International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Impact of Mining on Marine Gastropods Habitat: Basis for Information Education Communication (IEC) for Environmental Sustainability

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ABSTRACT

An alarming socio-economic and environmental impact of mining in the Municipality of Carrascal, Surigao del Sur led to this study. It is important to assess the impact of mining on marine habitats and the diversity of gastropods in the area. The collection of gastropods is done in the selected four sampling areas, which include Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango. Based on the sampling, 228 marine gastropod species were collected, consisting of 53 genera belonging to 10 families. The findings highlight the low diversity of the marine gastropods in the study area as the diversity index is less than 1.99. In addition, the physico-chemical parameter assessment of the study area reveals conditions ranging from slightly alkaline water with low oxygen content to very warm temperatures. These conditions suggest a delicate balance in the aquatic ecosystems, which could be sensitive to changes and affect marine gastropod populations and distributions. With regards to the average concentration of nickel (mg/kg) sediments as a result of the mining activities in the study area, the atomic absorption spectrophotometry result shows that Brgy. Gango is heavily polluted in comparison to other sampling areas. Additionally, the multiple regression analysis reveals that there is a positive and significant association between the nickel concentration and the diversity of gastropods in Brgy. Gango. This could indicate that some gastropod species, specifically those that are found in areas with high nickel concentrations, have acquired tolerance to nickel pollution. However, the regression analysis reveals that in the other sampling sites, such as Brgy. Adlay and Brgy. Caglayag, the presence of nickel sediments as a result of mining activities has a negative and significant impact on the marine habitat and diversity of gastropods. The findings suggest the importance of developing an information education and communication program addressing the negative impacts of mining and promoting environmental sustainability in the research locale.

Keywords: environmental sustainability, gastropods, IEC program, marine habitat, mining

INTRODUCTION

1.1 Background of the Study

The Philippines is renowned for its abundant mineral and natural resources and over the years, the miniing sector has made a significant economic contribution, particularly due to the growing need for minerals and energy resources (Tuaño, n.d.). Despite the economic significance of the mining sector in the country, it is one of the pressing concerns due to its impact on the environment and society. Mining activities, including prospecting, exploration, construction, operation, maintenance, expansion, closure, and repurposing of mines, could have positive and negative effects on social and environmental systems, according to Haddaway et al. (2019). Mining has been found beneficial as it has significantly contributed to transforming communities into modern civilizations and enhancing the quality of life through job creation, skills, and knowledge, promoting equitable income distribution, and upgrading infrastructure, public health services, and education (Hosseinpour, Osanloo, & Azimi, 2022). Thus, the mining sector had a positive effect on the economic growth. Despite the beneficial effects of mining, undeniably, it harmed the environment and ecosystem as well as the affected communities. These detrimental effects included loss of vegetative cover, massive devastation of water bodies, environmental degradation, land-use changes, and food insecurity, increasing social conflicts, high living costs, and pollution (Worlanyo & Jiangfeng, 2021).

In addition, mining activities could have devastating consequences for marine biodiversity which pose threats to the aquatic organisms (Alhassan et al., 2022), including gastropod habitats. Gastropods are important ecological indicators that play a vital role in marine biodiversity. In fact, these aquatic species have long been used to detect heavy metal pollution in aquatic habitats (Krupnova et al., 2018). However, mining activities can cause significant disturbances to their habitat, leading to a decline in their population. Despite their ecological significance, the impact of mining on marine gastropod habitats has received limited attention, thus, a need for further research in this area is necessary.

In the Philippines, particularly, in Carrascal, Surigao del Sur, mining companies such as the Carrascal Nickel Corporation and the Kafugan Mining Incorporated continued their operation. These mining companies have been providing livelihood and income to the residents. Businesses and several economic development activities flourished in the mining and neighboring areas. Additionally, as part of their corporate social responsibility (CSR), these companies supported developmental projects that benefit communities as well.

Despite the socio-economic contributions of mining companies to the municipality of Carrascal, the effect of the mining operations to the environment in the area is alarming. Runoff sediments from mining sites in Surigao del Sur may devastate marine ecosystems like coral reefs and seagrasses. The continuing mining operations in Carrascal, Surigao del Sur are also having an impact on marine life in the area (Colina, 2018). The study of Cuartero (2015) indicated that the mining activities in some areas of Surigao del Sur, including the municipality of Carrascal resulted to problems such as land degradation, water pollution, the depletion of aquatic organisms and threats to wildlife diversity, which all of these were attributed from mining. Aside from environmental problems, the municipality also encountered issues on how the mining operations contributed to the increased incidence of respiratory health problems among affected communities near the mining areas (Arreza et al., 2022). Given these problems, there is a need of urgent solution addressing the impacts of mining to the environment and the host communities, especially, in the municipality of Carrascal, Surigao del Sur.

Furthermore, effective communication and education programs are needed to raise awareness among the residents and the general public about the impact of mining on the environment and promote environmental sustainability. There is a need to develop effective communication strategies to raise awareness about the ecological significance of marine gastropods and the impact of mining on their habitats. An effective Information Education Communication (IEC) program can facilitate this process and promote environmental sustainability. The IEC aims to create awareness, motivate, and educate target individuals or groups through utilization of relevant communication media and other methods that could be used to influence knowledge, beliefs, attitudes, and behaviors (Sachdeva et al., 2015). The IEC program could serve as instrument in providing awareness to people and other important stakeholders regarding the importance of addressing the impacts of mining on the aquatic organisms including gastropods and in promoting sustainable mining in the concerned locale. Thus, this study aims to examine the impact of mining on marine gastropods and habitats aimed at develop an IEC program for promoting environmental sustainability, particularly, in the coastal region of Carrascal, Surigao del Sur where mining activities are prevalent.

1.2 Statement of the Problem

Some studies noted that mining activities have positive and negative impacts on the communities situated in the Municipality of Carrascal, Surigao del Sur. Despite the positive impact of mining operations in Surigao del Sur such as employment and education opportunities for local residents and the development enterprises and social infrastructures for the community, undeniably, the mining operations have negative impacts on the environment and even public health (Arreza et al., 2022; Cuantero, 2015; Cuartero-Enteria, 2018;) It was also reported that the mining operations in Surigao del Sur will likely to devastate marine ecosystems which pose risks to the aquatic organisms (Colina, 2018). Given the negative impacts of mining in the locale of Carrascal, Surigao del Sur, there is a need to address these issues, especially, the threat of mining to the aquatic organisms, especially, to the gastropod species, which are important bio-indicators of environmental health. These issues underscore the need for the development of Information, Education, and Communication (IEC) programs. Such programs must be grounded on scientific research and adapted to address knowledge gaps, effectively communicating hazards, and offering practical solutions addressing the impact of mining on the marine habitat and to the gastropod species in the municipality of Carrascal, Surigao del Sur. Thus, this study attempts to answer the following research questions addressing the need to investigate the impact of mining on marine gastropod habitat.

1. What is the status of gastropods in the selected sampling areas of Carrascal, Surigao del Sur, in terms of their morphological structure?
2. What is the status of the marine habitat in the selected sampling areas of Carrascal, Surigao del Sur in terms of the physico-chemical conditions?
3. What is the prevalence of nickel concentrations attributed to mining activities in selected sampling areas in Carrascal, Surigao del Sur?
4. What is the significant relationship between the nickel concentration and the diversity of gastropods in each sampling site?
5. What are the socio-economic impacts of mining companies on the host communities in Carrascal, Surigao del Sur?
6. What are the existing communication and education programs related to the impact of mining on marine biodiversity in the research locale?
7. How can an Information Education Communication (IEC) program be developed to effectively communicate information related to the impact of mining on marine gastropod habitats, promote behavior change, and promote environmental sustainability?

1.3 Objectives of the Study

This study aims to assess the impacts of mining on gastropods and their habitat. Specifically, the study will try to determine how mining it affects the diversity of gastropods and their habitat along the intertidal zones in the municipality of Carrascal, Surigao del Sur. Moreover, this study aims to encourage the different stakeholder actors to work for environmental sustainability taking into account the three components of sustainable development, namely: economy, environment, and social. Lastly, this study will also identify strategies for information and education communication (IEC) for the community, LGUs, and the mining sector's involvement in ensuring the sustainability of gastropods in Surigao del Sur. Specifically, the objectives of the study are the following:

1. To identify the gastropod species as to their morphological structure, including their shape and variations of the species.
2. To assess physico-chemical conditions such as water pH level, dissolved oxygen (mg/L), salinity, and temperature in the selected sampling areas.
3. To examine the presence of nickel concentrations in the environment resulting from mining activities in selected sampling areas.
4. To analyze the significant relationship between the nickel concentration and diversity of gastropods in each sampling site
5. To assess the socio-economic impact of mining companies on their host community.
6. To assess the existing communication and education programs related to the impact of mining on marine biodiversity.
7. To develop an Information Education Communication (IEC) program promoting environmental sustainability.

1.4 Conceptual Framework

Figure 1 shows the schematic diagram of this study indicating how mining activities, resulting in–the presence of nickel concentrations would affect the marine gastropods' habitat and the host community in the affected areas. The presence of heavy metals due to mining activities could cause pollution in the marine environment (Suratissa & Rathnayake, 2017).

In this study, it is expected that the mining activities could have effects on the habitat of marine gastropods, particularly, their physico-chemical conditions such as water pH level, dissolved oxygen (DO), salinity, and water temperature. The presence and diversity of marine organisms such as gastropods can be considered indicators of a healthy marine environment (Fitria, 2023; Ladias et al., 2020).

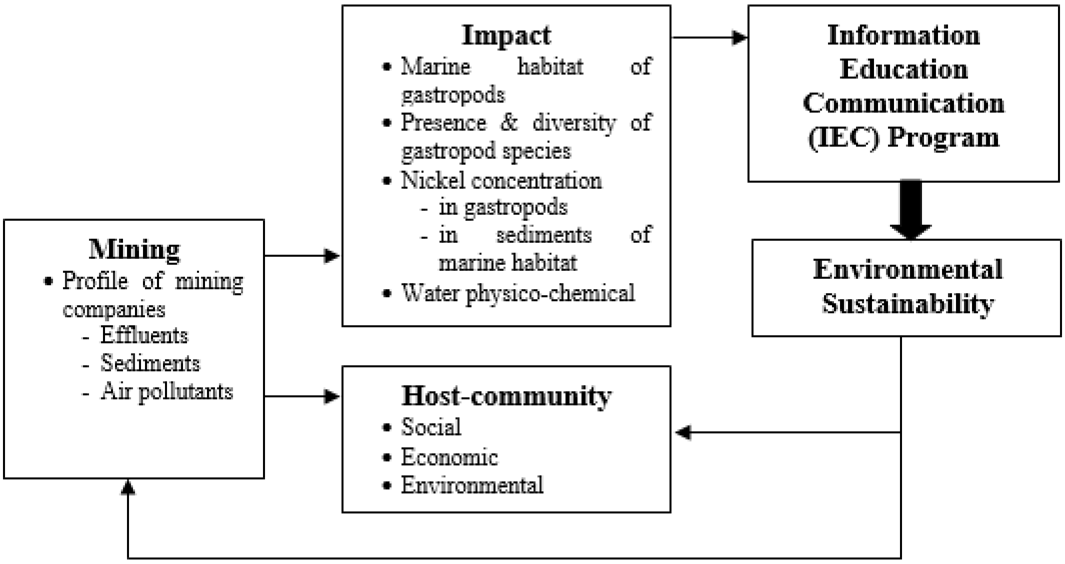


Figure 1. Conceptual Framework

In addition, as shown in Figure 1, the nickel concentration interferes with the connection between the mining activities and the marine habitat of gastropods. It is hypothesized in this study that the presence of heavy metals, for instance, nickel concentration, could be a significant factor influencing the change in environmental conditions in the affected habitat of marine gastropods. Heavy metals, including nickel, is one of the most widely known environmental pollutants as a factor in how anthropogenic activities such as mining affect the marine environment (Silva et al., 2014). Another study on heavy metals such as nickel have been shown to accumulate in gastropods, acting as bioindicators of pollution and straining marine ecosystems (Rainbow, 2002). These results demonstrate a clear connection between nickel concentration and the factor that influences the impact of mining activities on marine gastropod populations and ecosystems.

Aside from the environmental impacts of mining activities, this study would also look into the socio-economic impact of mining on their host communities. As presented in the schematic diagram, mining activities are positioned to have positive socio-economic impacts on the host community. The study by Cuartero-Enteria (2018) revealed that mining companies have positively impacted people's socio-economic status as they lead to job creation and increased local revenue, resulting in enhanced infrastructure and services. Despite the positive impacts of mining activities on the socio-economic status of the community, undeniably, these could also result in social dislocation, environmental damage, and health problems, resulting in long-term economic hardships and societal turmoil (World Bank & International Finance Corporation, 2003). Mining activities have adverse effects on the environment, and poor resource governance during active mining, resulting in economic reliance, limited diversification, and depletion of natural resources (Syahrir et al., 2020), all of which could potentially affect the socio-economic status of the affected community.

Given the potential environmental impacts of mining activities on the habitat of marine gastropods and their socio-economic impacts on the host community, it is envisioned that from this study an Information and Education Communication (IEC) program will be formulated to help ~~that would~~ promote environmental sustainability. An Information and Education Communication (IEC) program may make a significant difference in reducing the effects of mining on the marine environment and host community.

This IEC program that focuses on increasing awareness, educating the public on the effects of mining activities, and advocating sustainable practices may help to create a more educated and engaged community that actively participates in conservation efforts. It is shown in Figure 1 that the IEC program could potentially help ensure environmental sustainability as it continues to address the negative impacts of mining on marine habitats through collaborative engagement between mining companies and host communities through IEC campaigns.

1.5 Significance of the Study

The impact of mining on the marine environment, particularly on marine gastropods' habitats, is a growing concern for ecologists, environmentalists, and the general public. Mining activities have the potential to cause significant and long-term damage to marine biodiversity, with negative effects on the health and survival of gastropod populations. Despite the importance of these issues, few studies have comprehensively examined the impact of mining on marine gastropods and their habitat, and there is a limited understanding of the factors influencing this impact.

This study is significant because it aims to provide valuable information on the key factors contributing to the negative impacts of mining, and create a better understanding of the issue to help mitigate the negative effects of mining on marine biodiversity. In addition, this study will assess the effectiveness of existing communication and education programs related to ensuring a balance between mining and marine biodiversity protection. Through the development of an IEC program, it is anticipated that better promotion of environmental awareness may contribute to more targeted and participatory approaches to environmental sustainability.

The findings of this study will be of significant value to various stakeholders, including mining companies, government agencies, environmental groups, academe, future researchers, and the general public. Mining companies can use the information to develop more sustainable practices and reduce their impact on the marine environment. Government agencies can use the results to develop more effective regulations and guidelines to minimize the impact of mining on the marine environment.

