting the province, municipality, and coastal barangays covered, the "RAND" function in MS Excel was then employed to select households administered with the questionnaire.

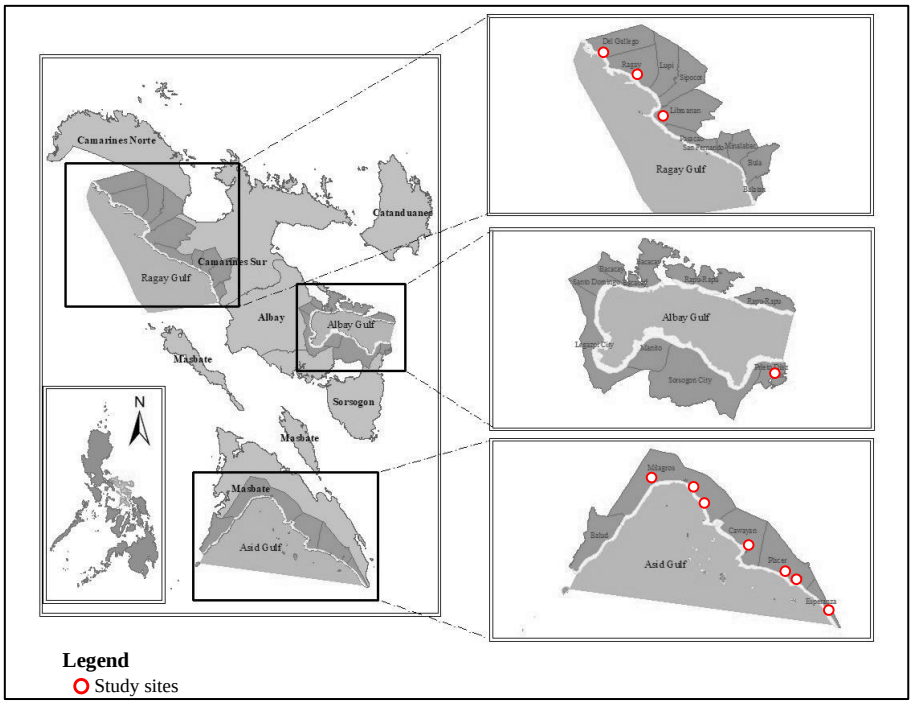

Figure 1. Map of the Bicol Region showing the eleven study sites.

Table 1. Sample respondents by municipality and livelihood in Bicol Region, Philippines.

Province	Municipality	Livelihood	Population (N)	Sample (n)
Sorsogon	Prieto Diaz	Danggit Processing	81	14
Camarines Sur	Libmanan	Bangus Culture	138	24
	Del Gallego	Grouper Culture	109	19
	Ragay	Grouper Culture	92	16
Masbate	Milagros	Aquasilviculture	127	22
	Placer	Aquasilviculture	46	8
	Milagros	Kropek Industry	58	10
	Milagros	Fish Drying	29	5
	Cawayan	Seaweed Culture	219	38
	Esperanza	Seaweed Culture	109	19
	Placer	Seaweed Culture	144	25
Total			**1,152**	**200**

Data Collection

Respondents were provided informed consent before the interview. The interview process also observed the anonymity and confidentiality of the responses given. Furthermore, it was made clear that their participation was voluntary and that they may choose to end the survey at any time, with their information remaining confidential. A field survey was conducted face-to-face with household heads from February 2021 to May 2021. The data used for this study were generated using structured questionnaires divided into two sections: household profile and asset ownership.

Theoretical Framework

This study utilized the theory of change (ToC) for asset ownership developed by the Consultative Group to Assist the Poor (CGAP) and World Bank (Kumaraswamy et al. 2020). The asset ownership was categorized into income-generating assets (productive assets) and quality-of-life-enhancing assets (physical assets). The ToC suggests the importance of asset ownership to improving household well-being by building resilience and capturing opportunities. For instance, productive assets like agricultural land, livestock, farm equipment, and fishing equipment have income-generating potential because they can be used as part of a livelihood or lent out for a fee. On the other hand, quality-of-life-enhancing assets such as lighting, toilets, and home appliances may not directly produce income for households. However, they may increase the household's well-being by reducing time and effort spent on household tasks, providing more time for leisure and other productive activities. According to the ToC, these assets help households build resilience and capture opportunities. Productive assets, in particular, can increase income, diversify income streams, and mitigate risks within livelihood activities. While non-productive assets cannot generate income, they can be liquidated to cope with shocks.

The ToC for asset ownership addresses the gaps in analyzing poverty. Thus, it provides a comprehensive approach to understanding the underlying causes of poverty by focusing on the factors that constrain or enhance livelihood opportunities. Such constraints might spring from the foundational capabilities at the household level or may result from macroeconomic stability, good governance, institutional norms, the existence of government social protection programs, and community asset at the macro level. Hence, the ToC was built on a 'micro–macro' perspective and is more likely to lead to more strategic interventions.

In the context of the study, the ToC was adopted to estimate a model that would explain the effects of asset ownership on the poverty status of households during the pandemic. Based on the assumptions outlined by the ToC, the study came up with three hypotheses: (1) productive asset significantly increased the likelihood of households living above the poverty threshold during the pandemic, (2) physical asset significantly decreased the likelihood of households living above the poverty threshold during the pandemic, and (3) household head characteristics significantly affected the likelihood of households living above the poverty threshold during the pandemic.

