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Marine Zooplankton Distribution Model and Seriation Index across Different Habitat Types

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Abstract: Zooplankton play an important role in ocean food web as they ingest phytoplankton which in turn ingested by small fishes. Thus, the decrease population of zooplankton may indicate less population of fish. The study was conducted to provide analysis of marine zooplankton distribution model and seriation index across different types of habitat in the marine water of Opol, Misamis Oriental Philippines. The integration of the occurrence of data sets obtained from the three (3) sampling sites along with the environmental variables from BIO-ORACLE and Maxent software was able to generate the GIS-based zooplankton distribution model. Findings revealed that three (3) groups of zooplankton were identified namely, copepods, non-copepods and gastropods, with the total of twenty nine (29) species. Copepods mainly consume phytoplankton and other photosynthetic plants (herbivores), while non-copepods mainly consume its own kind (carnivores). The findings implied that the marine water is still suitable for its survival. However, the predominating carnivorous zooplankton species may indicate slight tolerance to the existing water quality as well as to the insufficient food resources. Similarly, Geographic Information System (GIS) is an effective tool for generating maps on the distribution of species that will be used for future conservation and protection of coastal waters.
Keywords: Zooplankton, Seriation, GIS, Habitat

I. INTRODUCTION

Zooplankton are the major grazers in ocean food web, which is also important to the fish population (Mollman , Karulis, Kornilovs and John *et al.* 2008). These organisms play an important role as they ingest phytoplankton, which in turn ingested by small fishes. Spatial scale influences the physical and biological processes on the distribution of zooplankton. Thus, these organisms mainly rely on physical and chemical characteristics of water such that, variation of its quality alter its population. Thus, decrease population of zooplankton may indicate less population of fish. Furthermore, zooplankton species may also provide an early warning of climate-related environmental degradation and a valuable bio indicators of climate-driven changes in marine ecosystem (Follows and Dutkiewicz, 2011). The municipality of Opol, Misamis Oriental, Philippines is one coastal area surrounded by business establishments, residential and a public market. It is identified as an important tourist destination due to its white beaches and strategic location in the Macajalar Bay area. This in turn, could encourage stakeholders to invest in an effective way. In aquatic ecosystem such as marine and fresh water, development and establishment of industries and other infrastructures have been major issues. These could greatly affect the environment and aquatic species. Fish is one of the major sources of food for the locals living nearby seas wherein marine and fresh water ecosystems are mostly found. To some extent, it may have been overlooked by its local government units that environmental concern is important to balance economic development.

Geographic Information System is used to establish maps to further determine species richness and endemism(Peterson *et al.*, 2000). This study is useful to further predict ecological effects of anthropogenic activities, determine the species occurrence or tolerance limit to some environmental variables, map out distribution of vulnerable species (Bryan and Metaxas, 2007; Holmes et al., 2007; Embling et al., 2010) as well as to assess protected areas for future conservation actions using the generated data on distribution(Jones, Dye, Pinnegar, Warren and Cheung, 2011).

Furthermore, the study answers the following objectives: (i) Identify the species composition of zooplankton species in the three (3) sampling sites; (ii) Determine the seriation of zooplankton species in every site,(iii)Establish a GIS Map on the distribution of zooplankton species, and (iv) Determine the species-habitat relationship of zooplankton across different habitat types.

II. MATERIALS AND METHODS

A. Study Area

The study was conducted in the coastal marine waters of Opol, Misamis Oriental, Philippines. The geographic coordinates of Opol are 8° 31' 0" N, 124° 34' 0" E. With the vast changes in the area, most of their barangays were used to many developments such as

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resorts, hotel and restaurants, industrial companies and more. Three sampling sites that were identified in the study were categorized as recreational (site 1), commercial (site 2) and residential (site 3) (Figure 2). These sites were chosen based on the initial assessment impact done from LGUs on the human-related activities such as bathing, improper waste disposal, constructions of establishments, public market waste.

Figure 2. Map of Opol, Misamis Oriental showing the identified sampling sites.

