SUCCESSION OF *Casuarina equisetifolia* AFTER THE MUD VOLCANIC ERUPTION AT PULAU TIGA, SABAH

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THE DISSERTATION SUBMITTED TO UNIVERSITY MALAYSIA SABAH IN PARTIAL FULFILLMENT OF THE DEGREE OF BACHELOR OF SCIENCE WITH HONOURS IN CONSERVATION BIOLOGY

CONSERVATION BIOLOGY PROGRAMME

SCHOOL OF SCIENCE AND TECHNOLOGY

UNIVERSITY MALAYSIA SABAH

2010

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JUDUL: SUCCESSION of Casuarina equisetifolia AFTER THE MUD VOLCANIC ERUPTION AT PULAU TIGA, SABAH

Ijazah: B.Sc (Hons) Conservation Biology

SESI PENGAJIAN: 2009/2010

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ACKNOWLEDGEMENT

First and foremost, I offer my sincerest gratitude to my supervisor, Mr. Robert Francis Peters, who has encouraged and guided me throughout my thesis. I would also like to thank every lecturer in ITBC for their advice and comments regarding my thesis.

Special thanks to En. Azrie and En. Cornelius for helping me with my field work at Pulau Tiga. I would also like to thank the staff of Sabah Parks, the staff at the Kuala Penyu branch of Sabah Parks and also the staff at the Pulau Tiga Park for their help and guidance throughout my stay in Pulau Tiga.

I would also like to thank my parents, Mr. and Mrs. Selva Mohan and my sisters, Rajathi and Ashwiini for supporting me throughout my studies from primary to tertiary level. Sincere gratitude to my fellow course mates who helped me in completing my thesis. A special thanks to Nur Adillah for guiding me with the write up of my thesis.

Lastly, I offer my regards to all of those who supported me in any respect during the completion of my thesis.

ABSTRACT

Pulau Tiga was formed by continuous mud volcanic eruption. The most recent and major eruption was 20 years ago. This eruption had influenced the trend of vegetation in Pulau Tiga. The study was carried out to know the direction of succession and to identify species that lives in a mud volcanic area. The type of succession that has occurred in Pulau Tiga was also determined by carrying out this study. The *dbh* of the species were taken into account to determine the age of each tree roughly. The line transects and quadrate method was used in the study. The diachronic technique was used to observe the species in the study site. The *dbh* of species of plants that are above 10 cm only is taken into consideration. The line transects were constructed at the mud volcanic areas. The mud volcanoes are in the Casuarina Trail, Mud Volcano Trail and Larai-larai Trail. The most active mud volcano is in the Mud Volcano Trail. The most dominant species in the mud volcanic areas were the *Casuarina equisetifolia*. The species could be found in every area of the island. However, the *Casuarina equisetifolia* found in the mud volcanic areas were below 40 cm in diameter. This shows that the trees are still young and succession just happened in the area. The *Casuarina equisetifolia* could be found in almost all the area in the island proves that the succession was random and not directed to a certain area. The species *Casuarina equisetifolia* is the species that lives and survives in the mud volcanic area. This species serves as a pioneer species in the area. As the 1990 mud volcanic eruption was not the first to occur at Pulau Tiga, the type of succession that occurred in the secondary succession.

ABSTRAK

SESARAN *Casuarina equisetifolia* SELEPAS LETUSAN GUNUNG BERLUMPUR DI PULAU TIGA, SABAH

