Distribution pattern of macroalgae community in Pecaron Beach, Kebumen Regency

D S Widyartini[1*], H A Hidayah[1], A S Piranti[1], and A Warihjati[1]

[1] Faculty of Biology, Jenderal Soedirman University. Jl. Dr. Soeparno 63, Purwokerto, Banyumas 53122, Central Java, Indonesia. Tel.0281-638794, Fax: 0281-631700.

*Email: dwi.widyartini@unsoed.ac.id

Abstract. Macroalgae have a high species diversity but are very susceptible to environmental changes or ecological pressures that can affect their existence. Pecaron Beach conditions have a substrate type of sand and coral fragments. This study aims to determine the distribution pattern of macroalgae in the waters of Pecaron Beach Kebumen. The research method uses a survey method with *a purposive random sampling* technique. Variables observed in this study are macroalgae distribution patterns. The observed parameters consist of the main parameters and supporting parameters. The main parameters consist of macroalgae biomass, while the supporting parameter consists of depth values at low tide, salinity, temperature, acidity degree (pH), wave height, phosphate levels, and nitrates of water. The data obtained were then analyzed for distribution patterns using calculated of the Morisita index. The results of the study on Pecaron Beach found 12 species, i. e. *Valoniopsis pachynema*, *Chaetomorpha antenina*, *C. crassa*, *Ulva lactuca*, *U. rigida*, *U. fasciata*, *Chondracanthus harveyanus*, *Tricleocarpa fragilis*, *Gelidium rigidum*, *Palmaria palmata*, *Eucheuma spinosum*, *Callophyllis crispata,* and *Sargassum crassifolium,* with distribution patterns at clustered species, with the highest distribution pattern values in *Ulva lactuca*, *U. rigida,* and *U. fasciata* species (12,000), and the lowest distribution pattern in *Chondracanthus harveyanus* (2,121).

Keywords: Distribution, Diversity, Macroalgae, Pecaron Beach

1. Introduction

Macroalgae or better known as seaweed have a high species diversity, but macroalgae are very susceptible to environmental changes or ecological pressures that can affect their existence. Environmental influences such as substrate, water movement, temperature, salinity, tides, light, pH, nutrients, and water quality will cause damage and even extinction. Macroalgae are low-level plants that grow attached or stuck to certain substrates such as corals, mud, sand, rocks, and other hard objects. In addition to inanimate objects, macroalgae can also be attached to other plants epiphytically. The growth of substrate-dependent macroalgae is directly influenced by sedimentation [1].

The presence of macroalgae has functions in terms of biological, ecological, and economic. Ecologically, macroalgae communities have a role and benefit to the surrounding environment, namely as a refuge for certain species of fish (nursery grounds), spawning grounds, and as a place to find natural food for fish and herbivorous animals (feeding grounds) [2]. From an economic point of view, macroalga is an excellent commodity to develop considering its chemical content. Macroalgae is widely used both in the form of raw material for all parts of plants and in processed form.

Macroalgae diversity shows the relationship between the number of species and individuals in a community. The difference in the diversity index can be influenced by competition. The seaweed that wins in the competition will grow well so that some species become dominant, while the seaweed that loses the competition in number will be reduced [3]. Live macroalgae attach to substrates [4], in coastal areas. According to [5], coastal areas are confluence areas between land and sea, towards land coastal areas include land parts, both dry and submerged in water, which are still influenced by marine properties such as tides, sea breezes, and saltwater seepage, while towards coastal areas include parts of the sea that are still influenced by natural processes that occur on lands, such as sedimentation and freshwater flows as well as those caused by human activities on lands such as deforestation and pollution.

An autotrophic organism is defined as an organism that can synthesize all the material in a cell from carbon dioxide as the only source of carbon. Autotrophic organisms provide reduced carbon into organic compounds that can then be utilized by heterotrophic organisms, so autotrophic organisms can be called primary producers [6], so that as autotrophic organisms macroalgae play a lot of role in the environment as a buffer for other organisms that are around them. According to [7], macroalgae play a role as producers in the food chain and can be utilized directly by herbivorous organisms. Macroalgae, which are usually found alive by being attached to substrates, are also known to play a role in providing carbon and helping to maintain the stability and presence of coral reefs.