Environmental groups can use the information to raise awareness about the negative effects of mining on marine biodiversity and advocate for better protection of marine environments. Finally, the general public can use the information to make informed decisions and take action toward protecting the marine environment. Overall, this study will contribute to promoting environmental sustainability and the conservation of marine biodiversity.

1.6 Scope and Limitations

This study focuses on the impact of mining on marine gastropod habitats in the Municipality of Carrascal, Surigao del Sur. The study is limited to one municipality location an established mining area in a coastal region of the town. The selected sampling areas only include Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango.

Due to the limitations of resources, parameters that are measured only cover the physico-chemical conditions of marine habitat such as water pH level, dissolved oxygen (mg/L), salinity, temperature and nickel concentration in the habitat and the gastropod species.

In addition, specific limitations of this study focus only on marine gastropods and will not consider other species or ecosystems.

Moreover, the sample size of gastropods collected in all sampling areas consists only of 53 genera belonging to ten families: Cypraeoidae, Neritiidae, Toridae, Terebiidae, Strombidae, Patellidae, Trochiidae, Olivoidea, Pisaniidae, and Ochiodoidae, all under the class Gastropoda.

The most important output generated from the study is the development of the Information Education Communication (IEC) program for promoting environmental sustainability. This provides for a data-driven (bottom-up) approach utilizing indicators based on the findings of the study.

The IEC program is limited to infographics on the background of the developed IEC material, the effects of mining on marine biodiversity, the socio-economic impact of mining on the host communities, and the call to action addressing the identified issues concerning the impact of mining to the marine gastropods and their habitat.

Finally, while the IEC program developed in the study is based on the needs and preferences of the local community, its implementation and effectiveness may be influenced by a range of external factors beyond the scope of this study.

1.7 Definition of Terms

The following are the terms used in this study as well as their respective operational definitions.

Environmental Sustainability. This has been defined as a state of balance, resilience, and interconnectedness that lets people meet their needs without overburdening the ecosystems that support them and stopping them from regenerating the services they need, or destroying biological diversity (Morelli, 2011, p.5).

Gastropods. These are diverse groups of mollusks (seashells) such as snails, slugs, or whelk that live on land, in the sea, and in freshwater. The majority of gastropods have an external shell (snails), but certain groups lack one. They include well-known groups such as periwinkles, whelks, cowries, and sea butterflies (Schiaparelli & Linse, 2014). As used in this study, the term has been defined as an English term for *"kinason"* which is a Bisaya term for gastropods. The gastropods used in this study are only limited to marine gastropods, which are found in the seawater area.

Host Community. This refers to the localities that possess abundant mineral resources and serve as the primary sites for mining activities. Communities are collectives of individuals who possess the same goals, principles, and heritage (Ramoshaba, 2019). In this study, the host community refers to the local residents who are affected by the mining activities in the Municipality of Carrascal, Surigao del Sur.

Information Education Communication (IEC). This is strategy aims to exert influence on behavior by emphasizing the delivery of information and education. The concept integrates a range of tactics, ideas, and methodologies that enable individuals, families, groups, companies, and communities to actively participate in enhancing, safeguarding, and maintaining their own well-being (Global Health Learning, n.d.). This also encompasses environmental education, which empowers individuals to explore environmental issues, engage in innovative problem-solving, and actively contribute to environmental improvement (EPA, 2023b). In this study, the IEC refers to the strategy on how to disseminate information about the impacts of mining to the community and marine environment. This also involves promotion of sustainable mining practices and environmental sustainability.

Marine Habitat. This refers to an environment that supports marine life or aquatic organisms (Abercrombie et al., 1966). The marine environment provides a rich and intricate setting for the proliferation of various types of microorganisms, such as archaea, bacteria, and eukarya (Karl &

Letelier, 2008). In this study, marine habitat refers to the seawater environment where the marine gastropods are living.

Mining. This term has been defined as the process of harvesting valuable materials such as minerals from the Earth's surface, including the seas (Hustrulid et al., 2024). This involves obtaining coal or another mineral from a mine with "close linkages between mining and other sectors of the economy". As used in this study, this term refers to the mining activities or operations conducted by mining companies in Carrascal, Surigao del Sur.

Morphological structure. As used in this study, this refers to the its shape and variations of the gastropods collected from the sampling sites.

Nickel Concentration. As used in this study, the term *"nickel concentration"* denotes the amount of nickel that is present in a certain seawater sample from the different sampling sites considered in this study. Nickel (Ni) is a chemical element that belongs to Group 10 (VIIIb) of the periodic table. It is classified as a ferromagnetic metal and has notable resistance to oxidation and corrosion. Nickel is renowned for its extensive use in currency, but it has more significance in both its pure metal state and as alloys due to its many domestic and industrial applications (Britannica, 2024).

Physico-chemical parameter. This term refers to the assessment of water quality that includes tests for the water pH level, dissolved oxygen, temperature, salinity, total dissolved solids, total dispersed solids, and the detection of sulfate, nitrate, heavy metals, and phosphate in the certain body of water (Xaaceph & Butt, 2023). In this study, the physico-chemical parameter is used to assess the quality of the seawater samples in terms of its water pH level, temperature, salinity, and dissolved oxygen.

Socio-economic impact. This term refers to the total impacts on social and economic elements of the population, such as changes in living standards, opportunities, capacities, or resources (Bandeira, 2021). As used in this study, this term refers to the effects of mining to the socio-economic welfare and quality of life of the local residents living in the Municipality of Carrascal, Surigao del Sur. The socio-economic impact could be positive and negative.

Sustainability. This refers to the fulfilling the needs of current generations without compromising the needs of future generations while ensuring a balance between economic growth, environmental care, and social well-being.

Sustainable Mining. This term has been defined as the process of extracting valuable mineral resources that is both an objective and a technique for striking a balance between economic, social, and environmental concerns (Kokko et al., 2015). This is based on a sustainable mining framework which focuses on reducing the detrimental effects of mining to the environment. This also involves strategies for evaluating the sustainability of mining operations which includes measuring, monitoring, and improving several environmental performance criteria, which are used to evaluate whether a mine is sustainable (Gorman & Dzombak, 2018).

CHAPTER 2
REVIEW OF RELATED LITERATURE

2.1 Mining in the Philippines

The Philippines is considered as the top contributor of mining products, especially, nickel minerals. Based on the report, the country continues to contribute significantly to nickel markets, generating an expected 360,000 metric tons of contained nickel in 2022, accounting for 11% of world output and ranking the nation second only to Indonesia (Dela Cruz, 2023). In the mining industry, Nickel is mainly used for the production of nickel steel, iron alloys, and electroplating. The Philippines continues to rank among the top in the Asia-Pacific area in terms of metal reserves, most notably nickel, and fourth in the world in nickel deposits, accounting for 10% of the total; however, it lags behind in gold and copper reserves. The majority of the copper and nickel deposits are located in undeveloped projects, presenting a potential for the government to capitalize on, particularly given the growing worldwide demand for green metals (Dela Cruz, 2023). Moreover, one of the nickel production areas in the country is found in the CARAGA region which has five provinces which are (1) Dinagat Province, (2) Surigao del Norte, (3) Surigao del Sur, (4) Agusan del Norte, and (5) Agusan del Sur. At present, the region hosts multiple mining operations producing different mineral commodities, including but not limited to gold, copper, chrome, nickel, iron, and limestone for concrete cement manufacturing (PANDI Claims Management Inc., 2022).

With regards to the existing mining policies in the Philippines, the Philippine Mining Act of 1995 or the Republic Act (RA) No. 7942 which was by President Fidel Ramos on March 3, 1995, serves as the major mining law in the country (Salazar, 2023). This policy was an effort to address some of the problematic issues of mining from the past, including a lack of respect for the rights of indigenous peoples, the failure to include local and regional governments in revenue sharing, and insufficient environmental and social requirements of mining operations. It embedded provisions on mining rights, incentives, government shares, social responsibilities, financial responsibilities, and environmental responsibilities. Its initial passage was immediately hailed by the Chamber of Mines of the Philippines. However, the Act was opposed by environmentalists, social activists, and indigenous peoples' organizations (Rovillos 2003).

In addition, the Department of Environment and Natural Resources (DENR) – Mines and Geosciences Bureau (MGB) oversees the mining sector and assures compliance with the Mining Act. The DENR-MGB also enforces the relevant environmental legislation. The Executive Order (EO) No. 79, s. 2012, as amended by EO No. 130, s. 2021 was established to institutionalize and implement reforms in the Philippine Mining Sector. This also provides Policies and Guidelines to Ensure Environmental Protection and Responsible Mining in the Utilization of Mineral Resources. The said executive order established the Mining Industry Coordinating Council (MICC), which is in charge of reforming the mining sector, including mine safety and environmental regulations (Salazar, 2023). Currently, the Philippine Development Plan (2023-2028) of the National Economic and Development Authority (NEDA) emphasizes the importance of sustainable and responsible mining and considers the restoration of mining sites from different parts of the Philippines as the mining sector plays an important role to the economy (Ordinario, 2023).

The notion of sustainable development has given rise to various visions of the future of the world, possible trade-offs, and externalities (Hilson, 2001). Although sustainable development requires the integration of the economic, environmental, and social dimensions of development, economic considerations often override the environmental and social considerations in most developing countries. According to Obiri (2016), many of the social elements of sustainable development can be cast in light of socio-economic considerations as the link between the economic, environmental, and social dimensions. The ultimate goal should be to identify ways to maximize the positive effects of mining on the lives of people while minimizing the negative effects. These effects should reflect the impact of mining on the present generations as well as future generations of miners and their families. Based on the paper of Morris and Baartjes (2010), it is widely accepted that developmental activities like mining are expected to contribute to both the social and economic development of the localities in which they are situated, either directly or indirectly. Yet, the socio-economic impact represents both the negative and positive developmental influences that mining activities have on the social and economic well-being of communities.

Understanding the impact of mining on local communities before during, and after the life of a mine is a vital part of responsible mining. This includes dealing not only with national governments but understanding the needs and aspirations of indigenous communities to ensure positive impacts (World Gold Council, 2018). According to Holden (2007), mining companies are expected to provide employment opportunities to communities in their vicinity directly during the construction and operation phases of their processes, and indirectly through the demand for goods and services from the miners. This process creates a revenue generation cycle and circulates currency, which is expected to enhance the quality of life of those living in mining localities.

2.2 Potential Impact of Mining to the marine habitat and gastropods

Gastropods have the greatest number of named mollusk species. Estimates of the total number of gastropod species vary widely, depending on cited sources. They can be found abundantly in ecosystems such as marine, freshwater, or estuary areas (Galan et al. 2015; Gregoric & de Lucia 2016; Miloslavich et al. 2013; Maia & Countinho 2013; Ruppert et al. 2004) and these are classified as detritus feeder (Liu et al 2014). Gastropods are among the promising organisms used in bio-monitoring studies focusing on pollution in intertidal areas, especially heavy metals, which are common environmental pollutants. For a long time, gastropods have been thought of as bio-indicators of heavy metal pollution in the area where they live (Abdel Gawad, 2018; Krupnova et al., 2018). Understanding how gastropods can handle contaminants from mining including nickel sediments is very important as nickel could have negative effects on the environment and ecosystems (Yap et al., 2022).

Previous study of Rois-Java et al. (2001) noted that most of the gastropods and mollusks have economic value that are distributed in coastal water. Although they can be found in a variety of habitats, the spread of *gastropods* is highly correlated with the physical and/or environmental condition of their habitat. For instance, the biochemical and physical/environmental factors such as the texture of the sediment, temperature, salinity, pH, organic matter content, and oxygen could affect the marine habitat and the diversity of gastropods in the area (Blanco & Cantera, 1999; Pyron & Brown, 2016). The study of Sharma et al. (2013) claimed that the physical and chemical conditions of the waters showed a significant effect on the diversity of the *gastropods*. Likewise, Garg et al. (2009) indicated that the physico-chemical conditions of the marine habitat such as the pH level, alkalinity, phosphate, sodium, and potassium significantly influences the diversity of *gastropods*. Another study of Sahin (2012) found that the physicochemical condition of the marine environment such as the dissolved oxygen (DO), temperature, NO2-N, and NO3–N significantly influences the diversity of gastropods. In addition, Salam & Nasar (2012) indicated that the environmental factors such as temperature, pH, TDS, TSS, DO, and BOD have significant relationship with the diversity of *gastropods*.

It can be seen in the existing literature that the physico-chemical parameters of the marine habitat are important factors to be considered as these have implications on how the environment could support the life of gastropods and the sustainability of these species (Bae & Park, 2020). For example, previous studies showed that the water pH level could significantly affect the marine habitat and the diversity of gastropods (Garg et al., 2009; Salam & Nasar, 2012). The gastropods are vulnerable to ocean acidification because their calcium carbonate shell erodes when exposed to low water pH level (Parker et al 2013). Excessive hydrogen ions in the ocean could interfere with the formation of the shell (Orr et al., 2005). Mollusks tend to have lower metabolic rates and cannot easily compensate for the interference of pH (Wittmann & Pörtner, 2013). A condition of chronic stress due to sub-optimal conditions can result in decreased growth and reproduction, increased susceptibility to disease, and decreased survival rate of Gastropods (Hooper et al., 2014; Kroeker et al., 2013; Byrne & Przeslawski. 2013). The analysis identified mollusk as one of the invertebrate taxa that were the most vulnerable in the changing ocean conditions (Wittmann & Pörtner 201leker et al., 2013).

In addition, with regards to the other physico-chemical parameters such as temperature, salinity, and dissolved oxygen, previous literature noted that these factors could influence the marine habitat and the diversity of gastropods (Lovel & Terray, 2016; Parker et al., 2013; Sahin, 2012). It was noted that higher water temperature is associated with the decreased dissolved oxygen and changes in salinity could have negative impact to the gastropods and their marine habitat (Parker et al., 2013). The increased water temperature was caused by the imbalance of energy in the atmosphere so that it is accommodated in the sea (Abraham et al 2013). In addition, the study of Lungay et al. (2023) revealed that higher salinity and temperature are associated with the lower the gastropod dispersion, and that all of the gastropods found are relatively abundant on sunny days with low sea levels. Such circumstances may have a deleterious impact on gastropod diversity and abundance, causing physiological stress, disrupting metabolic activities, and increasing competition with pH-tolerant species. The changes in the physicochemical factors of the water greatly affect the biological system of aquatic organisms, especially gastropods. However, these organisms were known to survive and adapt to a narrow temperature tolerance (Harley et al 2009). But then, temperatures beyond the optimal range can lead to stress thus causing metabolic malfunctions (Nguyen et al., 2012).

