COHORT ANALYSIS, VIRTUAL POPULATION ANALYSIS, AND DISTRIBUTION OF HAIRY COCKLE (*Scapharca inequivalves*) IN THE EAST COAST OF SAN MIGUEL ISLAND, TABACO CITY

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Faculty of the Fisheries Department
Bicol University Tabaco
Tabaco City, Albay

In Partial Fulfillment
of the Requirement for the Degree
Bachelor of Science in Fisheries

by

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MAY 2024

ABSTRACT

COHORT ANALYSIS, VIRTUAL POPULATION ANALYSIS, AND DISTRIBUTION OF HAIRY COCKLE (*Scapharca inequivalves*) IN THE EAST COAST OF SAN MIGUEL ISLAND, TABACO CITY, MAY 2024

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This study aimed to analyze the hairy cockle collected on the East Coast of San Miguel Island, Tabaco City. Specifically, this study characterized the population dynamics of this collected species through an in-depth analysis of growth patterns, abundance, distribution, and spatial, and temporal distribution. Over a 6-month sampling period, 6000 individual hairy cockles were collected and measured using a digital caliper, revealing a total density of 18.2 within the study area. The Bhattacharya method was employed to analyze modal progression and identify three distinct cohorts within the hairy cockle population. The first cohort likely represents a younger age group or a recent recruitment event. The second cohort corresponds to an intermediate age group with slightly larger individuals. The third cohort represents the oldest individuals in the population. These cohorts represented different age groups and growth stages, with the presence of varied cohorts indicating continuous recruitment and growth processes within the population. The species that experienced a higher mortality rate started at 21.1 - 22.2 mm and concluded that the medium and large sizes of hairy cockles have higher mortality than the recruited individuals. Overexploitation was identified in the medium and large size stocks of hairy cockle, emphasizing the need for effective management and conservation strategies to prevent excessive exploitation of bivalve species. The nearest neighbor analysis revealed a clustered distribution pattern, indicating that individuals were closely spaced or aggregated together rather than being randomly dispersed. The spatial distribution analysis considered the distance of the collected specimens from the shore, with consistent temporal presence of hairy cockles across different seasons, suggesting a level of resilience to environmental fluctuations. This study provides valuable insights into the population dynamics and ecological significance of the Hairy Cockle, highlighting the importance of sustainable management practices for the conservation of bivalve populations on the East Coast of San Miguel Island.

Keywords: Hairy cockle; Population dynamics; Distribution; Sustainable management

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RECOMMENDATION FOR ORAL EXAMINATION

This thesis entitled **"COHORT ANALYSIS, VIRTUAL POPULATION ANALYSIS AND DISTRIBUTION OF HAIRY COCKLE *(Scapharca inequivalves)* IN THE EAST COAST OF SAN MIGUEL ISLAND, TABACO CITY"** prepared and submitted by **CRISTINE C. BUELLA**, and **MARYCRIS A. BURCE**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN FISHERIES**, is hereby recommended to the thesis committee for consideration and approval.

March 20, 2024

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EDITOR'S CERTIFICATION

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CHAPTER 1

THE PROBLEM

Introduction

Mollusca is a phylum that contains hundreds of species that live predominantly in aquatic environments, primarily saltwater. Mollusks are the most diverse phylum of marine invertebrates, with over 80,000 species described (Barnes 1974). These are soft-bodied animals, yet most are protected by a hard shell. Bivalves are a type of shellfish found all over the world. Their hinged, two-part shells encase all of their organs and muscles. For thousands of years, these marine and coastal organisms have provided vital protein sources for humans (Paul *et al*., 2015). In 2011, global production of marine bivalves from fisheries and aquaculture was about 14 million metric tons, with aquaculture accounting for more than 90% of this total. The community of bivalves is significant in ecological and biological processes (Poore and Wilson, 1993).

The hairy cockles are commercially important shellfish belonging to the Arcidae family of bivalves. Their shells are covered in brown or black hairs, and they feature a pair of spherical valves (Vongpanich,1996). Dixon *et al.,* (1995) discovered that adventitious hairs generated from the periostracum served as the valve's outer layer. Hairs have been proposed as a defensive role against predation (Harper and Skelton, 1993) and produced as a type of self-protection against the threat of environmental concern**.** Adventitious hairs are seen in a variety of different bivalves, including Arcoidea, Mytiloidea, and Veneroidea (Watabe, 1988).

The East Coast San Miguel Island, located in Lagunoy Gulf, is renowned for its rich marine biodiversity and extensive coastal habitats. It is recognized for its unique shellfish populations and rich coastal ecosystems. The Hairy Cockle has historically been harvested and traded in the region, providing local inhabitants with a significant source of livelihood and food. One of the species typically seen in seagrass beds inside coastal water, the hairy cockle or "kudkud," is normally distributed in the area. It can also be found in mud or stuck to rocks. However, there is limited information available on the population dynamics and distribution of the hairy cockle in this region. Assessing the status and understanding the underlying factors influencing the distribution patterns of this species is crucial for developing sustainable management strategies and ensuring the continued productivity of the local fishery.

This study focused on utilizing cohort analysis and virtual population analysis (VPA) to investigate the population dynamics and distribution of the hairy cockle on the East Coast of San Miguel Island, Tabaco City. Cohort analysis provided valuable insights into the growth, survival, and mortality rates of different cohorts within the population, while VPA offered a powerful tool for estimating population size, recruitment, and fishery yield. By combining these approaches, the study aimed to gain a comprehensive understanding of the hairy cockle population and its potential implications for resource management. Furthermore, this research contributed to the development of evidence-based policies and regulations for the sustainable use of hairy cockle resources. It generated essential information on the status and ecology of this commercially important shellfish species, contributing to its long-term management and the conservation of coastal ecosystems.

Objectives of the Study

Generally, the study aimed to assess the population of hairy cockles on the East Coast of San Miguel Island, Tabaco City, specifically in Sagurong, Sitio Matuwoy Visita, and Puro, Malictay.

The specific objective is intended to:

1. Determine the growth patterns of hairy cockle by conducting cohort analysis;
2. Estimate the abundance and distribution of the hairy cockle across different size classes by using virtual population analysis (VPA) techniques; and
3. Investigate the spatial and temporal distribution patterns of the hairy cockle population and identify the type of distribution in the study area through mapping and analysis of distribution data.

Significance of the Study

The general objective of the study was to describe the population of hairy cockles on the East Coast of San Miguel Island, specifically in Sagurong, Sitio Matuwoy Visita. The results of the study were beneficial for the students and researchers mainly focusing on hairy cockle studies. The essence of this study mainly emphasized the following:

To researchers and fisheries students, the results and findings of this study would give them additional information and knowledge on the species *Scapharca inequivalves.*

To the residents of San Miguel Island, they would gain knowledge and awareness of the resources on which they depend for their food and livelihood.

To the Bureau of Fisheries and Aquatic Resources (BFAR), they would come to know the condition of inshore resources, specifically hairy cockles, and imply regulations to monitor and secure threatened species.

To fisheries technologists and extension workers, the study would provide a supplementary guide to information about the hairy cockle and fisherfolks who utilize the species as a natural food source.

To future researchers, the result of this study would serve as a guide or reference if they want to undergo a similar study.

Scope and Delimitation

The study was conducted on San Miguel Island, specifically in Sagurong, Sitio Matuwoy, Visita, and Puro, Malictay. The study was a quick stock assessment covering 6 months that focused on the sampling stock of hairy cockles in San Miguel Tabaco City, Albay. The collected samples were subjected to cohort virtual population and nearest neighbor analysis. It described the population of hairy cockles on the East Coast of San Miguel Island. Moreover, distribution patterns and the type of distribution were investigated. The study focused only on the objectives that were enumerated; any studies related to the other species were not treated in this study.

Definition of Terms

To understand and clarify the terms used in the study, the following terms were operationally and conceptually defined:

Abundance - A very large quantity of something or the state or condition of having a copious quantity of something. In the study, this refers to the quantity or number of hairy cockles *(Scapharca inequivalves)* on San Miguel Island.

Arcidae- A family of ark shell mollusks in the class Bivalvia. They have soft bodies with platelike gills enclosed within two shells hinged together. In the study, this refers to the taxonomic family of hairy cockles.

Bivalves- Aquatic mollusks that have a compressed body enclosed within a hinged shell, such as oysters, clams, mussels, and scallops. In the study, this refers to the type of shellfish found in the seawater.

Bhattacharya method- It is useful for splitting a composite distribution into separate normal distributions. In the study, this was one of the methods used to determine the number of cohorts of hairy cockles involved in the study.

Caliper- An instrument used to measure the distance between two points. In this study, it refers to a tool used for measuring the length width, and height of the collected species.

Cohort analysis – A tool that extracts a group (=a cohort) that needs to be analyzed. In the study, this refers to the tool for assessing the demographic characteristics of the hairy cockle.

Distribution- The geographic occurrence or range of an organism. In the study, this refers to the range of hairy cockles on the East Coast of San Miguel Island.

Gleaners- Someone who collects something. In this study, it refers to someone who does the gleaning of the hairy cockle.

Hairy cockle (*Scapharca inequivalves*)- Also called the heart clam, is any of the approximately 250 species of marine bivalve mollusks, or clams, of the family Cardiidae. In the study, this refers to the species on San Miguel Island that underwent stock assessment.

Kudkud- This refers to the local name of the hairy cockle (*Scapharca inequivalves)* in San Miguel Island.

Mollusks- Any animal that has a soft body, no spine, and is often covered with a shell.

Nearest Neighbor Analysis (NNA)- A method for assessing the degree to which a spatial point pattern departs from randomness in the direction of being either clustered or regular.

Sagurong- One of the barangays in San Miguel Island, Tabaco City. In this study, it is one of the barangays that had the most abundant population of hairy cockles.

Sitio Matuwoy, Visita- Situated at approximately 1.3941,123. 7741, on the island of San Miguel. In the study, this is one of the gleaning areas of hairy cockles in San Miguel Island.

Spatial distribution- A study of things in terms of their physical condition. In the study, this pertains to how far the distance of collected hairy cockle from the shore is.

Puro, Malictay- One of barangays in San Miguel Island. This is one of the areas involved in the study.

Temporal distribution- It describes a phenomenon at a certain location and time. In the study, this refers to the time that the hairy cockle can be found throughout the year.

Virtual population analysis- A cohort modeling technique used to reconstruct the historical population structure of a fish stock using information on the deaths of individuals in each time step. In the study, this refers to the technique used to describe the abundance and distribution of the hairy cockle population in the area.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents a discussion of related literature and studies reviewed by the researcher which gives information about the study.

Related Literature

Biology of Bivalves

Bivalves, marine creatures, are the second most dominant class in the Mollusca phylum. They have a laterally compressed body and an exterior shell divided into two pieces, connected by interlocking teeth. The skull is primitive and lacks buccal or radar equipment. The mantle lobes feed primarily through cilia, with sieve and sorting mechanisms found on labial palps and leaf-like ctenidium. The mantle cavity comprises a pair of ctenidia suspended laterally. The mouth and anus are located at opposite ends of the body, and the gut is convoluted. The foot is compressed and used for burrowing, except in sedentary forms (Vidya *et. al*, 2017)

Bivalves have evolved to become flattened from side to side. They have two hinged dorsally hinged shell valves, secreted by two mantle lobes over the body organs. Over 80% of species live in ocean habitats and exhibit varied ecologies. Sessile epifaunal bivalves, like oysters and mussels, attach themselves to hard surfaces using cement or byssal threads, while infaunal burrowers bury themselves in sand or sediment. Some species, like scallops, can move through the water by clapping the two shell valves together or using their muscular feet. Most bivalves use enlarged gill surfaces to filter food particles from the surrounding water (Gosling, 2015).

Among molluscan shellfish, bivalve is the most biologically diverse of all organisms. Bivalve makes up the largest second molluscan class behind gastropods. (Storer *et al*.,1979). Bivalves, with their strong shells, have a complete fossil record but lag behind other animal groups in systematics. However, researchers are increasingly involved in large-scale phylogenetic analyses using morphological, palaeontological, and molecular data sources (Bieler & Mikkelsen, 2006). Historically, single-character systems were heavily relied on, but numerical systematics in the 1970s allowed simultaneous analysis of multiple-character systems. Gene sequence data, available since the early 1990s, has significantly contributed to systematic studies, encompassing all Bivalvia and major groups within the class (Giribet 2008; Plazzi & Passamonti 2010; Plazzi *et al*. 2011; Tsubaki *et al*. 2011; Sharma *et al*. 2012; Yuan *et al*. 2012**)**.

Bivalves, a diverse group of 15000 species, play a crucial role in ecological and biological processes. The family Arcidae, consisting of 300 species, inhabits the world's oceans, with around 180 species from 30 genera living in Indo-Pacific waters. These bivalves are traded locally and internationally, with the hairy ark cockles of the family having unique characteristics such as brown or black hairs covering their shells and round valves. These hairs have been proposed as having a defensive role against predation and self-protection from environmental fluctuations. In Indonesia, there are six dominant species of hairy ark cockles, including *A. inaequivalvis, A. antiquata, A. pilula, A. antiquata, A. gubernaculum, and A. cornea* (Fitriawati, *et al.* 2016).

The individual ages of bivalve mollusks can be inferred from the age rings laid down every year in the shell, especially in species inhabiting areas with seasonal and variability in environmental factors such as food supply and temperature. Animals obtained from different environmental settings can therefore be used to investigate how specific environmental factors shape the process of aging in the animal class. Some bivalves have extraordinarily long life spans. Species like the ocean quahog *Arctica islandica* and the freshwater pearl mussel *Margaritefera margariteferalive* for hundreds of years.

Distribution of Bivalves

Bivalves are essential for the survival of marine ecosystems and communities. An exploited bivalve population's abundance is determined by the balance of inputs (reproduction/recruitment and growth) and outputs (mortality and fisheries removals). Population sustainability requires successful reproduction and recruitment (Magalhães *et al*., 2016). With 12% of their species living in freshwater, 35% on land, and 53% in the sea, bivalves are members of the phylum Mollusca. Few species of bivalve creep down the bottom; most prefer to dig in the sand or mud. Since they carry out nutrient cycling, filter organic materials, and capture waterborne plankton, they are crucial to coastal ecosystems. In the substrate, where marine macrophytes and algae use the nutrients, their waste products are left behind. Along with other species, they are preyed upon by crustaceans, fish, and shorebirds (Vito, 2018).

