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## CHEMICAL CHARACTERISTICS AND MICROBIAL DIVERSITY OF SOILS FROM MENENGA CRATER IN KENYA

Paul Njenga Waithaka<sup>1\*</sup>, Francis B. Mwaura<sup>1</sup>, John M. Wagacha<sup>1</sup>, Eliud M. Gathuru<sup>2</sup>,  
Francis M. Ngumbu<sup>2</sup> and Anderson K. Mwangi<sup>2</sup>

<sup>1</sup>University of Nairobi,  
School of Biological Sciences,  
P. O. Box, 30197-00100 Nairobi, Kenya

<sup>2</sup>Egerton University,  
Department of Biological Sciences,  
P. O. Box, 536 Njoro, Kenya

Corresponding author; Paul Njenga Waithaka, Cell; +254 721104637,  
Email; waithakanj@gmail.com, waithakanj@yahoo.com

**ABSTRACT.** A total of 98 soil samples collected from Menengai geothermal site located in Nakuru, Kenya were analyzed for their chemical and microbial components. In region A, phosphorus, sodium, nitrogen and carbon were deficient, region B and C, phosphorus and Manganese, while in D the deficient minerals were phosphorus, sodium, nitrogen and carbon. Toxic minerals were calcium and magnesium in regions A, B, C and D. The most prevalent bacteria were Escherichia coli with a mean of  $(3.35 \times 10^7)$  while the least were Bacillus sp. ( $1.40 \times 10^5$ ). Among the fungi, the most dominant were Aspergillus nomius with a mean of  $4.42 \times 10^4$  with the least being Panicillium sacculum ( $8.09 \times 10^3$ ). As much as geothermal exploration is important in boosting the country's energy reserves, there is a need to rehabilitate the caldera so as to restore the microbial composition of the region.

**KEYWORD.** Diversity, crater, geothermal, Menengai, microbial, chemical.

### INTRODUCTION

Microorganisms are found in all environments owing to their small size and easy dispersal and the ability to grow and multiply under anaerobic conditions (Dhiva *et al.*, 2016). In addition, their metabolic versatility and flexibility to utilize a broad range of nutrients, and the ability to tolerate and colonize otherwise unfavourable locations such as geothermal environments help them to thrive in many environments. Microorganisms that grow in extreme environments which include but are not limited to hot deserts, polar regions, geothermal areas, are referred to as extremophiles (Abdullah *et al.*, 2016).

Geothermal sites provide a unique ecological site to different microbes (Commichau *et al.*, 2013). Although the sites are deficient in carbon and other nutrients, geothermal ecosystems harbor diverse microbial communities which can adapt themselves in the extreme conditions witnessed in these regions (Galperin *et al.*, 2012). The microorganisms

help in recycling and transformation of various nutrients. The microorganisms of geothermal sites are essential in the productivity, conservation, and rehabilitation of geothermal ecosystems (Martins *et al.*, 2013). The importance of bacteria in promoting of halotolerant plants have been studied (Sunita and Kanwar, 2016). Culturable bacterial distribution in volcanic soils has been reported (Kumar *et al.*, 2014). Volcanic soils sites shows diversity of microbes such as bacteria and fungi. Although a lot of studies have been carried out on microbial components of volcanic areas, little is still known about the microbial diversity of soils in volcanic calderas. Soil samples from four regions in Menengai caldera were collected and analyzed for their chemical and microbial components.