However, the physico-chemical conditions of marine habitat could be altered due to the anthropogenic activities including mining. In fact, mining operations may cause acidification, heavy metal contamination, sediment loading, and a decrease in calcium levels in aquatic habitats (Kirsten et al., 2020). Mining could also lower the pH level of the water environment and leach heavy metals from mine waste, poisoning water resources (Anita et al., 2021). Mining operations that alter habitat quality may also have an impact on the variety and availability of the aquatic organisms such as fish and gastropods (Andrades et al., 2021; Gomes et al., 2017; Vilar et al., 2023). For instance, the presence of nickel, which is a commonly found in the Philippine mining industry, could pose threat to the biodiversity (Willis, 2023). Nickel is one of many trace metals widely distributed in the environment, being released from both natural sources and by anthropogenic activity, with input from both stationary and mobile sources (Cempel and Nickel, 2006).

The nickel-laterite mining in the Philippines is one of the significant environmental issues as the sediments of nickel and other mineral products of mining silted on the streams, rivers, and estuaries, which has a detrimental effect on agricultural and fishing communities around mine sites (Opiso et al., 2023). The mining wastes could be transported by water runoffs from hilltops into freshwater and marine environments downstream of the site. For example, the study of Apodaca et al. (2018) found that the siltation owed from the nickel laterite mining threatens the coastal water quality of Hinadkaban Bay, Surigao Provinces, Philippines as this could contribute risks to the aquatic organisms and the livelihood of fishing communities in the area. Likewise, previous studies revealed that the nickel sediments from mining negatively affect the marine habitat and the diversity of gastropods (Mat et al., 2006; Plaza-

Cañete, 2018; Yogesh Kumar & Geetha, 2012). Indeed, nickel concentrations around mines and infrastructure provide a threat of poisoning to tropical marine creatures including marine gastropods (Gissi et al., 2018; Kakade et al., 2023; Zhang et al., 2022).

However, previous studies found that if the marine habitat is highly polluted from nickel sediments due to mining, the marine gastropods of that environment could acquire tolerance to nickel pollution (Zhou et al., 2008). For instance, a previous study by Krupnova et al. (2018) found that heavy metals such as copper (Cu) and zinc (Zn) had the greatest bioaccumulation factors (BAFs) in gastropod soft tissues. The said study also found a substantial correlation coefficient between heavy metal concentrations found in the soft tissues and shells of gastropods and the quality of the marine habitat. Marine gastropods are known to collect large levels of metals in their tissues (Silva et al., 2014). The buildup of high metal concentrations in the tissues of marine gastropods implies that they may be used as bioindicators to monitor environmental contamination. This event emphasizes the possible damage that these metals offer to gastropods and to the other aquatic species. In addition, some edible gastropods may contain high concentrations of nickel sediments or other heavy metals, which this situation could pose heath risk to humans who consume them (Kunkalikar, 2023). Thus, the impact of mining to the marine habitat and to the gastropods could potentially affect the human being.

2.3 Potential Socio-economic Impacts of Mining

Aside from the marine environment, mining has substantial impacts to the affected communities residing nearby mining areas. According to Holden (2007), mining companies are expected to provide employment opportunities to communities in their vicinity directly during the construction and operation phases of their processes, and indirectly through the demand for goods and services from the miners. This process creates a revenue generation cycle and circulates currency, which is expected to enhance the quality of life of those living in mining localities. Based on the paper of Morris and Baartjes (2010), it is widely accepted that developmental activities like mining are expected to contribute to both the social and economic development of the localities in which they are situated, either directly or indirectly. In addition, previous study of Balanay and Yorobe (2014) found that mining companies have brought positive impacts on the socio-economic status of the people. The resources were wisely shared with the community through offering various activities and programs. Undeniably, the mining sector made a significant contribution to transforming communities into modern civilizations and improving quality of life by creating jobs, skills, and knowledge, promoting equitable income distribution, and upgrading infrastructure, public health services, and education (Hosseinpour, Osanloo, & Azimi, 2022).

However, the mining industry could have negative socio-economic impacts to the communities. These negative impacts might vary from relocation and loss of livelihood for local populations to broad economic and social disturbances. For example, mining activities often result in the displacement of local communities, when their houses and lands are purchased for mining operations, resulting in loss of livelihoods and disruption of community structures (Downing, 2002). Economic disparities or inequalities may also arise, with income created by mining activities not evenly benefitting local populations, typically leading to higher poverty levels and expanding inequality gaps (Yeboah, 2023). In addition, the environmental degradation associated with mining, such as water pollution and deforestation, may harm local economies that rely on natural resources, thereby creating socioeconomic vulnerabilities (Dehghani et al., 2022). These negative consequences of mining to environment could lead to land-use shifts and food insecurity, increased social conflicts, high living expenses, and pollution

(Worlanyo and Jiangfeng, 2021). All of these could potentially affect the socio-economic well-being of the impacted community.

2.4 Information Education Communication (IEC)

Given the impact of mining on the marine environment, aquatic species, and host communities, there is a need to develop an intervention that could mitigate the negative impacts of mining. The information education and communication (IEC) program could be an appropriate technique to promote sustainable mining and environmental sustainability. The IEC seeks to raise awareness, motivate, and educate target people or groups by using appropriate communication mediums and other means that may affect knowledge, beliefs, attitudes, and behaviors (Sachdeva et al., 2015). Such initiatives strive to establish a multimodal evidence-based technique, emphasizing the need for stakeholder participation in addressing the negative effects of mining on the environment and community (Haddaway et al., 2019).

The IEC provides an opportunity for addressing important environmental problems to increase understanding of the concepts, basic principles, and benefits of environmental protection initiatives. This also promotes people's conduct toward their surroundings. According to Loseñara (2020) and Morren and Grinstein (2016), environmental behavior encompasses pro-social activities that prioritize the well-being of people, future generations, and ecosystems. Sustainable mining is therefore a joint endeavor that incorporates community participation, economic appraisals, environmental monitoring, and education initiatives to increase community environmental literacy. These initiatives are important, especially in nations that largely depend on natural resources, to guarantee that the policies that result from them are comprehensive and sustainable (Tyson, 2015).

Furthermore, assessing the use of printed IEC materials demonstrated the significance of allowing successful education programs that could be useful in executing government programs and efficiently employing resources across other industries (Geleta et al., 2022). Based on the literature review, only few studies dwell into the incorporation of the IEC program as intervention in addressing the impacts of mining to the marine environment and to the host community. Most existing studies focuses the role of IEC program on health education (Acharya et al., 2020; Geleta et al., 2022; Singh & Kumar, 2023).

CHAPTER III
MATERIALS AND METHODS

This chapter presents the research design and methods used in this study. This also includes the research locale and subjects of the study, sampling design, data gathering procedures, research ethics, statistical tools, and analysis of data.

3.1 Research Description of the Study Area

The study was conducted in the northern part of Surigao Del Sur province, particularly in the municipality of Carrascal, a fourth-class municipality with an increasing income sourced from mining activities. The municipality's land area is 265.80 square kilometers (102.63 square miles), accounting for 5.39% of Surigao del Sur's total area. The population as of the 2020 Census was 24,586. This accounted for 3.83% of the entire population of Surigao del Sur province, or 0.88% of the overall population of the CARAGA Region (PhilAtlas, 2024). Before the mining started its operation, Carrascal had an income of 1.3 million pesos from its main source of livelihood that is agriculture. When Carrascal municipal officials decided to let mining companies in, local ordinances were created, as well as Memoranda of

Understanding with the mining firms, with the goal of equitable sharing of profits to give maximum benefits to the town and its people. The mining companies operating in the area include Carrascal Nickel Corporations (CNC) and Marc Ventures Mining and Development Corporation (MMDC) (Lopez, 2013). The study area, which is the Municipality of Carrascal, Surigao del Sur, is situated approximately along the coordinates of 9° 22' North, 125° 57' East, in Mindanao Island. In addition, this study selected four sampling sites namely: Brgy.Dahican, 9° 41′ 78″ N, 125° 89′ 48″ E Brgy. Adlay 9° 41′ 43″ N, 125° 89′ 23″ E Brgy.Bon-ot, Sitio Gango 9° 39′ 52″ N, 125° 93 ′ 78″ E and Brgy. Caglayag 9° 40′ 30″ N, 125° 89′ 83″ E. Figure 2 shows the map of the study area.

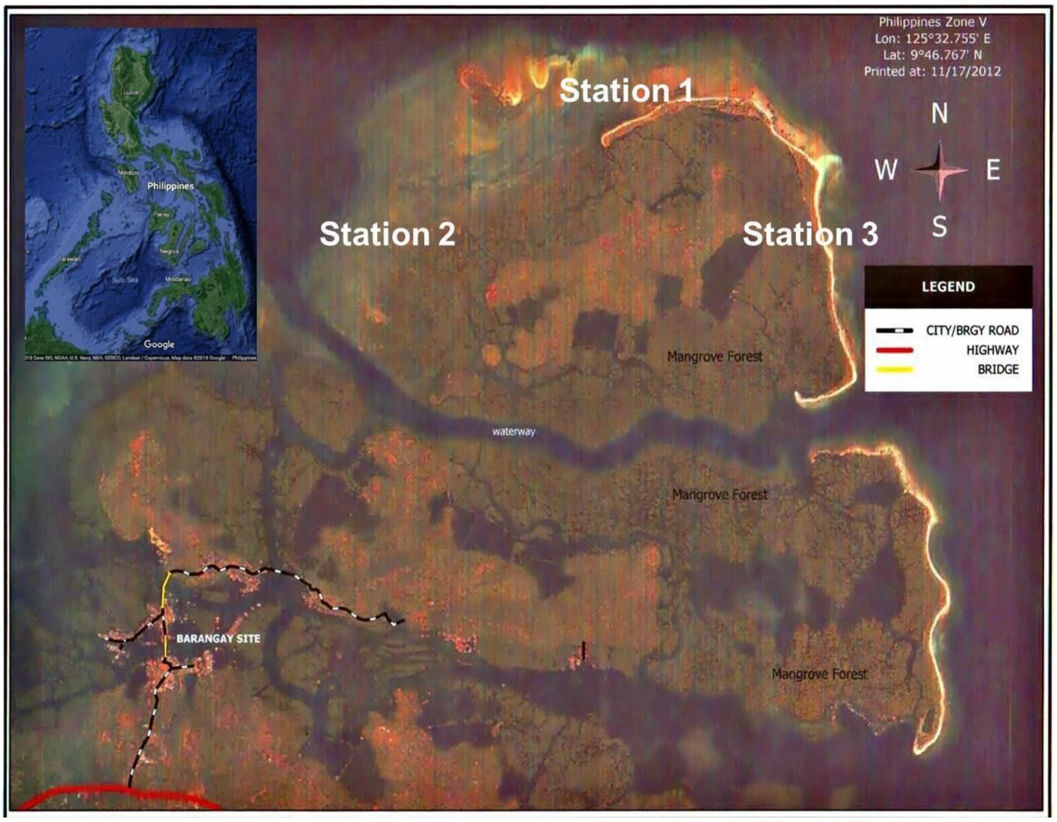


Figure 2. Map, Sampling Stations

At the start of the investigation, the shore of Carrascal was surveyed to record intertidal gastropods. The shoreline of Carrascal has a mix of rock, sand, and muddy coastline. Gastropods were observed on the stony coast. The physical properties of the chosen sites were measured, including elevation, longitude, and latitude. Moreover, shown in Figure 3 is the satellite view of the Mindanao map, where the Municipality of Carrascal, Surigao del Sur is situated. Meanwhile, Figure 4 shows the map of Surigao del Sur indicating the sampling areas which are the Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango. Four sampling sites (Brgy.Dahican, Brgy.Adlay, Brgy. Bon-Ot, and Bgry. Caglayag) were identified utilizing the map provided by CNC and coordinated with the satellite images retrieved from Google Earth.

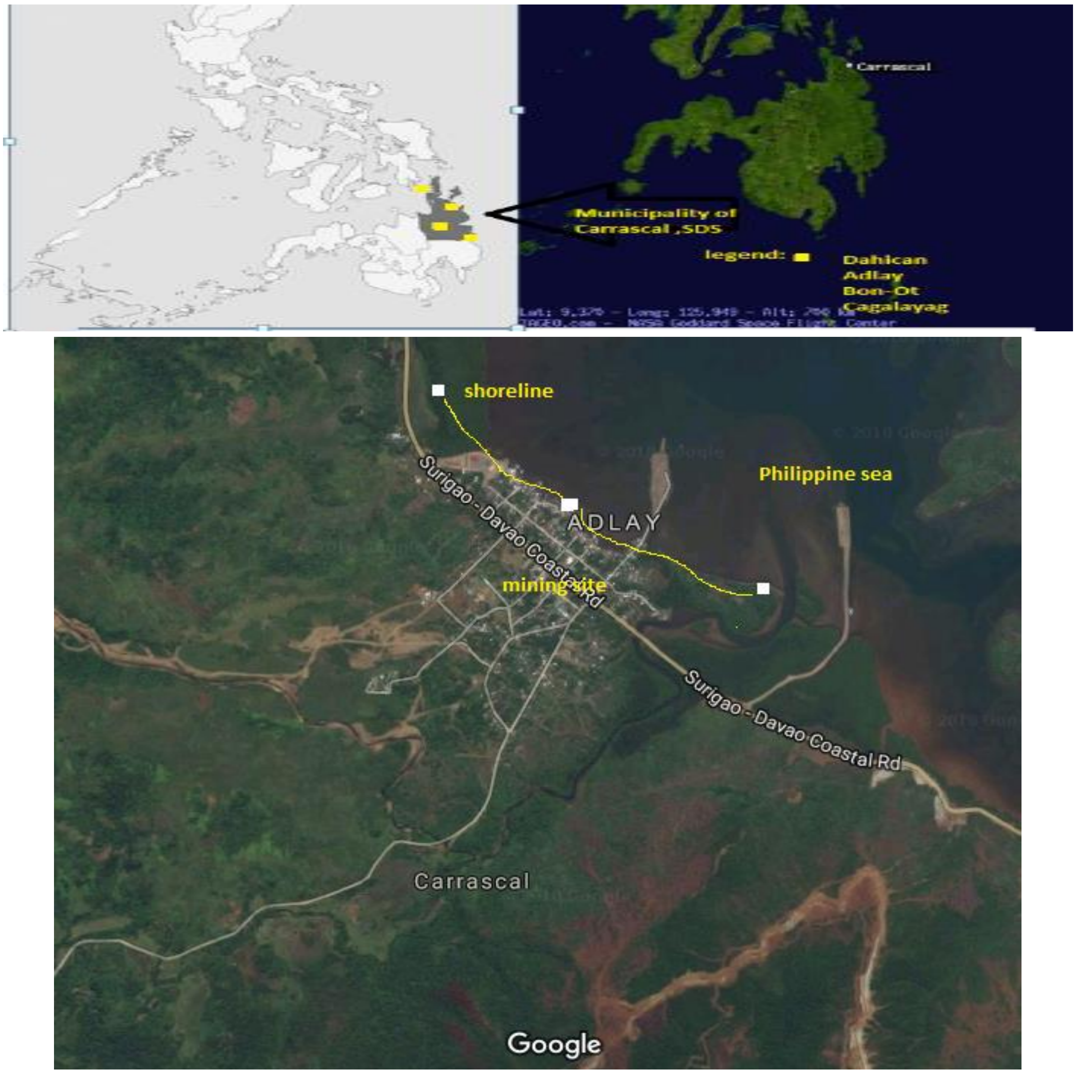


Figure 3. Satellite View, Sampling Areas, Carrascal, Surigao del Sur

Figure 4. Satellite Map, Study Area by Barangay, Carrascal. Surigao del Sur

3.2 Data Gathering Procedures

This study includes data gathering procedures such as the collection of gastropods in the selected four sampling areas located in the Municipality of Carrascal, Surigao del Sur namely: Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango. The data gathering includes recording intertidal gastropods, assessing the physico-chemical parameters, and detecting the average concentrations of nickel sediments in each sampling site. In addition, key informant interview was also used as a method to gather data regarding the socio-economic impacts of mining on the affected host communities and to determine the existing Information, Education, and Communication (IEC) programs in the Municipality of Carrascal, Surigao del Sur.