Information about species diversity and distribution patterns of natural resources and environmental conditions is basic information that is indispensable in exploring the potential of seaweed because the life and growth of a type of seaweed have different living requirements. Pecaron Beach in Kebumen has a rock bottom substrate, rocky sand, mixed, high current, and wave speed. The higher the speed of currents and waves of the waters, the stronger the holdfast will be, usually seaweed stuck in the rock substrate will be able to withstand high current and wave speeds. Beaches with a substrate of dead rock fragments, massif corals, and more stable sands have a high diversity of seaweed compared to beaches with only a substrate of sands and mud [8]. Given the absence of specific studies on the diversity and distribution patterns of seaweed on Pecaron Beach, a study was conducted aimed at determining the diversity, and distribution patterns of seaweed in each type of substrate. The results of the study can be used as basic seaweed data for the development, utilization, and sustainable management of seaweed resources. Local communities can utilize the basic data in cultivation activities to improve the economic standard of living of the surrounding community. Seaweed development needs data on diversity and seaweed distribution patterns.

Seaweed grows in tidal areas or areas that are always submerged in water (subtidal) and is attached to substrates at the bottom of the waters in the form of dead rock corals, living rock corals, limestone, or Mollusca shells. Seaweed prefers habitats with small daily temperature variations and dead rock substrates [9]. The seaweeds found on rocky shores are generally of the classes Chlorophyceae, Phaeophyceae, and Rhodophyceae. Seaweed grows clustered with various other types of seaweed [10]. The presence of a seaweed community in a body of water acts as a habitat for other marine organisms, both large and small. In addition, seaweed communities in a body of water have a considerable role in marine life as shelters and foraging places such as *Ampiphoda*, crabs, and other marine life [11].

According to [12], seaweed communities can ecologically enrich primary products in coastal waters as stabilizers of sediments and coastlines, spawning grounds for fish, and habitats for various species of fish and invertebrates. Aquatic substrates as places of attachment of macroalgae can vary from soft substrates (mud, sand, soft corals) to hard substrates (coral fragments, igneous rocks, dead corals, soft corals, seagrasses, other macroalgae, mollusk shells). Macroalgae are able to grow in certain substrates because they have unique morphological characteristics. Macroalgae are divided into three divisions, namely red macroalgae (Rhodophyta) which contains phycoerythrin pigment, brown macroalgae (Phaeophyta) which contains fucoxanthin pigment, and green macroalgae (Chlorophyta) which contains chlorophyll. This division is based on the character of the pigment content that each division has [13]. Brown macroalgae (Phaeophyta) according to [14], is known as a group of macroalgae that have a more perfect morphological shape than macroalgae from other divisions (Rhodophyta and Chlorophyta) because some species of this division have a body shape that resembles a stem, base of the stem, leaves, roots, flowers, even some kind of fruit between the leaves. The size of this in Phaeophyta is higher than in other divisions. Red macroalgae (Rhodophyta) is a group whose species have various leaf shapes with color variations. The size of the thallus in Rhodophyta is generally not so large, with the thallus being cylindrical, flattened, or sheet. The branching system is simple (in the form of filaments) and there is complex branching. This macroalgae contain chlorophyll a and d and contain photosynthetic pigments in the form of phycoerythrin, carotene, xanthophyll, and phycobilin which causes a red color in the algae. Green macroalgae (Chlorophyta) have filamentous thalli (both branched and unbranched) and are leaf-shaped. The green color of this macroalgae is due to the chlorophyll content a and b which gives it a green color. In addition, Chlorophyta macroalgae contain alpha and beta carotene, lutein, and zeaxanthin [15].

Pecaron Beach is one of the beaches located in Ayah District, Kebumen Regency. Pecaron Beach location is located east of Menganti Beach. The condition of Pecaron Beach consisting of coral fragments and sand supports the place of attachment and growth of macroalgae but it is not yet known how the distribution pattern is, therefore a preliminary study is needed to determine the distribution pattern of macroalgae on Pecaron Beach. Information on macroalgae distribution patterns can be used to describe the interaction of the macroalgae community with its environment.

2. Research methods

The materials used in this study include the materials used in this study including macroalgae, water samples, sulfuric acid solution, HCl, potassium antimonyl tartrate, ammonium molybdate, ascorbic acid, and aqueous. The tools used in this study include sampling equipment (view rangers, thermometers, electric pH meters, hand refractometers, water sample bottles, transect squares, identification equipment, and identification books.