B. Collection of Samples and Environmental Data

Three sampling sites were identified. Quadrates were established in the identified sampling areas measuring 50m from the shoreline to seaward and 1000m perpendicular to the shore using transect line (50m x 1000m). Collection of samples was done within the established quadrate. Zooplankton were collected using LaMotte 1063 plankton net with a cone-shaped net of 10 mesh, 153 micron nylon cloth having 15" height and 5" diameter in the surface water of Opol, Misamis Oriental. This was done by boat and there were three replicates performed for every site. Samples were collected once a week from the month of February to April 2016 at 7-10AM in the morning.

The collected specimen was fixed using 10% borax-buffered formaldehyde to avoid any biological decomposition caused by bacteria. The fixative was prepared by diluting by 100ml of concentrated formalin solution with 900ml of filtered seawater from the sampling site. Preservation and Fixation of zooplankton samples was done as described by Goswami (2004) and Metillo (2011) with some modification. Then samples were also stored at room temperature less than 25 ^{0}C placed in a 300mLwide-mouthed plastic bottles.

Zooplankton species was initially identified by the researcher using the book of Mulyadi (2004), guide from different coastal and surface waters on zooplankton species as well as its taxonomic keys, and from the Marine Species Identification Portal, Marine Plank tonic Copepods and Census of Marine Zooplankton (CMARZ) website (http://www.cmarz.org). Am Scope with 10x-60x magnification Stereo Microscope was also used. After initial identification, the samples were brought to an expert of zooplankton for final identification and confirmation.

Sampling activities were documented using Canon EOS 700D and micro-camera for stereomicroscope on the initial identification of zooplankton species. Photographs of initial identification of species were also done with the use of stereomicroscope placed in the high power objectives. The list of collected zooplankton species from the three sampling stations in Opol along with its environmental variables were carefully georeferenced using a Global Positioning System (GPS) and these data sets were saved as a csv file.

III. RESULTS AND DISCUSSION

A. Composition of Zooplankton species

Zooplankton species are described as holoplanktonic, where it permanently lives in pelagic habitats; other taxa are considered as meroplanktonic, which are found only as eggs and larvae, while adults are considered as nekton and benthos (Lopes, 2007).

Results of the study revealed that the marine water in Opol, Misamis Oriental is made up of three (3) groups of zooplankton namely: *Copepods; Non-copepods;* and *Gastropods.* The copepod group is composed of three (3) orders which include Cyclopoida, Harpacticoida, Calanoida. The non-copepod group is consist of five (5) orders, these are Euphausiacea, Aphragmophora, Halocyprida, Decapoda, Spionida while the gastropod group is made up of three (3) orders namely; Mesograstropoda, Thecosomata, Myida. In general, Opol is composed of eleven (11) orders of zooplankton and these consist of 29 genera (Appendix A). Among the aforementioned Orders, eleven (11) genera were observed under Calanoida; Cyclopoida, is consist of six (6) genera; two (2) genera each for Harpacticoida, Aphragmophora, Euphausiacea; one (1) genus each under Mesogastropoda Thecosomata, Halocyprida, Decapoda, Myida and Spionida.

Figure 3 shows the images of zooplankton species observed and collected from the three (3) sampling sites of Opol, Misamis Oriental.