Bivalves, a representative group in the Phylum Mollusca, have over 1,100 freshwater species worldwide, including 900 in the Unionida Gray, 1854 order. The distribution of Unionida in South America includes all countries and extends as far south as Argentinean-Chilean Patagonia. The study analyzed 1,833 lots and geo-referenced 1,503 lots, analyzing species richness using surface drainage basins. Only 18% of

Unionida in Argentina have been classified by the IUCN, and over 95% of the distributional range lacks protected areas. Conservation management is crucial for preserving Unionida diversity in southern South America (Torres *et al*., 2018).

Bivalve species called razor clams live in shallow waters in tropical, subtropical, and temperate oceans. The most hospitable conditions for Razor clams and 14 Solen species were predicted using the species distribution modeling program "maximum entropy." With a depth of 0-150 m, a wave height of 5-7 m, and a mean chlorophyll-a content of 0.7 mg m3, the environment between 0 and 100 km was the most ideal. According to future environmental scenarios, the majority of species were expected to shift their distribution ranges poleward, with northern hemisphere species relocating northward and southern species shifting southward. Furthermore, with future climate change, 29% of the species' distributions will not alter, while 21% will see a reduction in their ranges. An increase in the number of species and better species richness at the regional level would result in the expansion of geographic ranges. According to model predictions, the global temperature change will cause the peaks in species richness at mid-latitudes to become farther apart from one another and will cause a greater dip in richness near the equator (Saeedi *et al*., 2016).

In soft-sediment ecosystems off the Atlantic Ocean, such as the European margin and the Bay of Biscay, bivalve mollusks constitute the major benthic group. Bivalve samples from two oceanographic missions in the middle Bay of Biscay, including the Avilés Canyons System, were studied in research. A total of 84 living species from 36 families were found, including the first record of *Cetomya neaeroides* in the region. Three species assemblages were discovered in the study: one in shallow waters (continental shelf), one in intermediate depths (upper slope and shelf), and one in deep waters (slope and abyssal plain). The key structural element affecting the distribution of the species that were observed was depth (López-Alonso *et al*., 2022).

Sediment granularity and depth were the primary determinants of the distribution of bivalves. The analysis of *Macoma balthica*, *Mytilus edulis,* and *Cerastoderma glaucum* populations on the Polish coast (up to 4 Nm) and estuary zones of Middle Pomerania showed that their density and environmental factors, such as distance from the shore, substrate type, coast type, and depth, significantly influenced their abundance (Zbigniew *et al*., 2009). Along the Hungarian Danube River system, the geographical distribution of bivalves about environmental variables was investigated. In all, 1662 specimens were gathered in 2007, and 22 different bivalve species were identified. The distribution of bivalves is considerably influenced by ten environmental parameters, with substrate types, current velocity, and sedimentological features being the main explanatory variables (Bódis *et al*., 2011).

Bivalves in the Philippines

Mollusks have soft bodies made up of a dorsal visceral mass, a ventral foot, and an anterior head. They are widely dispersed in both time and space. They exhibit adaptability to various habitats. The largest number of species of marine shells are found in Southeast Asia. Even today, rare inquiries into biodiversity have occasionally focused on the Philippines. The southern regions are no exception. Even though the attention paid to them is typically out of proportion to the abundant resources that are truly available, The Philippines is fortunate to have a wealth of aquatic resources due to its archipelagic geography. The establishment of biological and taxonomic links between closely related taxa requires a thorough understanding of the distribution patterns of molluscan species. Unfortunately, little is known about the distribution patterns of a vast number of Philippine mollusks, and what little is known can frequently be inconsistent (Minguez-Galenzoga, 2018).

Bivalve mollusks in the Philippines exhibit a great deal of diversity and abundance, with novel species constantly being discovered. This particular marine molluscan class constitutes a significant proportion of the country's molluscan species, comprising about 27% of the total molluscan population. The Tubbataha Reefs Natural Park, located in Palawan, boasts a wide assortment of bivalves, with 17 new species having been identified within the region (Cabrera, 1987). The Iwahig River Estuary, also situated in Palawan, is host to a diverse array of molluscan fauna, which includes 15 bivalve species distributed across various habitats (Dolorosa *et al*., 2015). Furthermore, it has been discovered that bivalves that are edible and originate from Manila Bay have been contaminated with human pathogens, such as Cryptosporidium (Tabugo *et al.*, 2013). These findings underscore the importance of examining and monitoring bivalves in the Philippines for both ecological and public health reasons.

With more than 1,100 different marine bivalve species found throughout its coastal regions, the Philippines relies heavily on bivalves as a food source and export commodity. Oysters, mussels, pearl oysters (MOP), windowpane shells, gigantic clams, scallops, ark shells, venerid shells, and angel wing shells are some of these species. These shells are utilized in the production of pearls and are used to make pearl buttons, decorative plates, accessories, and other shellcraft items. With an estimated export value of P199 million in 1987; shellcraft is one of the country's top dollar earners. Bivalves are a crucial supplemental source of protein since they are the least expensive in regions where malnutrition is common. Bivalves are an important resource, but study into their cultivation is limited. Early studies focused on taxonomic and anatomical studies of oysters, mussels, and window-pane shells, while recent work focused on the biology and culture of giant clams, scallops, and kapis. During a seminar-workshop on the condition of mollusc resources in 1986, research gaps were discovered, with one concern being the assessment of the country's bivalve resources and their regional distribution. (The Philippine Journal of Fisheries, 1975)

The Philippines is home to a diverse range of marine organisms, yet addressing this diversity has been challenging due to security concerns in some sections of the archipelago. Marine mollusk research continues, but there is a shortage of fundamental information, such as diversity and species checklists, making it difficult to estimate the pace of population decline among existing marine mollusks. A study investigated, documented, and identified economically significant mollusks on the island of Hadji Panglima Tahil in the Philippines' province of Sulu. There were 18 mollusks (marine bivalves and gastropods) discovered and recognized on the island, which served as food, ornaments, and a source of income for the locals. The northwestern section of the island is strategically protected, rendering it undisturbed by powerful waves, whereas the eastern portion facing Jolo is more exposed to strong waves, providing an advantage to mollusks that thrive in deeper coral zones (Tabugo *et al*., 2013)

Cohort and Virtual Population Analysis

Cohort analysis and virtual population analysis (VPA) are widely used techniques for analyzing exploited fish populations. These methods estimate the past numbers and exploitation rates of distinct cohorts of a population when the history of catch in numbers of individuals is available from these cohorts. These methods are not limited to fish populations, as they are used in fisheries management to estimate large exploited fish stocks and time series of stock sizes and recruitment numbers. The term “virtual population analysis” was introduced by Fry, Gulland, and Murphy, while “general cohort analysis” has the equations of Pope’s cohort analysis as a special case (Askland, 1994).

Cohort analysis is a simplified version of Gulland’s virtual population analysis that allows for the estimation of fishing mortality, natural mortality, and fishing mortality at the end of exploitation. This technique can be used to evaluate a fishery by estimating the population at age and fishing mortality independent of effort measurement. The simplicity of applying cohort analysis enables for analysis of lapses caused by arbitrary fishing mortality rate selection and sampling errors in catch-age data. Gulland’s virtual population study (1965) is a very handy tool for evaluating fisheries because it allows for population estimations at various ages and fishing mortality to be calculated separately from the measurement of effort (Pope, 1972).

Virtual population analysis (VPA) is a crucial method for assessing freshwater and marine fisheries resources. It involves calibrating abundance estimates with time series of abundance indices, often using simultaneous estimations of cohort sizes across all ages and years. This method reduces the model's flexibility in accounting for age- and year effects, particularly in the presence of an age-specific curvilinear relationship between abundance index and stock abundance. In a study comparing the simultaneous method and the stepwise approach, the stepwise method performed better with no apparent retrospective errors in estimated stock biomass. The stepwise method yielded more reliable results and was less risk-prone when using VPA for fisheries stock assessment (Chen, 2008). The VPA method is a widely used method for assessing fish stocks in various regions, including the Northeast and Northwest Atlantic, the Northern Pacific, Australia, New Zealand, South Africa, Argentina, Chile, Peru, and CCAMLR and CECAF. It has been expanded to include multispecies interactions and has been used in assessment work since the 1980s and early 1990s (Lassen, 2001).

Application of Cohort Analysis, Virtual Population Analysis, and Distribution of Bivalves

Cohort analysis is a tool for analyzing and evaluating changes in the behavior of a group of organisms who share a common demographic attribute over time (Ryte Wiki, 2021). A cohort is a group of organisms who share a particular attribute or experience over a specific period. It enables researchers to investigate how distinct cohorts evolve and change over time, providing insights into the influence of specific events, policies, or experiences on the behavior or results of individuals within the cohort. Analyzing the demographic processes of the hairy cockle will provide insights into its life history and an understanding of how various factors influence its population dynamics. Additionally, virtual population analysis (VPA) is an effective method in fishery management for estimating population size, recruitment, and fishery productivity. Applying VPA techniques to estimate the abundance of the hairy cockle population and examine the potential implications of fishing operations. Cohort analysis of bivalve mollusks has been conducted in several studies. Way's survey of life history traits in pisidiid bivalves identified groupings of traits that strongly covary at genus and interspecific levels. Giribet and Wheeler provided a phylogenetic estimate for bivalve mollusks, supporting the monophyly of bivalves and the paraphyly of protobranchiate bivalves. Hmida *et al*. developed an oocyte maturation scale for razor clam populations, identifying a 4-stage maturation process. Virtual Population Analysis (VPA) is a widely used model for analyzing fish populations and calculating stock size based on catches without making statistical assumptions (Saraiva *et al*., 2014). It is applied to bivalve mollusks to study population dynamics and assess fishing impacts. VPA assumes discrete age classes and estimates the abundance of each age class based on catch data and growth and mortality rates. It has been applied to bivalve species in marine and freshwater environments, providing valuable insights into their dynamics and the effects of fishing pressure (Lassen, 2001).

A study presented a cohort analysis method for exploited wildlife populations, an analysis of basic mathematical properties, and a flexible technique for stepwise back calculation. The technique can replace biased virtual population analysis techniques and provide better estimates. The analysis also demonstrates the sensitivity of back-calculated cohort numbers and exploitation rates to input parameters and functions (Xiao and Wang, 2007). Raup, 1978, used cohort analysis to study the extinction pattern of an organism. This procedure consists of calculating the survivor data of a cohort of taxa. A cohort is a group of taxa that originated at a given moment of geologic time, by analogy with organism cohorts of a population in ecology. The method consists of linking percent points of surviving taxa for specific times by broken lines, and this is represented in a semilogarithmic graph of geologic time/proportion. The alignments, always with a negative slope, provide a qualitative image of extinction rates and allow us to compare them and follow their fate until the Holocene. Nine cohorts are considered in the study interval (Induan to Sinemurian) (Ros *et al*., 2011).

Virtual Population Analysis (Gulland, 1965) and its approximation, Cohort Analysis (Pope, 1972), are standard techniques for stock assessment when historical catch-at-age data are available. Jones (1979, 1984) suggested a length-cohort analysis (LCA), which uses length-frequency data to create a synthetic cohort when growth and mortality data are available but age data are not. It is assumed that a steady state exists and that the length-frequency distribution of a catch, which is made up of multiple-year classes, at any given time is reflective of the catch from one cohort across the years in the fishery. The techniques have been used in the investigation of dynamics and management of the bivalves in Garrison Bay. According to the study, inaccurate input parameters consistently lead to relative abundance and fishing mortality mistakes in Pope's Cohort Analysis and LCA. LCA has larger relative errors, though. Although long-frequency distributions can be used to assess steady-state assumptions, their greater reliance on a steady state and the von Bertalanffy growth model suggests that Pope's Cohort Analysis results should be trusted more than LCA results (Lai & Gallucci, 1988).

To study age-specific mortality in this softshell clam population, the Mya arenaria generation in the White Sea was observed for almost its entire cycle. A cohort life table was created. Throughout the study period, the death rate varied over 10 times, with periods of low mortality and periods of significantly greater mortality. Early life in the surface sediment layer, intense intraspecific relationships in clam aggregates, increased intraspecific competition during rapid individual growth, and aging—which causes clam mortality to rise with age—are some of the causes of the rise in mortality rate. Clams have an average and maximum lifespan (Gerasimova *et al*., 2014).

Using Jones' length-based cohort method, a virtual population analysis of the Glory scallop (*Mimachlamys gloriosa Reeve, 1853*) from Asid Gulf, Philippines, was performed. The objective of the study was to reconstruct the biomass and population structure to calculate the stock's maximum sustainable yield (MSY) and fishing mortality. The proportion of *M. gloriosa* was examined using length-frequency information from commercial catches from April 2018 to March 2019. *M. gloriosa* has an estimated population of about 300,000 people and a mean biomass of 6.76 metric tons. A higher-than-MSY anticipated total output of 8.09 metric tons points to excessive harvesting and heavy fishing pressure. The breeding stock would be endangered by this excessive harvest and high exploitation ratios, which would result in overfishing during recruitment. The Thompson and Bell model demonstrated that implementing a minimum size constraint boosted yearly production and biomass by 7.62% and 20.45%, respectively, showing a positive implication of this method (Buban & Soliman, 2021).

In a study on the determination of the growth parameters of the *Anadara cornea*, the Bhattacharya were used for age determination in mollusk species which requires microscopically studied shells. This method, implemented in the LFSA computer program, splits the composite distribution of length into separate normal distributions to identify different cohorts. The mean length of components derived from the Bhattacharya method is plotted against time series to obtain the assumed cohorts. The FISAT package program was used for the application, and the study demonstrated that the Bhattacharya method provides reliable results for *A. cornea* populations when aging is not possible or difficult. Frequent and abundant sampling can be used directly for population analyses, allowing for more accurate and reliable age determinations.

In the study of Vito, (2018) about the diversity and abundance of economically important bivalves in north-western Bohol, Philippines, she found out that there were diverse bivalve species present in mangroves and seagrass ecosystem of Northwestern, Bohol, Philippines which were represented by the 35 identified species. Their abundance was due to the muddy substrate in the area which was favorable for these bottom dwellers.