The study was conducted at Pecaron Beach located in Srati Village, Karangduwur, Ayah District, Kebumen Regency (7°46'14.022 - 7°46'18.405 LS and 109°25'16.209 - 109°24'58.738 BT) (Figure 1).

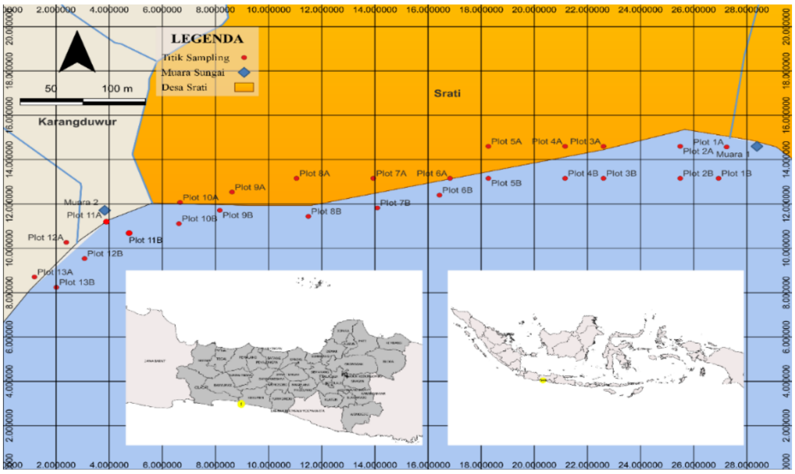

Figure 1. Macroalgae sampling location

The study was conducted by survey method and sampling was carried out using the *purposive random sampling* method. Based on coastline measurements using the QGIS 3.16.14 Application, it is known that Pecaron Beach has a coastline of 678.385 m so the sampling point is placed along 650 m following the coastline and 50 m towards the sea, by making a quadrat 1x1 m^2 at each sampling point. Macroalgae samples were taken in 2 plots, randomly at every 50 m in the observation area (Figure 2).

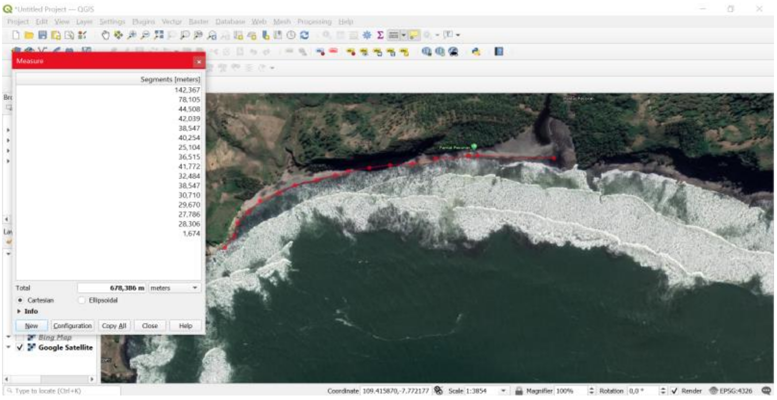

Figure 2. Pecaron coastline measurement using QGIS 3.16.14

Sampling was carried out at the time of the lowest receding conditions of macroalgae samples taken by *purposive random sampling* with quadrat transects. Samples were identified by observing morphological forms that included thallus forms, branching types, and *holdfasts*. Samples were measured using millimeter blocks and rulers and then documented by being photographed using cameras and identified using identification books according to [16] as well as *algaebase* and naturalist pages. Identification of macroalgae was carried out in the Aquatic Biology Laboratory of the Faculty of Biology, Jenderal Soedirman University.
Analysis of distribution patterns using the Morisita Index following the reference of [17] using the Microsoft Excel 2019 application, with the formula:

$$I\delta = \frac{ni\sum(Xi(Xi-1))}{N(N-1)}]$$

Information:
Iδ = Morisita spread index
Ni = Number of sampling units
N = Total number of individuals
Xi = Number of individuals of a species on the i-th plot

Environmental parameters as supporting data measured in this study consist of physical and chemical parameters. Physical parameters include depth, significant wave height, and temperature, while chemical parameters include salinity, acidity (pH), water phosphate content, and aquatic nitrates. These parameters are measured except for significant wave measurements accessed through the BMKG (https://peta-maritim.bmkg.go.id/ofs/#), phosphate and nitrate content tested at the UPTD Environmental Laboratory of the Banyumas Regency Environmental Service.