## **MATERIAL AND METHODS**

### **The study area**

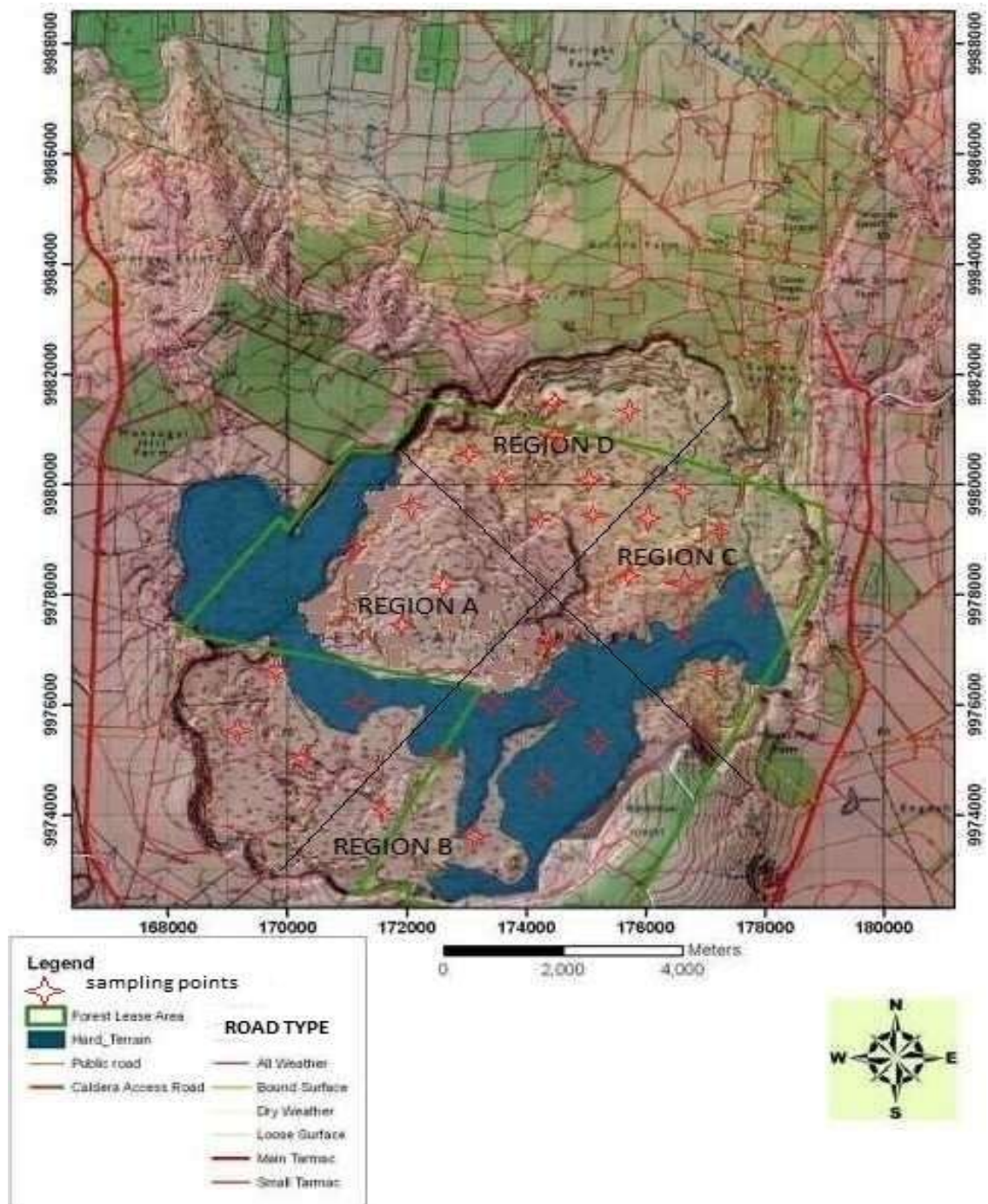
The study was carried out in Menengai crater which lies in the North of Lake Nakuru. It rises to a height of 2,278 m above sea level, and is a product of a volcanic eruption that occurred about 200,000 years ago. The crater is considered a dormant volcano with the occurrence of a high temperature geothermal resource, manifested mainly by steaming grounds at a temperature of 88°C. After the eruption, the sides of the volcanic crater collapsed inwards forming a large hole in the crust, called a caldera (Figure 1). Menengai caldera occupies an area of 90 km<sup>2</sup> and a diameter of 12 km. It is the second largest caldera in Africa after Ngorongoro in Tanzania. Menengai caldera is located in Rongai and Nakuru North Sub-counties at 35° 28', 35° 36'E, and 0° 13', 1° 10'S (Omenda *et al.*, 2000).

### **Soil sample collection**

Soil samples were separately collected from the top 5cm using a sterile spatula from the 8 sampling points in each region. The samples for each region were mixed to make a composite sample. The composite samples were placed in sterile plastic bags and transported to the department of biological sciences, Egerton University for analysis.

### **Chemical analysis of the soil**

The soil samples were suspended in distilled water. Soil pH was determined according to the procedure described by Martins *et al.*, (2013). The pH meter was standardized using a standard solution provided. Immediately before immersing the electrode(s) into the sample, the sample was well stirred with a glass rod. The electrode(s) were placed into the soil slurry solution and the beaker was gently turned to make good contact between the solution and the electrode(s). Organic carbon was determined using the wet oxidation method (Ramanadevi *et al.*, 2013).



**Figure 1:** Map of Manengai crater caldera and its environs (Mariita, 2003)



The Kjeldahl method (Khursheed *et al.*, 2014) was used to determine total nitrogen. phosphorus was extracted by the Bray and Kurtz-1 method and determined spectrophotometrically (Osakwe, 2014). Available potassium and sodium content in the soil were determined by using turbiditometric methods; calcium was determined by titration with standard KMnO<sub>4</sub> solution, magnesium by precipitation in alkaline medium as magnesium ammonium phosphate (Guo *et al.*, 2014). Manganese was analyzed by Atomic Absorption Spectrophotometer using GBC Avanta version 1.31 by flame Automization. (Egejuru *et al.*, 2014)

### **Microbial isolation and identification**

The microorganisms were isolated using serial dilution plate method. About 1 g of the sample was weighed and suspended in 9 mL of distilled water to make 10<sup>-1</sup> to 10<sup>-3</sup> dilutions. Using a micropipette, 1 mL aliquots of each concentration were added to sterile petri dishes containing 15 mL of sterile sabouraud dextrose agar for fungi, and nutrient agar for bacteria isolation in triplicate. Incubation was carried out at 37°C for 24 h (bacteria) and 28°C for 4 days (fungi). Growth of the organisms were counted using colony counter, and the microbial loads were calculated in CFU/mL. To obtain pure cultures, the microbes were sub-cultured by streaking on new solidified media. The pure isolates were stored in slant bottles for characterizations using colony morphology and biochemical characteristics.

### **Data analysis**

Data were presented using tables. All the data analysis were carried out using Statistical Package of Social Sciences Software (SPSS) software version 17.0 software and Microsoft 2010 spreadsheet. One way ANOVA was used in comparing the means.

## **RESULT AND DISCUSSION**

### **Chemical characteristics of soil from Menengai crater**

The pH ranged between 6.2 in region D to 5.52 in region C, phosphorus from 15.53 in region C to 4.15 in region A, potassium from 1.50 in region C to 0.35 in region A, nitrogen from 0.29 in region C to 0.10 in region A, calcium from 16.56 in region B to 3.45 in region B, magnesium from 2.56 in region B to 2.35 in region D, manganese from 0.51 in region B to 0.31 in region A, sodium from 0.15 in region C to 0.00 in region D, carbon from 2.50 in region C to 1.05 in region A (Table 1). The Ca: Mg ratio varied from 21.78 in region D to 15.61 in region B. In region A, phosphorus, sodium, nitrogen and carbon were deficient, region B and C, phosphorus and manganese while in D the deficient minerals were phosphorus, sodium, nitrogen and carbon. Toxic minerals were calcium and magnesium in region A, B, C and D.