3.2.1 Identification and Classification of Species

The purpose of gathering data for the identification and classification of gastropod species is to determine their common characteristics in the sample area. By collecting detailed data about their morphological structure, shape, and variations of the species, this study can track the distribution of these species in the area. The identification of the species in the sampling area would serve as a basis for how diverse are the species in the research locale.

Collection of gastropods in the selected four sampling areas

The sampling was undertaken from July 2023 to December 2023 in the selected sampling sites of the study area. The sampling period was done during low tide season in a month between 7:00 am to 7:00 pm. To ensure the visibility of the gastropod species, the specimens were collected by hand (live specimens only) during low tide. The coast of Carrascal is characterized by a mixture of rock, sand, and muddy shore.

To define the sampling zone, 50 meters from the highest tide was assumed to encompass the intertidal zone. Each sampling site had three stations and the species were collected for 30 minutes at each site.

Recording intertidal gastropods

Initially, the inquiry started by surveying the beach of Carrascal to document the presence of intertidal gastropods. The collected gastropods in the area were then recorded. The collected gastropods were also cleaned, sorted, and identified. Collected samples were brought to the Biolab for identification to the lowest possible taxonomic level based on morphological characteristics using references in gastropods' taxonomic identification.

Gastropods were identified and classified based on their families utilizing relevant literature. Identification was based on the morphological characteristics of each specimen. The species' names were verified using a database for marine species of gastropods. Using taxonomic classification, identified gastropods were categorized into three hierarchies or categories namely: (1) family, (2) genus, and (3) species. In addition, the collected gastropods were photographed with a digital camera. Pictures were taken using a high-resolution digital camera to identify the species and document them properly. A handheld Global Positioning System (GPS) receiver was used to identify their position, which was taken at the center of the map.

Collected specimens and shells were measured end-to-end from the longest point of the axis for the length using a Vernier caliper with ±0.01 mm accuracy and likewise photographed in the laboratory. The images of the shells were always taken in the same position, with the columella at 900 of the x-axis in an aperture view or in the orientation that displayed the apex. The resulting image was then processed using geometric morphometric methods. Gastropods were identified and classified based on their families utilizing relevant literature. Identification was based on the morphological characteristics of each specimen, with many guides used to identify gathered samples.

3.2.2 Physico-chemical parameters

The physicochemical parameters of the seawater at each sampling site were measured in terms of water pH level, dissolved oxygen (DO), salinity, and water temperature. These physicochemical parameters were determined in situ using a mercury-in-glass thermometer, buffer electronic pH meter (Kent EIL 7020), and handle salinity refractometer. Meanwhile, the DO was determined using the titration method (APHA, AWWA, WEF 1999). The elevation, latitude, and longitude of the chosen areas were also measured.

Water pH level

Water pH was measured using an HM Digital pH-200 waterproof pH meter, with the electrode dipped into the water surface until the values stabilized. Following the reading, the electrode was completely cleaned with distilled water before another reading was obtained. The determination of water pH was done using pH paper submerged in the water three times and referred to a standard color chart and calculated.

Dissolved Oxygen

Dissolved oxygen (DO) was measured using the PINPOINT II Dissolved Oxygen Monitor. Before taking any readings, the DO meter was calibrated. The probe was then immersed for approximately 1 inch beneath the seawater's surface. While obtaining a reading, the probe was progressively swirled into the seawater at a depth just below the surface until an accurate reading was obtained. The value was obtained directly from the meter and expressed in mg/L.

Salinity

The salinity value was measured using the calibrated eyepiece and expressed in parts per thousand (ppt). The salinity of the seawater in the sampling area was determined using a refractometer. A glass dropper applied a little drop of seawater to the testing prism.

Water Temperature

The temperature of the seawater was taken by submerging the laboratory thermometer in the water's surface for five minutes. The average temperature in terms of degrees Celsius °C was then recorded.

3.2.3 Nickel Concentration by Atomic Absorption Spectrophotometry

The Atomic Absorption Spectrophotometry (AAS) was used to determine the average concentration of nickel sediments (in mg/kg) in environmental samples. This is important for determining nickel concentrations in environmental samples around mining sites, enabling for pollution assessment and ecological effect. By detecting high nickel levels, AAS aids in determining the extent of contamination and the efficacy of mitigation efforts in mining sites. This method has been commonly used to determine the sample of the nickel concentration of a certain area (Kuliev et al., 2020). Previous study of Mohammadi et al. (2019) used this method in assessing the nickel concentration of the sampling area as defined in their study.

In this present study, the AAS test for identifying nickel concentration in each sampling area was conducted by the First Analytical Services and Technical (FAST) Cooperative Laboratory. The interpretation of the results was based on the Environmental Protection Agency (EPA) heavy metal guidelines for sediments (mg/kg) given that Nickel is the parameter as cited in Sylvanus et al. (2020, p. 190). The categories on the interpretation of the nickel concentration is divided into three: Not polluted (<20 mg/kg), Moderately polluted (20 – 50 mg/kg), and Heavily polluted (> 50 mg/kg).

To determine the concentration of nickel in a marine environment, water and sediment samples were collected from the sampling sites. A clean and metal-free equipment was used to avoid contamination. Water samples were collected in acid-washed, polyethylene containers and immediately preserved with a few drops of concentrated nitric acid to stabilize the nickel ions. Sediment samples were scooped using a plastic sampler and stored in clean plastic bags. The water and sediment samples were transported to the First Analytical Services and Technical (FAST) Cooperative Laboratory for analysis. The water samples were filtered and digested using a strong acid, typically nitric acid, to extract nickel from the samples.

In the laboratory, the collected samples were prepared and then analyze using Atomic Absorption Spectrophotometry (AAS). Several preparation steps were conducted to guarantee precise measurements of nickel concentrations. Initially, samples are gathered and subjected to regulated heat in order to eliminate any moisture. After the sediments have dried, they are pulverized into a fine powder to ensure the sample is consistent, which is important for precise analysis. The powdered silt is subjected to digestion using powerful acids such as hydrochloric acid or nitric acid, which results in the dissolution of the metals into a liquid solution. Following the process of digestion, the solution undergoes filtration to eliminate any solid particles and is subsequently diluted to an appropriate concentration for further analysis. The prepared sample is thereafter inserted into the AAS apparatus, where it is vaporized in in a flame. The AAS measures the concentration of nickels from the sample by detecting the light absorbed by the vaporized metal atoms, providing a quantitative analysis of metal content in the sediment. Moreover, these steps were conducted by the laboratory chemist of the FAST Cooperative Laboratory located at Cagayan de Oro City.

3.2.4 Relationship of Nickel Concentration and Diversity of gastropods

To analyze the relationship between the nickel concentration and diversity of gastropods on each sampling site, a scatter plot and multiple linear regression analysis were used. Scatter plots graphically present the data points, with the concentration of nickel on one axis and the diversity of gastropods on the y-axis. One scatter plot of each sampling site was presented to determine the patterns or r trends in the data, such as the correlation between concentrations of nickel and diversity of gastropods. Subsequently, multiple linear regression analysis was utilized to assess how the nickel concentration significantly predicts the diversity of gastropods by sampling site (per barangay). If the p-value is less than 0.05, then there is a significant relationship between the variables. The regression analysis was used to determine whether the nickel concentration was positively or negatively associated with the diversity of gastropods. Moreover, statistical software was used to analyze the data using multiple regression analysis.

3.2.5 Key Informant Interview

Key informant interview (KII) was conducted to gather information about the socio-economic impacts of mining companies on the host communities in the Municipality of Carrascal, Surigao del Sur. These selected informants are residents of the municipality. An open-ended questionnaire that includes questions about the positive and negative impacts of mining on them and the existing IEC programs of the municipality concerning sustainable mining and promoting marine biodiversity was used.

A total of 18 key informants were engaged in the key informant interview. These include 2 key informants from the Municipality of Carrascal, who are local government unit (LGU) personnel. Additionally, from each sampling area, four key informants were interviewed. These informants are residents of the area. Some hold significant positions within their barangays, a number are fisherfolks,

others are employees of the mining company, and the rest are typical residents of the area. These respondents were selected in a purposive manner, considering their knowledge regarding the socio-economic impacts of mining and the existing communication and education programs related to the impact of mining on marine biodiversity.
Before the interviews, each informant was provided with an overview of the study's objectives. Also, informed consent was obtained from the participants to ensure ethical standards were maintained. The Informed Consent consists of information indicating the study's purpose, how the data will be used, and any potential risks or benefits to them as participants of the study. Interviews were conducted in a quiet and private setting to facilitate open communication and were recorded with the informants' permission for accuracy. Each session lasted approximately 10 to 20 minutes, allowing sufficient time for informants to elaborate on their responses. Responses were written in the guide questionnaire, translated into English and stored as a file. The data was systematically coded and analyzed to identify recurring themes and unique viewpoints. This methodical approach ensured that the data collected was both comprehensive and representative of the different opinions and experiences within the community. Moreover, the data from the key informants were analyzed using thematic analysis. This is a qualitative type of research method that is used to analyze qualitative data such as opinions and experiences (Nowell et al., 2017). According to Braun & Clarke (2006), thematic analysis can be done through these six steps, which are: (1) familiarizing with the data, (2) generating codes, (3) searching for themes, (4) reviewing the themes, (5) defining themes, and (6) doing the write-up. In addition, the process of thematic analysis usually has a few main steps. The first step is to get to know the data. The second step is to code the data to show important or common ideas. After the data is coded, themes are made and checked to make sure they truly show the data. The last step is to define and identify the themes. These are then carefully checked to make sure they fit the subtleties and complexities of the data (Saunders, 2023).

3.2.6 Assessment of the existing IEC campaigns in the research locale

In order to assess the existing IEC campaigns of the research locale, this study utilized information gathered from the informants and records. Based on this information, IEC strategies were identified along with the aims and accomplishments. After identifying these strategies, an assessment was conducted, where the researcher identified the gaps in these IEC campaigns. These gaps could serve as the basis for the proposed IEC program. This proposed IEC aims to promote environmental awareness and education to the affected host community while addressing the impacts of mining to marine biodiversity. This proposed IEC aims to promote sustainable mining and achieve environmental sustainability in the Municipality of Carrascal, Surigao del Sur.

3.3 Data Analysis

3.3.1 Gastropod Diversity, Richness and Evenness

The shannon-Weiner index was used to identify the diversity of the collected marine gastropods from each sampling site. This method was used to determine the richness of the gastropod species in each sampling area. The Shannon-Wiener Index (H′) was computed using the following formula:

$H' = -\sum i{=}s \; pi \log p\, i$

where H′ = value of Shannon-Wiener diversity index; Pi = proportion of its species; loge = natural logarithm of pi; s = number of species in the community or species richness. Using the Shannon-Wiener diversity index (H′), species of gastropod in the assemblage were classified based on the following category: low (H′ < 2); moderate (2 < H′ < 4); and high (H′ > 4).

The species evenness index was determined using Pielou's evenness index with the formula:

$$J' = H' / H' \max$$

where H′ = Shannon-Wiener diversity index; Hmax = natural logarithm of species richness. Species range from zero to one; zero means no evenness and one means complete evenness.

3.3.2 Nickel Concentration and Gastropod Diversity

Moreover, a scatter plot was used to illustrate the relationship between the Nickel concentration and the number of species of gastropods in each sampling site. In addition, a multiple Linear regression was employed to analyze the effect of Nickel content on gastropod species diversity in each selected sampling area. The multiple linear regression is a statistical analysis technique that extends linear regression by incorporating more than one independent variable into an equation to investigate their relationship with the dependent variable. For this study, the independent variables are the nickel concentrations from the sampling sites, while the dependent variable is the diversity of gastropods. This technique is appropriate to assess the impact of mining as presented by the nickel concentration on the marine gastropods in the Municipality of Carrascal, Surigao del Sur.

Furthermore, concerning the data analysis from the key informant interview, descriptive statistics were employed. This includes describing the themes drawn based on the responses of the key informants from the interview. This approach also involved summarizing the qualitative data to highlight recurring patterns and significant insights, thereby providing a presentation of the collective viewpoints and experiences of the respondents expressed during the interviews.

CHAPTER 4
RESULTS AND DISCUSSION

This chapter shows the results of the study based on the data gathering, which includes the collection of gastropod species in selected sampling sites of the municipality of Carrascal, Surigao del Sur, physicochemical tests for water quality, atomic absorption spectrophotometry, and multiple linear regression analysis. This also presents the proposed Information Education Communication program for environmental sustainability, addressing the impacts of mining on marine biodiversity and host communities in Carrascal, Surigao del Sur.

4.1 Gastropod's morphological structure, shape, and variations of the species

The list of gastropods in the four sampling sites is presented in Table 1. In this study, a total of 228 marine gastropod species were gathered and identified from the following sampling sites: Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango. These marine gastropod species consist of 53 genera belonging to ten families: Cypraeoidae, Neritiidae, Toridae, Terebiidae, Strombidae, Patellidae, Trochiidae, Olivoidea, Pisaniidae, and Ochiodoidae, all under the class Gastropoda.

In Table 1, shows that most of the gastropods collected in the four sampling areas belong to the family of Neritidae, comprising 69% (157 out of 228) of the sample. Neritidae are gastropod mollusks that inhabit marine, brackish, and freshwater environments. Among the Nerita species, the *nerita polita* has the smallest breadth (Haumahu & Uneputty, 2018). The *Nerita* species is known for having the most adaptable radiation mechanisms among gastropods (Quintero-Galvis et al., 2013). Most of the gastropods found in the area are in a globular, ear-like shape.