3. Results and discussion

The results of the analysis of the distribution pattern of macroalgae in Pecaron Beach waters using the Morisita index have a clustered distribution pattern. Observation of macroalgae diversity identified as many as 12 species of macroalgae, found in waters with hard substrates (in the form of dead coral). Distribution pattern calculation data shows that all macroalgae on Pecaron Beach are 2,121-12,000 or greater than 1 (Iδ>1), shown in Table 1. According to the interpretation of [17], if the index value is less than 1 (Iδ <1) it means that the biota has a uniform distribution pattern (Uniform), if it is equal to 1 (Iδ = 1) then the biota has a random distribution pattern (Random) and if greater than 1 (Iδ> 1) then the biota has a clustered distribution pattern (Clustered).

Table 1. Pecaron Beach macroalgae species distribution patterns

Species	Morisita Index Value	Spread Pattern
Chaetomorpha antenina	2,590	Clustered
Valoniopsis pachynema	2,862	Clustered
Chondracanthus harveyanus	2,121	Clustered
Tricleocarpa fragilis	7,863	Clustered
Gelidium rigidum	7,409	Clustered
Palmaria palmata	3.333	Clustered
Sargassum crassifolium	5,029	Clustered
Ulva fasciata	12,000	Clustered
Ulva lactuca	12,000	Clustered
Ulva rigida	12,000	Clustered
Callophyllis crispata	5,760	Clustered
Chaetomorpha crassa	6,009	Clustered

Description: Uniform ($I\delta <1$) Random ($I\delta = 1$) Clustered ($I\delta > 1$)

All macroalgae divisions are found in Pecaron Beach waters, including the Chlorophyta division consisting of 6 species namely *Chaetomorpha antenina*, *C. crassa*, *Valoniopsis pachynema*, *Ulva lactuca*, *U. rigida*, and *U. fasciata*. The Rhodophyta division consists of 6 species: *Chondracanthus harveyanus*, *Tricleocarpa fragilis*, *Gelidium rigidum*, *Palmaria palmata*, *Eucheuma spinosum*, and *Callophyllis crispata*. Phaeophyta division consisting of *Sargassum crassifolium*. Chlorophyta grows on hard substrates and has a structure that is resistant to water movement, found in water areas close [18]. [19] state Phaeophyta is generally found on hard substrates in the form of rocks and coral fragments, with conditions that are more exposed to waves and still inundated with water at low tide.

Valoniopsis pachynema is a green macroalga that has the shape of a rigid thread-shaped thallus (filament) to form rigid fibers, the thallus of this species collects so that it looks dense, this species has irregular branching at the terminals and curves to form dense bunches, living by attaching to rocks (epilithic), which are exposed to air at low tide but are consistently exposed to waves [20] [21]. This species has a wider surface area than other species. This is related to the effectiveness of the species in receiving sunlight which plays a role in photosynthesis. [22] explain that the size of the blade and thallus owned by macroalgae will affect the capture of light entering the plant for the process of photosynthesis.

Chaetomorpha antenina has a filament-shaped thallus with a rigid structure, has no branching, is bright green (in observations on the coast of Pecaron it is bright green – dark green), and has a smooth texture. Living attached to rocks (epilithic) in zones that are fully covered by water bodies at the highest tide (high intertidal zone) along the coast exposed to waves [20] [23] [21]. *C. crassa* has an unbranched filament-shaped thallus of green, yellowish-green to dark green color. This species is found living attached to hard substrates (dead rocks) in shallow waters [24] [25].

Ulva lactuca has a thin thin sheet-shaped thallus of wide size, usually round or oblong in shape with wavy edges, bright green in color, and has a disc-shaped holdfast [26] [23]. *U. fasciata* has a thallus resembling a smooth sheet-shaped thallus with a choppy curly fringe [27]. *U. rigida* has jagged thallus edges (denticulates), and irregularly round-shaped blades with a light green to dark green color [28], according to [29], the blades are circular and flattened (orbicular) so they look wider than long and have *discoid* (disc-like) holdfasts of small size.