These economically important bivalves with high abundance and distribution can be monitored for the sustainability of wild stocks in the area. A law regulating the intense collection of economically important bivalves in Northwestern Bohol could help mitigate the loss of these organisms. Also, considering, the economic value-gleaning activity of these least abundant species may be regulated for the sustainability of these wild stocks in the area.

Related Studies

A study analyzed biometric features and relationships between samples of blood cockle, *Scapharca inequities*, a benthic exotic bivalve species from the Black Sea Turkey. Over 12 months, 4,543 samples were collected, measuring length, width, thickness, weight, and total weight and meat weights. SL changed between 0.45 and 7.18 cm with an average value of 3.77 ± 0.02 cm. The average TW of the samples was 22.37 ± 0.26 g. The average MW of *S. inequivalves* was calculated as 10.66 ± 0.32 g with a rate of 26.85 % of TW. Results showed small monthly variations n SW and MW, while monthly ST varied greatly. Correlation and cluster analysis revealed weak associations between MW and other variables, with the strongest correlation between ST and SWe in October. The findings provide valuable information for the exotic species, but further research is needed to better understand its biological characteristics and long-term effects on the ecosystem (Aydin, 2015).

The population parameters of blood cockles, *Tegillarca granosa*, were studied in the intertidal zone of Marudu Bay, Sabah, Malaysia. A total of 279 cockle individuals were studied, with shell length and weight ranging from 27.7 mm to 82.2 mm and 13.11 g to 192.7 g. Tegillarca granosa in Marudu Bay had a relatively high condition index of 4.980.86 throughout the year, with negative allometric growth, according to the study. T's asymptotic length, growth coefficient, and growth performance are estimated. In Marudu Bay, the granulosa population was 86.68 mm, 0.98 a1, and 3.87, respectively. The greatest shell length measured was 82.55 mm, while the projected maximum shell length was 84.44 mm. The greatest projected life span was 3.06 years. The level of exploitation (E) was 0.45. The study also discovered two big recruitment peaks in March and October, with T. Granosa in Marudu Bay nearing its maximum utilization level. If the current trend continues or if the demand for *T. granulosa* grows, and there is no efficient fisheries control in place, the probability of T. The collapse of the granulosa population in Marudu Bay is likely to worsen (Doinsing *et al*., 2021).

The exploitation of bivalve mollusks in new fishing areas often lacks biological and fishery information to support management measures. This study aimed to estimate morphometric relationships, growth parameters, and natural mortality in recently exploited populations of *Megapitaria aurantiaca*, *Megapitaria squalida*, and *Dosinia ponderosa* to generate information on population dynamics and support management and conservation measures. The length-weight relationship and relationships between shell length, height, and width were calculated to estimate morphometric size at first maturity. The von Bertalanffy growth model parameters were calculated through a modal progression analysis, and natural mortality was estimated depending on age. The morphometric relationships were allometric in all cases, with *M. aurantiaca* having a morphometric length of 67.60–77.20 mm. *M. squalida*, 35.40–40.32 mm, and *D. ponderosa*, 103.44 mm. The species exhibited moderate growth, with natural mortality oscillating between 0.71 and 1.45 y-1 during the adult phase and 1.26 and 1.97 y-1 during the juvenile phase. These estimates provide essential inputs for fishery management and conservation of the species. (Rocha *et al*., 2018)

Cockles, two sympatric species of cockles, are heavily harvested in Portugal, where they serve an important ecological and social function in coastal environments. They can co-occur in estuaries and coastal lagoons with diverse populations around the European Atlantic coast, including Portugal, France, and the United Kingdom. The growing importance of shellfish harvesting in Portugal necessitates a better understanding of cockle populations and temporal variability in stock levels to advise sustainable management techniques. This study looked at geographical and temporal variability in cockle populations in two Portuguese estuarine systems where the species is harvested at a low level. In each of the three sample years (2015, 2018, and 2019), a clam dredge was used to cover the whole potential region of occurrence in the Tagus and Sado estuaries at roughly the same time of year. The findings revealed that cockles are generally found in the middle of both estuarine systems, with the Tagus estuary being the most plentiful. The population structure analysis revealed that natural mortality is restricting cockle populations in both estuaries due to a scarcity of adult individuals of marketable size. This study emphasizes the significance of suitable management strategies to preserve the survival of these bivalve population stocks, which are important socioeconomically for residents (Santos *et al*., 2022).

Synthesis of the State-of-the-Art

The above-mentioned review of literature and studies revealed a greater understanding of the bivalve mollusk, which provided knowledge and additional information to the researchers for the current study. As mentioned by Storer *et al*. (1979), among molluscan shellfish, bivalve organisms are the most biologically diverse of all organisms. Bivalves make up the second-largest molluscan class behind gastropods. With 12% of their species living in freshwater, 35% on land, and 53% in the sea, bivalves are members of the phylum Mollusca. Vito (2018) reported that few species of bivalve creep down the bottom; most prefer to dig in the sand or mud. Since they carry out nutrient cycling, filter organic materials, and capture waterborne plankton, they are crucial to coastal ecosystems. Bódis *et al*. (2011) discovered that the distribution of bivalves is considerably influenced by ten environmental parameters, with substrate types, current velocity, and sedimentological features being the main explanatory variables.

Cohort analysis and virtual population analysis (VPA), on the other hand, are widely used techniques for analyzing exploited fish populations. These methods estimate the past numbers and exploitation rates of distinct cohorts of a population when the history of catch in numbers of individuals is available from these cohorts. Raup (1978), used cohort analysis to study the extinction pattern of an organism. This procedure consists of calculating the survivorship data for a cohort of taxa. In 2014, Gerasimova *et al*. created a cohort table to study age-specific mortality in the softshell clam population, the Mya arenaria generation, in the White Sea for almost its entire cycle and found out that clams have an average and maximum lifespan.

Gap Bridged by the Study

A review of related literature and studies by the researchers has been completed. It was observed that there are many related studies regarding the distribution of bivalves. However, in the Philippines, based on the related literature and other local studies, there has been no study conducted regarding the population analysis of the hairy cockle, or "kudkud," using cohort and virtual population analysis on the East Coast of San Miguel Island. The researchers assumed that this was the first study in the country and the first to provide data and information about the species in the said vicinity. The study therefore served to fill the gap as follows: (1) To determine the growth patterns of hairy cockles by conducting cohort analysis; (2) To estimate the abundance and distribution of the hairy cockle across different age or size classes by using virtual population analysis (VPA); and (3) To investigate the spatial and temporal distribution patterns of the hairy cockle population and identify the type of distribution in the study area through mapping and analysis of distribution data. Thus, it will serve as the basis for interim management and will contribute towards the conservation and enhancement of the hairy cockle, or kudkud," in San Miguel Island of Tabaco City.

Theoretical Framework

The theoretical frameworks of the study explain the different theories, perspectives, and models related to the problem as shown in Figure 1. The foregoing study was aimed to describe the population of hairy cockles (*Scapharca inequivalves*) on the East Coast of San Miguel Island, Tabaco City, Albay. The following theories apply to the study: Ecological niche theory, Ideal free distribution, Habitat suitability theory, and exploitation theory.

Ecological niche describes how an organism or population responds to the distribution of resources and competitors (for example, by growing when resources are abundant and when predators, parasites, and pathogens are scarce) and how it in turn modifies those same factors (for example, by limiting access to resources by other organisms, acting as a food source for predators, and consuming prey). Hardesty (1972) stated that an ecological niche includes all the requirements for an organism to exist. It can examine every interaction.

The ecological niche concept, as proposed by Hutchinson (1957), expresses the relationship of an individual or a population to all aspects of its environment. Studies on the relationship between human populations and environmental resources have employed niche concepts (Adams, 2002; Hanazaki and Begossi, 2004; Cavallini and Nordi, 2005; Silva and Begossi, 2009). It is essential for understanding species distributions, community dynamics, and the coexistence of species within ecosystems. It helps explain how species partition resources, compete with one another, and adapt to different environmental conditions.

Ideal free distribution (IFD) is a theoretical method for how organisms in a population should be distributed among various patches of resources in their environment to minimize resource competition and maximize fitness. According to this theory, individuals will move and settle in habitats or resource patches in a way that allows them to achieve an equal level of fitness regardless of the patch quality. It provides a theoretical framework for understanding how animals make foraging decisions and distribute themselves among resource patches based on their quality and availability. The theory has applications in various ecological contexts, including predator-prey interactions, competition for resources, and habitat selection.

Habitat Suitability Theory is a concept in ecology that focuses on the relationship between organisms and their preferred habitats. It posits that species exhibit preferences for specific environmental conditions and will occupy habitats that best suit their ecological requirements. It recognizes that different species have distinct ecological requirements and will occupy habitats that provide suitable conditions for their survival and reproduction. Furthermore, it encompasses a diverse array of environmental factors, including temperature, humidity, food accessibility, vegetation structure, and various abiotic and biotic components, all of which determine the suitability of a given habitat for a particular species.

Exploitation Theory is a crucial concept in fisheries research that endeavors to comprehend the intricate dynamics and influence of fishing on fish populations and ecosystems. The theory scrutinizes how fishing activities impact the abundance, age structure, size distribution, and reproductive potential of target species, as well as the broader ecological community. The seminal work of Beverton and Holt (1957) created the basis for Exploitation Theory, underscoring the significance of considering the biological and ecological ramifications of fishing activities. Their findings highlighted the need to comprehend the effects of fishing mortality on fish stocks and the implementation of sustainable fishing methods.

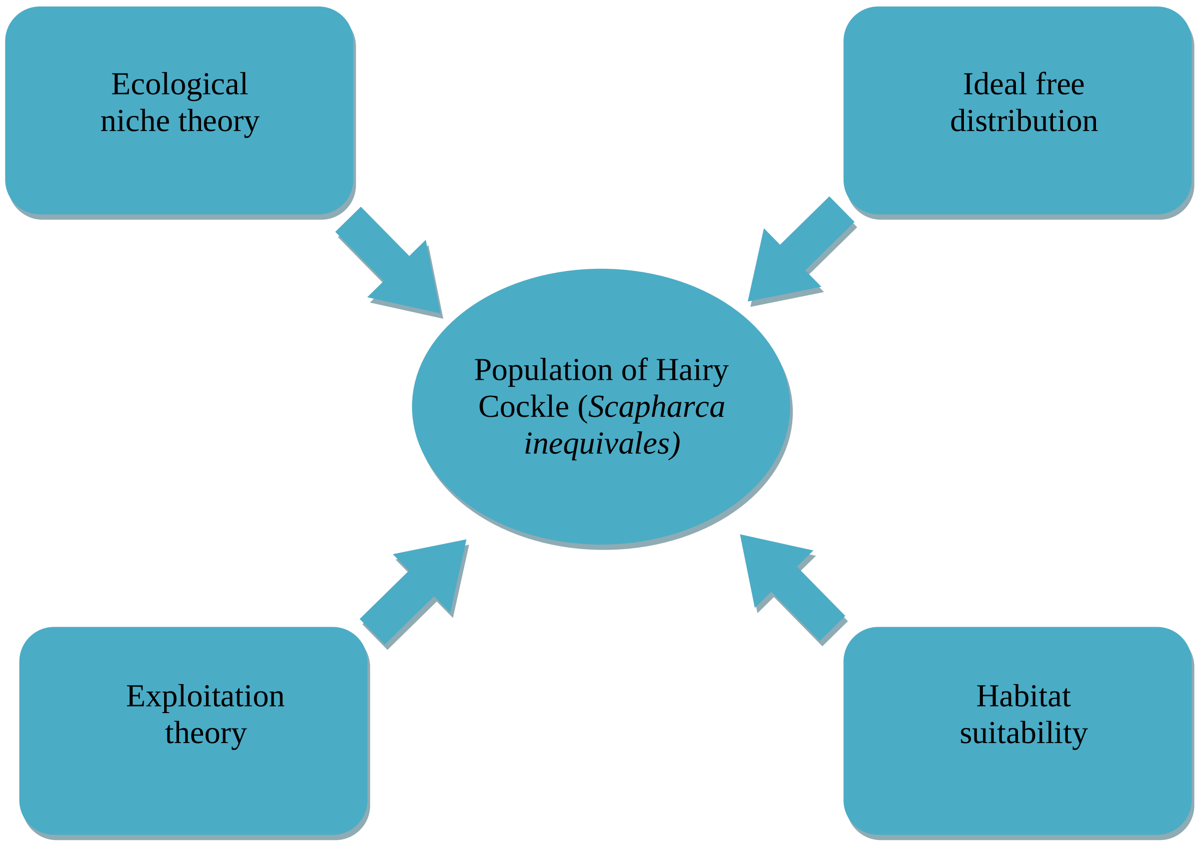

Figure 1. Theoretical Framework of the Study

Conceptual Framework

Many bivalve species contribute to aquatic and aquatic ecosystems by filtering water and acting as habitat and prey for a diversity of sea life (National Oceanic and Atmospheric Administration, 2023). It plays a vital role in marine ecosystems and has significant ecological and economic importance. They contribute to the overall health and functioning of coastal and estuarine environments, and they provide important ecosystem services.

Hence, the conceptual framework of the study was gathered as guided by literature, reviews, and other related studies. This study involved the assessment of the population of Hairy Cockle *(Scapharca inequivalves)* considering cohort analysis, virtual population analysis, and its distribution along the east coast of San Miguel Island. Figure 2 presents the conceptual of the study.

The input includes the collection of the samples, statistical tools, determining the distribution, and identifying the habitat references where hairy cockles lived. The collection of *Scapharca inequivalves* was conducted during the implementation of the study, within the proposed duration. This parameter was examined through observation, recording, and technical knowledge. The process of the study was based on the methodology applied, which includes analysis, data gathering, and measurements. The collection of samples required some procedures and the use of tools and equipment. The researchers used a caliper to get the length of the samples. The outputs were based on the input that was applied and the process that was gathered. This output included the growth patterns of hairy cockle, abundance, and distribution of the hairy cockle on the East Coast of San Miguel Island, Tabaco City.