Pulau Tiga terbentuk akibat letusan gunung berlumpur yang berterusan. Letusan yang terbaru yang dilaporkan berlaku kira-kira 20 tahun yang lalu. Letusan gunung berlumpur ini telah mempengaruhi corak vegetasi di Pulau Tiga. Kajian ini telah dijalankan untuk mengetahui arah sesaran yang telah berlaku and mengenalpasti spesis pokok yang dapat hidup di kawasan gunung berlumpur. Jenis sesaran yang telah berlaku di Pulau Tiga turut dikenalpasti melalui kajian ini. Untuk mengetahui usia pokok secara kasar, *dbh* pokok telah diambil kira. Kaedah garis transek dan kuadrat telah digunakan dalam melaksanakan kajian ini. Pemerhatian spesis di kawasan kajian telah dibuat dengan menggunakan teknik diakronik. Pokok yang mempunyai *dbh* lebih daripada 10 cm yang telah diambil kira. Garis transek telah dibina di kawasan gunung berlumpur. Gunung berlumpur di Pulau Tiga adalah di Casuarina Trail, Mud Volcano Trail dan Larai-larai Trail. Gunung berlumpur yang paling aktif adalah di Mud Volcano Trail. Spesis yang paling dominant dijumpai di kawasan gunung berlumpur ini ialah *Casuarina equisetifolia*. Spesis ini boleh dijumpai di seluruh kawasan pulau tersebut. Namun begitu, *Casuarina equisetifolia* yang dijumpai di kawasan gunung berlumpur mempunyai diameter di bawah 40 cm. Ini menunjukkan bahawa pokok-pokok di situ masih muda dan sesaran baru sahaja berlaku di kawasan itu. *Casuarina equisetifolia* dapat dijumpai di semua tempat di pulau berkenaan. Ini menunjukkan bahawa sesaran telah berlaku secara rawak. *Casuarina equisetifolia* ialah spesis yang dapat hidup dan bertahan di kawasan gunung berlumpur yang kekurangan air dan nutrien. Spesis *Casuarina equisetifolia* menjadi spesis perintis di kawasan Pulau Tiga. Letusan gunung berlumpur pada tahun 1990 bukan letusan yang berlaku buat pertama kali di Pulau Tiga, ini membuktikan bahawa sesaran yang berlaku di Pulau Tiga ialah sesaran sekunder.

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LIST OF SYMBOLS AND ABBREVIATIONS

H_0	null hypothesis
H_A	alternative hypothesis
km	kilometer
mm	millimeter
°C	degree Celsius
m	meter
cm	centimeter
dbh	diameter breast height
%	percent
Mg	Magnesium
P	Phosphorous
K	Potassium

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Vegetation refers to the plant life of a certain region. Flora is also used to describe plants. However, flora only refers to the composition of the species (Townsend, 2008). Vegetation suffers from various ecological stresses or natural disturbances that are natural and also man-made. This ecological stresses can cause degradation of vegetation. Example of such ecological stress is fire, landslides, volcanic eruption, soil erosion, flash floods and also human activities (Luken, 1990). Vegetation restoration and succession affects the ecosystem of a particular area. The place of species in succession does not depend on their colonization. Vegetation is restricted to a particular moment in the successional timetable. This is because they have to wait till their niche requirement is met. Vegetation changes during succession are difficult for successional changes of other organisms living in the same ecosystem. The changes in vegetation due to succession will also affect other organisms that live in the particular area.

Succession is a process that changes the composition or structure of an ecological community in an orderly manner. Succession is initiated by new and unoccupied habitat or some form of disturbance of an existing community (Grime, 2001). It takes decades or even centuries for succession to take place (Townsend, 2008). Succession explains the development of vegetation in the absence of disturbance. The concept of disturbance and succession are always linked with plant ecology (Johnson & Miyanishi, 2007). In order to study succession, the changes in plants should be studied.

Succession may be driven by allogenic or by autogenic. In allogenic succession, the composition of species in an area changes the physical environment of the area in an orderly manner. However, the interaction of the species is only given secondary importance. This is due to the abiotic conditions of the area. Succession that begins from the disturbance of an external physical factor is called autogenic succession. Interaction among species is given importance in this kind of succession (Townsend, 2008).

Autogenic succession is divided into primary and secondary succession. Primary succession occurs when a habitat lacks vegetation and also soil. Secondary succession happens when the vegetation of an area is removed either partially or completely. However, the soil and seed of the vegetation remains. The loss of trees through disease, wind, and fire starts a secondary succession. Abandonment of a previously cultivated field and mud volcanic eruptions also inhibits secondary succession (Townsend, 2008).