Analytical Design

The data collected were treated and analyzed using descriptive statistics. For the model estimation, logistic regression was applied to measure the influence of socio-economic and livelihood asset variables on household poverty status. The general derivation of a binary logistic regression model is as follows (Asterious and Hall 2011):

$$Logit(P_i) = ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{k=1}^{i} \beta_i X_i + \mu_i \quad \text{(Eq1)}$$

where $ln\left(\frac{P_i}{1-P_i}\right)$ explains the odd ratio of households being nonpoor, β_0 is an intercept of the designated model, β_{ij} represents the slope coefficient of the model, X_i is representative of all the explanatory variables of the model, and μ_i is the error term of the estimated model.

The dependent variable was created by applying the income threshold, the amount needed to meet basic food and non-food needs set by the PSA in 2018. In other words, the total annual expenditures of households covered were converted into binary variables, 1 for nonpoor and 0 for poor.

Principal component analysis (PCA) is used when independent variables display collinearity (Mooi et al. 2018). To mitigate this and avoid biased results, PCA was used to convert a large number of independent variables into a lower number of variables, called principal components, independent of each other. Based on Kaiser–Meyer–Olkin (KMO) statistic, the variables are sufficiently correlated for PCA (80%). An intuitive way to decide on the number of factors is to extract all the factors with an eigenvalue greater than 1. This is called the Kaiser criterion or latent root criterion. However, the Kaiser criterion is well known for over-specifying the number of factors (Russell 2002). In addition, the components are ordered so that the first component (PC1) explains the largest possible amount of variation in the original data. The second

component (PC2), on the other hand, explains additional but less variation than the first component. Therefore, each component captures an additional dimension in the data while explaining smaller and smaller proportions of the variation of the original variables. Hence, for this study, the analysis settled on two principal components.

Principal component analysis was applied to physical assets using the corresponding set of asset indicators. These indicators include wall material, roof material, and ownership of radio, television, washing machine, mobile phone, and stove. A separate PCA was applied to productive assets using a set of asset indicators for financial and natural assets. These assets are refrigerator, motorized boat, motorcycle, fishing equipment, farm equipment, savings account, credit access, agricultural land, large livestock, and small livestock. Factor scores of the first two principal components with eigenvalues greater than one for each asset category were used as independent variables. In addition, household size, household head sex, and squared value of household head age were also used as independent variables. Moreover, diagnostic tests were performed to validate model adequacy, such as the test of independence of observations, multicollinearity test, and specification error test. Regression models estimated were tested for model fit using the likelihood ratio Chi-square statistic, Hosmer-Lemeshow test, and pseudo-R-square. These calculations in modeling were aided with STATA version 15.1.

RESULTS

Socioeconomic and Demographic Profile

The majority of the fishing households were headed by male household members (88%) and belonged to the age group of 35–54 years (64%), indicating that the majority of the household heads were in their prime working age. In terms of educational attainment, most of them were elementary undergraduates (34%). Only 16% was at least high school graduates. The average household size was five members for nonpoor households and six for poor households.

Asset Ownership

The fishing households reported ownership of physical and productive assets. For instance, they reported ownership of some basic consumer durables like mobile phones (87%), television (72%), radio (37%), gas stove (24%), and washing machines (23%) (Table 2). Most of them had housing made of strong materials for walls (46%) and roofs (72%). In addition, the majority of them owned productive assets like a motorized boat (59%) and fishing equipment (59%). They also had a savings account (54%) and access to credit (61%). Most households also possessed farm equipment (42%) and large livestock (45%). Only a few owned a refrigerator (17%) and a sewing machine (3%) (Table 2).

Table 2. Livelihood assets owned by households in Bicol Region, Philippines.

Livelihood Assets Owned	Frequency	Percentage
Physical Assets		
Consumer durables		
Mobile phone	173	87
Television	144	72
Radio	74	37
Stove	47	24
Washing machine	45	23
Housing material (wall)		
Strong materials	91	46
Mixed (predominantly strong materials)	32	16
Mixed (predominantly light materials)	20	10
Light Materials	57	29
Housing material (roof)		
Strong materials	144	72
Mixed (predominantly strong materials)	15	8
Mixed (predominantly light materials)	5	3
Light Materials	36	18

Livelihood Assets Owned	Frequency	Percentage
Productive Assets		
Credit access	122	61
Motorized boat/banca	117	59
Fishing equipment	117	59
Savings account	107	54
Small livestock	96	48
Large livestock	90	45
Agricultural land	85	43
Farm equipment	83	42
Motorcycle/Tricycle	75	38
Refrigerator	33	17
Sewing machine	5	3

Table 3. Poverty incidence and annual per capita expenditure (PCE) of poor and nonpoor in the study areas.