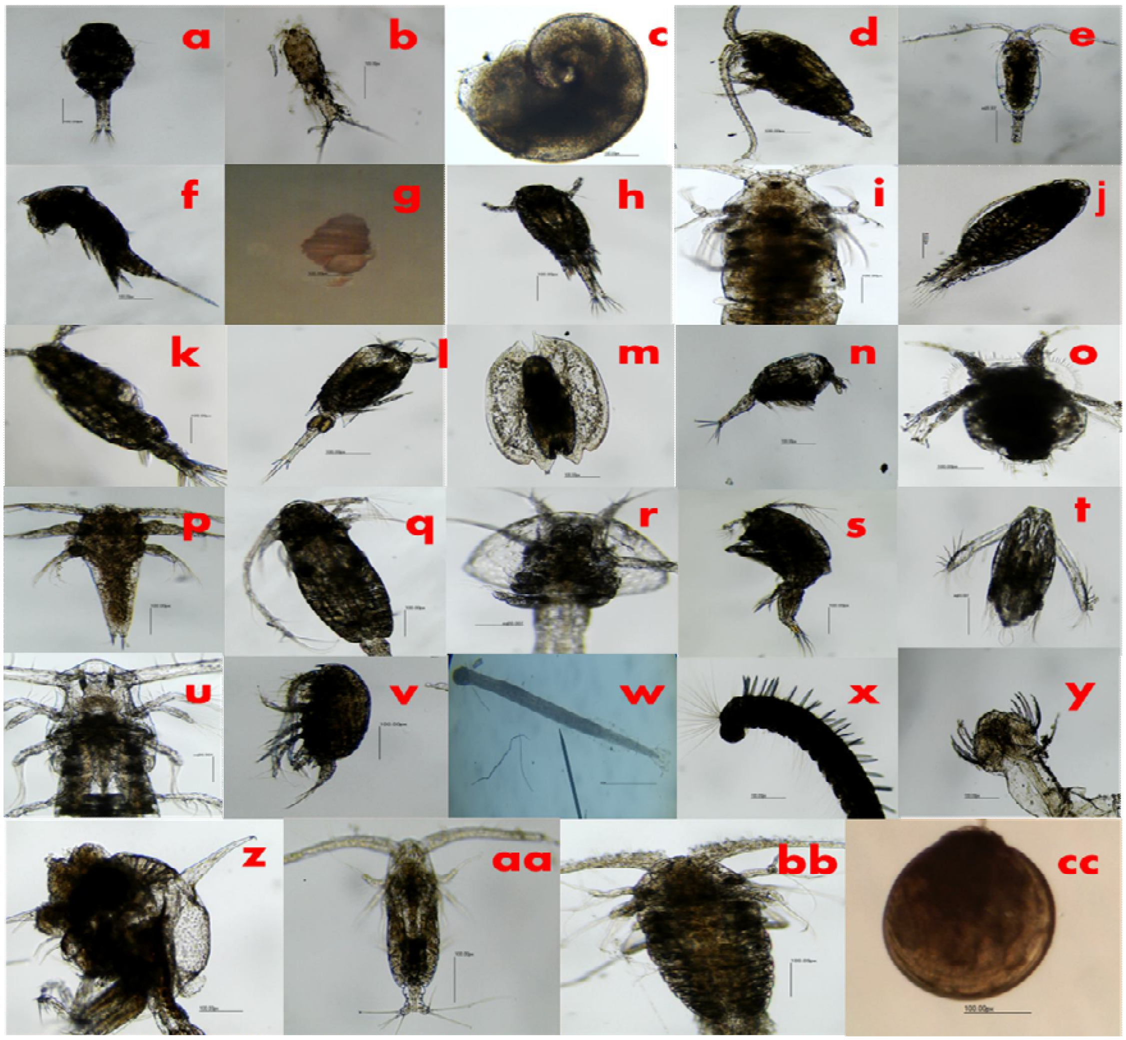

Figure 3. Zooplankton Species Composition. a-Dioithona sp., b- Clytemnestra sp., c- Atlanta sp., d-Calannus sp., e-Clausocalanus sp., f-Euterpina sp., g-Limacina sp., h-Oithona sp., i-Centropages sp., j-Paracalanus sp., k-Neocalanus sp., l-Ditrichocorycaeus sp., m-Euchonchoecia sp., n-Corycaeus sp., o-Euphausia sp., p-Calanoid nauplius, q- Acartia sp., r-Meganyctiphanes sp., s-Oncaea sp., t-Cyclopoid nauplius, u-Eucalanus sp., v-Parvocalanus sp., w-Aidanosagitta sp., x-Poecilochaetus sp., y-Parthenope sp., z-Flaccisagitta sp., aa-Calocalanus sp., cc-Lucicutia sp., and cc-Teredo sp.

A. Seriation of Zooplankton species

The relationship of the different study sites showing the seriation based on the similarities and differences on the presence and absence of zooplankton species is presented in figure 4.