Chondracanthus harveyanus has a ribbon-shaped thallus (*ligulate*) that numbers more than one, is pink to red in color, and has the form of side (marginal) growths on its thallus strands [30] *Tricleocarpa fragilis* has the shape of a regularly branched cylindrical thallus, with a smooth surface, this species has an olive-red color [31]. *Gelidium rigidum* has a cylindrical thallus shape with pinnate branches [32] [33]. *Palmaria palmata* has a sheet-shaped thallus with a small disc-like holdfast, the thallus is erect and elongated with a tip that forms a fork or palm, and has a purple, tofu red, or brownish-red color. The morphology of this species can differ depending on environmental variations [34]. *Callophyllis crispata* has the form of a branched sheet thallus with dichotomous branching, the edges of the thallus are serrated, and the ends of the thallus are rounded. Dark red (*blooded/rosy*). *Holdfast* is discoid (*disc-like*) [35].

Sargassum sp. It has a shape like a land plant that can already be distinguished between stipe (stem), blade (leaf), and holdfast. This species has a cylindrical thallus with a fawn to dark brown color. The blade is oblong in shape with a rod-like stipe of cylindrical shape, has air bubbles, and the holdfast is disc-shaped. *Sargassum* sp. Species are commonly found attached to rocky substrates [36] [37].

Macroalgae can live by sticking to the substrate, [38] state that macroalgae have various places to live, such as corals, muddy corals, dead corals, muddy sand, mangroves, seagrasses and it is not uncommon to be found living and attached to other macroalgae (epiphytes). Pecaron Beach has a substrate in the form of sand and coral fragments, but all macroalgae found on this beach are only found attached to coral fragments. No living macroalgae are found attached to the sand substrate. Macroalgae are sessile organisms, so a strong sticking substrate is needed so that the attached macroalgae are not eroded by the waves, this is supported by [39], the growth and presence of macroalgae are influenced by the stability, hardness, surface profile, and porosity of the substrate.

This spread pattern is the most common spread pattern in nature. Individuals who live in groups have low mobility abilities so it is difficult to spread and move. In addition, individuals with clustered distribution patterns indicate if the individual needs a distinctive habitat, so the distribution pattern of the biota is narrow and limited [40] [41]. This is in accordance with the macroalgae conditions on Pecaron Beach, where all macroalgae can only be found on hard substrates, namely dead corals. Species distribution patterns can be formed by interactions that place individuals in populations with the influence of environmental structure, clustered distribution patterns that are the presence of individuals at one point decrease the chances of the existence of the same individual at other points nearby [42].

The existence of macroalgae is influenced by physical and chemical factors present in its environment (Table 2), the physical parameters measured include temperature, depth, and height of significant waves. Chemical factors measured include salinity, acidity, nitrates, and phosphates.

Table 2. Results of measurement of environmental factors at Pecaron Beach

Environment parameters	Value
Temperature (°C)	28,5 – 30.5
Salinity	25.0 – 35.0
Acidity degree (pH)	8.2 – 10
Depth values at low tide	56.0 – 76.0
Nitrate	2.5
Phosphate	0.3
Wave height (m)	1.8 – 2.0

The results of temperature measurements carried out at the study site ranged from 28.5 – 30.5 °C. Temperature affects the life performance of biota (such as affecting growth and photosynthesis) and tolerance to temperature differences that do not match the temperature that supports living biota [43]. According to [44], the optimal temperature for macroalgae growth ranges from 26-33 °C, so the temperature on Pecaron Beach supports the presence of macroalgae. According to [45], the temperature will affect the solubility of carbon dioxide (CO_2), the higher the temperature, the lower the CO2 content, and the higher the temperature will result in CO_2 gas escaping from the water. This will result in the acidity of the water will be alkaline.