Province	Poverty Incidence	Poor	Nonpoor
Sorsogon	43%		
Mean annual PCE		23,427.87	31,194.19
Standard Deviation		1,454.09	2,854.89
Coefficient of Variation		6.21	9.15
Camarines Sur	42%		
Mean annual PCE		19,698.90	27,971.61
Standard Deviation		2,585.79	2,554.97
Coefficient of Variation		13.13	9.13
Masbate	26%		
Mean annual PCE		19,770.32	28,428.14
Standard Deviation		2,165.36	3,109.57
Coefficient of Variation		10.95	10.94
Overall	32%		
Mean annual PCE		20,085	28,477
Standard Deviation		2,504	3,030
Coefficient of Variation		12.5	10.6

Poverty Situation

During the pandemic, the fishing households in the study areas recorded around 32% poverty incidence at PHP 20,085 average annual per capita expenditure (PCE) (SD = PHP 2,504, COV=12.5%) (Table 3). On the other hand, nonpoor households who could maintain at least the minimum living standard recorded an average of PHP 28,477 annual PCE (SD = PHP 3,030, COV = 10.6%).

Model estimation on the influence of asset ownership on poverty situation

The first two components of PCA for physical assets accounted for at least 40% of the total variation (Table 4). For productive assets, the first two components of PCA accounted for at least 50% of the total variation. A closer look at the first two principal components of each livelihood asset is outlined in Table 5. The first component for the physical asset was primarily a measure of roofing material (48%), while the second component was associated with radio ownership (70%). On the other hand, the first component for the productive asset was primarily associated with large livestock ownership (46%). The second component was a measure of access to credit (61%).

The results of binary logistic regression showed that household size was significantly associated with poverty situation (Table 6). Specifically, households with larger family sizes were more likely to be poor. The findings also suggest that the relationship between household head age and poverty was negative and significant for Model 1 and Model 2. In other words, households with older heads have a higher chance of being poor. Meanwhile, household head sex was not statistically significant in all four models.

Table 4. Eigenvalues and the proportion of variation explained by the principal components for physical assets and productive assets in Bicol Region, Philippines.

Component	Eigenvalue	Proportion	Cumulative
Physical Assets			
1	2.0054	0.2507	0.2507
2	1.1955	0.1494	0.4001
3	1.0328	0.1291	0.5292
4	1.0301	0.1288	0.6580
5	0.7703	0.0963	0.7543
6	0.7514	0.0939	0.8482
7	0.6499	0.0812	0.9294
8	0.5646	0.0706	1.0000
Productive Assets			
1	4.0753	0.3705	0.3705
2	1.4681	0.1335	0.5039
3	1.1405	0.1037	0.6076
4	0.9581	0.0871	0.6947
5	0.9106	0.0828	0.7775
6	0.7429	0.0675	0.8450
7	0.4735	0.0430	0.8881
8	0.4423	0.0402	0.9283
9	0.3925	0.0357	0.9640
10	0.2329	0.0212	0.9851
11	0.1634	0.0149	1.0000
Overall KMO	**0.7953**		

Table 5. Principal component analysis results using indicators for physical and productive assets.

Livelihood Asset	Component 1	Component 2
Physical Assets		
Wall material	0.3640	-0.3662
Roof material	0.4839	-0.1758
Radio	0.0880	0.6965
Television	0.4108	0.1358
Washing machine	0.3883	-0.0283
Mobile phone	0.3686	0.4361
Stove	0.3975	-0.0177
Productive Assets		
Refrigerator	0.0605	-0.1247
Motorized boat	-0.0055	-0.2238
Motorcycle	0.0261	0.2876
Fishing equipment	0.3775	-0.0179
Farm equipment	0.4352	-0.1340
Savings account	-0.0331	0.5779
Credit access	0.0397	0.6111
Agricultural land	0.4266	-0.0884
Large livestock	0.4550	-0.0437
Small livestock	0.3096	-0.0047

Table 6. Logistic regression results. Standard error is enclosed with parenthesis; *$P < 0.10$; **$P < 0.05$; ***$P < 0.01$, ns-not significant.

Variable	Model 1	Model 2	Model 3	Model 4
Household size	0.6716*** (0.1035)	0.6791** (0.1120)	0.6283*** (0.0673)	0.6338*** (0.0709)
Household head sex	0.3035^{ns} (0.2287)	0.2834^{ns} (0.2458)	0.8327^{ns} (0.4741)	0.9176^{ns} (0.5710)
Household head age squared	0.9995* (0.0003)	0.9994* (0.0003)	0.9999^{ns} (0.0002)	0.9998^{ns} (0.0002)
Physical Asset	1.2871^{ns} (0.2443)	0.3683*** (0.1146)	1.2010^{ns} (0.1517)	0.4015*** (0.0849)
Productive Asset	9.0586*** (3.4743)	9.2288*** (3.6558)	2.5403*** (0.4407)	2.3608*** (0.4212)

The four models were further tested for model fit upon complying with the assumptions underlying the use of logistic regression (Table 7). The likelihood ratio Chi-square for each model tells us that each model fits significantly better than a model with no predictors. Except for Model 3, the Hosmer-Lemeshow test indicates that the deviation is not statistically significant for all models, which means that the models satisfactorily fit the whole set of observations. On the other hand, the higher pseudo-R-square indicates that the model better predicts the outcome. While pseudo-R-squares cannot be interpreted independently or compared across datasets, they are valid and helpful in evaluating multiple models predicting the same outcome on the same dataset. Hence, based on the pseudoR-squares reported, the results suggest that Model 2 fits the outcome data better than the three models.

Table 7. Overall model fit results. **$P < 0.05$; ***$P < 0.01$, ns-not significant.