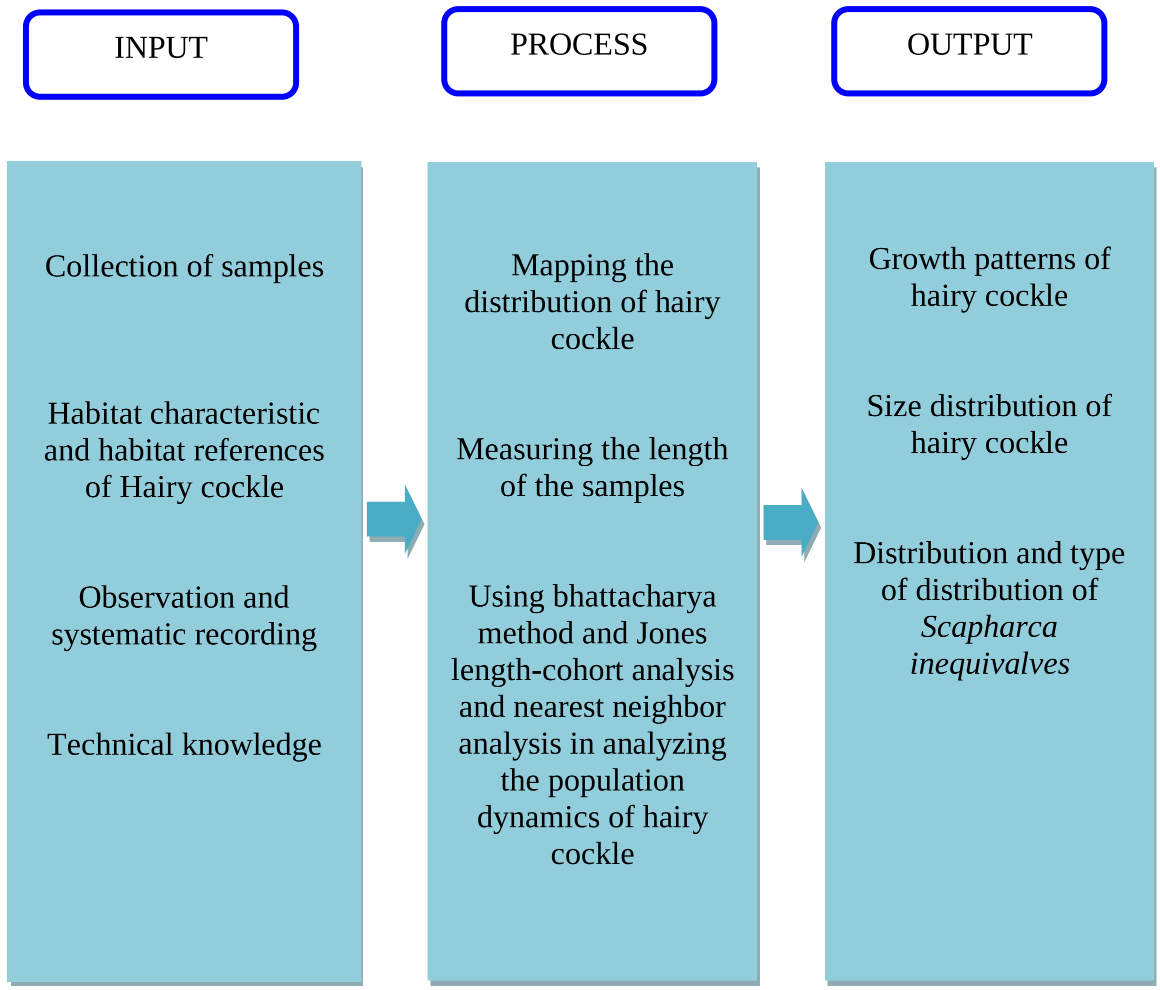

Figure 2. Conceptual Framework of the study

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This chapter presents the materials and methods employed in the research entitled "Cohort analysis, Virtual population analysis, and Distribution of Hairy Cockle *(Scapharca inequivalves)* on the East Coast of San Miguel Island, Tabaco City". It also includes the research design, methodology, data source, data collection, data analysis, and statistical analysis that were used in the study.

Description of the Study Area

The study was conducted on the East Coast of San Miguel Island Tabaco City, Albay, specifically in Sagurong, Sitio Matuwoy Visita, and Malictay (Figure 3). The island, which is under the jurisdiction of the City of Tabaco, comprises five barangays: Rawis, Visita, Sagurong, Hacienda, and Malictay, and is located at approximately 13.3779 near Lagonoy Gulf. The island could be accessed in about 30 minutes by motorized boat from Tabaco Maritime Port. Hairy cockle (*Scapharca inequivalves*) in particular was collected in 3 areas: Sagurong, Sitio Matuwoy Visita, and Malictay. These 3 areas have a seagrass-seaweed zone with diverse fauna and were particularly known for fishing grounds where different bivalve mollusk species, particularly hairy cockles, were being harvested by gleaners. Aside from the fishing grounds, gleaning was also one of the major sources of livelihood for the residents of coastal areas. The Rapid Resource Assessment (RSA) discussed by Nieves *et al.* (2010) indicated that women constituted the majority of gleaners in Sagurong, Tabaco City, and the activity of gleaning was typically carried out in the company of children and family members. It was found that children accounted for 58% of gleaners, while adults made up the remaining 42%, with women constituting 66% and men 34%. Gleaning activity coincided with the occurrence of low tide. The areas where gleaning was conducted included shallow coastal areas, reef flats, mud flats, sandy or rocky areas, and seagrass areas, which had made the gleaners well acquainted with coastal habitats.

Figure 3. Location of the study, East Coast of San Miguel Island, Tabaco City

Research Design

The methods of the study were undertaken through quantitative research to describe the population of Hairy cockles that were collected in San Miguel Island, Tabaco City. Moreover, this study used descriptive research design specifically observational as a research method that described and explained the population and distribution of the species. This method was appropriately used in the study because the researcher intended to investigate and gather information about growth patterns, size distribution, and the type of distribution of hairy cockles in San Miguel Island of Tabaco City. Figure 4 states the process of the collective species to data analysis.

Data Source

Primary and Secondary data were the two types of data resources. The primary data were gathered through first-hand observation and sample collection during field research in San Miguel Island of Tabaco City. Secondary data included information gathered from books, encyclopedias, printed materials, unpublished theses, articles published in professional journals, related literature, and other sources that could make a significant contribution to data presentation and thus be useful and relevant to the study.

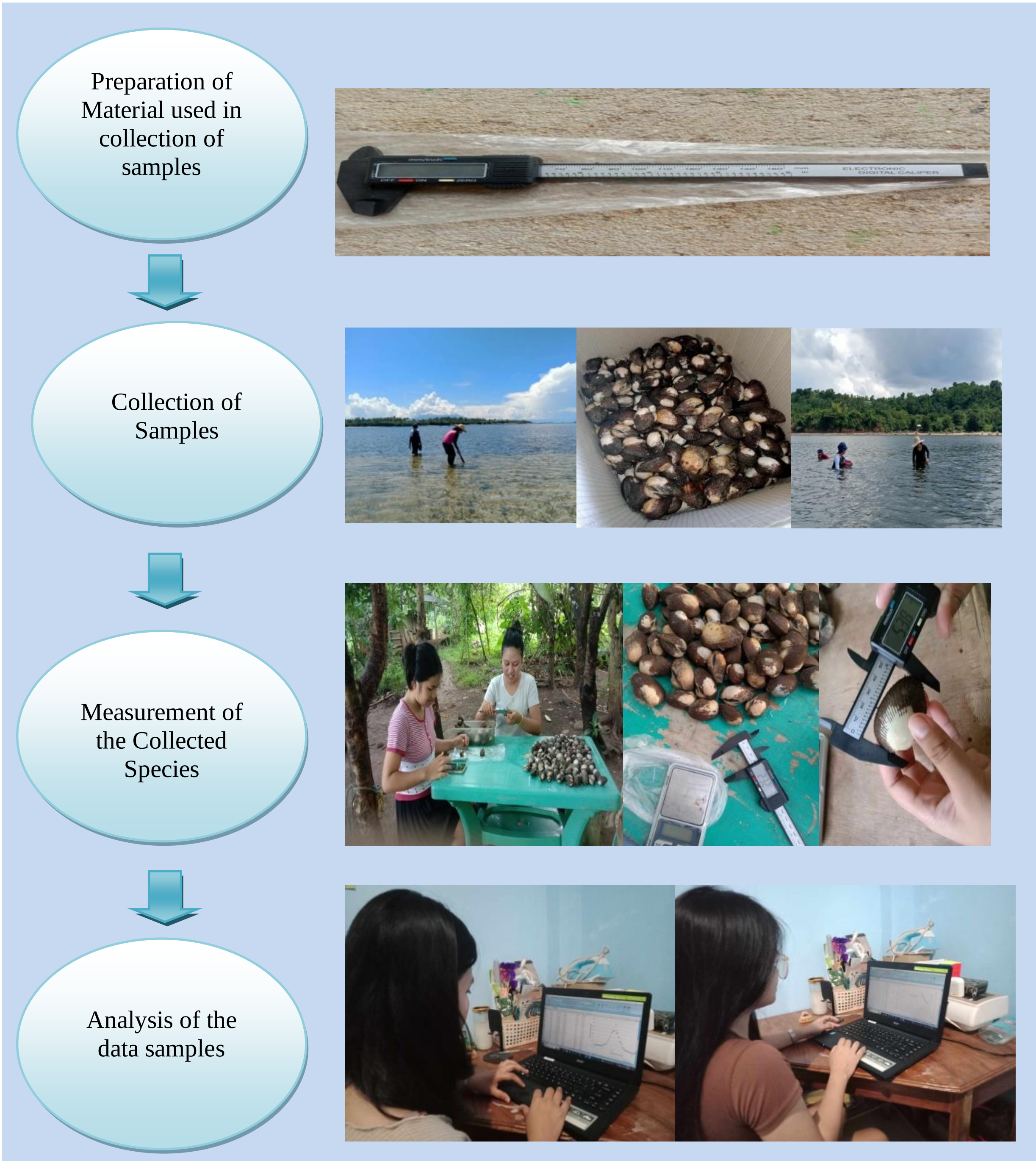

Figure 4. Experimental Design of the Study and Actual Data Gathering

Data Collection

Field sampling was conducted in 3 areas (Sagurong, Sitio Matuwoy Visita, and Malictay) at San Miguel Island of Tabaco City. These 3 barangays have the most abundant population of hairy cockles on San Miguel Island. The species were collected randomly and executed within a period of 6 months, starting from July to December 2023 as shown in Table 1. The collection of species varies on the low tide in the area which is most sampling date conducted during winter equinox. In the sampling area of San Miguel, the estimated water depth where the species were found was about half a foot to 3 feet, which usually occurred during low tides. This helped the researchers collect the samples efficiently and secure both systematic procedures and safety. The samples were collected by bare hands, scraping, dancing techniques, and visual cues. Six thousand pieces (6000) of hairy cockle in the 3 samplings area were collected within the 6-month duration. One thousand two hundred (1200) samples were collected in July to October while 600 samples were collected in November and December. The collected species were measured for their length using a caliper. After obtaining and recording all the needed data from the samples, it underwent different statistical analyses.

Table 1. Schedule of Activities

Date	Daytime (Actual time of sampling)	No. of Samples (pcs.)
July 2023	Morning- Afternoon (10:00-1:30)	1,200
August 2023	Morning-Afternoon (10:30-2:00)	1,200
September 2023	Morning-Afternoon (11:30-2:30)	1,200
October 2023	Morning-Afternoon (11:00-2:00)	1,200
November 2023	Morning (10:00-11:30)	600
December 2023	Morning (10:30-11:30)	600
	TOTAL:	6,000 pcs.

Data Analysis

The standard length of the collected species was measured using a caliper. The shell length of the hairy cockle was measured in the anteroposterior and dorsoventral directions. It was measured using a caliper that was corrected to 0.1 mm (see Fig. 5). Length measurements were used to determine the number of individuals in different size classes, with cut-off lengths defined as ≤15 mm for recruits, ≥30 mm for large individuals, and medium-sized individuals at sizes between these two size classes. (Neubauer *et al.*, (2021). The taxonomic identification was presented in Figure 6.

Figure 5. Size measurement of *Scapharca inequivalves* caught in San Miguel Island

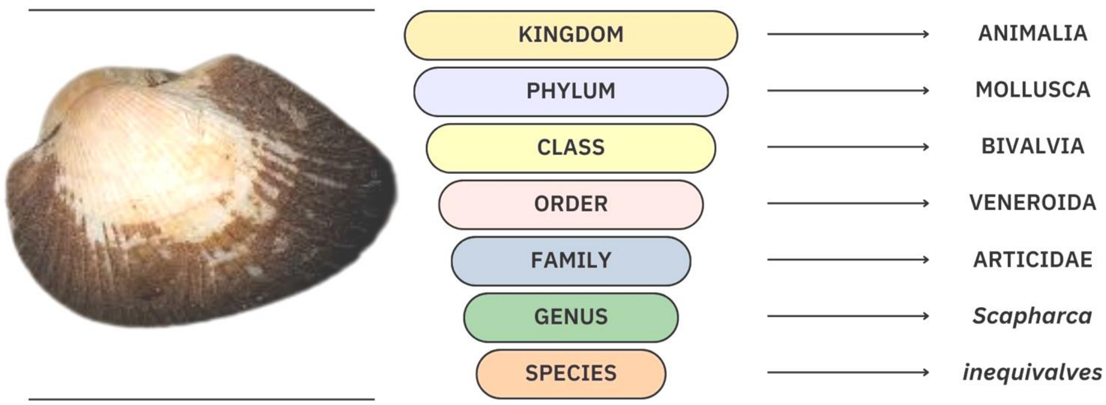

Figure 6. Taxonomic Identification of Hairy Cockle (*Scapharca inequivalves*)

Determining Growth Patterns of Hairy Cockle

The Bhattacharya method is a mathematical approach used to determine growth patterns of bivalve populations, including the hairy cockle (*Scapharca inequivalves*). Figure 7 shows the general procedures for applying the Bhattacharya method to determine growth patterns:

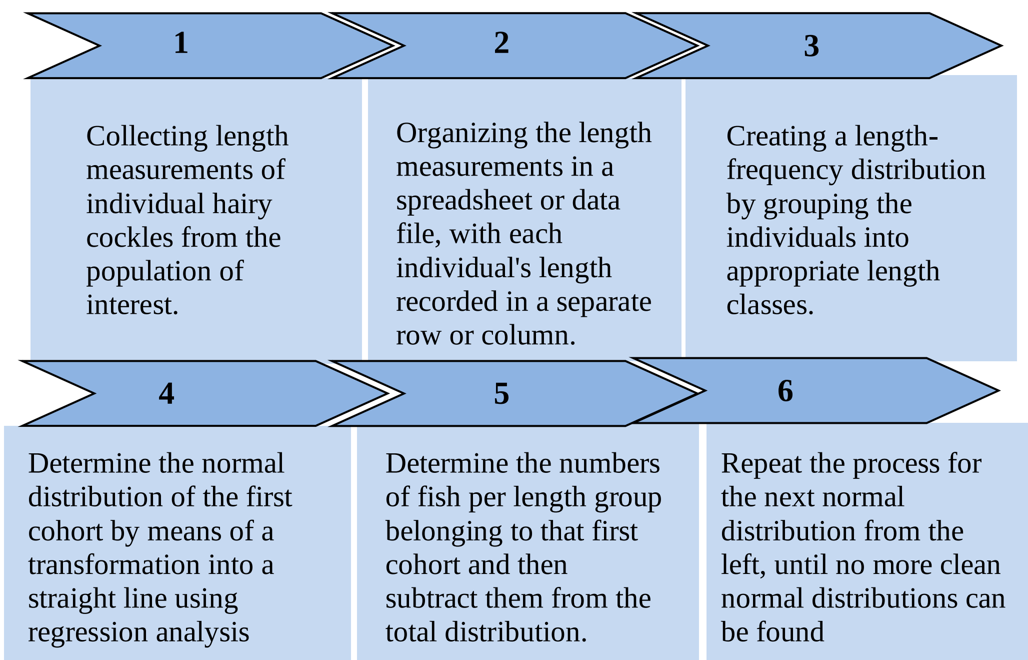

Figure 7. Determining growth patterns of hairy cockle

Estimating the Size Distribution of Hairy Cockle

To estimate the size distribution of the hairy cockle using Jones' length cohort analysis, the following parameters and measurement procedures were considered (Figure 8):

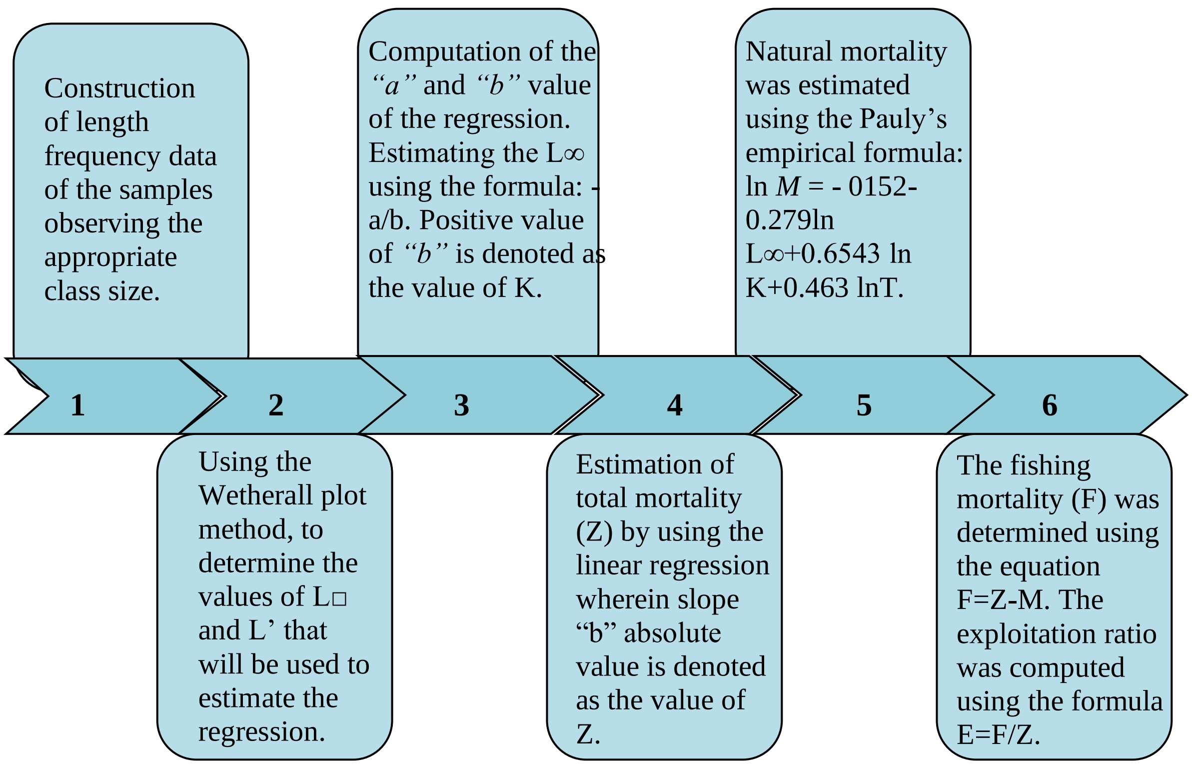

Figure 8. Estimating the Size Distribution of Hairy Cockle

Investigating the Spatial, Temporal, and Type Distribution of the Hairy Cockle Population

In investigating the spatial and temporal distribution patterns of the hairy cockle population, certain parameters and measurement procedures were considered as shown in Figure 9.

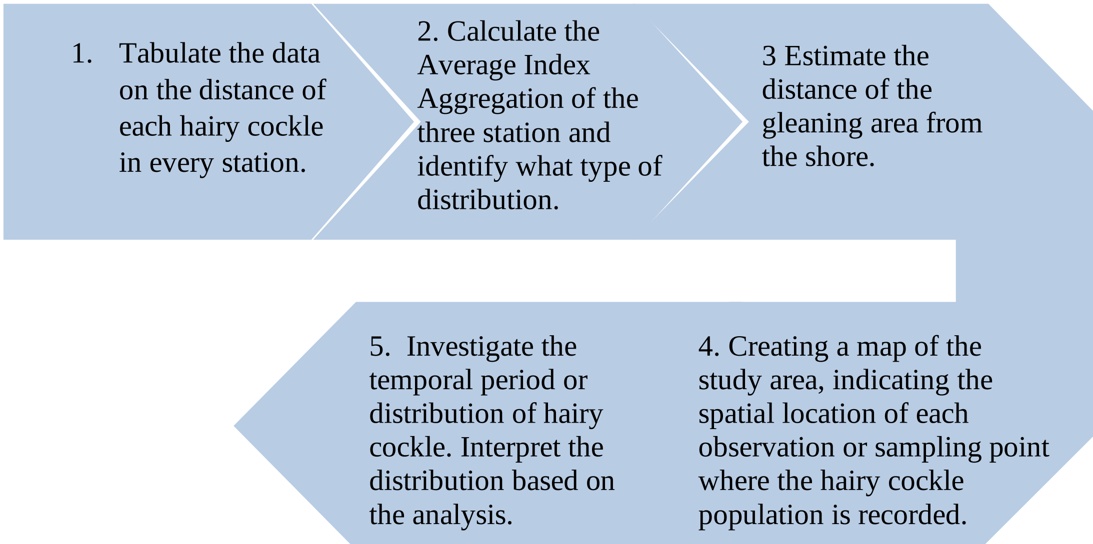

Figure 9. Investigating the Spatial, Temporal, and Type of Distribution of the Hairy Cockle Population

Statistical Analysis

The acquired data on Hairy Cockles collected was presented in various statistical tools and different descriptive analyses to show that the obtained significant values as well as the overall results proved the general statement of the study. The different statistical analyses are coherently discussed as follows:

Descriptive Analysis

The data on the length of the shell species was analyzed descriptively. Microsoft Excel was used to calculate the mean, median, mode, and standard deviation as well as the correlation between the length and weight of the species. In the determination of the smallest and greatest size of species, a descriptive statistical measure was utilized.

Linear Regression

The linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable, and the other is considered to be a dependent variable. A linear regression line has an equation of the form **Y = a+bX**

Where;

X = explanatory variable

Y = dependent variable

b= slope of the line

a= intercept (the value of **y** when **x**=0

Logarithm

The logarithm is the inverse function of exponentiation. That means that the logarithm of a number ***x*** to the base ***b*** is the exponent to which ***b*** must be raised to produce ***x*.**

CHAPTER 4

COHORT ANALYSIS, VIRTUAL POPULATION ANALYSIS, AND DISTRIBUTION OF HAIRY COCKLE (*Scapharca inequivalves*) IN THE EAST COAST OF SAN MIGUEL ISLAND

This chapter presents the result, interpretation and data analysis of the Study entitled Cohort Analysis, Virtual Population Analysis and Distribution of Hairy Cockle *(Scapharca inequivalves)* in the East Coast of San Miguel. The study was conducted to determine the distribution and abundance of the species in the area. The data were generated from three (3) sampling sites from July to December 2023. Six thousand individuals were collected and were used for population analyses of hairy cockles using cohort, virtual population, and nearest neighbor analysis. The spatial and temporal distribution was also investigated.

Growth Patterns of Hairy Cockle on the East Coast of San Miguel

One of the biological parameters in this study is to determine the growth patterns of hairy cockle species to provide a better assessment. The length data measurement was used to determine the number of cohorts of hairy cockles contained in the study. A length frequency data table was constructed for the 6000 samples collected. Given the different length samples, 43 class sizes were constructed with an interval of 1 mm in every class.

The Bhattacharya method (Bhattacharya 1967) analyses modal progression with the assumption of normally distributed cohorts. The Bhattacharya method was used to determine the cohort of the hairy cockle species from the total distribution. Size cohorts were assumed to represent recruitment from one year because mass spawning events occur only in the summer and growth is seasonal. The number of cohorts presents growth patterns of gathered hairy cockle. In the whole distribution, length sizes were logarithmically converted and three cohorts were discovered.

The first cohort's length shown in Figure 9 ranges from 12.2 to 17.2 mm, with a mean length of 17.27 mm and a standard deviation of 2.49 mm. The first cohort likely represents a younger age group or a recent recruitment event.

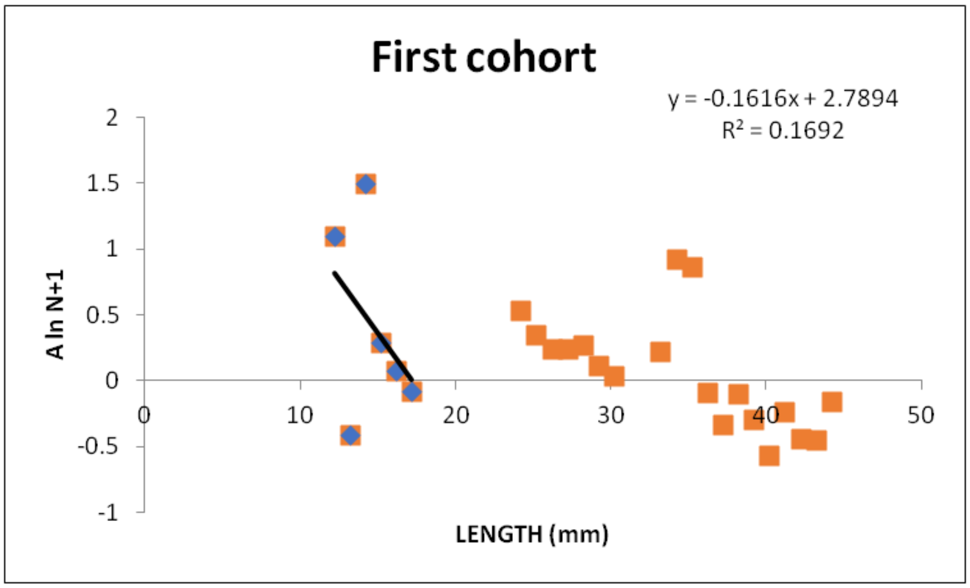

Figure 10. Bhattacharya Method: Regression Line Estimated for the First Cohort

The length range of the second cohort was 24.2 to 30.2 mm resulting in a mean length of 30.89 mm and a standard deviation is 3.80 mm as shown in Figure 11. The second cohort may correspond to an intermediate age group with slightly larger individuals.

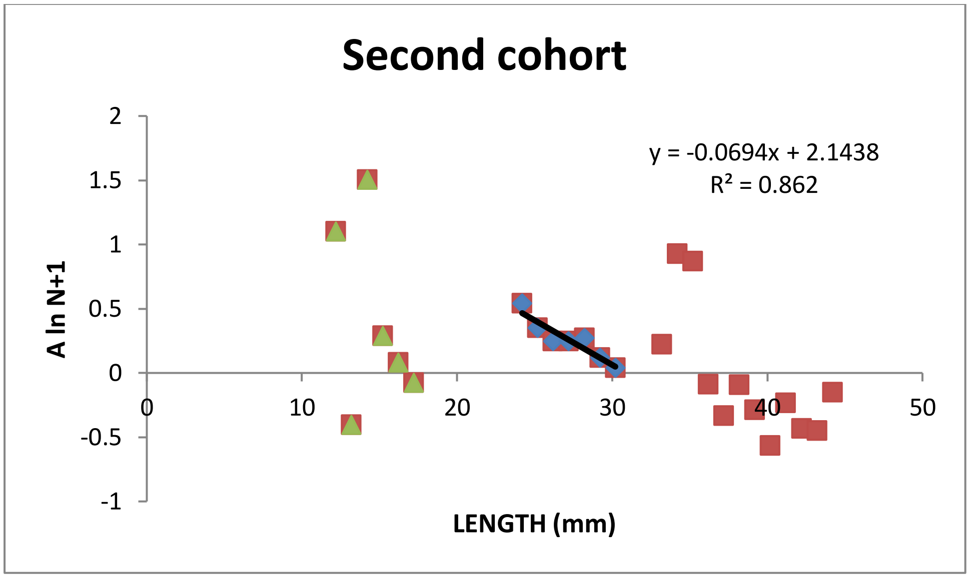

Figure 11. Bhattacharya Method: Regression Line Estimated for the Second Cohort

The third cohort's mean length is 38.13 (Figure 12), with a standard deviation of 3.24 mm ranging from length 33.2 to 44.2 mm. The third cohort represents the oldest individuals in the population.