Mud volcano is a mound of mud that piles up through overlying sediments. These sediments are created by hot springs and oily-field regions. The mud is formed by reaction between volcanic gases and the rocks below. The mud volcano is made up of a cone with mud and also clay. It is usually about one meter to two meter in height. The mud volcano is built as mud is thrown into the air which allows volcanic gases to escape

and to dissolve into hot ground water. It creates an acidic mixture that turns solid rock into fragments that are in clay size (Dalimin & Ahmad, 1999).

Mud volcano is observed in areas of rapid deposition and lateral tectonic compression. Mud volcano originates from sediment over pressurization of hydrocarbon formation, thick depositing clay sediments, fluid expulsion and mineral hydration (Sun *et al.*, 2009). The activity and behaviour of a mud volcano is classified as eruptive, dormant or sleeping and extinct (Mazzini *et al.*, 2008). The mud volcano in Pulau Tiga is dormant. This is because it has short duration of eruptions (Chin *et al.*, 2009).

Pulau Tiga is an island which was formed by continuous mud volcanic eruption (Chin *et al.*, 2009). The island was formed in the 19th century. Pulau Tiga is located between 5° 42' and 5° 43' and 115° 37' and 115° 39' South West from Kota Kinabalu (Sanudin *et al.*, 1999). There are three islands in that area. There are Pulau Tiga, Pulau Kalampunian Besar and Pulau Kalampunian Damit. Pulau Tiga is the biggest among the three islands. Pulau Kalampunian Besar is well known for its clear sand and white water. Meanwhile, Pulau Kalampunian Damit is the location for mating of poisonous snakes. The island is also called Pulau Ular.

Pulau Tiga is managed as a forest reserve by the Sabah Parks Department. This makes it one of the undisturbed islands in Sabah. There a number of species of animals and plants that can be found in Pulau Tiga. Animals that can be seen easily in Pulau Tiga are birds. Hornbills and megapodes are most common in the island. Proboscis and macaque monkeys, monitor lizards and poisonous sea snakes can also be found in the surroundings of Pulau Tiga. Groundwater has been the regular water supply in Pulau Tiga (Chin *et al.*, 2009). This is done even with the presence of mud volcano in the area.

The vegetation in Pulau Tiga is classified into land vegetation and also beach vegetation. The most common vegetation in Pulau Tiga is *Calophyllum inopyllum, Barringtonia asiatica, Terminalia catappa, Nypa fruiticans, Xylocarpus* sp., *Caesalpina bonduc, Hoya* sp., *Pangium edule, Dipterarocarpus oblongifolius, Entada phaseoloides* and *Casuarina equisetifolia.* There is also *Hibiscus tiliaceous* which is used as ropes, timber, fire wood and medicine.

The volcanic eruptions that have happened caused the area to have gone through succession. The cause of mud volcano is because of the movement of the Earth's tectonic plates. The same event has also been reported in Tabin, Sabah. The flow of warm mud still continues till today. The flow of the mud volcano has also influenced the trend of the vegetation in the area. The mud in the area is very salty which makes it difficult for plants to survive in Pulau Tiga. Not all plants can survive in muddy areas. Plants which adapts well to muddy area are the plants that can survive in an area like Pulau Tiga (Dalimin & Ahmad, 1999).

1.2 Problem Statement

There is no sufficient study conducted about the succession that has happened in Pulau Tiga and also its vegetation. It is necessary to do research on succession there and also its vegetation because the management of ecosystem and also the sustainable development in Pulau Tiga is less. This study will provide data on the vegetation in Pulau Tiga, thus help in understanding the current conservation status of the vegetation in that area. This data will also help in managing the ecosystem of the area well. Besides that, by conducting the study, the potential of Pulau Tiga to become a destination for nature tourism will also be highlighted.