**Table 1:** Chemical properties of soil samples from Menengai crater.

Chemical properties of soil	Region A	Region B	Region C	Region D	Recommended Levels	
					Low	High
pH	6.01	5.62	5.52	6.20	5.50	7.00
Phosphorus (mg kg <sup>-1</sup> )	4.15	15.00	15.53	5.00	20.00	100.00
Potassium (cmol kg <sup>-1</sup> )	0.35	1.23	1.50	0.33	0.20	1.50
Nitrogen (%)	0.10	0.24	0.29	0.18	0.20	0.80
Calcium (cmol kg <sup>-1</sup> )	3.45	16.56	15.34	4.84	2.00	10.00
Magnesium (cmol kg <sup>-1</sup> )	2.40	2.65	2.59	2.35	1.00	3.00
Manganese (cmol kg <sup>-1</sup> )	0.31	0.51	0.45	0.34	0.10	1.00
Sodium (cmol kg <sup>-1</sup> )	0.02	0.10	0.15	0.00	0.10	2.00
Carbon (%)	1.05	2.40	2.50	1.84	2.00	5.00
Ca: Mg ratio	20.14	15.61	16.00	21.78	4.00	7.00

### Identification

Identification of the isolates based on cultural characteristics, colony morphology, motility and biochemical characteristics are presented in Table 2 and 3. The bacteria isolates were identified as *Geobacillus* sp., *Bacillus* sp., *Escherichia coli* and *Proteus mirabilis*, while the fungi were *Fusarium oxysporum*, *Aspergillus nomius*, *Penicillium sacculum* (Plate 1), *Mucor* sp. and *Rhizopus* sp.

**Figure 2:** Pure culture of *Penicillium sacculum* growing on sabouraud dextrose agar.

**Table 2:** Cultural and morphological characteristics of microorganisms isolated from the soils of Menengai crater

Microorganism		Cultural characteristics	Morphological characteristics
<b>Bacteria</b>	<i>Geobacillus sp.</i>	Rod shaped cells, 1 $\mu$ m diameter	spores that are slightly ovoid
	<i>Bacillus spp.</i>	large, flat colonies	The endospores were oval or round, cylindrical.
	<i>Escherichia coli</i>	rod-shaped cells, flagellated	No spore formation
	<i>Proteus mirabilis</i>	Swarming non-hemolytic colonies	No spore formation
<b>Fungi</b>	<i>Fusarium oxysporum</i>	Rapidly growing wooly to cottony lemon and yellow	Multicellular distinctive sickle shaped macro coniclia.
	<i>Aspergillus nomius</i>	Very common colours of colony (black and white)	Conidia borne in 360 arrangements covering the upper 2/3 of the conidiophores.
	<i>Penicillium sacculum</i>	Large fluffy white colonies almost covering the whole surface	Non – septate branched hyphal enlarge at the apex to form cornidophorex.
	<i>Mucor sp.</i>	Cream white/large fluffy white colonies almost covering the whole surface	Sporangium comes out directly from the hypha
	<i>Rhizopus sp.</i>	Large fluffy white milky colonies which later turns black as culture ages.	Non-septate hyphal with upright sporagioshere connected by stolon and rhizoids, dark pear-shaped sporagium on hemispherical columella.

**Table 3:** Biochemical characterization of microorganisms isolated from the soils of Menengai crater.

Microorganism		Citrate	Urease	Motility	MR	VP	Indole
<b>Bacteria</b>	<i>Geobacillus spp.</i>	+	+	+	+	-	+
	<i>Bacillus spp.</i>	+	+	+	+	-	-
	<i>Escherichia coli</i>	+	-	+	+	-	+
	<i>Proteus mirabilis</i>	+	+	+	+	-	-
Fungi		Carbohydrate assimilation	Spore formation	Amino acid assimilation	Motility	Hydrolysis	Lipase Activity
	<i>Fusarium oxysporum</i>	+	-	+	-	-	+
	<i>Aspergillus nomius</i>	+	-	+	-	-	+
	<i>Penicillium sacculum</i>	+	-	+	-	-	+
	<i>Mucor sp.</i>	+	+	-	-	-	-
	<i>Rhizopus sp.</i>	+	+	+	-	-	-

**Key:** +: Positive; -: Negative, MR: Methyl Red test, VP: Voges- Proskauer test.

### Isolation of microbes from the soils of Menengai crater

Among the bacteria, *Geobacillus sp.* ranged from  $7.40 \times 10^5$  in region D to  $2.22 \times 10^2$  in region C, *Bacillus sp.* from  $5.34 \times 10^5$  in region D to  $1.43 \times 10^1$  in region C, *Escherichia coli* from  $9.19 \times 10^7$  in region B to  $5.26 \times 10^3$  in region D, *Proteus mirabilis* from  $3.34 \times 10^7$  in region C to  $1.10 \times 10^1$  in region A. The fungus *Fusarium oxysporum* ranged from  $2.20 \times 10^4$  in region C to  $1.50 \times 10^1$  in region D, *Aspergillus nomius* from  $2.40 \times 10^4$  in region B to  $2.40 \times 10^1$  in region D, *Penicillium sacculum* from  $2.10 \times 10^4$  in region C to  $1.60 \times 10^2$  in region D, *Mucor sp.* from  $2.20 \times 10^4$  in region C to  $2.30 \times 10^1$  in region D, *Rhizopus sp.* from  $3.49 \times 10^4$  in region C to  $1.96 \times 10^2$  in region D (Table 4). The bacterial ( $F=0.95$ ,  $P=0.44$ ) and fungal ( $F=29.83$ ,  $P=0.00$ ) isolates in this study varied significantly.