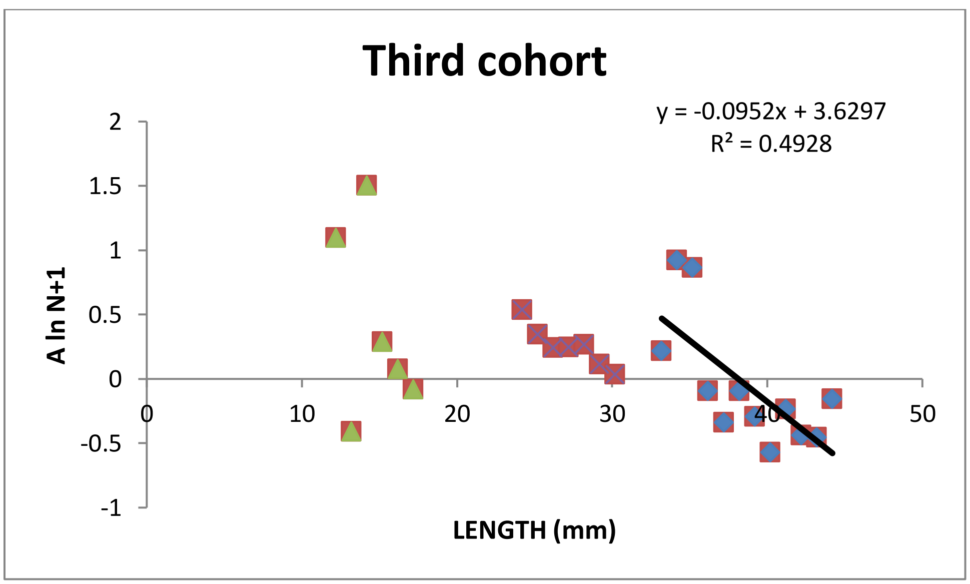

Figure 12. Bhattacharya Method: Regression Line Estimated for the Third Cohort

This varied cohort arrangement in the distribution of hairy cockles shows continuous recruitment and growth processes within the population. Understanding the dynamics of these cohorts is essential for assessing population health, reproductive success, and overall resilience to environmental pressures and exploitation. According to Turkmen *et al*. (2002), different growth patterns seemed to be related to environmental conditions, differences in age, food supply, gonad development, disease, and parasitic pressure.

Abundance and Distribution of the Hairy Cockle

Another objective of the study was to estimate the abundance and distribution of the hairy cockle across different sizes on the East Coast of San Miguel Island. The total species collected within 6 months of the sampling period was 6000 and their length was measured using the digital caliper. The established class size was 9.2 mm to 62.2 mm. The length was inputted in the histogram to graph the trend of the distribution shown in Figure 13. The large sample size (n=6000) collected in the study allowed the inclusion of the very large and very small species of hairy cockle species that afforded the representation of the growth parameters of stock. The class size with the highest number (633) of individuals length classes ranges from 31.2-32.2 mm followed by the length range from 32.2-33.2 with a frequency of 473 (Figure 13). Class interval with the smallest number of individuals ranges from 9.2-10.2, 9-25.2, and 61.2-62.2. The Figure shows the length distribution of hairy cockles on the East Coast of San Miguel Island. It implies that most of the observation is located in the middle of the distribution depicting an approximately normal data set.

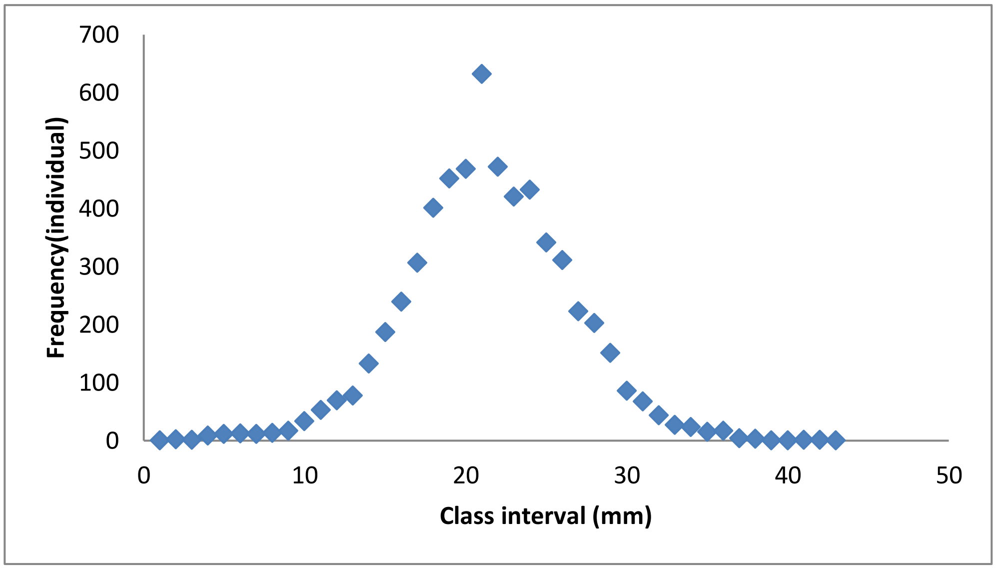

Figure 13. The Scattered Plot of the Length Frequency Distribution of Hairy Cockle

In virtual population analysis, the set of gathered can estimate the theoretical population. There are several steps were used including the Wetherall plot method to determine the value of ‘a’ or intercept, ‘b’ the slope, ‘L∞’ and K. The value of the mean length of the shell is computed through backward calculation where the highest-class size is the first to be computed. The values of the mean length of the highest-class size and the lower limit are used in the regression line of 30.2-31.2 mm up to 38.2-39.2 mm. The value of ‘a’ or the intercept of the regression analysis was 11.41 while the ‘b’ or the linear slope was -0.23 (Figure 13. Modified Wetherall et.al plot). The result of the regression of the value of ‘L∞’ can be computed with the formula: -a/b which is equal to 49.41 mm, so the hairy cockle can reach up to this size which is considered the mean length of the very old shell. The positive value of ‘b’ is denoted as the value of ‘K’ or the constant growth of hairy cockle; it shows a low growth rate of this species in the area.

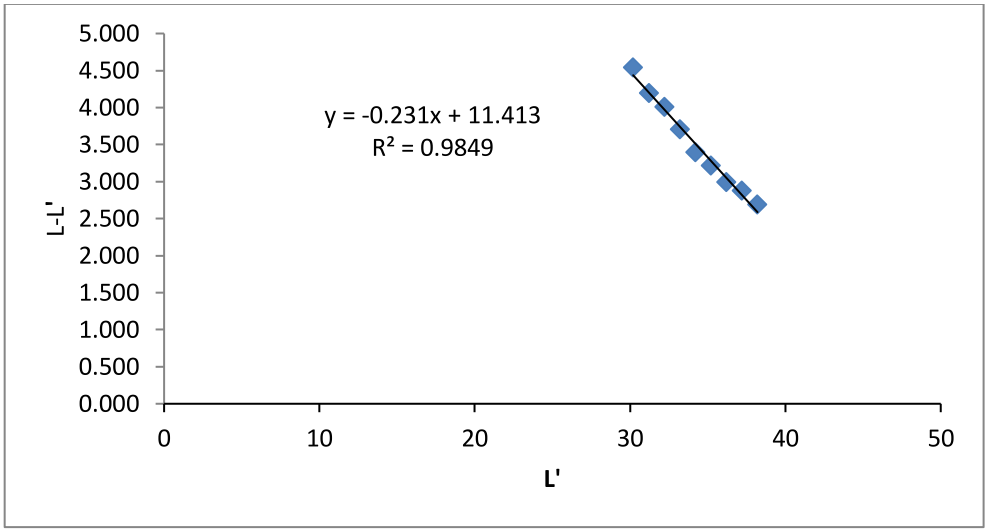

Figure 14. Modified Wetherall *et.al* plot

Estimating the mortality of certain stocks is very important in determining the abundance of hairy cockles on the East Coast of San Miguel Island. The result of the computed data in the Wetherall method was used in the calculation of the Jones Length Cohort Analysis (Table 2). The first column was the length interval of the distribution. The established length size was 9.2 mm to 62.2 mm. The second column was the number of catches or frequency. The length size ranges from 31.2-32.2 has the highest number of individuals (633) while the length ranges from 9.2-10.2, 49.2-52.2, and 61.2-62.2 have the smallest number of individuals (1). Third in the column was the conversion of length data to age data (age of individuals). This was followed by the difference in age and the natural mortality per class size. The next is the number of theoretical survivors of hairy cockle. The number of survivors indicates the proportion of individuals within the population that have survived up to a certain point in time. In this study, recruited individuals have higher numbers of survivors which suggests a healthier population with better survival rates. Determining the natural mortality (M) of marine species is important for understanding the health and productivity of their stocks. The Natural Mortality was estimated using Pauly's Empirical Formula where the input data used in computing the 'M' are $L\infty = 49.41$ and K -1.47 per year and also the annual mean surface temperature during the sampling period was T 28.0℃. Therefore M= 0.69 per year, natural mortality is due to different causes of diseases, cannibalism, competition, predation, and pollution resulting in death of species. Also, as shown in Table 2, the species that experienced a higher mortality rate started at 21.1 -22.2 mm and concluded that the medium and large sizes of hairy cockles have higher mortality than the recruited individuals. This was supported by J. Guillou *et al*. (1994) that as cockles reached a size of 10 to 12 mm, there was a notable decrease in the mortality rate, with values approaching zero or near-zero levels. To describe the abundance of hairy cockle species, the number of survivors indicates the proportion of individuals within the population that have survived up to a certain point in time. In this study, recruited individuals have higher numbers of survivors which suggests a healthier population with better survival rates. They experienced a high survival rate since their fishing mortality was low.

Furthermore, the exploitation rate was also applied to determine the quantity of the species *Scapharca inequivalves* removed by gleaning in the area. According to the study of Gulland (1965), the yield is optimized when fishing mortality (*F*) is equal to natural mortality (*M*), therefore when the exploitation rate (E) is more than 0.50, the stock is over-fished. In this study, the overexploitation starts at the length of 25.2 mm and up to 53.2 mm while the length below 25.2 mm experienced a normal and under exploitation. This means that the medium and large size stock of hairy cockles (*Scapharca inequivalves*) on the East Coast of San Miguel Island was overexploited. Hence, there is a dire need for proper management and conservation of the stock to prevent overexploitation of bivalve species, particularly the hairy cockle.

Table 2. Virtual Population Analysis (Jones Length Cohort Analysis)

Length Interval L1-L2	Frequency C(L1-L2)	Relative Age t(L1)	Difference in Age (Δt)	Age where M is applied T(L1,L2)	Number of survivors N(L1)	Exploitation rate F/Z	Fishing mortality F	Total mortality Z
9.2-10.2	1	0.141	0.053	1.0185	9445.1	0.0029	0.002	0.581
12.2-13.2	3	0.194	0.018	1.006229	9105.0	0.0260	0.015	0.595
13.2-14.2	2	0.212	0.019	1.006577	8989.6	0.0168	0.010	0.589
14.2-15.2	9	0.231	0.020	1.006924	8870.5	0.0690	0.043	0.622
15.2-16.2	12	0.251	0.021	1.007271	8740.0	0.0872	0.055	0.635
16.2-17.2	13	0.272	0.020	1.006924	8602.4	0.0994	0.064	0.643
17.2-18.2	12	0.292	0.022	1.007619	8471.6	0.0860	0.055	0.634
18.2-19.2	14	0.314	0.022	1.007619	8332.0	0.1004	0.065	0.644
19.2-20.2	17	0.336	0.023	1.007967	8192.6	0.1166	0.076	0.656
20.2-21.2	34	0.359	0.024	1.016698	8046.8	0.1150	0.075	0.655
21.2-22.2	53	0.383	0.024	1.008314	7751.2	0.2947	0.242	0.821
22.2-23.2	70	0.407	0.026	1.00901	7571.3	0.3431	0.303	0.882
23.2-24.2	78	0.433	0.026	1.00901	7367.3	0.3745	0.347	0.926
24.2-25.2	133	0.459	0.028	1.009707	7159.0	0.4950	0.568	1.147
25.2-26.2	188	0.487	0.029	1.010055	6890.3	0.5827	0.809	1.388
26.2-27.2	240	0.516	0.030	1.010404	6567.7	0.6450	1.053	1.632
27.2-28.2	307	0.546	0.031	1.010752	6195.6	0.7060	1.391	1.970
28.2-29.2	402	0.577	0.033	1.01145	5760.7	0.7626	1.861	2.440
29.2-30.2	452	0.610	0.035	1.012148	5233.6	0.7910	2.192	2.771
30.2-31.2	469	0.645	0.036	1.012497	4662.1	0.8120	2.502	3.081
31.2-32.2	633	0.681	0.039	1.013546	4084.6	0.8636	3.667	4.246
32.2-33.2	473	0.720	0.041	1.014246	3351.6	0.8449	0.579	1.159
33.2-34.2	421	0.761	0.043	1.014946	2791.7	0.8481	3.234	3.813
34.2-35.2	433	0.804	0.047	1.016347	2295.3	0.8673	3.784	4.364
35.2-36.2	342	0.851	0.049	1.017049	1796.0	0.8637	3.670	4.250
36.2-37.2	312	0.900	0.054	1.018805	1400.1	0.8729	3.977	4.556
37.2-38.2	223	0.954	0.059	1.020564	1042.6	0.8574	3.482	4.061
38.2-39.2	203	1.013	0.063	1.021973	782.5	0.8753	4.066	4.645
39.2-40.2	152	1.076	0.071	1.024797	550.6	0.8703	3.888	4.467
40.2-41.2	86	1.147	0.078	1.027275	375.9	0.8316	2.861	3.440
41.2-42.2	68	1.225	0.089	1.031181	272.5	0.8275	2.779	3.358
42.2-43.2	44	1.314	0.102	1.035816	190.4	0.7940	2.233	2.812
43.2-44.2	28	1.416	0.120	1.042269	134.9	0.7449	1.692	2.271
44.2-45.2	24	1.536	0.145	1.051297	97.3	0.7477	1.717	2.296
45.2-46.2	16	1.681	0.185	1.065906	65.3	0.7008	1.357	1.936
46.2-47.2	17	1.866	0.255	1.091961	42.4	0.7585	1.819	2.399