Table 1. List of Gastropods in the four sampling sites

Family	**Genus**	**Species**	**Number of individuals per site**	**Morphological Structure**
Olivoidea	*Tectarius*	*spinulosus*	5	Conical shape; crescent-like structure
	Tectarius	*striatus*	10	conical- globular shape; crescent-like structure
Pisaniidae	*Gemophos*	*viverratoides*	2	conical shape with pointed apices
Cypraeoidae	*Mauritia*	*Arbica arabica* (Common Name: **Sigay**)	1	oval shape/ elliptical to egg-like shape
	Monetaria	*Annulus analus*	3	oval shape/ elliptical to egg-like shape
	Notocypraea	*subcarnea*	1	oval shape/ elliptical to egg-like shape
Neritidae	*Nerita*	*Incerta (Common Name: Takdagon)*	33	Globular shape; ear-like shape
	Nerita	*adenensis*	3	Globular shape; ear-like shape
	Nerita	*maura*	15	globular or rounded shape
	Nerita	*quadricolor*	33	globular to slightly ovate in shape with well-defined spiral pattern
	Nerita	*Polita polita*	6	Semi-circular shape; smooth and rounded structure
	Nerita	*patula*	2	globular to ovate shape with a short spire
	Nerita	*ocellata*	6	rounded and somewhat globular in shape
	Nerita	*alveolus*	30	rounded or globular shape
	Nerita	*polita*	20	Semi-circular shape; smooth- rounded structure
	Nerita	*crassa*	9	Semi-globular shape with large and rounded aperture
Tornidae			2	circular, coiled shape with a flat or slightly convex base and a raised spire
Terebridae	*Strioterebrum*	*Swainsoni (Common Name: Samong)*	2	slender, elongated shape with a high spire; turriform
Strombidae	*Strombus*	*ostergaardi*	2	conical and spindle-shaped with stout and thickened outer lip
	Canarium	*betuleti*	5	fusiform or spindle-like shape

	Canarium	*olydium*	2	fusiform or spindle-like shape
	Dolomena	*dilatata orosmina*	6	fusiform or spindle-like shape; wider outer lip
	Dolomena	*variabilis*	2	fusiform or spindle-like shape wider outer lip
	Canarium	*urceus*	4	urn-shaped
	Strombus	*blanci*	3	conical shape with a high spire
	Persististrombus	*glanulatus*	16	Conical-globular shape with granulations along shoulders and spire
Patellidae	*Patella*	*piperata*	2	low-conical or dish-shaped
Trochidae	*Calliostoma*	*gubbiolli*	2	conical shape
Ochiodoidae	*Ochiodoidae*	*borealis*	1	elongated, conical shape; turriform

In addition, most of the Neritidae gastropods are *incerta* and *quadricolor* species, which comprise 14.5% of the total sample. This is followed by *Nerita alveolus* and *Nerita polita*, which comprise 13.2% and 8.8%, respectively, of the total sample of gastropods. The prevalence of *nerita incerta* and *nerita polita* gastropods in maritime ecosystems implies that they contribute significantly to the biodiversity of these environments. Both species are members of the genus Nerita, which is noted for its diversified and broad presence in tropical and subtropical marine settings. The genus has a wide range of species with varied ecological activities, from grazing on algae to helping the nitrogen cycle in their environments (Postaire et al., 2014). Additionally, the abundance of *nerita quadricolor* and *nerita alveolus* indicates a successful adaptation strategy that may involve aspects such as eating habits, reproductive mechanisms, and habitat selection, all of which contribute to their predominance in marine habitats. This finding, although particular, is consistent with larger marine biodiversity studies that record the distribution and abundance of gastropod families throughout various maritime environments, emphasizing their relevance in these ecosystems (Garrity, 1984; Pastorino, 2009).

Moreover, in the sample area in Brgy. Adlay, most of the species that were collected in the area belong to the family Olividae, while the least of them belong to the family Pisaniidae. The morphological structure of these species is conical, or crescent-like. The Olivoidea *tectarius striatus* species are mostly present in the area and have a conical-globular shape. The gastropod family Olivoidea is often found in coastal waters in tropical and subtropical latitudes around the world's oceans, and most of these gastropods have big, nimble feet with a crescent-shaped propodium that is typically free on exterior corners (Kantor et al., 2017). The presence of these species has ramifications for the local ecosystems in these places. As a marine gastropod, it most likely participates in nutrient cycles and food webs, contributing to the biodiversity and ecological balance of its environment (Pastorino, 2009). However, in Brgy. Dahican, Caglayag, and Gango, most of the species were found belong to the family of Neritidae, characterized by a globular or ear-like shape. The Nerita shell is thick and firm, resembling a half-moon or ear shape. It features a smooth/concentric ridged/spirally ribbed/sculpting dorsal surface, a broad columellar deck, and a callus or parietal wall with ridges, wrinkles, or granular/small bumps/nodules in colored or uncolored places. The spire is typically low or very low (Susintowati et al., 2018; Tan & Clements, 2008).

Table 2. Diversity of Gastropods in the sampling area

Brgy./ Areas	Number of gastropods collected	Shannon's Index of Diversity
Adlay	**17**	**0.84**
Sitio Gango, Bon-ot	**87**	**0.81**
Caglayag	**70**	**0.86**
Dahican	**54**	**0.79**

Note: Very Low=1.99 and below; Low=2.00-2.49; Moderate = 2.50-2.99; High = 3.00-3.49; Very High = 3.50 and above (Fernando, 1998; Baliton et al., 2020).

As presented in Table 2, the Shannon's Index reveals that the diversity of gastropods in all sampling sites is very low ranging from 0.79 to 0.84. A very low Shannon index value for marine gastropods in an area typically indicates a lack of diversity within the gastropod community. This can be due to various factors including environmental stressors like pollution, and habitat loss, which reduce species diversity and richness. Such low diversity in gastropods indicates concerns in the health and function of the marine environment, highlighting the need for conservation and management efforts to restore diversity (Barrientos-Luján et al., 2021).

4.2 Physico-chemical conditions of the sampling areas

Table 3 shows the status of marine gastropod habitat considering the physico-chemical conditions of four selected sampling areas in Carrascal, Surigao del Sur. The water pH level result of each sampling area, as seen in Table 3, indicates that the water condition is slightly alkaline as the pH level is greater than 7. The pH level of each area is typically acceptable based on the water quality guidelines of the Environmental Protection Agency (EPA). Different aquatic species can still thrive at this level, as the optimal pH for most aquatic creatures is between 6.5-8 (EPA, 2024).

Table 3. Summary Results for Physico-chemical conditions in four areas selected in Carrascal, Surigao del Sur

Brgy./ Areas	pH	Dissolved Oxygen (mg/L)	Salinity	Temperature
Adlay	**8.1**	**3.25**	**1.013**	**33.37**
Bon-ot,Sitio Gango	**7.9**	**2.88**	**1.017**	**35.24**
Caglayag	**8.0**	**2.79**	**1.024**	**33.80**
Dahican	**8.1**	**2.84**	**1.034**	**32.20**

In addition, with regards to the dissolved oxygen parameter, all of the sampling areas have a dissolved oxygen level range from 2.0 to 4.0 mg/L, indicating that the body of water has a low oxygen content. This shows that only a few aquatic species could survive (Annis, 2020). These circumstances are often caused by the breakdown of abundant organic materials, such as massive algae blooms, which deplete oxygen. When DO levels fall below 5 mg/L, it is considered stressful for fish, and values below 3 mg/L are insufficient to maintain many species (EPA, 2023a). The dissolved oxygen parameter is essential for the life of fish, invertebrates, and other aquatic animals since it is the amount of oxygen that is present in the water (Water Science School, 2018).

On the other hand, in terms of the salinity parameter, Table 3 shows that the salinity level of each sampling area is between 1 and 2 ppt, indicating that the water is slightly saline, which is situated between freshwater and brackish water. The salinity of brackish water, which is a mixture of fresh water and saltwater, ranges from 0.5 ppt to up to 30 ppt in more salty situations (Horiba, 2016; Rizal et al., 2020). This modest salinity may occur in natural areas where freshwater and saltwater mingle, such as estuaries, or it can be found in groundwater sources with naturally greater mineral content. The salinity content affects the water's capacity to sustain aquatic life, with various species exhibiting varied degrees of tolerance to salt. Furthermore, salinity affects the physical characteristics of water, such as density and the solubility of gases like oxygen, which decrease as salinity rises (Bal, 2022).

Furthermore, with regards to the water temperature level, Table 3 depicts that the water temperature level of the sampling sites ranges between 32 and 36 degrees Celsius. This indicates very warm conditions in the bodies of water, which may have a considerable impact on the aquatic ecosystem and the behavior of species that live there. Among the sampling areas, Brgy. Gango has the highest temperature, which is 35.24 degrees Celsius, while the sampling site in Brgy. Dahican has the lowest temperature, which is 32.20 degrees Celsius.

The temperature conditions of the sampling areas also indicate that only a few aquatic species could survive. Most aquatic species are cold-blooded because they cannot adjust their body temperature. Thus, temperature has a significant impact on the biological activity and development of aquatic species (Jain et al., 2013). Although some aquatic species, such as gastropods, may survive in warm water temperatures, higher warming temperatures could reduce their survival (Falkenberg et al., 2021). In addition, warmer waters may change the conductivity of water because many salts become more soluble at higher temperatures. Salts dissolve to form ions, increasing the ionic concentration and, as a result, the conductivity of the water (Fondriest). In addition, the rising water temperature could be attributed to climate change. As the level of greenhouse gases rises, they trap a greater amount of the sun's energy, resulting in higher temperatures in the marine environment. As a consequence, there is an increase in both the temperature and level of the Earth's oceans. The changes in water temperature in marine areas, caused by climate change, are anticipated to alter worldwide climatic patterns (EPA, 2023c).

Given the physico-chemical conditions of the sampling sites, the results in Table 3 provide important information in understanding the implications of these conditions and are significant for managing aquatic habitats, particularly in locations where water temperatures may be affected by human activity. These are also vital for the conservation and management of gastropods and other aquatic species since these circumstances directly affect their survival, development, and reproduction.

4.3 The presence of nickel concentrations in the environment resulting from mining activities in selected sampling areas starts here.

Table 4 shows the result of nickel concentration in each sampling as a result of the mining activities in Carrascal, Surigao del Sur.

Table 4. Nickel Concentration of each sampling site

Site	Average Concentration of Nickel (mg/kg) sediments	Interpretation
Brgy. Caglayag	3.21	Not Polluted

Brgy. Gango	551	Heavily Polluted
Brgy. Adlay	2.93	Not Polluted

Note: <20 mg/kg = Not polluted; 20 – 50 mg/kg = Moderately Polluted; > 50 mg/kg = Heavily Polluted

Based on the Environmental Protection Agency (EPA) heavy metal guidelines for sediments (mg/kg) given that Nickel is the parameter as cited in Sylvanus et al. (2020, p. 190)

Based on the result shown in Table 4, among the sites from different barangays, the site in Brgy. Gango is heavily polluted as the average concentration of nickel (mg/kg), which is 551 mg/kg (ppm), is too high. This could be also associated with the diversity of gastropods in the area. As presented previously in Table 2, the Shannon's diversity index of gastropods in Brgy. Gango, which is 0.81, indicates very low diversity. This means that the stress on the environment caused by high nickel levels could adversely affect the diversity of gastropod species in the marine environment. Such high quantities of nickel indicate significant anthropogenic impacts, particularly from mining operations. This could have negative implications regarding the soil quality of the said area. High nickel concentrations may pose toxicological risks to aquatic and terrestrial organisms (Genchi et al., 2020). The community in the area is also affected, as human exposure to heavily nickel-polluted areas via oral ingestion routes may result in a variety of adverse outcomes, including health problems (Yap & Al-Mutairi, 2022).

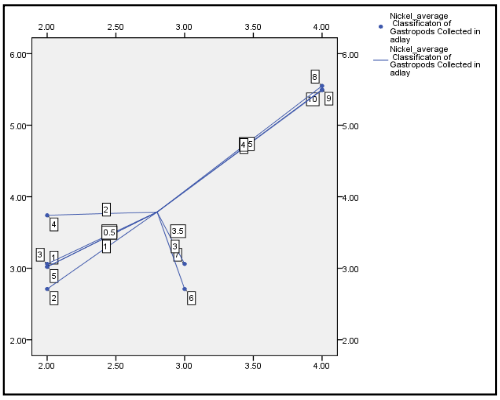
In addition, the high concentration of nickel in Brgy. Gango could be linked with its physico-chemical conditions. As shown previously in Table 3, Brgy. Gango has low pH level in comparison to other sampling areas. Nickel may react with hydroxide ions, making them less useful for balancing acidity and lowering the water pH level. Studies show that these chemical reactions are very important for figuring out how nickel affects marine life and water quality in a wider sense (Van Nostrand, 2005).

Additionally, Brgy. Gango has also higher water temperature compare to the other sampling areas. Higher water temperatures can make nickel more soluble, thereby increasing its concentration in water (Al-Asadi et al., 2020). This happens because higher temperatures can change the chemical speciation of nickel, which makes it easier for marine creatures to move around and take in. Nickel becomes more soluble at higher temperatures, which can put marine life at greater risk of being exposed to it (Coppola et al., 2020; Liu et al., 2021)

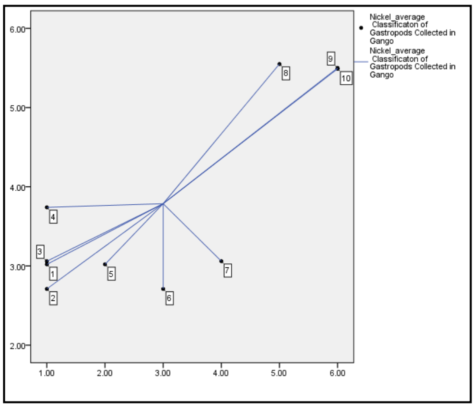
On the other hand, the sampling sites from Brgy. Caglayag and Brgy. Adlay are not really that polluted, as the average concentration of nickel (mg/kg) is only 3.21 and 2.93, respectively. The result indicates that these sites are not significantly polluted with nickel, suggesting a minimal anthropogenic impact on these areas. These values are most likely within the natural background amounts of nickel in soil and sediment. However, the result could pose a health risk to humans and other living organisms in the area (Buxton et al., 2019).