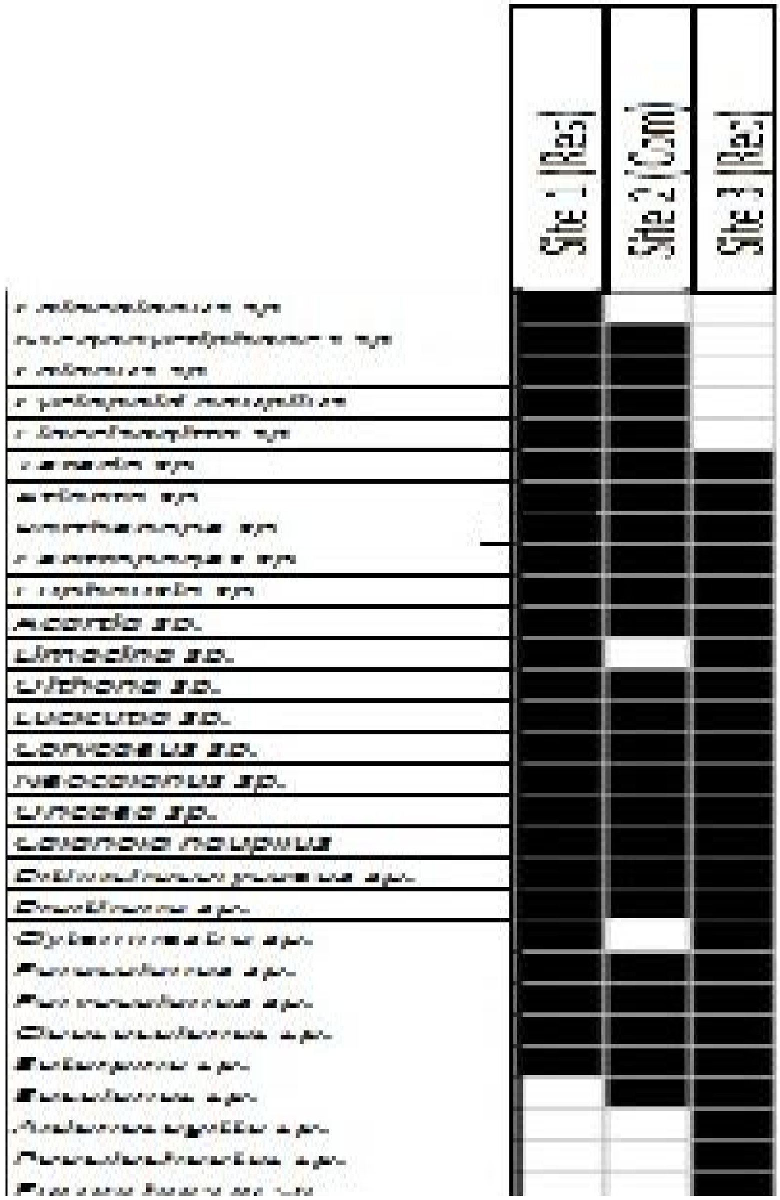

Figure 4. Seriation of zooplankton species in three (3) sampling sites.

Among the eleven (11) Orders of zooplankton species found, every individuals of each genus were almost present in the three (3) sampling sites. Of the twenty-nine (29) genera identified, a total of eleven (11) were not present in some of the sites in Opol, Misamis Oriental. Four (4) genera were not observed in site 1 namely, Aidanosagitta sp., Poecilochaetus sp., and Eucalanus sp., and Euconchoecia sp. while Calocalanus sp. Limacina sp., Parthenope sp., Clytemnestra sp., Aidanosagitta sp., Poecilochaetus sp., Euconchoecia sp., were absent in site 2. On the other hand, those that were not observed in site 3 includes Calocalanus sp., Flacisagitta sp., Calanus sp., cyclopoid nauplius, Meganyctiphanes sp.. Zooplankton species that were found in site 1 and site 2 indicated high tolerance in terms of deteriorating environment, which means that most of these species were able to adopt in polluted areas.Meanwhile, most zooplankton species that were absent in site 3 indicated high sensitivity to the present environment.