47.2-48.2	5	2.121	0.411	1.15234	20.0	0.5388	0.677	1.256
48.2-49.2	4	2.532	1.196	1.510771	10.7	0.4611	0.496	1.075
49.2-50.2	1	3.728	-1.463	0.603666	2.1	-0.5197	-0.198	0.381
51.2-52.2	1	2.265	-0.303	0.900743	4.0	5.3932	-0.711	-0.132
52.2-53.2	2	1.962	-0.607	0.811059	3.8	4.0519	-0.769	-0.190
56.2-57.2	2	1.355	-0.377	0.878038	3.3	1.5409	-1.650	-1.071
61.2-62.2	1	0.978	-	-	2.0	0.5000	0.579	1.159

Relative Age	1/k ln(1-L,/L∞)
(Δt)	t2-t1
X(L1,L2)	Exp(MΔt/2)
Number of survivors	[N(L2) X(L1,L2) + C(L1,L2)] X(L1,L2)
Exploitation rate	C(L1,L2) / [N(L1) – N(L2]
Fishing Mortality	M (F/Z) / (1-F/Z)
Total Mortality	F + M
N(61.2- 62.2)	C(61.2-62.2) / (F/Z) = 1/.5= 2

INPUT	OUTPUT
K	-1.47 per year
L∞	49.41
M	0.69 per year
T	28.2 °C

Spatial and Temporal Distribution and Type of Distribution of Hairy Cockle

The spatial and temporal distribution patterns of the hairy cockle population were investigated and the type of distribution in the study area was identified through mapping and analysis of distribution data. A nearest neighbor analysis (NNA) is a descriptive statistic that shows a pattern of locating features by comparing graphically the observed nearest neighbor distance. The estimated area of every station is 32400 square meters. The researchers used the distance of the first 15 pieces of gleaned hairy cockle in each area. The summation of distance in Station 1 (Sagurong) was 13.89 m, station 2 (Matuwoy, Visita) was 13.13m, and station 3 (Puro, Malictay) was 6.86 m with a mean distance of 0.75 m and an expected distance of 23.24 m. Index aggregation was computed through the mean distance over the expected distance resulting in the average index aggregation of 0.03. With this result, the researchers determine the type of distribution of hairy cockles on the East Coast of San Miguel Island in Tabaco. From the 3 types of distribution which are cluster, random, and regular, the type of distribution present in the area was cluster type shown in Table 3: Distribution of Hairy Cockle. This means that individuals are more closely spaced or aggregated together rather than being randomly or uniformly dispersed in the area. The clustered distribution pattern in Figure 15 may indicate specific habitat preferences or localized environmental conditions that attract or support higher densities of hairy cockles in certain areas. Factors such as substrate type, food availability, and shelter may contribute to this clustering. According to Callaway *et al.* (2014), the growth and dispersion of bivalves are commonly affected by elements like the availability of food, hydrodynamic forces, and sediment properties, which are essential in promoting recruitment and facilitating the persistent establishment of these organisms. Understanding cluster distribution can help fisheries managers identify areas with higher densities of target species also gatherers can easily collect species. Overexploitation of clustered populations of species can disrupt the ecosystem balance and lead to cascading effects on other species within the ecosystem.

Table 3. Distribution of Hairy cockle

	Station 1 (Sagurong)	**Station 2 (Matuwoy, Visita)**	**Station 3 (Puro, Malictay)**
Sum of distance	13.89	13.13	6.86
No. of individuals (n)	15	15	15
Mean distance (rA)	0.93	0.88	0.46
Size of the study area (cm2)	32400	32400	32400
Density of organisms	0.0005	0.0005	0.0005
Expected distance (rE)	23.24	23.24	23.24
Index Aggregation	0.04	0.04	0.02
Average Index Aggregation		**0.03**	

The type of distribution of hairy cockles in the East Coast of San Miguel is **cluster type** where the result is near 0 which is 0.03

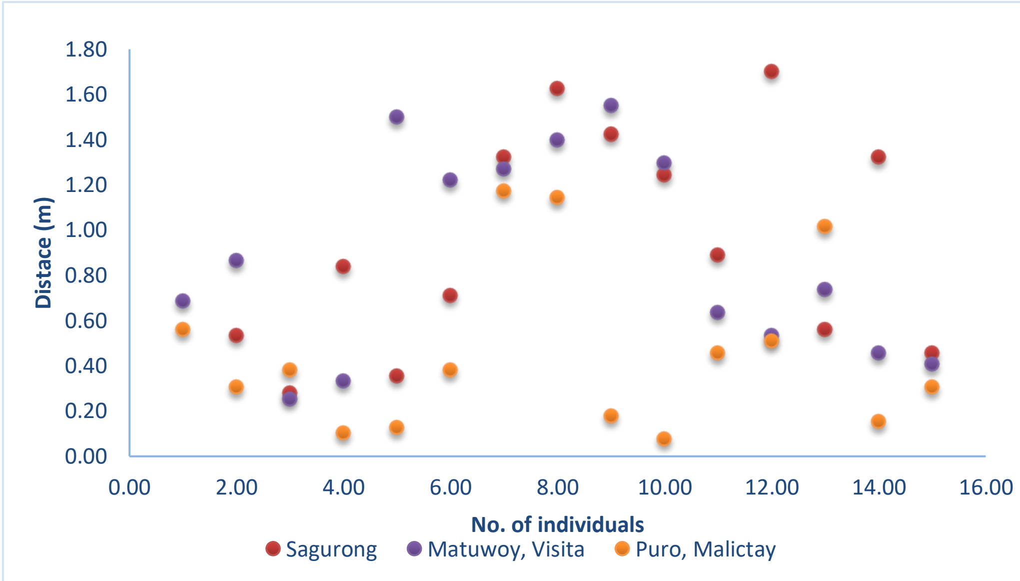

Figure 15. Distribution of Hairy Cockle Caught on the East Coast of San Miguel

The spatial distribution in the study pertains to how far the distance of collected hairy cockle from the shore is. Figure 16 shows the map of the study area, showing the locations of different sampling stations or areas where hairy cockles were collected. The first station was in Bakuludan, the second was close to the mangrove area and the third was located on seagrass meadows as shown in the figure below. They were around 60 m, 50 m, and 40 m far from the shore, respectively. According to J. Cardoso *et al.* (2007), the growth and reproductive output variations of bivalves were linked to the particular environmental conditions found in the surrounding local area. The varying distances of hairy cockles from the shore at different sampling stations (e.g., bakuludan, near mangrove area, sagkad, or fish pen) suggest that the species may exhibit specific habitat preferences related to proximity to the shoreline. The distance from the shore can influence the availability of resources such as food, shelter, and substrate for hairy cockles.

Figure 16. Spatial Distribution of Hairy Cockle in the East Coat of San Miguel

The temporal distribution of hairy cockles in time can be found throughout the year. The findings are supported by the discussion and an informal interview with the fishers. The implication of this was the species exhibits a consistent presence or availability over different seasons. Also, it indicates a level of resilience to environmental fluctuations, including seasonal changes and disturbances. According to Zhaoqun Liu *et al.* (2018), marine bivalves have developed advanced stress response mechanisms that involve neuroendocrine regulation to manage immunity, energy metabolism, shell formation, and larval development when faced with environmental stressors. Also, according to J. Fouw *et al.* (2020) highly complex habitats, for example, may reduce predation and competition, allowing more individuals to live together in a certain area.

CHAPTER 5

SUMMARY, CONCLUSION, AND RECOMMENDATION

This chapter provides the summary, conclusion, and recommendation of this study based on the data gathered during the sampling period.

SUMMARY

The study was conducted on the East Coast of San Miguel Island specifically in Sagurong, Sitio Matuwoy Visita, and Puro, Malictay facing Lagonoy Gulf. The methods of the study were undertaken to describe the population of hairy cockle (*Scapharca inequivalves*) which includes the growth patterns, abundance and distribution, and the type of distribution of hairy cockle. Within the conducted 6-month sampling period (from August to December) on the East Coast of San Miguel Island a total of 6000 individual species of hairy cockle were collected within the 3 sampling stations mainly; Sagurong, Sitio Matuwoy, Visita and Puro, Malictay, having a total density of 18.2 within the area. In measurement of their lengths using a digital caliper, researchers established a class size ranging from 9.2 mm to 62.2 mm.

The growth patterns of hairy cockle species were investigated to provide a comprehensive assessment. Researchers utilized length data from 6000 samples to determine the number of cohorts present in the population. A length frequency data table was constructed with 43 class sizes, each with a 1 mm interval. The Bhattacharya method, which assumes normally distributed cohorts, was employed to analyze modal progression and identify cohorts within the hairy cockle population. Three distinct cohorts were identified in the distribution of hairy cockles. The first cohort, with a mean length of 17.27 mm and a standard deviation of 2.49 mm, likely represents a younger age group or a recent recruitment event. The second cohort, ranging from 24.2 to 30.2 mm with a mean length of 30.89 mm and a standard deviation of 3.80 mm, may correspond to an intermediate age group with slightly larger individuals. The third cohort, with a mean length of 38.13 mm and a standard deviation of 3.24 mm spanning from 33.2 to 44.2 mm, represents the oldest individuals in the population. The presence of these varied cohorts indicates continuous recruitment and growth processes within the hairy cockle population. Understanding the dynamics of these cohorts is crucial for assessing population health, reproductive success, and resilience to environmental pressures and exploitation.

The distribution pattern indicated a concentration of observations in the middle of the distribution, suggesting an approximately normal dataset. Estimating the mortality of a stock is crucial for determining the abundance of hairy cockles on the East Coast of San Miguel Island. The study utilized the Wetherall method in the calculation of Jones Length Cohort Analysis to assess the number of survivors, indicating the proportion of individuals that have survived up to a certain point in time. The findings revealed that recruited individuals exhibited higher survivor numbers, suggesting a healthier population with better survival rates. Natural mortality was estimated using Pauly's Empirical Formula with input data of $L\infty$= 49.41 and K= -1.47 per year, resulting in M= 0.69 per year. Medium and large sizes of hairy cockles experienced higher mortality compared to recruit individuals. Also, the study emphasized that higher survivor numbers among recruited individuals signify a healthier population with improved survival rates. Moreover, there are identified overexploitation in the medium and large size stock of hairy cockle *(Scapharca inequivalves*) on the East Coast of San Miguel Island, emphasizing the urgent need for effective management and conservation strategies to prevent the overexploitation of bivalve species, particularly the hairy cockle.

Prior to the distribution, the Nearest neighbor analysis revealed a clustered distribution pattern having an average index aggregation of 0.03., indicating that individuals were more closely spaced or aggregated together rather than being randomly or uniformly dispersed in the area. The spatial distribution analysis also considered the distance of the collected hairy cockle specimens from the shore. The study area map displayed the locations of the sampling stations, with the first station in Bakuludan, the second near the mangrove area, and the third situated near the sagkad or fish pen. The distances from the shore varied, with the first station approximately 60 m, the second 50 m, and the third 40 m away. Regarding the temporal distribution of hairy cockles throughout the year, the findings indicated a consistent presence or availability of the species across different seasons. This observation was supported by discussions and informal interviews with fishers, suggesting a level of resilience to environmental fluctuations, including seasonal changes and disturbances.

CONCLUSION

In this study, the researchers combine the obtainable knowledge, scientific findings, and biological information to describe the population of hairy cockles (*Scapharca inequivalves*) on the East Coast of San Miguel Island. Within the six (6) months of a study conducted by researchers in the 3 different sites of the gleaning area of San Miguel Island, three distinct cohorts were identified from 6000 samples such as the first cohort representing a younger age group or recent recruitment event, the second cohort representing an intermediate age group, and the third cohort representing the oldest individuals in the population. The researchers concluded that there's a continuous recruitment and growth process within the population. The research highlighted a higher survival rate among recruited individuals, suggesting that gatherers may selectively target specific sizes during collection. However, the study also noted overexploitation of medium and large-sized hairy cockles, underscoring the importance of implementing effective management and conservation measures to prevent further exploitation of bivalve species, particularly the hairy cockle.

The distribution of hairy cockles indicates that the species tended to be closely clustered together rather than dispersed randomly, as shown by an average index aggregation of 0.03. The varying distances of the hairy cockles from the shore at different sampling locations suggest that the species may exhibit specific habitat preferences based on their proximity to the shoreline, given that the first station was located in bakuludan, the second near a mangrove area, and the third in sagkad or fish pen, with distances from the shore approximately 60 m, 50 m, and 40 m, respectively. In terms of the temporal distribution in time of hairy cockles throughout the year, the results suggested a consistent presence or availability of the species across various seasons.

In conclusion, the application of cohort analysis, virtual population analysis, and nearest neighbor analysis has proven to be invaluable in describing the population dynamics of the hairy cockle species. These analytical methods have provided insights into the growth patterns, size distribution, and abundance of hairy cockles on the East Coast of San Miguel Island. By utilizing these techniques, researchers have been able to identify distinct cohorts within the population and highlight the need to implement efficient management and conservation measures to safeguard bivalve species such as the hairy cockle from excessive exploitation.

RECOMMENDATIONS

The study about Cohort Analysis, Virtual Population Analysis, and Distribution of *Scapharca inequivalves* on the East Coast of San Miguel Island purposely serves as a reference in understanding the hairy cockle population and its potential implications for resource management. Also, the study will serve as essential information that could be implied in managing the bivalve species in many regions, where these species are found.

Based on the findings and conclusion of the researchers, the following were some of the ideal recommendations in the area.

1. Conduct extension education for the fisherfolk and gleaners to enhance their understanding of local resources, while also offering training in coastal resource management to prevent excessive exploitation of the stock in the region.
2. Conversion of the species into essential by-products due to its consistent availability throughout different seasons.
3. Further studies on Hairy cockle regarding reproduction and the presence of microplastic contamination in this species, given its significance as a food source for the residents of the island.
4. Individual study per barangay to identify the most abundant population of hairy cockle in San Miguel Island.