**Table 4:** Microbial colony forming units from soil samples obtained from Menengai crater

Microorganism		Region A	Region B	Region C	Region D	Mean
<b>Bacteria</b>	<i>Geobacillus sp.</i>	$5.60 \times 10^4$	$5.00 \times 10^2$	$2.22 \times 10^2$	$7.40 \times 10^5$	<b><math>1.99 \times 10^5</math></b>
	<i>Bacillus sp.</i>	$2.32 \times 10^4$	$5.70 \times 10^1$	$1.43 \times 10^1$	$5.34 \times 10^5$	<b><math>1.40 \times 10^5</math></b>
	<i>Escherichia coli</i>	$3.59 \times 10^4$	$9.19 \times 10^7$	$4.15 \times 10^7$	$5.26 \times 10^3$	<b><math>3.35 \times 10^7</math></b>
	<i>Proteus mirabilis</i>	$1.10 \times 10^1$	$5.32 \times 10^6$	$3.34 \times 10^7$	$2.10 \times 10^2$	<b><math>9.68 \times 10^6</math></b>
<b>Fungi</b>	<i>Fusarium</i>	$3.40 \times 10^2$	$1.50 \times 10^4$	$2.20 \times 10^4$	$1.50 \times 10^1$	<b><math>1.09 \times 10^4</math></b>
	<i>oxysporum</i>					
	<i>Aspergillus nomius</i>	$9.30 \times 10^1$	$2.40 \times 10^4$	$1.90 \times 10^4$	$2.40 \times 10^1$	<b><math>4.42 \times 10^4</math></b>
	<i>Penicillium</i>	$2.10 \times 10^2$	$1.10 \times 10^4$	$2.10 \times 10^4$	$1.60 \times 10^2$	<b><math>8.09 \times 10^3</math></b>
	<i>sacculum</i>					
	<i>Mucor sp.</i>	$4.20 \times 10^2$	$1.20 \times 10^4$	$2.20 \times 10^4$	$2.30 \times 10^1$	<b><math>8.66 \times 10^3</math></b>
	<i>Rhizopus sp.</i>	$2.80 \times 10^3$	$2.27 \times 10^4$	$3.49 \times 10^4$	$1.96 \times 10^2$	<b><math>1.52 \times 10^4</math></b>

## DISCUSSION

The chemical characteristics of soils obtained the current study are typical of volcanic calderas. The results concur with a previous study carried out in Manikaran, Himachal Pradesh (Sunita and Kanwar, 2016). According to Waithaka *et al.*, (2015), this could be attributed to formation of soils of menengai from solidification of magma. However the low phosphorus content observed in this study differed with a study carried out elsewhere (Jugran *et al.*, 2015) which may be due to differences in the parent material from which the magma was formed prior to volcanic activity (Gagliano *et al.*, 2014).

Although Menengai crater presents a hostile environment for microbial growth, the number of microbial isolates was high (Table 4). This could be explained by the capability of microbes to change their genetic constitution so as to suite different environments.

According to Sharma *et al.*, (2013) microorganisms are in a constant mission of making themselves better so as survive in the ever changing microbial niches.

The high numbers of *Bacillus sp.* witnessed in this study agree with a study previously carried out by Ramanadevi *et al.*, (2013). This could be attributed to the ability of *Bacillus sp.* to form spores which are resilient to changing and environmental conditions (Connor *et al.*, 2010). In contrast, the number of *E. coli* isolates in this study was higher than those obtained in Japan (Guo *et al.*, 2014). The presence of humans and animals in national reserves leads to increased isolation of *E. coli* (Dhiva *et al.*, 2016) which may have led to the differences.

A study carried out in Nigeria by Umar *et al.* (2016) obtained higher levels of *Proteus mirabilis* than the current study. This could be attributed to differences in the samples from which the bacteria were isolated. *Proteus mirabilis* is essentially a pathogen, hence its isolation from environmental samples largely originates from poor disposal of human wastes (Umar, *et al.*, 2015).

On the other hand, the isolation of *Fusarium oxysporum* agreed with a study carried out elsewhere (Rohilla and Salar, 2012). This could be attributed to the type of samples from which the fungus was isolated coupled with the fact that the fungus is a spore former (Das and Anitha, 2011). However the values of *Aspergillus nomius* and *Penicillium sacculum* obtained in this study were lower from those that were obtained from India (Mamta *et al.*, 2013). This difference may have resulted from differences in environmental conditions from the two study areas.

In a study carried out in polyhouse agriculture soil of Rajasthan India, Jasuja *et al.*, (2013) observed that *Mucor sp.* and *Rhizopus sp.* are common fungi in soils. This may explain the high number isolated in this study because the two study sites experiences high temperatures. Contrary to these findings, Karthik *et al.*, (2012) obtained very low values for the fungi from volcanic agricultural waste dump soil. This may be due to constant spraying of crops grown in the region with fungicides, while as volcanic soils of the current study were obtained from virgin caldera that has never been cultivated.

## **CONCLUSION**

The current study establishes that the chemical characteristics of soils obtained from Menengai geothermal caldera are typical of soils formed from solidification of magma. Some of the mineral elements are at the levels toxic to growth of microorganisms. However, the number of isolated microorganisms suggest that they have developed the necessary mechanism to enable them survive in this hostile environment.

## **RECOMMENDATION**

Currently, there are a lot of activities going on in Menengai crater. Cutting down of trees for charcoal burning is a normal scenario, followed by geothermal exploration and intensive grazing. This may have had a negative impact on the microbial diversity in the soils of this important geographical region. There is a need to rehabilitate the caldera to avoid further negative effects on this important volcanic site.