Order Cyclopedia recorded six (6) species which includes Dioithona sp, Oithona sp, Ditrichocorycaeus sp, Corycaeus sp, Oncaea sp, and cyclopedia nauplius. Two (2) genera were also identified under Order Harpacticoida (Clytemnestra sp, Euterpina sp.), two (2) under Order Aphragmophora (Aidanosagitta sp. and Flaccisagitta sp.) and two (2) under Order Euphausiacea (Euphausia sp. and Meganyctiphanes sp.). Further, Atlanta sp from Order Mesograstropoda, Limacina sp (Order Thecosomata), Poecilochaetus sp. (Order Spionida), Euconchoecia sp. (Order Halocyprida), Parthenope sp. (Order Decapoda) and Teredo sp. (Order Myida). From the species observed and collected, Calanoida recorded the highest individuals identified; among these were Calanus sp, Clausocalanus

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sp, Centropages sp, Paracalanus sp, Neocalanus sp, Acartia sp, Eucalanus sp, Parvocalanus sp, Calocalanus sp, Lucicutia sp, and calanoid nauplius.. However, most of the species not found in some of the sites belong to Class Copepoda namely, Calanus sp, Eucalanus sp, and Calocalanus sp., in which this taxa outnumbered all taxa in the marine zooplankton. This phenomenon may be explained with twilight Diel Vertical Migration or DVM, which involves two processes, ascent and descent. During sunset, it ascends to the surface then at midnight, it descends to a deeper water, followed by a second ascent to the surface and during sunrise, it descents to deeper water (Cohen and Forward, 2002). Furthermore, compositional change can be affected by to a stressor such as construction of buildings and highways, improper waste disposal and many other human-related activities, or it can be that a stressor is used as a predictive to future changes in ecosystem properties at the same time. Such changes may link to biomass and nutrient cycling, and may allow early intervention and detection (Philippi et. al. 1998). As suggested by Underwood (1992), to predict community or ecosystem consequences of change, assemblage composition or analysis of species is required. Moreover, for fisheries and marine ecosystems, species composition have given importance to determine the growth and survival of fish (Keister, Di Lorenzo, Morgan and Combes, 2011).

B. GIS-based map on Zooplankton Distribution Model

Modeling method is used to predict the suitability of species in its environment that functions with the given environmental variables. This pertains to the study area with the same geographical area, which has been partitioned into grid of pixels in a form of GIS format (Phillips, Anderson, Schapire, 2006). This is the general purpose of Maxent method, use for predictions or inferences in which an approach mainly entails on the presence-only datasets (Jaynes, 1957).

The integration of the occurrence of data sets obtained from the three (3) sampling sites along with the environmental variables from BIO-ORACLE and Maxent software was able to generate the GIS-based zooplankton distribution model as shown in figure 5.