1.3 Objectives of Study

a) To know the direction of succession of *Casuarina equisetifolia* after the mud volcanic eruption.
b) To identify the species that lives in a mud volcanic area.
c) To determine the type of succession that has occurred in Pulau Tiga.

1.4 Scope of Study

To ensure that the objective is achieved, all three mud volcanic area in Pulau Tiga was studied. This is to know if *Casuarina equisetifolia* is found in all the mud volcanic areas in Pulau Tiga. The whole area around the mud volcano is also studied in order for the direction of the succession of *Casuarina equisetifolia* is known. The jetty was also studied as it served as a control in this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Vegetation Succession

In the year 1916, Clement came up with the idea of succession (Noble & Slatyer, 1980). According to Clement, succession happens by stages. Clement also introduced six stages of succession. The end of succession is when the area that has undergone succession becomes stabile. The end of succession also means when the area is recolonised by vegetation again. The first stage in succession according to Clement is when the area is bare. This means the area lacks vegetation and also soil. During this stage, an area is ready to undergo succession. Seeds of plants in the area would have been dispersed by wind, water, animal or even human. The seed should be able to survive in its new habitat.

This new habitat is a disturbed habitat. If the seed is able to grow in its new habitat, competition between plants will occur. This competition is to compete for the limited resources that are available in the new disturbed area. Reaction is the interaction among the plants in the area. The final stage is stabilization of the area. The relay floristic model of succession by Clement considers succession as a directional replacement of vegetation types. Each type of vegetation creates a favourable condition for its successor.

In order to study vegetation succession, frequent and continuous time series is required (Zhao *et al.*, 2009). Succession takes a long time to happen. The duration of vegetation succession varies according to conditions (Wang *et al.*, 2007). The volcano in Mount St. Helens erupted in 1980. The vegetation in that area has reestablished itself a few years later covering about 38% of the area. It will take decades for the place to recover and for a vegetation community to exist (Dale & Adams, 2003).

Vegetation succession is determined by abiotic site conditions, species pool and interspecific competition. Other kind of tropic levels also affects vegetation succession. Not much attention has been paid to the effect of soil invertebrates on the communities of vegetation. Soil biota also affects the successional changes of vegetation by effects on nutrient availability.

The process of vegetation restoration is viewed as succession (Zhang *et al.*, 2005). Species diversity is a part of the plant communities and is significant in the study of succession. Variations in diversity of plant communities in an area correlate with the stability of biotic and abiotic components of an ecosystem. Plant diversity is a cause of early succession in an abandoned agricultural field. The diversity of plant species that are present at certain stages of succession will affect the course of succession.

In the year 1954, Egler came up with another idea about succession (Noble & Slatyer, 1980). Egler mentioned that seeds in a disturbed area are mixed. Egler also said that the colonist plants dominate the disturbed area at first. As time goes by, this colonist plants undergo competition with other plants. This eventually will become a cause on the loss of colonist plants in the area. The relay floristic model was dismissed by Egler in 1954 in a post-fire diachronic study.

Connell and Slatyer introduced the facilitation, tolerance and inhibition model. These models were introduced in the year 1977 (Debussche *et al.*, 1980). In the facilitation model, it is said that the first species to dominate the disturbed area will change or modify the physical structure of the area. This is to help other species to live in that area. At the end of this model, it is common to see late successional plants dominating the area compared to the early successional plants. The tolerance model occurs when the first species and also species that are going to live in the area exist in the disturbed area at the beginning of a successional period.

The first species will change or modify the physical structure of the area enabling the latter to dominate the area. In the inhibition model, the first species exist in the disturbed area. It modifies the physical structure of the area according to its convenient. This will disable other species to colonise that area. It is only possible for other plants to colonise that area if the former species is dead.

The transition from vegetation is dominated by annual plant. Domination by perennial species is affected by the status of soil nutrient. High levels of nutrients are usually found in former agricultural land. This is because of the usage of large amount of inorganic fertilizers over the years. Increased level of nitrogen in soil is able to retard the rate of succession in an area.