4.4 The relationship between Nickel concentration and diversity of gastropods

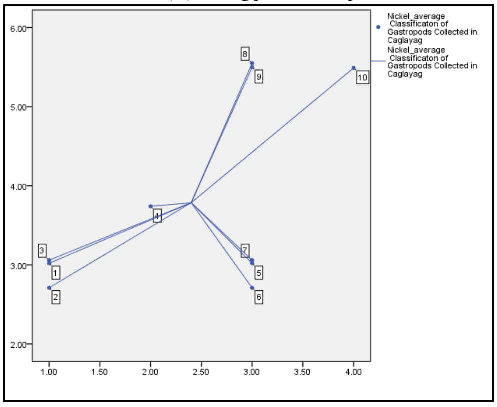
Based on the scatter plot results, the data points are widely spread and it appears that there is a positive trend between the average concentration of nickel and the presence of gastropods in each barangay. In Brgy. Adlay, it can be seen in Figure 5 that there are only a few species of gastropods that can be seen when the average nickel concentration is between 2.00 and 3.00. Yet, the number of different classifications of gastropods is higher when the nickel concentration is between 3.50 and 4.00.



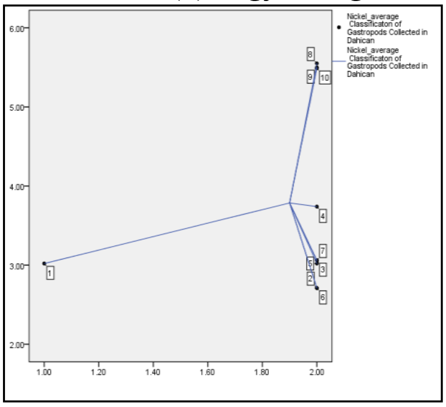
(a) Brgy. Adlay



(b) Brgy. Gango



(c) Brgy. Caglayag



(d) Brgy. Dahican

Figure 5. Relationship between the average concentration of Nickel and the presence of Gastropods (by classification) collected in each barangay

Likewise, in Brgy. Caglayag, a higher number of different classifications of gastropods is visible when the nickel concentration is between 3.00 and 4.00. On the other hand, in Brgy. Gango, a higher number of some classifications of gastropods are visible even when the nickel concentration is higher, which is within the range of 4.00 to 6.00. Meanwhile, in Brgy. Dahican, as shown in Figure Panel (d), most of the classifications of gastropods are visible when the nickel concentration is higher, which is within 1.80 to 2.00. It can also be observed that only a few classifications of gastropods are present in Brgy. Dahican as compared to other barangays.

To determine the effect of nickel concentration from mining on marine gastropods, this study used an empirical analysis, particularly, the multiple linear regression analysis. This analysis is being used to assess the significant effect of nickel concentration on the diversity of marine gastropods in each sampling area in Carrascal, Surigao del Sur. As shown in Table 5, the effect of nickel on the diversity of gastropods is significant in Brgy. Adlay, Brgy. Gango, and Brgy. Caglayan at the 5% level of significance. Meanwhile, in Brgy. Dahican, the effect of nickel on gastropods is statistically insignificant.

Table 5. Summary results for the relationship of nickel on gastropods in four areas (Brgy). Selected in Carrascal, Surigao del Sur, using Multiple Linear Regression Analysis

Brgy./ Areas	Coefficient (B)	t-vaue	P-value (Sig)	Description
Adlay	-.336	-.169	.031*	Significant

Bon-ot,Sitio Gango	.731	.721	.043*	Significant
Caglayag	-.540	-.744	.049*	Significant
Dahican	.423	.316	.053	Not Significant

*Note: *p-value is significant (<0.05)*

Based on the result, it is shown that in the areas of Brgy. Adlay and Brgy. Caglayan, the presence of nickel sediments as a result of mining activities has a negative and significant effect on the diversity of gastropods at the 5% level of significance. The negative and significant effect of nickel on the diversity of gastropods in Brgy. Adlay and Brgy. Caglayan indicates that an increase in nickel sediments by 1 mg/kg will cause the diversity of gastropods to decrease by 0.336 and 0.540 units, respectively. A heavy metal called nickel may accumulate in sediments and then enter marine life, including gastropods. The presence of heavy metals in the marine environment may cause toxicity, making them a potential danger to aquatic ecosystems that compromise the health and variety of marine species (Kakade et al., 2023; Zhang et al., 2022). Gastropods, being essential components of marine ecosystems, act as bioindicators of the health of their surroundings (Tallarico, 2015). The earliest reaction to heavy metal contamination in gastropods is diminishing abundance (Gümüş et al., 2022; Zou et al., 2019). Thus, a reduction in gastropod variety may also influence the larger ecosystem services they perform, including nutrient cycling and food web dynamics, emphasizing the serious ecological consequences of nickel sediment contamination.

However, in Brgy. Dahican and Brgy. Gango, the effect of nickel on gastropods is positive. Yet, the result is only significant in Brgy. Gango. This shows that an increase in nickel sediments in Brgy. Gango by 1 mg/kg will tend to increase the gastropods by 0.731 units, assuming that other factors are constant. This result contradicts known knowledge of heavy metal contamination in aquatic ecosystems. Yet, the positive relationship between the presence of gastropods and the higher concentration levels of nickels could be associated with the fact that these species could acquire metals, for instance, nickel, at a higher rate in comparison to others (Zhou et al., 2008). For instance, in Brgy. Gango, it was found that the sampling site is heavily polluted with nickel sediments as a result of mining activities. This could indicate that some gastropod species, specifically those that are found in areas with high nickel concentrations, have acquired tolerance to nickel pollution. In fact, gastropods have long been thought of as bio-indicators of heavy metal contamination in their surroundings (Abdel Gawad, 2018; Krupnova et al., 2018). Thus, addressing gastropod tolerance to nickel sediments is critical owing to the bioaccumulation and probable toxicity of nickel, which may have serious environmental and ecological consequences (Yap et al., 2022).

4.5 Assessment of the socio-economic impact of mining companies on their host community

The existence and activities of mining corporations in the area have raised environmental and social issues. These issues originate from the negative environmental repercussions of mining, which affect the livelihoods and social fabric of the host communities. The operation of mining companies in Carrascal, Surigao del Sur, had positive and negative socio-economic impacts on the host communities, including Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango. Based on the assessment, the positive socio-economic impact of mining companies in the host communities includes job creation, the development of small enterprises, and improved access to social infrastructure. Meanwhile, the negative impacts of mining activities on the affected community in the research locale are health issues, environmental degradation, and social disruption and displacement. According to the report, locals are not very pleased with the presence of mining sites in their community. There is also evidence that locals are not benefiting, despite the advantages brought by the mining companies to them. This aligns with the findings of Wangchuk et al. (2023), indicating that the costs of mining companies to the community outweigh the benefits.

Moreover, Table 6 is the descriptive statistics summarizing the positive and negative socio-economic impacts of mining to the host community. As shown in Table 6, half percentage of the key informants, 9 out of 18 (50%), indicated that job creation and livelihood opportunities are positive impacts of mining. In addition, this is followed by improve access to social infrastructure (44%), development of small enterprises (28%), and support to the LGU social development programs (17%). Meanwhile, 11% of the respondents indicated that mining doesn't contribute positively to the host community.

Table 6. Descriptive Statistics on the socio-economic impacts of mining to the host community

Impacts	**f**	**%**	Sample Statements (Translated)
Positive Impacts			
Job Creation and Livelihood Opportunities	9	50%	"Has given people jobs and livelihoods" "It has provided us jobs, without the mining company, I will be unemployed..."
Improve access to social infrastructure	8	44%	"It has provided schools with buildings and scholarships for students." "It provided opportunities for social infrastructure development such as schools and etc."
Development of small enterprises	5	28%	"It has provided as small enterprises and livelihood opportunities… "I benefited from their enterprise development program for the communities."
Support LGU's social development programs	3	17%	"They provided LGU support for its social development programs for the community…" "I think they provided social programs for youth and students, such as scholarships, and they also supported government programs in our local barangay."
None	2	11%	"I didn't see any positive impacts as mining degrades the environment. I find it hard to sustain my fishing livelihood." "None, because mining has always had negative impacts on the marine life and livelihood of fishermen."
Negative Impacts			

Marine habitat degradation	13	72%	“It destroys the environment. It reduces our fish catch, and sometimes when we glean, we only get a small number of shells, gastropods, or "kinason." I sometimes find it dangerous to glean gastropods because nickel may be present in that certain species.” "It truly harms the environment, and some fishermen have small fish catch, and this is always the complaint."
Social disruption and displacement	8	44%	“Some people, including us, relocated because mining was present in our previous residence." This had caused us to adjust in our life”
Health issues	5	28%	“It gives asthma problems due to the fumes emitted from the mining…” “This is the reason why I suffer from respiratory health problems. I occasionally inhale mine dust and fumes while working at mining site.”

However, Table 6 shows that most of the respondents, comprising 72% of the sample, indicate that environmental degradation is the negative impact of mining. This is followed by social disruption and displacement (44%), and health issues (28%).

Positive socio-economic Impacts of Mining

Job Creation and Livelihood Opportunities

Mining companies provide a substantial contribution to employment creation and socio-economic development in host communities, particularly in Carrascal, Surigao del Sur. Mining's influence on job creation and community development is varied and may be seen via a variety of channels, including direct employment, corporate social responsibility (CSR) activities, and the development of local infrastructure and services. Based on the socio-economic impact assessment, the mining companies situated in Carrascal, Surigao del Sur have been providing employment opportunities to the communities including the conduct of pieces of training that improves their capabilities. The companies have been also hiring employees from the local communities. However, the community moderately observed that the mining companies provide a good and safe culture among their employees and to the local communities while considering their well-being. The findings coincide with the previous studies of Cuartero-Enteria (2018) and Doloriel & Cortex (2022) showing the impact of mining companies in providing employment opportunities to the affected local communities.

Development of small enterprises

The development of small enterprises in the host communities is one of the positive socio-economic impacts of mining companies to the host communities in Carrascal, Surigao del Sur. The mining companies support the growth of small businesses in host communities via a variety of programs and initiatives aimed at promoting socioeconomic development. These are often part of larger Corporate

Social Responsibility (CSR) initiatives, with the goal of ensuring long-term development and community empowerment. The presence of mining activities in the area has led to the establishment of small businesses in the host and nearby communities. Additionally, mining companies in the area sponsor livelihood programs that provide employment and revenue. These activities will automatically boost the local economy (DENR-MGB, 2017). Some beneficiaries of the sponsored livelihood programs of the mining companies successfully managed funds and they were able to utilize the investment returns to finance and grow their small enterprises. The livelihoods provided by these mining companies to some of the afflicted people helped them meet their daily needs. However, these corporations come and go, leaving them unsure when they would be able to give them employment and livelihood opportunities again (Department of Agriculture RFO XIII, 2020).

Improve access on social infrastructure and support in LGU's social development programs

Mining firms play an important role in increasing access to social infrastructure in host communities, so contributing considerably to socioeconomic development and poverty eradication. Most of the locals agree that the mining companies help to improve the access of the host communities on social infrastructures such as schools, pave roads, potable water system, health facilities, wet markets, and grocery stores. The findings on how mining companies improve the access of the communities to the social infrastructure aligned with the study of Doloriel & Cortex (2022).

The mining companies in Carrascal, Surigao del Sur provide donations of these social infrastructures to improve access to water, schooling, health care, food security, and economic opportunities for local communities. This involves creating direct jobs, paying taxes and royalties to host governments, and purchasing products and services from local and host-country vendors. In fact, many mining firms invest in social infrastructure outside their local activities. Partnerships with national or regional governments or community groups help tailor funding to address local needs (World Golf Council, 2018). Such projects not only assist urgent community needs, but also help to long-term socioeconomic upliftment (Barrick, 2021). These provide an important implication on how mining companies play a critical role in enhancing host communities' access to social infrastructure. By concentrating on ethical mining practices and community involvement, mining firms may guarantee that their operations have a long-term beneficial influence on the communities in which they operate.

Negative socio-economic Impacts of Mining

Marine habitat degradation

The operations of mining companies have adverse effects on the fishing livelihood of the host communities in Carrascal, Surigao del Sur due to the degradation of marine habitat that poses risks to marine life. It was found that most of the fisherfolks observe the reduction of their fish catch nowadays in comparison to their fish catch before. It was even reported before that the runoff sediments, for instance, nickel, from mining activities endanger marine life in Surigao Sur (Colina, 2018). This is in line with the paper of Macusi et al. (2022) indicating that mining activities reduce fish catch. This could be due to the negative impacts of siltation from mining activities that adversely affect marine habitats (Ranada, 2015). Heavy metals in the marine environment may be hazardous, posing a threat to aquatic ecosystems and jeopardizing the health and diversity of marine species (Kakade et al., 2023; Zhang et al., 2022). These issues affected the livelihood and the income of the fisherfolks and their family, whose primary source of income is fishing. Thus, the operations of mining activities could worsen the socio-economic status of the affected communities. This highlights the need for sustainable methods and rigorous adherence to environmental standards to safeguard maritime ecosystems and maintain the livelihoods of host communities in Carrascal, Surigao del Sur. Addressing these problems is critical for the preservation of biodiversity and the well-being of local communities who rely on fishing for a living.

Health Issues

Mining companies have a substantial influence on host communities' health and well-being, with both positive and negative consequences. On the positive side, mining initiatives may stimulate economic growth in low- and middle-income nations, leading to improved public infrastructure, higher wealth, and perhaps better health outcomes, such as lower childhood mortality (Leuenberger et al., 2021). Despite that it can be observed that mining companies in Carrascal, Surigao del Sur assure that they will address the risks of their operations on the health and environment of the affected communities, most of the residents indicated that the mining activities somehow affected their health and the environment that they are living in. Most of the residents have respiratory problems due to their exposure to dust from mining operations. These respiratory health issues include upper respiratory tract infection, pneumonia, chronic obstructive pulmonary disease, and acute bronchitis.

The findings of this study are in line with reports of the Rural health unit (RHU) of the Carrascal, Surigao del Sur as well as in the study of Arreza et al. (2022). The study indicated that during peak mining activities, there was a significant rise in mortality and morbidity cases associated with dust inhalation, including upper respiratory tract infections and pneumonia (Arreza et al., 2022). Nickel and nickel compounds have also been linked to an increased risk of cancer and respiratory diseases. Hence, companies that use nickel to follow safety regulations, and personnel must be aware of the health threats and employ protective measures to avoid exposure. This also highlights mining companies' joint obligation to maintain the health of local populations. This involves meeting workplace health and safety regulations, improving living circumstances, offering health services, and investing in preventive health initiatives (Osewe, 2015).