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## **CONFLICT OF INTEREST**

Authors declare that they have no conflict of interest.

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## TYPE AND QUANTITY OF MARINE DEBRIS AT SELECTED PUBLIC BEACHES IN SABAH (TG. ARU & KOSUHOI) DURING DIFFERENT MONSOON SEASONS

Julyus Melvin Mobilik<sup>1\*</sup>, Teck Yee Ling<sup>1</sup>,  
Mohd Lokman Bin Husain<sup>2</sup>, and Ruhana Hassan<sup>1</sup>

<sup>1</sup>Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Malaysia

<sup>2</sup>Institute of Oceanography and Environment, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

\*Email: julyus.mobilik@gmail.com

**ABSTRACT.** *Marine debris is widely distributed at the coastal area of the global oceans, but their specific sources, quantities and distribution remains inconclusive. Although the threat from marine debris pollution has beginning to be recognized in Malaysia, comprehensive studies are still lacking to document the pollution. This study has adopted a standard method of beach marine debris survey to assess the type, amount and sources of debris on a one kilometer section in Tg. Aru and Kosuhoi beaches, Sabah, during surveys in December 2012 (northeast monsoon, NEM), May 2013 (intermediate monsoon, IM) and July 2013 (southwest monsoon, SWM). The mean total debris items was  $1,220 \pm 532$  items/km and weighing at  $52.8 \pm 17.2$  kg/km, where, Kosuhoi beach (1,241 items/km or 57 kg/km) received substantially greater quantities of debris compared to Tg. Aru beach (1,199 item/km or 48 kg/km). Total debris items were more abundant during SWM (1,789 items/km) compared to NEM (1,139 items/km) and IM (733 items/km) seasons. Plastic category objects were the most numerous amounting to 1,057 item/km (86.64%) in total debris items. Clear plastic bottles, food wrappers, plastic fragments, colored plastic bottles and cups were the most abundant objects collected which they contributed 606 items/km (49.69%) from the total debris item collected. The main source of debris objects abundance was from common source which contributed 52% from the total debris objects, whereas, those from terrestrial and marine sources contributed 32% and 16% respectively. The high percentage of terrestrial and common sources debris require marine environment stakeholders to diversify their approach and priority in mitigating this alarming result especially during SWM period. Awareness program was an effective preventive measure that should be continued and intensified. However, the program should focus on target group to ensure the awareness effectiveness to reduce if not totally eliminate the debris in the marine environment.*

**KEYWORDS.** Beach pollution, plastic, monsoon seasons, marine debris source, Sabah

## INTRODUCTION

Marine debris can be found on coastal areas or surfaces of the ocean as a result of improper handling of rubbish that may derived from land, blown by winds, intentionally dumped from shore and from ocean-based activities (Somerville *et al.*, 2003; Horsman, 1982). Marine source debris is light weighted and can travel long distance which may result in ingestion and entanglement to marine wildlife (Derraik, 2002; Ryan & Moloney, 1993) beside threaten global biodiversity through colonization of alien marine organism (Barnes, 2002).

Marine debris can be found in Malaysian beaches, however, less attention is given as compared to water quality and toxicology pollution (Ngah *et al.*, 2012; Abdullah *et al.*, 2011; Law & Hii, 2006). The local government is the responsible body in managing solid waste found on beaches and enforcing Uniform (Anti-Littering) by-Laws 2010. This regulation may impose a compound of not more than RM 500 to littering offenders in public areas. However, only beaches in the urban areas are maintained by local authorities or appointed contractors. Furthermore, the presence of marine debris is not regulated and law enforcement in beaches is difficult (Agamuthu *et al.*, 2012).

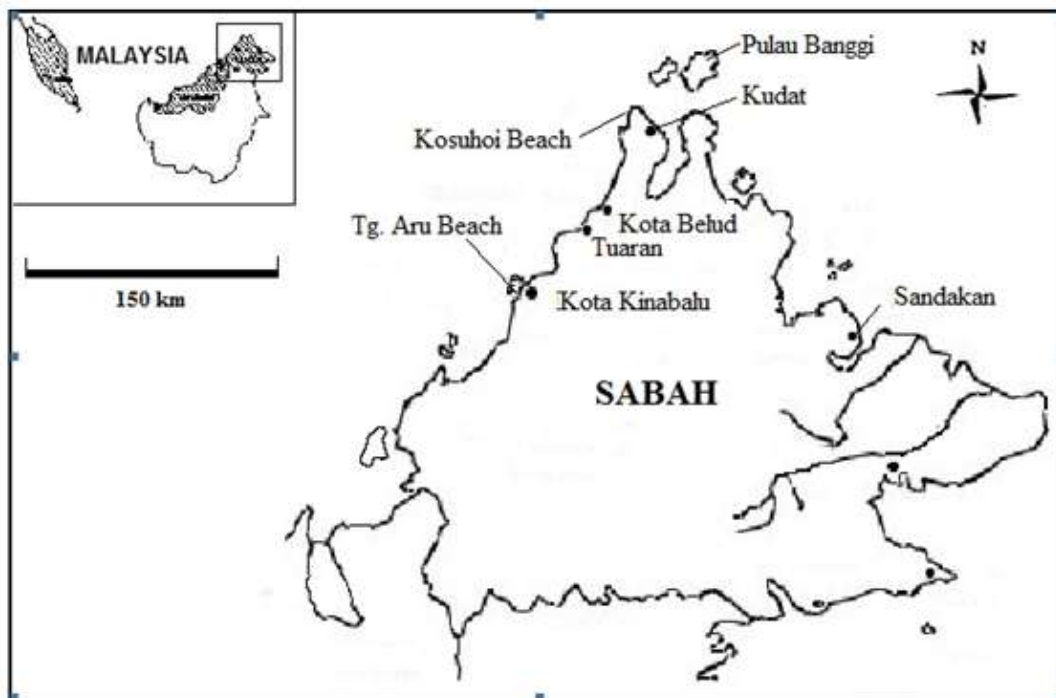
Previous marine debris study in Malaysia had applied various survey methods only during northeast monsoon (NEM) season. Those studies found plastic materials as the most abundant type of marine debris found in Port Dickson (Khairunnisa *et al.*, 2012), Sarawak (Hassan & Mobilik, 2012) and Terengganu (Chan *et al.*, 1996) beaches. Among the identified debris, 65% were from land-based debris, include; food wrappers, plastic shopping bags, cardboard cartons, aluminum cans, cloths, clear and colored plastic bottles. Although, these studies gave an overview debris pollution level in Malaysia beaches, however, were insufficient to generalize the contamination level and effects of marine debris on Malaysian beaches.