Model	Likelihood ratio chi-square test	Goodness-of-Fit (Hosmer-Lemeshow Test)	Pseudo R^2
Model 1	154.57***	6.20^{ns}	0.6164
Model 2	166.17***	6.99 ^{ns}	0.6627
Model 3	60.77***	15.59**	0.2424
Model 4	81.56***	8.86 ^{ns}	0.3253

DISCUSSION

Fishing Households' Socioeconomic and Demographic Profile

Fishing communities often face disadvantages due to demographic and socio-economic marginalization. Previous studies have shown that fisherfolks hardly advance their formal education (Huynh 2021; Macusi et al. 2022). In addition, they often lack functional literacy skills that would help them navigate by satellite, understand microfinance, use digital technologies, diversify their businesses, and deal with official documents (UN 2006). Those with lower educational levels tended to keep fishing as their primary source of livelihood because they only had fishing boats and nets (Blythe et al. 2014). However, when it comes to diversification of sources of income, large family size in fishing communities is often seen as an advantage. Increasing household size means more labor for agriculture activities and greater opportunity to exploit fishery resources (Amevenku et al. 2019).

Asset Ownership

Numerous studies in the literature cited the scant assets owned by fisherfolks. For instance, a study in Malangrapat village in Indonesia revealed that fishing households headed by women possessed a relatively low and unsustainable number of assets (Khodijah 2014). In Bangladesh, the level of different livelihood capitals of floating fishing households was also lower when compared to the national average (Ahmed et al. 2021). In a similar study in the Philippines, ownership of all forms of capital in fishing households around Laguna Lake was also reported at deficient levels (Palanca-Tan 2020). Many financial and insurance service providers in the Philippines are willing to provide their services to small-scale fisheries to increase their access to productive assets. However, financial institutions

struggle with providing credit to small-scale fisheries because of the seasonality of the fishing business, lack of insurance for fishing vessels, and internal lack of technical knowledge about fisheries (Badiola et al. 2021).

The ownership of physical assets of the households allowed them to produce essential services like entertainment, communication, food preparation, and laundry. A basic infrastructure through decent housing was also equally important to execute these productive life tasks. As input to household production, benefits associated with ownership of consumer durables included the reduced time required for household chores and increased participation of women household members in economic activities (Garone et al. 2019).

Meanwhile, productive assets are vital for producing food, generating income, accessing loans, and other opportunities (Winters et al. 2009). They serve as a buffer against shocks, such as the COVID-19 pandemic (Ferrer et al. 2021) and adverse weather conditions that threaten food production and supply (Johnson et al. 2016). For a fishing household, fishing equipment serves as the principal livelihood asset (Huynh 2021).

Poverty Situation

Fishing households can initially be above the poverty line. However, because of their vulnerable condition, they face the risk of instantly falling below the poverty threshold when shocks arise (Preña and Labayo 2022). The outbreak of COVID-19 has upended efforts to reduce poverty worldwide. As the UN (2021) noted, COVID-19 has devastating impacts on specific goals and targets, threatening decades of development gains. In 2030, the UN (2021) projects the global poverty rate at seven percent, therefore, missing the target of eradicating poverty. In 2020, an additional 119-124 million people were pushed back into extreme poverty due to COVID-19. In the Philippines, fisherfolks lament limited financial assistance and logistical constraints. According to the personal experiences shared by fisherfolks, the quarantine measures prevented them from going out and fishing which compromised their livelihoods and income (Preña and Labayo 2022).

Model estimation on the influence of asset ownership on poverty situation

Results presented that households with more dependents had more chance of being poor as there would be less expenditure on things like education and healthcare to meet basic food needs for survival (Wang et al. 2021). On a positive note, increasing household size can be associated with more diversified income. For instance, Abdulai and CroleRees (2001) argued that a larger household size means more labor supply, increasing the alternative sources of income for the household. Within the context of fishing households, this would imply more diversified sources of income in both fishery and agriculture (Asravor 2017). However, because of the larger household size, income earned from multiple income sources would mean a smaller share of the output that is marketed (Minot et al. 2006).

Household head sex was found to be not associated with the poverty condition of the fishing households. However, results from the literature indicated a significant relationship between household head sex and income diversification. Previous studies have shown that income diversification has a positive influence on income. Consequently, households with less diversified income tend to be poor (Kidane and Zegeye 2019).

Concerning household head sex, Hesselberg and Yaro (2006) concluded that female household heads are more diversified due to involvement in various income-generating activities. This was consistent with the study of Asravor (2017), wherein male household heads were less diversified in all their activities especially concerning income-generating activities. Empirical evidence shows that the life cycle affects asset accumulation, particularly in the productive age group (Mukuka et al. 2017). According to Majeed et al. (2015), the probability of being poor rises up to the age of 42 and then declines. A possible reason could be the accumulation of assets in old age.

Households with a low non-labor asset base tend to be poor (Etuk et al. 2015). Based on PCA, large livestock ownership was moderately correlated with the first component, while credit access was strongly correlated with the second component. Hence, productive asset, in this case, was primarily a measure of large livestock ownership and credit access. It should follow that households above the poverty threshold tend to own more productive assets. Whereas, households below the poverty threshold tend to own less productive assets. This discrepancy can be primarily attributed to the income disparity of households and variations in their access to resources, including credit, education, and networking opportunities (Knudsen 2016). This hypothesis was confirmed based on the logistic regression results. Households that owned productive assets during the pandemic were less likely to experience poverty. In other words, owning more income-generating assets, like livestock and access to credit, puts a household at greater odds of living above the poverty threshold than households that own less or have less access.