Displacement and Social Disruption

Mining companies had caused displacement and social disruption to the affected communities in Carrascal, Surigao del Sur. These displacements disproportionately impact impoverished rural households, who suffer the burden of the relocation and loss of livelihood assets. These displaced persons more vulnerable to livelihood shocks and poverty (Gukurume, S., & Tombindo, 2023). Some companies in the area, for instance, the Carrascal Nickel Corporation (CNC) was found to have violated the terms of its Environmental Compliance Certificate (ECC), caused siltation of coastal waterways and harmed marine life. Such environmental deterioration presents substantial hazards to the lives of local residents, especially those depending on fishing and agriculture, possibly resulting in displacement and socioeconomic instability.

Furthermore, mining activities have been connected to siltation issues that harm local ecosystems. Siltation from mining operations has been reported to jeopardize the lives of fishermen and farmers in the region. For example, during the rainy season, the waters surrounding particular locations become coffee-brown as a result of siltation caused by mining in Carrascal and adjacent cities, threatening coral reefs and marine reserves (Ranada, 2015). This environmental concern affects not just biodiversity, but also the economic well-being of people who rely on these natural resources. These underscores the complex challenges faced by communities in Carrascal, Surigao del Sur, where mining contributes to environmental degradation, leading to displacement and social disruption.

4.6 The existing communication and education programs related to the impact of mining on marine biodiversity

In the Municipality of Carrascal, Surigao del Sur, some existing IEC programs are related to environmental awareness, protection, and enhancement as presented in Table 7.

Table 7. Existing IEC campaigns in the Municipality of Carrascal, Surigao del Sur

Existing Strategies	Aims of these strategies	Accomplishments	Gaps
1. Environmental Awareness campaign as part of the Annual **Environmental Protection and Enhancement Program** of Carrascal Nickel Corporation (CNC).	This aims to raise awareness about the deteriorating status of the environment and encouraged individuals to be involved in different activities that would protect the environment. This also aims to motivate the community of spreading such awareness.	• In 2019, Carrascal Nickel Corporation completed its Environmental Enhancement and Protection Program (EPEP) in 2019 at a total cost of PhP65.58 million. • The mining company rehabilitated and reforested 555.17 hectares of mined-out and other sites using 1,224,431 seedlings (Philippine Nickel Industry Association, 2024). • Started in 2022, the CNC conducted environmental awareness, protection and enhancement program through radio broadcast every 1st and 3rd Monday of the Month. • In 2022, activities such as radio broadcasting program, slogan contest, environmental photography contest, landscaping contest, and reuse/recycling contest were conducted. These activities were participated by the	• The campaign is only one-time or event-based activities. • Involvement is only limited to the specific groups (e.g., students, employees, LGU) • Lack of follow-up evaluation about the campaign. • The negative impact of mining on the marine environment during radio broadcast may not that emphasized as it may cause conflict to the reputation of CNC.

		employees of CNC, and the students and teachers from different schools in the locality. • On May 2023, the employees from CNC conducted IEC campaign on Environmental Programs, Tree Planting Activity with a total of 550 planted bamboos and Clean up Drive were there are collected 7 sacks in amount weight of 37 kilograms solid wastes along the Babuyan River. • On June 2023, the CNC organized Envi-mini quiz through a radio-broadcast, which was participated by college students from the different schools.	
2. Environmental Awareness & Bamboo Planting Activity, which was facilitated by the LGU of Carrascal Carrascal Tourism Culture and Arts.	This initiative seeks to enhance local awareness of environmental concerns, while simultaneously aiding in the restoration and enhancement of local ecosystems through bamboo planting.	• On July 2023, a one-day event on environmental awareness and bamboo planting was conducted and participated LGU and the beauty queen contestants of the Municipality of Carrascal.	• Participants are only limited to the beauty queen contestants and to the concerned officials and staffs of the LGU. • Only one-time event. • Lack of evaluation on the impact of the campaign.
3. IEC campaign as part of Strengthening the management of the Carrascal Marine Protected Area (MPA)	This aims to strengthen the Conservation, Protection, and Management of Key	• In 2019, based on the self-report, Carrascal Bay was reported to be included as one of the MPA in the Philippines.	• The level of local community engagement and ownership in MPA

program, which was conducted by USAID in collaboration with the LGU and concerned government agencies.	Marine Biodiversity Areas in Carrascal, Surigao del Sur. The project also aims to raise awareness among stakeholders through a coherent communication strategy.	• Dissemination and usage of fisheries management information resources and training modules were delivered to the concerned communities since 2005. • The responsible partners achieved significant results in increasing awareness of government actors and communities about MPA issues.	management may be inadequate. • The campaign's exposure and media coverage may be inadequate, which is essential for generating widespread knowledge and garnering support from a larger audience.
4. Virtual IEC Campaign about the Environmental Protection and Enhancement Program in Caraga minerals industry	This aims to increase awareness of participants about the Mines and Geosciences Bureau's governing duties, especially the Environmental Protection and Enhancement Program.	• On June 30, 2021, via zoom platform, the DENR-MGB ROXIII conducted a Virtual Awareness campaign on intensifying awareness of Environmental Protection and Enhancement Program in Caraga minerals industry. This was participated by the students and faculty members from different schools, and stakeholders from mining industry in CARAGA, including the Municipality of Carrascal.	• The campaign is only one-time event. • Limitations of interactive engagement among participants. • Gaps of the access, especially to marginalized community, due to lack access on internet connectivity, digital illiteracy, and technology. • Virtual sessions often lack follow-up evaluation • Limited scope of audience.

Presented in the Table 7 are the existing communication and education programs and strategies related to environmental protection and the impact of mining on marine biodiversity in the research locale. First, the environmental Awareness campaign as part of the Annual Environmental Protection and Enhancement Program of Carrascal Nickel Corporation (CNC). This is part of the Social Development Management Program (SDMP) of the CNC mining company in Carrascal, Surigao del Sur. Based on DENR Administrative Order (DAO) No. 2000-99, the SDMP has been defined as "the comprehensive five-year plan of the contractor, permit holder, or licensee authorized to conduct actual mining and milling operations towards the sustained improvement in the living standards of the host and neighboring communities by creating responsible, self-reliant, and resource-based communities capable of developing, implementing, and managing community development programs, projects, and activities in a manner consistent with the principle of people empowerment" (Cerilles, 2001). The environmental awareness campaign of CNC focuses on disseminating information to the public through radio broadcasts which will be conducted every 1st and 3rd Monday of the Month by some of the employees of CNC. Aside from that, the mining company environmental awareness campaigns annually, highlighting activities such as slogan contests, environmental photography contests, landscaping contests, and reuse/recycling contests. These contests will be participated by the students and teachers from different schools of the municipality and even in other localities. In addition, the CNC conducted coastal clean-up and tree planting annually.

Another existing IEC campaign in the research locale is the environmental awareness and Bamboo Planting Activity, which was facilitated in July 2023 by the LGU of Carrascal Carrascal Tourism Culture and Arts. This activity was participated by the participated LGU and the beauty queen contestants of the Municipality of Carrascal. This activity was newly initiated and aims to promote local awareness of environmental issues in the area and the giving information to the community about the benefit of planting bamboo to the environmental conservation and protection. On the other hand, the program on strengthening the management of the Carrascal Marine Protected Area (MPA) program, conducted by USAID in collaboration with local government units (LGUs) and government agencies, focuses on enhancing conservation, protection, and management of marine biodiversity in Carrascal, Surigao del Sur. Part of this program is the IEC campaign, which aims to increase awareness of the locality about the MPA of the municipality. The campaign includes the dissemination and usage of fisheries management information resources and training modules. Since 2005, the project made significant efforts in this component. The IEC's efforts include creating posters and pamphlets in local languages, producing radio plugs and DVDs, organizing exposure tours, and initiating impactful events around important occasions like the Month of the Ocean and Fish Conservation Week. Training sessions were also held focusing on planning, law enforcement, MPA management, and other species-specific management trainings (USAID, 2006). As reported in 2019, the program included Carrascal Bay in the list of MPAs in the Philippines and has successfully increased awareness among government actors and local communities regarding marine protected area issues. According to Bujan & Arquiza (2021), mining is a significant contributor to erosion and sediment outflows that primarily affect the marine key biodiversity areas of General Island and Carrascal Bay. The MPA management plans include coastal land areas explicitly in their geographical scope; however, these plans do not specifically target the watersheds that contribute the most to the pollution load.

Moreover, in 2021, the DENR-MGB Caraga conducted a virtual IEC campaign, despite the COVID-19 pandemic. The said virtual campaign aims to increase awareness of the Environmental Protection and Enhancement Program in the Caraga minerals industry. The activity is carried out in accordance with the 2021 Philippine Environment Month Celebration under the theme "Sama-samang Pagkilos, Sama-samang Paghilom, Ikaw, Ako, Tayo, and Kalikasan." (DENR-MGB, 2021). It is essential to raise awareness of the Environmental Protection and Enhancement Program (EPEP) in the Caraga minerals sector to promote sustainability and appropriate mining practices in one of the Philippines' most mineral-rich areas. This project is crucial in reducing the environmental effects linked to mining activities, including deforestation, soil erosion, water pollution, and biodiversity loss. The EPEP strives to increase awareness among industrial stakeholders, local communities, and the general public to encourage the use of eco-friendly technology and rehabilitation activities that support the long-term health and productivity of natural ecosystems, including marine biodiversity. Furthermore, communities that are knowledgeable and involved are more capable of advocating for their rights, participating in environmental decision-making, and ensuring that mining firms fulfill their environmental obligations.

Overall, the existing IEC campaigns in Carrascal, Surigao del Sur have significant contributions to promoting environmental awareness, conservation, enhancement, and protection. However, despite these efforts, some gaps need to be addressed. First, usually, these campaigns are only one-time events, which could limit their effectiveness in fostering sustained environmental awareness and action to the targeted audience. This one-time event could encounter challenges in addressing environmental issues promptly, potentially leaving communities underprepared to handle negative impacts, especially from mining. As a result, the impact of environmental awareness efforts would be lessened, and opportunities for continuous community involvement and empowerment in environmental protection are missed.

Additionally, the involvement of the mentioned IEC campaigns is limited to specific groups such as teachers and students from different schools, employees of mining companies, and LGU. At some point, the affected marginalized communities could not absorb effectively the objectives of these IEC campaigns. There is a lack of IEC campaign targeting to the vulnerable and affected communities. There is also lack of engagement on the level of local community to these programs due to the limitations in terms of access to these campaigns. For instance, the virtual IEC campaign could not reach those communities who have no access to internet connection nor digital technologies. In addition, most of these campaigns may lack specificity in raising awareness about the impact of mining on marine biodiversity, which could be essential for effectively addressing and mitigating these environmental challenges.

4.7 Proposed Information Education Communication (IEC) program promoting environmental sustainability in Carrascal, Surigao del Sur

Despite the present programs and IEC initiatives in the municipality of Carrascal, Surigao del Sur, the IEC campaign focusing on the impact of mining on marine biodiversity was not really that visible. In addition, most of these campaigns are for short-term event only, which may not have long-term impact to the community and marine environment. Yet, most of the locals were aware of and even experienced the impact of unsustainable mining on marine biodiversity, which has multiplier effects on the livelihood and status of families whose primary source of income is fishing. Thus, there is a need to develop an IEC program promoting environmental sustainability and sustainable mining in the municipality of Carrascal, Surigao del Sur.

Given the gaps identified, this study proposes a campaign entitled "**Information Education Communication (IEC) program for Environmental Sustainability in Carrascal, Surigao del Sur: SUSTAINABLE COLLABORATION & PROTECTING MARINE BIODIVERSITY FROM MINING".** This program aims to provide community awareness and achieve environmental sustainability in Carrascal, Surigao del Sur by promoting marine protection and sustainable collaborative efforts. This focuses on partnership among host communities, mining companies, educational institutions, LGU, non-government organizations, and concerned government sectors. This collaborative campaign also focuses on promoting environmental sustainability and addressing the negative impacts of mining on the marine environment and community through sustainable mining. The IEC initiative includes environmental education that enables people to investigate environmental concerns, participate in problem-solving, and take steps to enhance the environment. Consequently, people have a more profound comprehension of environmental challenges and acquire the ability to make well-informed and conscientious choices (EPA, 2023b). The IEC offers a venue for discussing significant environmental issues to promote comprehension of the ideas, fundamental principles, and advantages of environmental protection-related programs. This also stimulates the behavior of individuals towards their environment. Environmental behavior is defined as a set of pro-social acts that demonstrate concern for others, future generations, and the health of ecosystems (Loseñara, 2020; Morren & Grinstein, 2016).

In order to deliver the proposed IEC program, several strategies will be taken as shown in Table 8. It is also necessary to emphasize collaboration among concerned sectors such as the mining industry, policymakers, LGU, educational institutions, NGOs, and the community. The roles of each actor should be cleared out during the meeting. For example, the mining industry is the one responsible for developing sustainable mining practices and mitigation of impacts to the environment; policymakers are responsible for formulating sound policies; the LGU is responsible for monitoring and implementation of policies; educational institutions are responsible for delivering research and impact assessment as well as educational campaigns to the target audience; the NGOs is responsible to facilitate and carry out necessary programs that would help the concerned communities and address the impacts of mining to the environment; and lastly, the community is responsible to use their resources in protecting the environment and help the government to monitor the situation.