This paper presented the data collected for surveys at Kushoi and Tanjung Aru beaches conducted on December 2012(NEM), May 2013(IM) and July 2013(SWM). This study assessed debris abundance during different monsoon seasons, categorized them by type of materials, and determined possible sources/origin. In addition, wind exposure of the beach was explored to determine marine debris abundance under different monsoon wind conditions.

## MATERIALS & METHODS

### Study Area

Two beaches had been selected for this study namely Tg. Aru and Kosuhoi beaches situated in the west coast of Sabah (Figure 1). These beaches were chosen due to factors that may contribute to garbage accumulation, including adjacent to residential areas, major shipping routes, popular among beach visitors and meteorological influence (Khairunnisa *et al.*, 2012; Garcon *et al.*, 2010; Walker *et al.*, 2006). Tg. Aru beach is popular among visitors located 7.4 km from Kota Kinabalu City. Whereas, Kosuhoi beach adjacent to village land, resort and privately owned land with one public entrance to the beach, located at the tip of Borneo Island, 28.3 km from Kudat town. Due to the location of Tg. Aru beach is within the urban area, regular schedule of rubbish collection of at least twice a week are maintained by the local authority appointed contractor. Unlike Kosuhoi beach, beach clean-up were organized and initiated regularly by villages, hotel and resort operators since there was no schedules of rubbish collection. Facing South China Sea, these beaches were exposed to swells and wind waves between 1.0-2.0 m during the NEM, 1.0-1.5 m during IM and 1.0-1.5 m during SWM seasons from the South China Sea (Chiang *et al.*, 2003). The directions of wave in Malaysia are influenced by the monsoon winds.



**Figure 1:** Map showing sampling sites involved in this study

## Survey Methods

Beach surveys were conducted at the study sites during the NEM, IM and SWM seasons (Table 1) according to standing crop method (Cheshire *et al.*, 2009). Identification of the starting and ending points of one km along the beaches were measured and recorded. During low tide, samples other than fragments smaller than 0.25 cm<sup>2</sup> covering from the high tide mark to the low tide mark at each study sites were collected and sorted into six categories; plastic, rubber, metal, glass, wood and cloth (Ribic *et al.*, 1992), then each category was further sorted into objects. Each sample collected was then identified according to potential source of origin according to list of items proposed by Ribic (1998) and were categorized as: marine, terrestrial and common sources. Common source refers to objects that could be originated from either terrestrial or marine sources. Results were presented in two different units; number of items (items/km) and weight (kg/km).

**Table 1:** Study sites with their respective GPS coordinates correspond to start and end points.

Study Site	Start Point	End Point	Sampling date	Beach Characteristic
Tg. Aru	05° 56' 4.1" N 116° 2' 48.6" E	05° 56' 29.3" N 116° 2' 47.5" E	NEM-6.12.12 IM-6.5.13 SWM-19.7.13	-7.4 km from Kota Kinabalu city -Public beach with one entry - Length 2.2 km - Width 30 m
Kosuhoi	07° 1' 24.3" N 116° 44' 39.1" E	07° 1' 53.4" N 116° 44' 47.4" E	NEM-21.12.12 IM-8.5.13 SWM-21.7.13	-28.3 km from Kudat town -163.4 km from Kota Kinabalu city -Public beach with one entry - Length 2.4 km - Width 30 m

## Beach Exposure

The wind and wave condition may determine the direction of floating debris that was present on the beach (Garcon *et al.*, 2010; Keddy, 1984). Using a method adopted from Keddy (1984), wind exposure was calculated for Tg. Aru and Kosuhoi beaches using Equation (1);

$$REI = \sum_{i=1}^{16} (V_i P_i F_i) \quad (1)$$

where REI is Relative Exposure Index,  $i$  is the cardinal wind direction 0° to 360° for every 22.5° interval;  $V_i$  is the average wind speed (km/h);  $F_i$  is the fetch distance (km); and  $P_i$  is the percent frequency from which the wind blew within each wind directions.