The results of salinity measurements in the waters of Pecaron Beach were obtained by 25.0–35.0 ‰. According to [46] [47], the optimal salinity value for macroalgae growth is 33–40 ‰, The salinity value that supports macroalgae growth will maintain the balance of cell membrane function so that nutrient absorption goes well and its growth will be optimal. The pH is a unit of measurement to measure the acidity level of a solution, the pH value unit is on a scale of 0 – 14. pH is measured from the concentration of hydrogen ions (H), if the concentration of H+ is greater than H- then a matter has acidic properties (pH less than 7), this jugs the opposite happens when the concentration of H^+ is smaller than H^- then a matter has alkaline properties (pH more than 7) [48]. The results of acidity measurements on Pecaron Beach range from 8.2–10.0, which means that the waters on Pecaron Beach are alkaline. According to [49], the acidity that supports the life of macroalgae is 6.8 – 9.6. High acidity has an effect on CO_2 levels. The residual result of biota respiration is one of the sources of carbon dioxide (CO_2) in water. According to [50], carbon dioxide can react with water to form carbonic acid which reduces to bicarbonate and carbonate, thereby reducing acidity. In addition to temperature, what affects the solubility of carbon dioxide is salinity. The higher the salinity, the higher the solubility of carbon dioxide.

The content of nitrates and phosphates is an indicator of the fertility of water, naturally, phosphates and nitrates come from the process of decomposition, weathering, and decomposition of dead organisms, household activities, and agricultural activities [51]. Phosphorus is a basic nutrient in biochemical reactions that plays a role in genetic material (DNA and RNA), energy transfer, and forms phospholipid membranes. Biota capable of photosynthesis use dissolved phosphorus to form tissues [52]. According to [53], macroalgae utilize nitrate (NO_3^-) as the main form of aquatic nitrogen and the main nutrient for growth. The main source of nitrogen in water comes from nitrogen gas in the air which is converted into nitrogen compounds (Nitrates) by bacteria and algae. The results of phosphate measurements in the waters of Pecaron Beach are 0.3 $mg.L^{-1}$. The results of nitrate measurements on Pecaron Beach are 2.5 $mg.L^{-1}$.

Waves in the waters of Pecaron Beach are included in the *moderate* category, this causes the nutrient-stirring process to take place optimally. According to [54], waves have an effect on water stirring, aeration, and nutrient transport in macroalgae. Ocean waves are the result of forces derived from atmospheric pressure (especially wind), earthquakes, gravitational forces from the earth and celestial bodies (moon and sun), coriolysis force (as a result of the earth's rotation), and surface tension [55], significant wave height is often used in expressing the height of sea waves in the implementation of marine methodology [56]. The results of measuring the speed of the water current (cm/s) and the height of significant waves (m) taking secondary data from the BMKG page obtained wave height values of 1.84 – 2.06 m (included in the moderate category in the library). According to [58] and [59], macroalgae whose lives are directly affected by waves are dominated by macroalgae that have a strong thallus structure with slow growth, while macroalgae that are not directly exposed to waves will have a weaker thallus structure with rapid growth. The movement of water is a physical factor that affects the distribution and abundance of marine organisms whose lives are attached (sessile). The movement of water plays a role in the transport of nutrients and gases so that it affects the growth, reproduction, and shape of an organism. Water movement has a role in macroalgae in obtaining nutrients and dissolved gases so the increasing rate of water movement will increase the rate of photosynthesis when the movement of water slows down, the transport of nutrients to macroalgae will be limited so photosynthesis is not optimal, and affects the growth rate of macroalgae. Water movement in addition to playing a positive role in nutrient transport also has a negative impact, namely, it can carry macroalgae that have unstable substrates or weak holdfast attachment

4. Conclusion

Macroalgae in the waters of Pecaron Beach are mostly found living by attaching to hard substrates, namely coral fragments. There are 12 species of macroalgae found in Pecaron Beach. The Chlorophyta division consists of *Chaetomorpha antennana*, *C. crassa, Valoniopsis pachynema, Ulva lactuca, U. rigida*, and *U. fasciata*. The Rhodophyta division consists of *Chondracanthus harveyanus*, *Tricleocarpa fragilis, Gelidium rigidum, Palmaria palmata, Eucheuma spinosum*, and *Callophyllis crispata*. The division Phaeophyta consists of *Sargassum crassifolium*. All macroalgae species have a clustered distribution pattern with the largest value of R found in the species *Ulva lactuca*, *U. rigida*, and *U. fasciata* (12,000), and the lowest in *Chondracanthus harveyanus* (2,121).

5. Acknowledgments

Acknowledgments to DRTPM Kemendikbudristek as research funder, contract number: T/1023/UN23.18/PT.01.03/2022 and LPPM Unsoed, number: 2131/UN23/PT.01.02/2022 as research funder, as well as Management Pedalen Beach for the assistance and permission given during the research.

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