Table 8. IEC program strategies to promote environmental sustainability in Carrascal, Surigao del Sur

IEC Strategies	**Objective**	**Activities**	**Gaps that were addressed based on existing IEC programs**
1. On-going Community Awareness, engagement, and educational **campaigns**	This aims to increase community knowledge and awareness about the impact of unsustainable mining and marine conservation issues and practices by conducting regular educational workshops, seminars, and outreach programs.	• Collaboration with the CNC and LGU (both municipal and barangay-level) in disseminating information about the impacts of unsustainable mining through radio broadcast programs, putting up visible posters in every barangay, and gathering the host community participants during the conduct of educational seminars. • Collaborate with educational institutions in	• This addresses beyond the limitations of one-time event activities of the existing IEC programs by establishing a continuous and sustained engagement approach, ensuring ongoing community involvement and lasting impact.

		conducting community awareness seminars as well as educational campaigns and engagement as part of their extension activities. • Utilize social media such as Facebook and Instagram to disseminate information.	• This will address the gaps of exclusive participation restricted only to specific groups through reaching affected host communities.
2. Conduct need assessment-based **research** and impact evaluation	This aims to assess the needs of the affected host community, considering that they are impacted by mining operations. This also ensures that the IEC activities conducted are suitable to address their needs. In addition, this strategy aims to conduct short-term and long-term impact evaluation of the IEC campaign activities conducted. This ensures that the content and structure of the campaigns are data-driven and tailored to effectively address specific environmental issues and community concerns, thereby maximizing outreach and conservation efforts.	• Conduct needs assessment research before delivering the campaign activities. • Collaborate with researchers from educational institutions in the locality or universities from other places, concerned government sectors, and NGOs that have a focus on conducting research. • Based on the assessment results, design tailored campaign activities that address the identified needs and leverage the strengths and resources of the community. • Conduct short-term and long-term impact assessments of every campaign activity delivered. • Compile findings and insights from the campaign evaluations into a detailed report. Share this report with all stakeholders and use it to guide future campaigns based on the lessons	• This strategy addresses the gap of inadequate needs assessment, follow-up, and evaluation of the existing IEC campaigns.

		learned.	
3. Encourage **responsible actions** through responsible mining and community involvement	This aims to encourage community and stakeholder involvement in promoting responsible mining practices. This also encourages the concerned mining companies to practice responsible and sustainable mining to mitigate its negative impact on the host communities, marine biodiversity, and environment.	• The government is encouraged to advocate for stricter regulations and enforcement to ensure sustainable mining practices. The LGU and concern departments are encouraged to monitor regularly the mining companies of the locality regarding their sustainable mining practices. • Organize community meetings, workshops, and educational sessions to explain the environmental and social costs of unsustainable mining. • Facilitate dialogue between community members and mining companies to address concerns and find solutions. • Partner with local schools and NGOs to integrate responsible mining education into curriculums and community programs.	• This addresses the gap of the lack of promotion of sustainable mining in the locality.
4. **Sustainable Collaborative Advocacy**	This aims to promote sustainable practices within the mining industry, and continual IEC campaigns to the community to address concerns in protecting the marine environment.	• Development and dissemination of policy briefs highlighting research on mining impacts and recommending sustainable practices. • Regular annual meeting discussions with	• This addresses the gap on lack of sustainable collaboration and advocacy.

		policymakers, LGU, mining industry leaders, educational institutions, and community stakeholders to advocate sustainable collaboration that promotes sustainable mining and protect marine environments.	
5. Educational **Learning** Materials to be disseminated door-to-door to the affected communities, schools, and concerned barangays.	This aims to provide resources for self-education regarding the environmental sustainability and impact of mining on marine biodiversity in Carrascal, Surigao del Sur.	• Brochures, fact sheets, and educational kits for schools, focusing on marine biodiversity, the effects of mining, and how to contribute to conservation efforts. • Conduct door-to-door dissemination of pamphlets about the IEC program, impact of unsustainable mining, marine protection issues, and actions needed to address the problems.	• This addresses the gap of the lack of access on environmental educational materials, especially to marginalized community, due to lack access on internet connectivity, technology, and resources.

In addition, as shown in Figure 6, this is a sample of infographics to be used for the implementation of the proposed IEC campaign program.

Figure 6. Sample Infographics for the IEC campaign

The target audience for this IEC campaign includes the local communities of Carrascal, Surigao del Sur, policymakers and local government officials, the DENR, the mining companies operating in the municipality, NGOs, and the educational institutions. The IEC campaign could provide key messages on

(1) the importance of marine biodiversity for ecological balance and human well-being; (2) the negative impacts of mining on marine ecosystems, including habitat destruction, pollution, and harm to marine species; (3) sustainable mining practices and alternatives that can reduce harm to marine environments; and (4) the role of policy, community action, and individual behavior in protecting marine biodiversity.
Furthermore, concerning the evaluation and feedback of the IEC program, essential methods such as surveys, feedback forms, and impact evaluations could be utilized to analyze the program's efficacy and gain ideas for improvement. In addition, partnerships or collaborations with environmental non-governmental organizations (NGOs), academic institutions, and government agencies for resources and expertise are necessary for the successful implementation of the IEC program. Partnering with media outlets or social media platforms would also be used to ensure widespread dissemination of the program's messages. This IEC initiative seeks to build a large and active community of people and organizations dedicated to conserving marine biodiversity from the effects of mining. It aims to build a sustainable and conservation culture through education, advocacy, and action.

CHAPTER 5
SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

This chapter presents the summary of findings, conclusion, and recommendations based on the analysis and results of this study.

5.1 Summary of Findings

Based on the sampling, 228 marine gastropod species were collected from the following sampling sites in Carrascal, Surigao del Sur. These marine gastropod species consist of 53 genera belonging to ten families: Cypraeoidae, Neritiidae, Toridae, Terebiidae, Strombidae, Patellidae, Trochiidae, Olivoidea, Pisaniidae, and Ochiodoidae, all under the class Gastropoda. First, in Brgy. Adlay, most of the species collected belong to the family Olividae, whose morphological structure is conical-globular and crescent-like. On the other hand, in Brgy. Caglayag, most of the marine gastropods found belong to the Neritidae family, particularly those under the genera Nerita alveolus and Nerita. Most of these marine gastropods have a globular shape or ear-like structure. Similarly, in Brgy. Dahican, the majority of gastropod species collected belong to the family Neritidae, and most of the species are Nerita incerta and Nerita polita, which have a globular morphological structure. In addition, in Brgy. Gango, the majority of the gastropods collected belong to the family Neritidae, particularly the N. quadricolor, which have a globular to slightly ovate shape with a well-defined spiral pattern.
In terms of the status of marine gastropod habitat in the sampling sites of Carrascal, Surigao del Sur, the physico-chemical test results reveal that the water pH level of each sampling area ranges from 7.9 to 8.1, which indicates that the water condition is slightly alkaline. With regards to the dissolved oxygen parameter, all of the sampling areas have a dissolved oxygen level range from 2.0 to 4.0 mg/L, indicating that the body of water has a low oxygen content. In terms of the salinity parameter, the water quality test shows that the salinity level of each sampling area is between 1 and 2 ppt, indicating that the water is slightly saline. This indicates that the sampling area of this study is situated between freshwater and brackish water. In addition, with regard to the water temperature level, the result depicts that the water temperature level of the sampling sites ranges between 32 and 36 degrees Celsius. This indicates very warm conditions in the bodies of water, which may have a considerable impact on the aquatic ecosystem and the behavior of species that live there. The temperature conditions of the sampling areas

also indicate that only a few aquatic species could survive. The physico-chemical conditions of the sampling sites provide importance for understanding the implications of these conditions for managing aquatic habitats, including marine gastropods.

With regards to the average concentration of nickel (mg/kg) sediments as a result of the mining activities in Carrascal, Surigao del Sur, the atomic absorption spectrophotometry result shows that among the sampling sites, Brgy. Gango is heavily polluted as the average concentration of nickel (mg/kg), which is 551 mg/kg (ppm), is too high. This suggests serious environmental contamination, surpassing normal natural background levels, and most certainly exceeding local and international sediment safety standards. Meanwhile, other sampling sites, such as Brgy. Caglayag and Brgy. Adlay, were found to be not really that polluted, as the average concentration of nickel (mg/kg) was only 3.21 and 2.93, respectively. The result indicates that these sites are not significantly polluted with nickel, suggesting a minimal anthropogenic impact on these areas.

In terms of the effect of nickel on the marine gastropods, based on the regression analysis, the effect of nickel on the diversity of gastropods is significant in Brgy. Adlay, Brgy. Gango, and Brgy. Caglayan at the 5% level of significance. Meanwhile, in Brgy. Dahican, the effect of nickel on gastropods is statistically insignificant. The regression result also reveals that in the areas of Brgy. Adlay and Brgy. Caglayag, the presence of nickel sediments as a result of mining activities has a negative and significant effect on the diversity of gastropods. However, in Brgy. Dahican and Brgy. Gango, the effect of nickel on gastropods is positive. Yet, the result is only significant in Brgy. Gango. Since the sampling site of Brgy. Gango is heavily polluted with nickel sediments as a result of mining activities, this could indicate that some gastropod species, specifically those that are found in areas with high nickel concentrations, have acquired tolerance to nickel pollution.

In addition, with regards to the socio-economic impact of mining companies on their host communities, based on the results of the interview, the existence and activities of mining companies in Carrascal, Surigao del Sur, brought positive and negative socio-economic impact to the host communities, including Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango. Based on the assessment, the positive socio-economic impact of mining companies in the host communities includes job creation, the development of small enterprises, and improved access to social infrastructure. Meanwhile, the negative impacts of mining activities on the affected community in the research locale are health issues, environmental degradation that threatens the fishing livelihood, and social disruption and displacement.

However, in terms of the existing communication and education programs related to the impact of mining on marine biodiversity, there was an initiative in the municipality that strengthened the management of the Carrascal Marine Protected Area (MPA) in Surigao del Sur. The IEC campaign includes the dissemination and usage of fisheries management information resources and training modules. In addition, the existing communication and education programs implemented by the mining companies and DENR of the municipality were aligned with the Social Development Management Program (SDMP). It was found out that most of the host communities in municipalities benefitted from the SDMP implemented by the mining companies. The identified community issues related to social services and infrastructure, livelihood activities, and technological knowledge were addressed by mining companies in the municipality through the implementation of SDMP. At present, the municipality of Carrascal, Surigao del Sur, has initiatives such as the Environmental Enhancement and Protection Program, Forest Development, Rehabilitation, Maintenance, and Protection Program, and the IEC campaign to increase awareness of the environmental protection programs of the mineral industry in

CARAGA. The IEC aims to increase awareness among industrial stakeholders, local communities, and the general public to encourage the use of eco-friendly technology and rehabilitation activities that support the sustainable development of natural ecosystems, including marine biodiversity.

Moreover, to address the impacts of mining activities on the marine biodiversity and local communities of Carrascal, Surigao del Sur, this study develops an IEC campaign focusing on "Sustainable Collaboration and Protecting Marine Biodiversity from Mining." The IEC program has strategies to promote environmental sustainability in the municipality. These strategies include educational workshops and seminars, awareness campaigns, educational material, policy advocacy, and community engagement programs. The proposed IEC program aims to provide community awareness and achieve environmental sustainability in Carrascal, Surigao del Sur by promoting marine protection and sustainable collaborative efforts. This focuses on partnership among host communities, mining companies, educational institutions, LGU, non-government organizations, and concerned government sectors.

5.2 Conclusion

This study conducted in Carrascal, Surigao del Sur, delves deeply into the status of marine gastropod biodiversity across several barangays, particularly Brgy. Adlay, Brgy. Caglayag, Brgy. Dahican, and Brgy. Gango, as well as the impact of mining operations on these species and their habitats. This also considers the effect of mining activities on the host communities of the municipality. The findings of this study highlight the diversity of marine gastropods at the sampling sites. The detailed analysis of these species distributions across sampling sites reveals differences in dominant families and morphological structures, indicating varied ecological niches and adaptation strategies among the gastropods. The physico-chemical parameters of the sampling sites reflect conditions ranging from slightly alkaline water with low oxygen content to very warm temperatures. These conditions suggest a delicate balance in the aquatic ecosystems, which could be sensitive to changes and might affect marine gastropod populations and distributions.

The study further sheds light on the environmental contamination due to mining activities, particularly highlighting the severe nickel pollution in Brgy. Gango. This contrasts with the minimal impact observed in other areas, suggesting localized but significant anthropogenic effects on marine ecosystems. Interestingly, the regression analysis indicates a significant relationship between nickel concentration and gastropod diversity, with some species showing tolerance to the presence of nickel sediments, suggesting intricate ecological interactions and possible adaptation mechanisms. Unlike Brgy. Adlay and Brgy. Caglayag, the regression analysis shows that the presence of nickel sediments from mining activities negatively and significantly affects marine gastropods. This result indicates that unsustainable mining activities could potentially pose a threat to marine species, including gastropods and fish. These effects could also pose risks to the health of individuals and the livelihood activities of the community, especially for those who depend on fishing as their primary source of income.

In conclusion, the study presents a compelling case for integrated conservation strategies that address both the ecological significance of marine gastropods and the socio-economic realities of mining-affected communities. It calls for a collaborative effort among stakeholders to foster a sustainable coexistence between industrial development and environmental conservation, ensuring the protection of marine biodiversity for future generations. Moreover, this study provides insights into the importance of the development of an IEC campaign focusing on "Sustainable Collaboration and Protecting Marine

Biodiversity from Mining." This embodies a strategic approach to enhancing environmental awareness, advocacy, and action towards preserving marine ecosystems for environmental sustainability.

5.3 Recommendations

Based on the findings of the study, the following are the recommendations for the development of an IEC program that promotes environmental sustainability in the municipality of Carrascal, Surigao del Sur. These recommendations could also address the impact of mining activities on marine habitats and the affected host communities.

1. This study suggests that the DENR and the concerned local government unit of Carrascal, Surigao del Sur, enhance monitoring and regulation of mining activities to minimize pollution, particularly concerning nickel and other harmful substances. An updated enforcement of regulations on waste management and pollution control from mining operations is necessary to ensure they are within safe limits for marine ecosystems.
2. The development and implementation of marine habitat restoration initiatives in the municipality, especially in Brgy. Gango, which is significantly affected by mining, is necessary to address the negative impact of mining activities to marine life. It is important to focus the initiative on restoring the natural conditions necessary for marine gastropods and other marine life. An advocate for the restoration of mangroves and coral reefs as part of the IEC program is necessary to address the negative impacts of mining on marine habitats and a variety of species.
3. Given that the sampling sites in Brgy. Adlay and Brgy. Caglayan has less polluted marine habitat, it is important to address the negative effect of nickel as an indicator of mining activities on the diversity of gastropods. Early intervention may also be used to prevent pollution levels from rising, guaranteeing the long-term viability of aquatic ecosystems and the services they give to humans, such as water purification, recreational possibilities, and fisheries support. Thus, even in less contaminated water basins, such as Brgy. Adlay and Brgy. Caglayan, addressing nickel contamination is critical for ecological health and resilience. Understanding their tolerance aids in estimating the danger and devising ways for the cleanup of nickel-contaminated areas, eventually helping to preserve aquatic life and the balance of marine ecosystems.
4. Given the socio-economic impacts of mining on the host communities, this study suggests to the local government unit and to the mining industries in the municipality of Carrascal, Surigao del Sur, enhancing community engagement in conservation efforts by providing alternative livelihood programs that promote sustainable use of marine resources. This suggests encouraging the involvement of local communities in monitoring and protecting marine biodiversity.
5. This study further suggests expanding environmental education programs through the IEC campaign for environmental sustainability, which targets schools, local communities, and stakeholders involved in or affected by mining activities to raise awareness about the importance of marine conservation. The development of the IEC campaign should focus on the impacts of mining on marine biodiversity and promote best practices for environmental protection.
6. In addition, policy advocacy and collaboration among government agencies, non-governmental organizations, academic institutions, and the mining sector to develop and implement strategies for sustainable mining practices are necessary. Promoting policies for environmental conservation and guaranteeing sustainable mining operations in Carrascal, Surigao del Sur, is encouraged.

7. Moreover, for future researchers, this study suggests widening the scope and exploring other methods for identifying the impacts of mining on marine biodiversity and host communities. They could also conduct regular biodiversity assessments to monitor the health and diversity of marine ecosystems, particularly focusing on the impact of environmental changes and pollution on marine species.

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