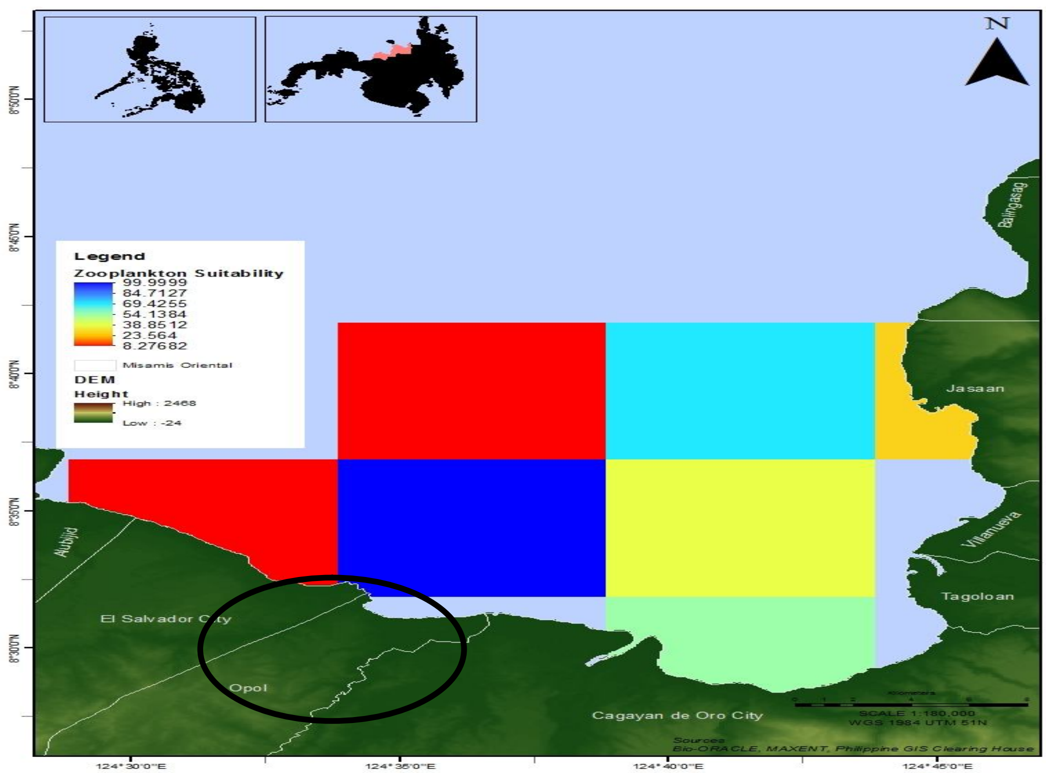

Figure 5. GIS-based map on the distribution of zooplankton species.

The map represents the overall suitability analysis of the different zooplankton species observed and collected within the sampling areas based from the different environmental and climatic variables.

The map used color to indicate whether predicted probability that conditions within the sampling site were suitable for zooplankton habitation. These predicted suitability sites were represented in a 9 kilometer by 9 kilometer squares in various color gradients. The color blue indicated high probability of suitable conditions for the zooplankton species while the colors yellow and the lighter shades of blue and green indicated conditions typical of those where the species is found and red indicated low predicted probability of suitable conditions.

It is worth noting that the coastal area of Opol, Misamis Oriental where the study was conducted is predicted to have the most favorable environmental conditions that make the area highly suitable for zooplankton existence. The reason for the absence of zooplankton appearance near the shoreline of the sampling area indicated that it is part of the landmass or may be attributed to low tide.

IV. CONCLUSION AND RECOMMENDATION

Zooplankton obtained from the study sites were divided into three groups: copepods, non-copepods and gastropods. Copepods mainly consume phytoplankton and other photosynthetic plants (herbivorous), while non-copepods mainly consumes its own kind (carnivorous). From the composition of zooplankton, most of the identified species belong to the herbivorous zooplankton (Copepoda). This group of zooplankton is under Order Cyclopoida and Calanoida. The presence of these taxonomic Orders imply that the marine water is still suitable for its survival. However, the predominating carnivorous zooplankton species may indicate slight tolerance to the existing water quality as well as to the insufficient food resources.

Geographic Information System (GIS) is an effective tool for generating maps on the distribution of species that will be used for future conservation and protection of coastal waters

On the trend of increasing population and urbanization of Opol, it is necessary to conduct periodic monitoring and evaluation of the marine water with multi-sectoral participation of LGUs, industries and local residents in the protection and management of the marine water.

Zooplankton studies should be given priority, since these organisms are fish primary consumers. Thus, classification of zooplankton species from different depths are recommended to know the trend of their existence and distribution based from their patterns of migration.

Since the study only focused on a single site, the pattern of zooplankton distribution is quite unclear due to less distances between sites. This was overlooked in the study since, zooplankton GIS-based maps has been less studied locally and abroad. Less data can also contribute errors to arise more often due to interpolated lower-resolution data, data manipulation, or an inaccurate climatic model that generates climatic variables.

The data focused only on the presence of species but difficulties arose when the only available data is the presence occurrence, which then makes it hard to evaluate the false-positive prediction (commission) errors. This may be due to lack of sufficient geographic detail, transcription errors or species misidentification. Second, it may exhibit spatial auto-correlation on the location of occurrence localities, exacerbated with the sampling methods and sampling intensity in the study area.