Previous studies had shown that productive asset grants were an effective tool in pushing poor households out of poverty. For instance, Edmonds and Theoharides (2019) observed improvements in the material well-being of the beneficiaries because of an asset transfer program in the Philippines. In a similar study in Malaysia, Azima et al. (2018) concluded that coastal fishermen were poor because of the lack of access to productive assets.

On the other hand, the physical asset was significantly and negatively associated with poverty for Model 2 and Model 4. The PCA suggests that roofing material was moderately correlated with the first component, while radio ownership was strongly correlated with the second component. Since physical assets refer to non-income generating but nonetheless enhance the quality of life, it follows that households that own productive assets have less ability to alleviate the effects of the pandemic. Based on the logistic regression, the results suggest that physical asset increases the odds of households experiencing poverty.

Given the few assets of fishing-dependent households, many households lacked viable ways and were unprepared to cushion the impact of the pandemic. In Southeast Asia, this represents more than 50 percent of the fisheries sector composed of small-scale fishers (Kaewnuratchadasorn et al. 2020). In the Philippines, short-term emergency support was provided to vulnerable families including in the fishing communities, through the SAP. Financial assistance has been helpful, especially in addressing immediate challenges related to consumption. However, the small-scale fishers had to fend for themselves for months right after implementing quarantine measures. According to the fisherfolks, government support for the fishers came later in 2020. As an adoptive response, fishers engaged in direct fish marketing and online selling. Similar cases were documented in other countries in Southeast Asia (Ferrer et al. 2021).

Poverty among fishing households in the Bicol Region can be considered an outcome of a lack of productive assets. Due to their restricted access to these assets, households face limitations in their ability to consistently generate income. Socioeconomic characteristics like household size and household head age also affect the poverty status of households when shocks arise. A larger family typically entails a higher demand for resources and necessities. Meanwhile, older household heads may encounter challenges when it comes to prolonged engagement in physically demanding fishing activities. This can significantly affect the household's capacity to generate income, especially when fishing serves as their primary livelihood. Households with larger family sizes and older household heads tend to fall into poverty. Thus, livelihood intervention programs should prioritize improving access to productive assets of fishing households with larger household sizes and old-age household heads to help them build resilience against current and future risks and capture opportunities. In addition, the provision of productive assets should be complemented with capacity-building services like training, mentoring, and providing market links.

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ETHICAL CONSIDERATIONS

Sensitivity and courtesy were observed during the whole process of the interviews. Respondents were given informed consent, emphasizing the anonymity and confidentiality of their responses. It was made clear that their participation was entirely voluntary and that their information would be kept confidential and anonymous.

DECLARATION OF COMPETING INTEREST

The authors declare that there is no competing interest to any authors.

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ROLE OF AUTHORS: *CPL – questionnaire preparation, research design, data analysis, and manuscript writing; EMP – data analysis, review of related literature, and manuscript writing*

Research Notes

First report of Noah's clam *Tridacna noae* (Röding, 1798) in the reef of Culion: An addition to the distribution range in Palawan, Philippines

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ABSTRACT

This study provides additional information regarding the distribution range and habitat characteristics of two specimens *Tridacna noae* (Röding, 1798), a previously misidentified giant clam species, encountered in Barangay Malaking Patag, Culion, Palawan, Philippines. The giant clams were identified as *T. noae* due to the presence of ocellate spots or teardrops and sparse hyaline organs on the mantle. The specimens measured 7.8 and 7.9 cm in shell length and were found partially buried in dead coral substrates at a depth of 2 meters. The current findings provide additional information on the distribution range of *T. noae* in the province of Palawan and the Philippines. Identification of the distribution of certain threatened species, such as the giant clams, is crucial step in protecting and conserving their population in the wild.

Keywords: Calamianes Islands, distribution, teardrops giant clams, northern Palawan

Tridacna noae, also known as Noah's clam or Teardrops giant clam, was initially described by C. Röding in 1798. However, Rosewater (1965) considered it a variant of *Tridacna maxima* (Röding, 1798) due to similarities in shell morphology. Only in 2014 was *T. noae* resurrected as a valid and distinct species of giant clam based on morphological characteristics, supported by molecular analysis (Su et al. 2014). Both *T. noae* and *T. maxima* have a similar maximum shell length of 40 cm, although Borsa et al. (2014) reported that *T. noae* can only reach up to 28 cm max shell length and possess almost the same number of radial ribs, making these two species challenging to distinguish on the reef. However, the two species differ in mantle coloration and pattern. The mantle of *T. noae* can be recognized by the presence of its unique ocellate spots or teardrops with sparse hyaline organs, while *T. maxima* has continuous hyaline organs on the mantle edge (Su et al. 2014). Meanwhile, the distribution of *T. noae* in coral reefs is inferred to be similar to *T. maxima* where they typically occur in shallow reef areas and lagoons with water depths between 1-15 m (Neo 2023). They can be found partially buried either on boulder coral or coral substrate surrounded by various macroalgae (Sue et al. 2014; Neo et al. 2017).