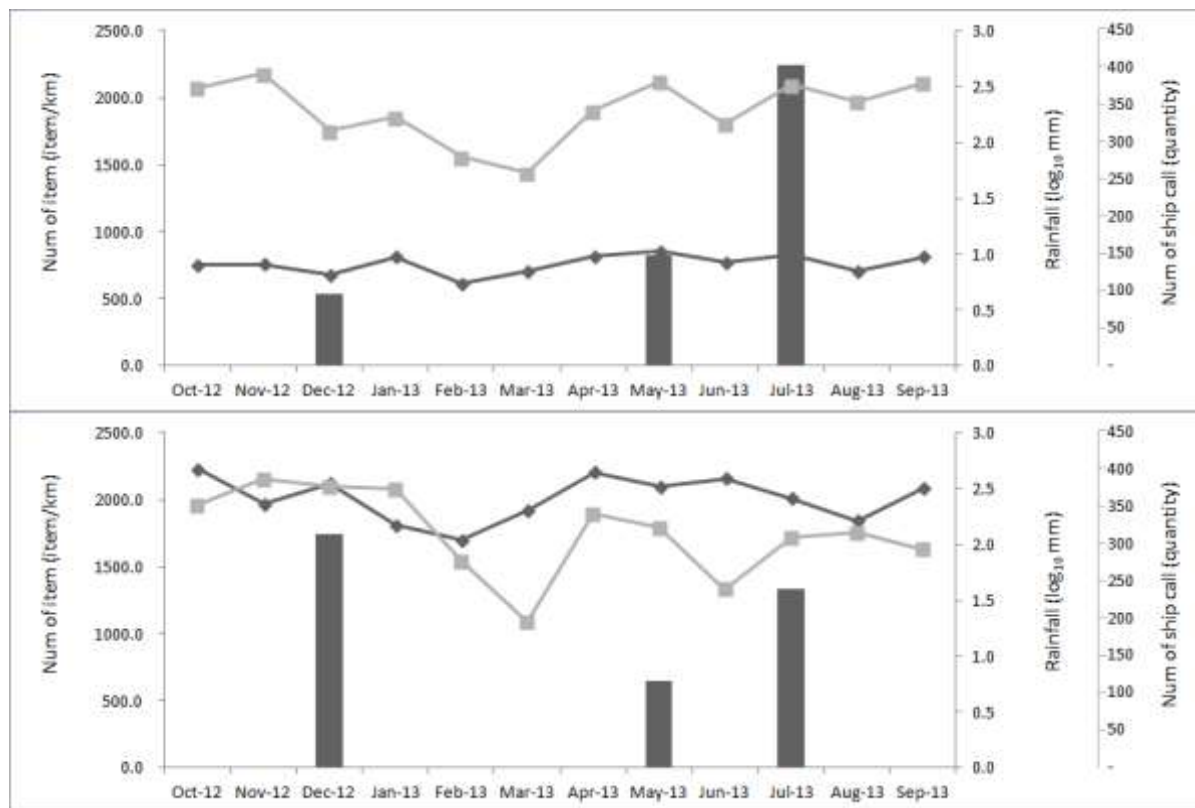
The REI is then normalized by dividing the site REI value with the average of total REI values. The calculated REI value was then rank following and adopted the proposed method by Guannel *et al.*, (2011) and Gornitz *et al.*, (1994)), from very low exposure (rank=1) to very high exposure (rank=5). The statistical software package R openair (Carslaw & Ropkins, 2014) was used to develop wind rose diagram using data collected by the Malaysian Metrology Department at Kota Kinabalu and Kudat weather observation stations.

For statistical analysis, relationship between total debris items (items/km), number of ships call to the port, rainfall, wind exposure (REI) and the total debris weight (kg/km) were analyzed using Pearson's correlation. If this test indicated significant difference, a linear regression model was used to identify the variable contributed to the total debris items abundance. Paired *t*-test was used to compare total debris items between debris categories and debris sources according to the study sites and monsoon seasons. All the data analyses were conducted using SPSS version 22.

## RESULTS & DISCUSSION

### Debris Abundance

A total of 7,320 items weighing at 316.3 kg were collected and sorted over the study period. This represented a mean total debris item accumulated of  $1,220 \pm 532$  items/km and weight of  $52.8 \pm 17.2$  kg/km respectively. The means which the total debris item accumulated during SWM season ( $1,789 \pm 640$  items/km) was higher when compared to NEM and IM at  $1,139 \pm 853$  items/km and  $733 \pm 122$  items/km respectively. Tg. Aru beach accumulated the highest total debris during IM and SWM at 819 items/km and 2,241 items/km respectively. Whereas, Kosuhoi beach had the highest amount of debris during NEM season (1,742 items/km). In terms of weight, the mean total debris weight was higher during SWM ( $63.8 \pm 24.0$  kg/km) season as compared to NEM ( $61.6 \pm 40.7$  kg/km) and IM ( $32.9 \pm 1.2$  kg/km) seasons. Kosuhoi beach had the heaviest debris accumulated during NEM and IM seasons at 90.3 kg/km and 33.7 kg/km respectively. While, Tg. Aru beach had the highest total debris weight during SWM at 80.4 kg/km. This indicated the increasing number of marine debris items stranded on beaches was a growing problem, which was related to solid waste pollution, depleting beaches aesthetical value, loss of economic revenue and possible invasion of alien organisms (Browne *et al.*, 2011; Barnes *et al.*, 2009; Barnes, 2002; Derraik, 2002). When compared monsoon seasons with higher total debris items accumulation were not significantly correlated with numbers of ship ( $r=0.26$ ) visiting to ports nearest to the study sites at Kota Kinabalu and Sandakan ports during the same month, with more debris items actually collected during SWM at Tg. Aru beach during low numbers of ship calls (Figure 2). The irregular distribution of rainfall ( $r=-0.36$ ), showed no significant correlation with total debris items abundance. However, total debris items (items/km) were significantly correlated ( $p<0.05$ ,  $n=6$ ) with total debris weight ( $r=0.91$ ). Linear regression result ( $R^2=0.96$ ,  $p<0.05$ ) showed total debris item increased by 23 items/km for every one kg/km ( $\beta=0.98$ ,  $t=11.63$ ,  $p=0.00$ ).



**Figure 2.** Comparison numbers of ships call (—◆—), rainfall (—■—) and total number of items (■) accumulating on (A) Tg. Aru and (B) Kosuhoi beaches.