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APPENDICES

Appendix A

Bhattacharya Method: Estimation of First Cohort

L1-L2	N1+	Ln N1+	Δ ln N1+	L	Δ ln N1c	Ln N1	N1	N2+
9.2-10.2	1	0	-	-	-		1	0
12.2-13.2	3	1.099	1.099	12.2 *****	0.818		3	0
13.2-14.2	2	0.693	-0.405	13.2*	0.656		2	0
14.2-15.2	9	2.197	1.504	14.2*	0.495	2.197	9.00	0.002
15.2-16.2	12	2.485	0.288	15.2*	0.333	2.530	12.55	-0.55
16.2-17.2	13	2.565	0.080	16.2*	0.171	2.702	14.90	-1.90
17.2-18.2	12	2.485	-0.080	17.2*	0.010	2.711	15.05	-3.05
18.2-19.2	14	2.639	0.154	18.2	-0.152	2.560	12.93	1.07
19.2-20.2	17	2.833	0.194	19.2	-0.313	2.246	9.45	7.55
20.2-21.2	34	3.526	0.693	20.2	-0.475	1.771	5.88	28.12
21.2-22.2	53	3.970	0.444	21.2	-0.637	1.135	3.11	49.89
22.2-23.2	70	4.248	0.278	22.2	-0.79812	0.337	1.40	68.60
23.2-24.2	78	4.357	0.108	23.2	-0.95972	-0.623	0.54	77.46
24.2-25.2	133	4.890	0.534	24.2	-1.12132	-1.744	0.17	132.83
25.2-26.2	188	5.236	0.346	25.2				
26.2-27.2	240	5.481	0.245	26.2				
27.2-28.2	307	5.727	0.246	27.2				
28.2-29.2	402	5.996	0.269	28.2				
29.2-30.2	452	6.114	0.118	29.2				
30.2-31.2	469	6.151	0.037	30.2				
31.2-32.2	633	6.450	0.299	31.2				
32.2-33.2	473	3.135	-3.315	32.2				
33.2-34.2	421	6.043	2.908	33.2				
34.2-35.2	433	6.071	0.028	34.2				
35.2-36.2	342	5.835	-0.236	35.2				
36.2-37.2	312	5.743	-0.092	36.2				
37.2-38.2	223	5.407	-0.336	37.2				
38.2-39.2	203	5.313	-0.094	38.2				
39.2-40.2	152	5.024	-0.289	39.2				
40.2-41.2	86	4.454	-0.570	40.2				
41.2-42.2	68	4.220	-0.234	41.2				
42.2-43.2	44	3.784	-0.436	42.2				
43.2-44.2	28	3.332	-0.452	43.2				
44.2-45.2	24	3.178	-0.154	44.2				
45.2-46.2	16	2.773	-0.405	45.2				
46.2-47.2	17	2.833	0.060	46.2				
47.2-48.2	5	1.609	-1.224	47.2				
48.2-49.2	4	1.386	-0.223	48.2				
49.2-50.2	1	0.000	-1.386	49.2				
51.2-52.2	1	0.000	0.000	51.2				
52.2-53.2	2	0.693	0.693	52.2				
56.2-57.2	2	0.693	0.000	56.2				
61.2-62.2	1	0.000	-0.693	61.2				

N1+	Frequency of all cohorts combined	Δ ln N1c	c= calculated number a+b* L =
Ln N1+	Logarithms of N1+	Ln N1	ln N1c (L1-L2)= Ln

			N1 (foregoing L1-L2) + Δ ln N1c (L)
Δ ln N1+	Current ln N1+ minus foregoing ln N1+	N1	Exp (ln N1)
L	Lower limit	N2+	N1+ - N1
OUTPUT			
A	2.7894	B	-0.1616
Mean length	17.26	standard deviation	2.49

Appendix B

Bhattacharya method: Estimation of Second Cohort

L1-L2	N2+	Ln N2+	∆ ln N2+	L	∆ ln N2c	Ln N2	N2	N3+
9.2-10.2	0	-		-			0	0
12.2-13.2	0	-		12.2			0	0
13.2-14.2	0	-		13.2			0	0
14.2-15.2	0	-		14.2			0	0
15.2-16.2	0	-		15.2			0	0
16.2-17.2	0	-		16.2			0	0
17.2-18.2	0	1.125		17.2			0	0
18.2-19.2	1.07	0.066	-1.059	18.2			1.07	0
19.2-20.2	7.55	2.021	1.955	19.2			7.55	0
20.2-21.2	28.12	3.336	1.315	20.2			28.12	0
21.2-22.2	49.89	3.910	0.573	21.2			49.89	0
22.2-23.2	68.60	4.228	0.318	22.2			68.60	0
23.2-24.2	77.46	4.350	0.122	23.2			77.46	0
24.2-25.2	132.83	4.889	0.539	24.2 *	-		132.83	0
25.2-26.2	188	5.236	0.347	25.2*	0.3949	5.236	187.92	0.08
26.2-27.2	240	5.481	0.244	26.2*	0.3255	5.562	260.22	-20.22
27.2-28.2	307	5.727	0.246	27.2*	0.2561	5.818	336.18	-29.18
28.2-29.2	402	5.996	0.270	28.2*	0.1867	6.004	405.19	-3.19
29.2-30.2	452	6.114	0.117	29.2*	0.1173	6.122	455.63	-3.63
30.2-31.2	469	6.151	0.037	30.2*	0.0479	6.170	477.99	-8.99
31.2-32.2	633	6.450	0.300	31.2	-0.0215	6.148	467.84	165.16
32.2-33.2	473	6.159	-0.291	32.2	-0.0909	6.057	427.19	45.81
33.2-34.2	421	6.043	-0.116	33.2	-0.1603	5.897	363.93	57.07
34.2-35.2	433	6.071	0.028	34.2	-0.2297	5.667	289.25	143.75
35.2-36.2	342			35.2				
36.2-37.2	312			36.2				
37.2-38.2	223			37.2				
38.2-39.2	203			38.2				
39.2-40.2	152			39.2				
40.2-41.2	86			40.2				
41.2-42.2	68			41.2				
42.2-43.2	44			42.2				
43.2-44.2	28			43.2				
44.2-45.2	24			44.2				
45.2-46.2	16			45.2				
46.2-47.2	17			46.2				
47.2-48.2	5			47.2				
48.2-49.2	4			48.2				
49.2-50.2	1			49.2				
51.2-52.2	1			51.2				
52.2-53.2	2			52.2				
56.2-57.2	2			56.2				
61.2-62.2	1			61.2				

OUTPUT			
A	2.1438	B	-0.0694
mean length	30.89	Sd	3.80

Appendix C

Bhattacharya method: estimation of third cohort

L1-L2	**N3+**	**Ln N3+**	**Δ ln N3+**	**L**	**Δ ln N3c**	**Ln N3**	**N3**	**N4+**
9.2-10.2	0			-			0	
12.2-13.2	0			12.2			0	
13.2-14.2	0			13.2			0	
14.2-15.2	0			14.2			0	
15.2-16.2	0			15.2			0	
16.2-17.2	0			16.2			0	
17.2-18.2	0			17.2			0	
18.2-19.2	0			18.2			0	
19.2-20.2	0			19.2			0	
20.2-21.2	0			20.2			0	
21.2-22.2	0			21.2			0	
22.2-23.2	0			22.2			0	
23.2-24.2	0			23.2			0	
24.2-25.2	0			24.2			0	
25.2-26.2	0			25.2			0	
26.2-27.2	0			26.2			0	
27.2-28.2	0			27.2			0	
28.2-29.2	0			28.2			0	
29.2-30.2	0			29.2			0	
30.2-31.2	0	2.196		30.2			0	
31.2-32.2	165.16	5.107	2.911	31.2			165.16	
32.2-33.2	45.81	3.824	-1.283	32.2			45.81	
33.2-34.2	57.07	4.044	0.220	33.2	0.469		57.07	
34.2-35.2	143.75	4.968	0.924	34.2	0.374		143.75	
35.2-36.2	342	5.835	0.867	35.2	0.279		342	
36.2-37.2	312	5.743	-0.092	36.2	0.183	-	312	
37.2-38.2	223	5.407	-0.336	37.2	0.088	5.407	222.96	0.04
38.2-39.2	203	5.313	-0.094	38.2	-0.007	5.400	221.42	-18.42
39.2-40.2	152	5.024	-0.289	39.2	-0.102	5.298	199.92	-47.92
40.2-41.2	86	4.454	-0.570	40.2	-0.197	5.101	164.12	-78.12
41.2-42.2	68	4.220	-0.235	41.2	-0.293	4.808	122.49	-54.49
42.2-43.2	44	3.784	-0.435	42.2	-0.388	4.420	83.12	-39.12
43.2-44.2	28	3.332	-0.452	43.2	-0.483	3.937	51.28	-23.28
44.2-45.2	24	3.178	-0.154	44.2	-0.578	3.359	28.77	-4.77
45.2-46.2	16	2.773	-0.405	45.2	-0.673	2.686	14.67	1.33
46.2-47.2	17			46.2				17

47.2-48.2	5			47.2				5
48.2-49.2	4			48.2				4
49.2-50.2	1			49.2				1
51.2-52.2	1			51.2				1
52.2-53.2	2			52.2				2
56.2-57.2	2			56.2				2
61.2-62.2	1			61.2				1

OUTPUT			
A	3.6297	B	-0.0952
mean length	38.13	Sd	3.24

Appendix D

Modified Wetherall et al Method

LENGTH INTERVAL	FREQUENCY	MEAN LENGTH	L-L'	DECISION
9.2-10.2	1	32.110	22.910	Not used in regression analysis
12.2-13.2	3	32.113	19.913	
13.2-14.2	2	32.123	18.923	
14.2-15.2	9	32.129	17.929	
15.2-16.2	12	32.155	16.955	
16.2-17.2	13	32.188	15.988	
17.2-18.2	12	32.222	15.022	
18.2-19.2	14	32.251	14.051	
19.2-20.2	17	32.283	13.083	
20.2-21.2	34	32.320	12.120	
21.2-22.2	53	32.387	11.187	
22.2-23.2	70	32.484	10.284	
23.2-24.2	78	32.603	9.403	
24.2-25.2	133	32.725	8.525	
25.2-26.2	188	32.917	7.717	
26.2-27.2	240	33.170	6.970	
27.2-28.2	307	33.474	6.274	
28.2-29.2	402	33.842	5.642	
29.2-30.2	452	34.310	5.110	
30.2-31.2	**469**	**34.837**	**4.537**	**Used in regression Analysis**
31.2-32.2	**633**	**35.392**	**4.192**	
32.2-33.2	**473**	**36.210**	**4.010**	
33.2-34.2	**421**	**36.906**	**3.706**	
34.2-35.2	**433**	**37.594**	**3.394**	
35.2-36.2	**342**	**38.412**	**3.212**	
36.2-37.2	**312**	**39.192**	**2.992**	
37.2-38.2	**223**	**40.079**	**2.879**	
38.2-39.2	**203**	**40.890**	**2.690**	

39.2-40.2	152	41.875	2.675	Not used in regression analysis
40.2-41.2	86	42.981	2.781	
41.2-42.2	68	43.902	2.702	
42.2-43.2	44	44.934	2.734	
43.2-44.2	28	45.908	2.708	
44.2-45.2	24	46.755	2.555	
45.2-46.2	16	47.761	2.561	
46.2-47.2	17	48.761	2.561	
47.2-48.2	5	50.950	3.750	
48.2-49.2	4	52.427	4.227	
49.2-50.2	1	54.557	5.357	
51.2-52.2	1	55.367	4.167	
52.2-53.2	2	56.100	3.900	
56.2-57.2	2	58.367	2.167	
61.2-62.2	1	61.700	0.500	
OUTPUT				
a		11.41		
b		-0.23		
L∞		49.41 mm		
K		-1.47 per year		

Appendix E

Distribution of Hairy cockle

	Station 1 (m)	**Station 2 (m)**	**Station 3 (m)**
1	0.64	0.69	0.56
2	0.53	0.86	0.30
3	0.28	0.25	0.38
4	0.84	0.33	0.10
5	0.36	1.50	0.13
6	0.71	1.22	0.38
7	1.32	1.27	1.17
8	1.63	1.40	1.14
9	1.42	1.55	0.18
10	1.24	1.30	0.08
11	0.89	0.64	0.46
12	1.70	0.53	0.51
13	0.56	0.74	1.02
14	1.32	0.46	0.15
15	0.46	0.41	0.30

	Station 1	**Station 2**	**Station 3**
Sum of distance (Σr)	13.89	13.13	6.86
No. of individuals (n)	15	15	15
Mean distance (rA)	0.93	0.88	0.46

Size of the study area (cm2)	32400	32400	32400
Density of organisms	0.0005	0.0005	0.0005
Expected distance (rE)	23.24	23.24	23.24
Index Aggregation ®	0.04	0.04	0.02
Average Index Aggregation	**0.03**		
	The type of distribution of hairy cockles in the East Coast of San Miguel is **cluster type** where the result is near 0 which is 0.03		

Column 3: rA= Σr/n
Column 5: n/Column 4(cm²)
Column 6: rE= 1/(2*SQQRT(column 5))
Column 7: R= rA/rE
Column 8: Average (R1:R3)

PLATES

Plate 1. Sampling Site

Plate 2. Measuring the Distance of Hairy Cockle

Plate 3. Sample Collection

Plate 4. Measuring the Collected Species

CURRICULUM VITAE

CURRICULUM VITAE

Name	**:**	Cristine C. Buella
Address	:	Sagurong, San Miguel, Tabaco City
Date of Birth	:	December 27, 2001
Place of Birth	:	Sagurong, San Miguel, Tabaco City
Civil Status	:	Single
Parents	:	Ronnel Buella
		Salvacion Buella

EDUCATIONAL ATTAINMENT

Elementary	:	Sagurong Elementary School
		Sagurong San Miguel Tabaco City, Albay
		2008-2014
Junior High School	:	San Miguel National High School
		Visita, San Miguel Tabaco City, Albay
		2014-2018
Senior High School	:	San Miguel National High School
		Accountancy Business and Management (ABM)
		2018-2020
College	:	Bicol University Tabaco
		Bachelor of Science in Fisheries
		2020- 2024

CURRICULUM VITAE

Name	**:**	Marycris A. Burce
Address	:	Sagurong, San Miguel, Tabaco City
Date of Birth	:	July 10, 2000
Place of Birth	:	Sagurong, San Miguel, Tabaco City
Civil Status	:	Single
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		Meriam Burce

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Elementary	:	Sagurong Elementary School
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Senior High School	:	San Miguel National High School
		Accountancy Business and Management (ABM)
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College	:	Bicol University Tabaco
		Bachelor of Science in Fisheries
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