Tridacna noae is geographically distributed in the Indo-West Pacific, extending from the Ryukyu

Archipelago in Japan, Kiribati, Cook Island, Christmas Island, Vietnam, and the Philippines (see Neo et al. 2017). In the Philippines, *T. noae* was first reported by Lizano and Santos (2014) from eastern Negros, followed by Ecube et al. (2019) in Port Barton, San Vicente, Palawan, facing the West Philippine Sea (WPS).

This study provides additional information on the distribution range and habitat characteristics of *T. noa*e in Palawan. Two specimens of *T. noae* were accidentally found in Pitchy One (11° 51.945'N; 119° 53.593'E) in 2021, a private beach area in Barangay Malaking Patag, directly facing the WPS in the municipality of Culion, Palawan, while engaging in recreational skin diving (Figure 1).

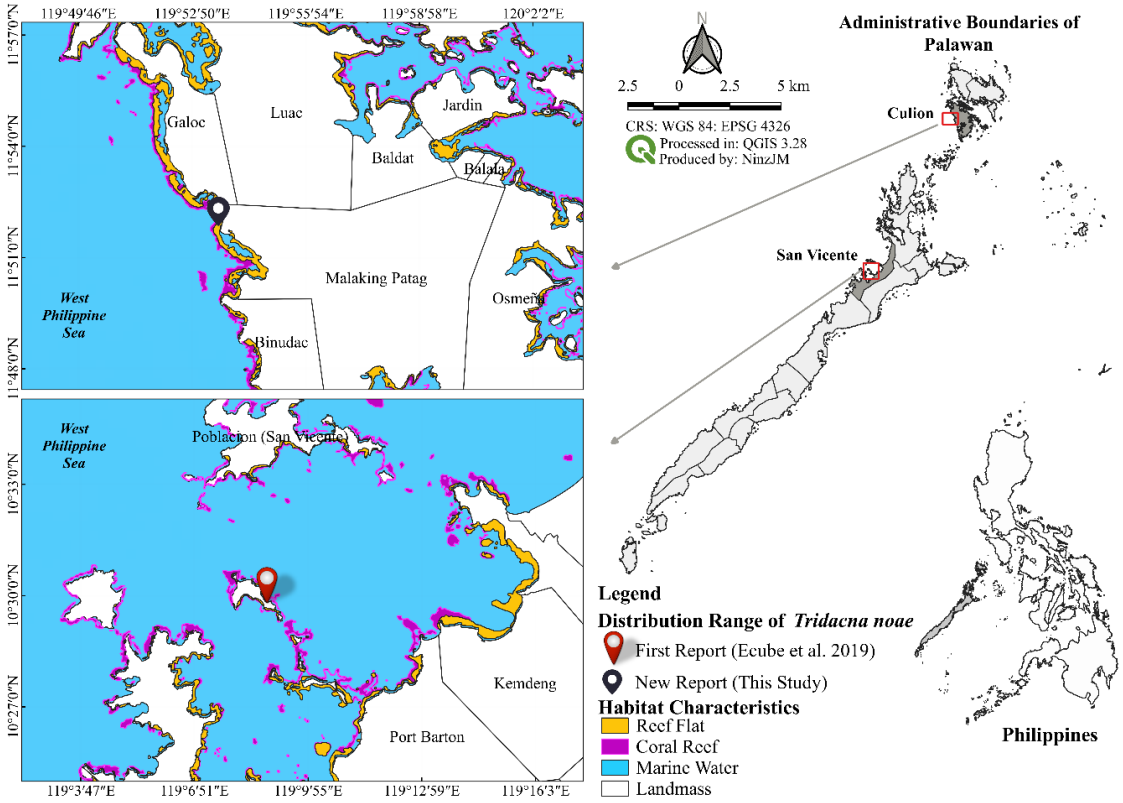

Figure 1. The current known distribution range of *Tridacna noae* in the reefs of Palawan, Philippines.

The two specimens were identified as *T. noae* due to the presence of ocellate spots or teardrops and sparse hyaline organs on their mantle (Figure 2), which are the unique morphological characteristics of the species (Su et al. 2014; Militz et al. 2015; Neo 2023). The specimens measured 7.8 and 7.9 cm in shell length, suggesting that both specimens were juveniles (Braley et al. 2018; Su et al. 2021). These sizes were considerably larger than those reported in Port Barton, San Vicente, Palawan (4.5 cm TL; see Ecube et al. 2019). Additionally, the two specimens were found approximately 110 meters from the highest shoreline at a depth of 2 meters and were partially buried in dead coral substrate surrounded by various macroalgae, such as *Sargassum* spp. and *Halimeda* spp. (Figure 2), similar to the findings of Ecube et al. (2019). These sizes and habitat characteristics of *T. noae* found in Palawan conform to the observation of Su et al. (2021) in Taiwan and Neo (2023) in Singapore.