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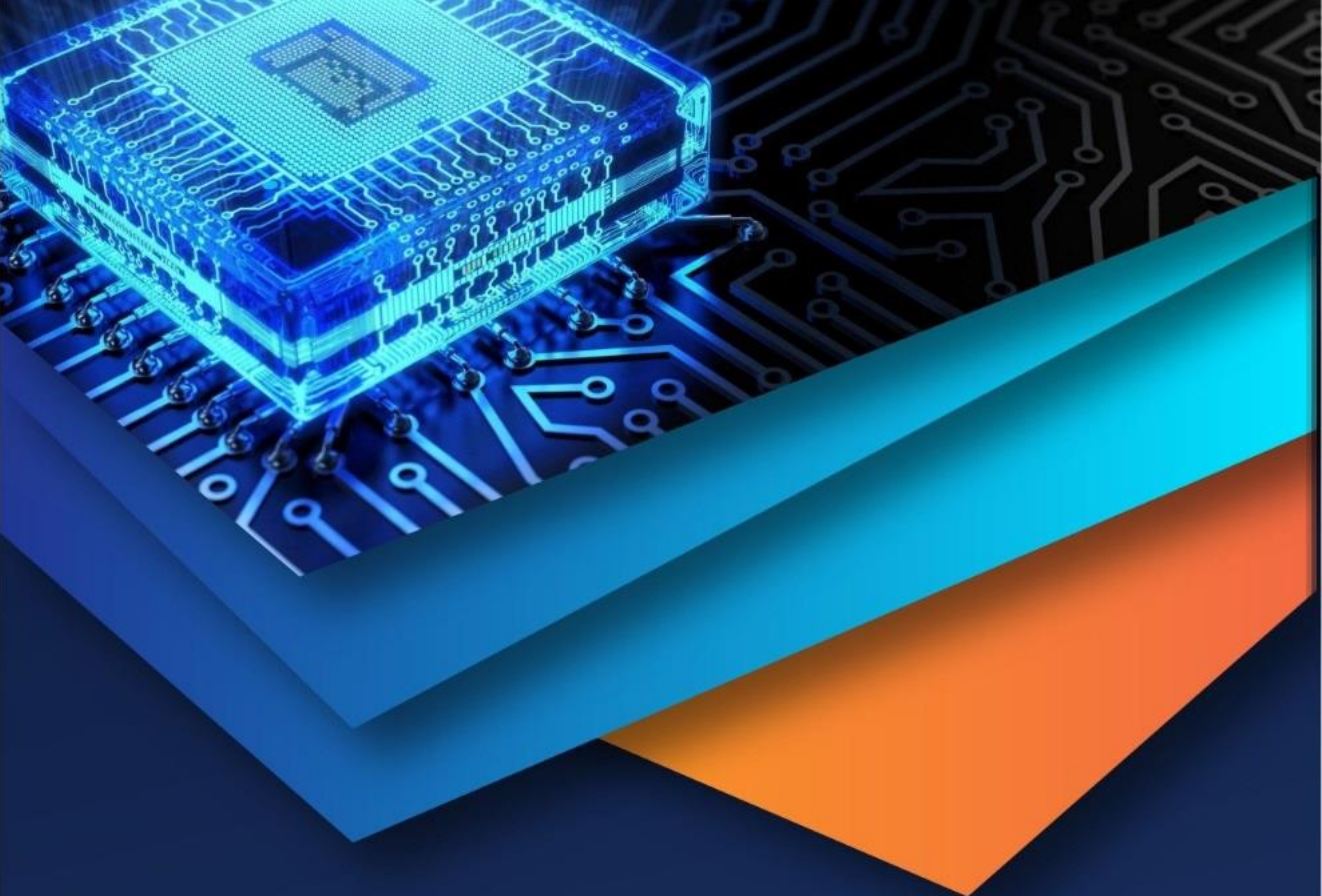

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