2.2 Concept of Successional Mosaic

Disturbances are in very large scale. Thousands of hectares of forest can be destroyed by any type of natural disturbances. The sequence of succession starts at the same time in an area. It also proceeds in synchrony. An area that has reached a stable community structure will be a mosaic of succession. Every time a tree falls or something happens to the vegetation in the area, a new succession starts. However, this is only on a small scale. This pattern is called the successional mosaic.

The frequency that the disturbance occurs influences the successional changes or the successional mosaic of an area. This successional mosaic also helps in determining the total number of species in the area that has undergone disturbance or succession. When disturbance happens frequently, succession cannot proceed further than the pioneer stage. However, if disturbance is infrequent, the successional mosaic will have only late successional species. When disturbance occurs at an intermediate frequency, species from all stages of succession can be found in the area. This also shows that the species richness in that area is at maximum level (Connell, 1978). Disturbance in an area does not have to be uniform or systematic.

In Pulau Tiga, the mud flow has only reached to certain areas of the island. There are also areas that are further from the mud volcano. This area will take a longer time for succession to happen compare to areas nearby the mud volcano. The age and size of the vegetation which is nearby the mud volcano is not the same as other areas in the island. In an area where the vegetation in that areas are taller and older compared to other areas, the vegetation there is called early successional plants. In areas where the plants are still young are late successional plants. This is the pattern of succession or the successional mosaic in Pulau Tiga.

2.3 Causes of Succession

Succession is a process that happens naturally. It happens because of the disturbance in its surroundings. Natural disturbance that initiate succession are fire, wind storms, flash floods, landslides and volcanic eruption (Luken, 1990). Natural disturbance and human disturbance has become serious threats to traditional succession. Traditional succession is the infrequent occurrences that initiate succession. This proceeds to the absence of further disturbances (Johnson *et. al*, 2007).

To study the ecological effect of disturbance, three processes have to be followed. The ecological processes that affect the disturbance must be precisely defined. The part of the disturbance process that causes the ecological effect must also be defined. The ecological and disturbance processes must be brought together (Johnson *et. al*, 2007). Disturbance can effect on individual plants, populations and also the communities. In Pulau Tiga, the ecological process that affects the disturbance in the area is the continuous mud volcanic eruption.

2.3.1 Mud Volcano

Mud volcanoes are the most important pathway for degassing of deeply buried sediments. They are mainly found in subduction zones where lateral tectonic compressional stress is dominant (Lykousis *et al.*, 2009). These mud volcanoes are widespread. They may host large masses of solid gas hydrates of potentially high economical interest and significant source of natural pollutant.

Sanudin & Mazlan in the year 1999 said that the mud volcano in Pulau Tiga is like ordinary volcanoes around the world. The mud volcano looks like a normal slope. However, it just gives out cold mud instead of hot lava. The eruption of the mud volcano emits greyish mud with a mixture of salt water. It also releases methane gas.

The mud volcano in Pulau Tiga is very young. The mud that is produced by the volcano is from a depth of 3 km. In Pulau Tiga, the mud has been the factor of disturbance. This disturbance causes succession. The flow of mud in Pulau Tiga has also influenced the type of vegetation there. This is because the physical and chemical properties of the mud do not allow all kind of plants to survive in that condition.

2.3.2 Landslides

Landslides are common incident at hill areas. This is especially common during heavy rains or strong winds. Many reports of landslides have happened in the country and also around the world. Landslide is a very common incident in Pulau Tiga. This is especially after a heavy rain. After the mud volcanic eruption in Pulau Tiga, it is followed by landslides and also soil erosion. Landslides caused by heavy mud causes the root of plants to loss its strength. This is because the plants are still young (Sanudin & Mazlan, 1999).

2.3.3 Soil Erosion

Soil erosion is one of the contributing factors of succession in Pulau Tiga. Pulau Tiga is a hill area. Primary succession is very common in this kind of conditions. Soil erosion is usually because of heavy rains. Heavy rain usually washes out important nutrients from

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