Giant clams are keystone species in the coral reef ecosystem, playing important ecological roles as a source of food and shelter for various marine organisms (Cabaitan et al. 2008; Neo et al. 2015). However, coastal inhabitants have traditionally used giant clams as a food source, particularly during adverse weather conditions. According to the caretaker, also a fisherman on the beach, this species is often collected along with other burrowing giant clam species such as *T. maxima* and *Tridacna crocea* (Lamarck, 1819), for food by local inhabitants during low tide. The caretaker's claims about the presence of *T. noae* in the area were based on the image of the species shown on an Android phone and verbal

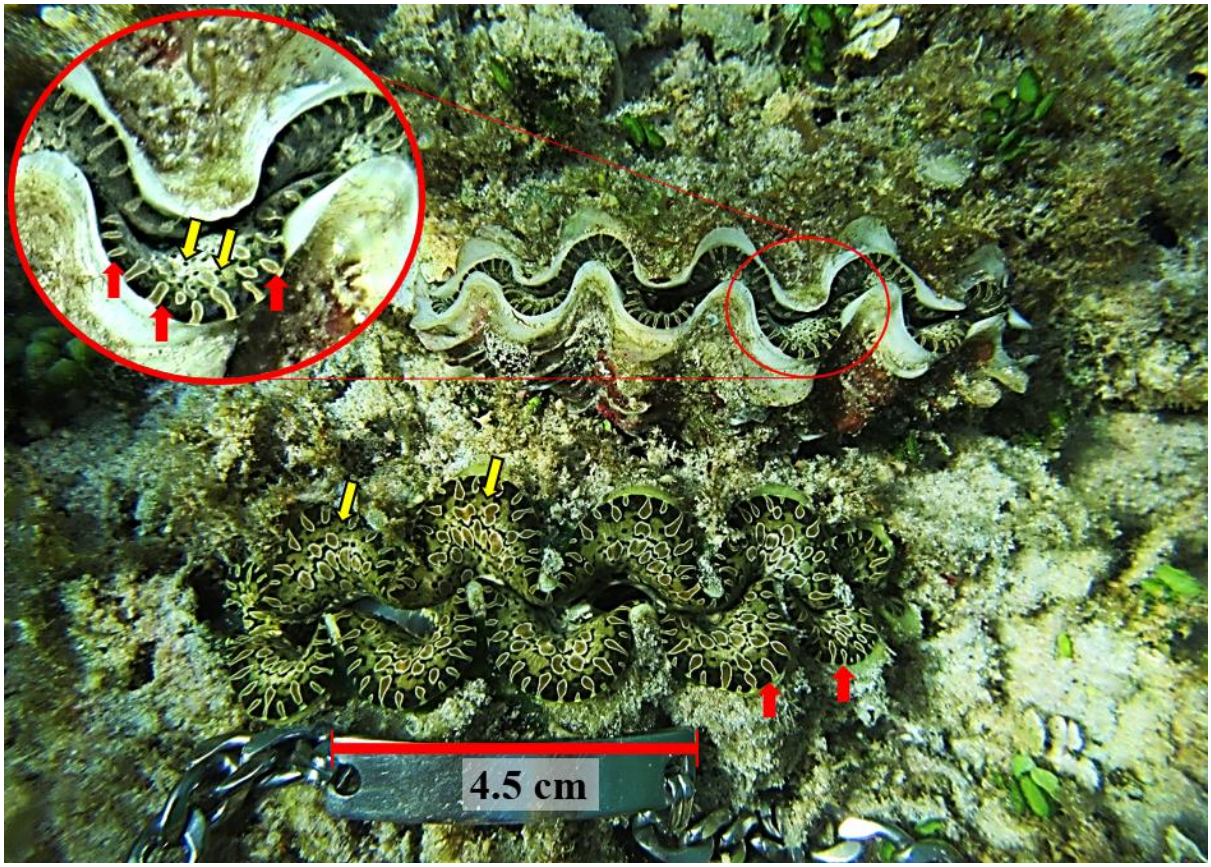

Figure 2. The two specimens of *Tridacna noae* found partly buried in the dead coral substrate at a depth of 2 m in Pitchy One, Malaking Patag, Culion, Palawan. The inset enlarged photo shows the ocellate spots or teardrops (red arrows) and sparse hyaline organs (yellow arrows) on the mantle of the specimens.

descriptions provided during an interview. Therefore, establishing a no-take zone MPA in the area could help protect giant clam species and other ecologically and economically important fauna, allowing local inhabitants to continue benefiting from these resources within the reef area through spill-over effects (Abesamis and Russ 2004; Alcala and Russ 2006; da Silva et al. 2015; Lenihan et al. 2021). Furthermore, the use of the "bareta de kabra" or crowbar for harvesting buried giant clams also poses a threat, as this can destroy the coral reefs while forcibly extracting the buried giant clams, necessitating immediate action from relevant authorities.

Understanding the distribution range and habitat characteristics of a threatened species is crucial (Militz et al. 2015; Marra-Biggs et al. 2022) and is an essential step in the conservation and protection management of its wild population. Unlike the semi-protected cove area in Port Barton, San Vicente, where *T. noae* was first reported in Palawan (see Ecube et al. 2019), the two specimens in Culion were found on a coastal beach directly facing the WPS (Figure 1), providing additional characteristic information about its distribution range in the province of Palawan. While there are similarities in the water depth and substrate characteristics where *T. noae* was encountered in Palawan, there is a need to conduct more inventory assessments in the reefs of Palawan to gain a deeper understanding of the distribution range, habitat characteristics, and the status of its population in the wild. In addition, the distribution status and habitat preferences of *T. noae* around the Philippines still warrant further investigation.

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ETHICAL CONSIDERATION

No animal was harmed during the conduct of this study.

DECLARATION OF COMPETING INTEREST

To the best of the author's knowledge, no conflict of interest exists.

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OBJECTIVES AND SCOPE

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   Dolorosa RG, Grant A and Gill JA. 2013. Translocation of wild *Trochus niloticus*: prospects for enhancing depleted Philippine reefs. Reviews in Fisheries Science, 21(3-4): 403-413. https://doi.org/10.1080/10641262.2013.800773
   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.
i. Citing of books – name(s) of author(s), year of publication, full title of the book (capitalize each main word), publisher, place of publication and total number of pages.
   Gonzales BJ. 2013. Field Guide to Coastal Fishes of Palawan. Coral Triangle Initiative on Corals, Fisheries and Food Security, Quezon City, Philippines. 208pp.
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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.
k. Citing a Webpage – names of the author (s), year, title of the article, webpage address and date accessed.
   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.
l. Citing a thesis or dissertation – author's family name, initial names of the author, year, title of the thesis, degree, name of institution, address of the institution, total number of pages (pp).
   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).
m. Citing a Report
   Picardal RM and Dolorosa RG. 2014. Gastropods and bivalves of Tubbataha Reefs Natural Park, Cagayancillo, Palawan, Philippines. Tubbataha Management Office and Western Philippines University. 25pp. (include weblink, if there's any, followed by accessed date).
n. In Press articles when cited must include the name of the journal that has accepted the paper.
   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.
o. Citing an article from an online newspaper.
   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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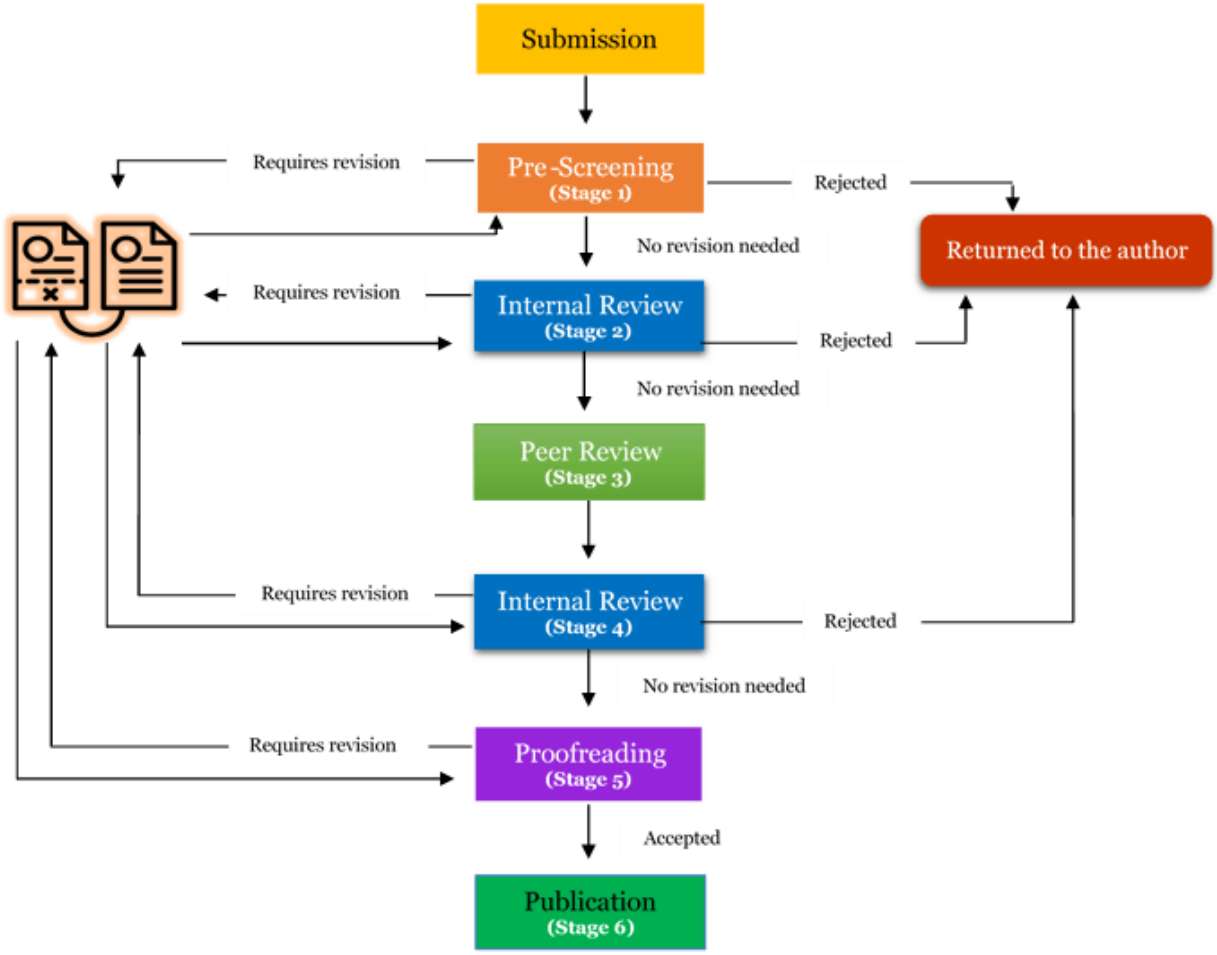

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