## Debris Category

The total debris items according to category (Table 2) showed plastic category contributed 1,057 item/km (86.64%) ranging from clear plastic bottles, plastic fragments, cups, packaging, food wrappers, plastic bottle caps, colored plastic bottles to plastic shopping bags. Similar studies (Rosevelt *et al.*, 2013; Barnes *et al.*, 2009; Walker *et al.*, 2006) also recorded that plastic-based objects were dominant. When compared these study site plastic category abundance to other studies in the region (Table 3), Tg. Aru accumulated the highest for plastic category. Relatively big size plastic-based materials would transform into plastic fragments through degradation process (O'Brine & Thompson, 2010) and remain contaminating the beach environment (Khairunnisa *et al.*, 2012; Barnes *et al.*, 2009) if effort to eliminate the source is neglected. Other categories contributed 13.36% to the overall composition. In term of weight, plastic category represents 58.65% of the total debris weight. Objects contributed 22.29% of the total debris weight in rubber and glass categories includes; glass bottle from kitchen household (*e.g.* ketchup), alcohol bottle and footwear. Clear plastic bottles, food wrappers, plastic fragments, colored plastic bottles and cups were the most abundant objects collected which they contributed 606 items/km (49.69%) from the total item collected (Table 4). However, in terms of weight they only contribute 14.8 kg/km



(28.14%). A paired samples *t*-test result shows that total debris item in plastic category was significantly difference ( $p=0.006$ ,  $n=6$ ) between rubber ( $1,021\pm553$  items/km), metal ( $1,013\pm528$  items/km), glass ( $1,056\pm569$  item/km), wood ( $1,055\pm569$  items/km) and cloth ( $1,048\pm564$  items/km) categories.

**Table 2:** Total number of items (item/km) and weight (kg/km) according to debris categories.

No.	Category	No. of item	% of total	Weight	% of total
1	Plastic	1,057	86.64	30.9	58.65
2	Wood	51	4.21	2.0	3.86
3	Metal	43	3.54	4.8	9.11
4	Rubber	35	2.90	6.1	11.60
5	Glass	25	2.01	5.6	10.69
6	Cloth/Fabric	9	0.71	3.2	6.10

**Table 3:** Comparisons of the percentage debris items represented by plastics on beaches in the present study with literature values.

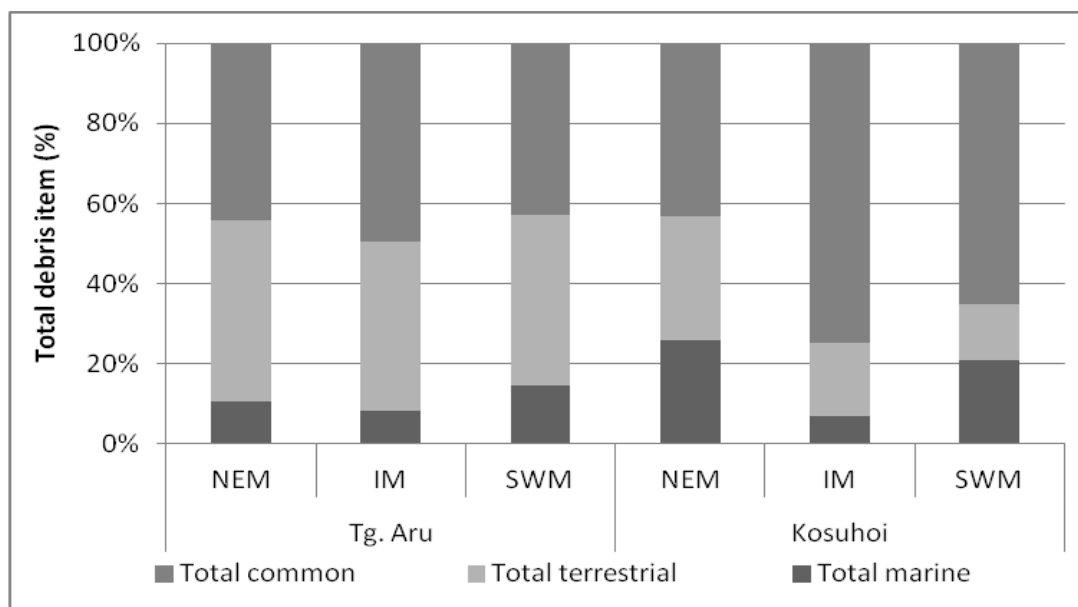
No.	Study Site	Percentage of debris items represented by plastics	Reference
1	Japan	92.2	Kusui & Noda, 2003
2	Tg. Aru	90.0	Present study
3	Sarawak	87.8	Mobilik <i>et al.</i> , 2014
4	Taiwan	85.5	Kuo & Huang, 2014
5	Kosuhoi	83.4	Present study
6	Mengabang Telipot, Terengganu	67.0	Chan <i>et al.</i> , 1996
7	Port Dickson	55.7	Khairunnisa <i>et al.</i> , 2012
8	Indonesia (23 Islands)	50.3	Willoughby <i>et al.</i> , 1997
9	Northern South China Sea	42.0	Zhou <i>et al.</i> , 2011

**Table 4:** Ten most numerous objects found at the survey site.

No.	Objects	Tg. Aru		Kosuhoi		Total	
		item/km	kg/km	item/km	kg/km	item/km	kg/km
1	Clear plastic bottles	118	4.2	284	6.9	201	5.6
2	Food wrappers	170	2.4	61	2.5	116	2.5
3	Plastic fragments	199	2.9	12	1.1	105	2.0
4	Coloured plastic bottles	65	2.3	122	4.6	94	3.5
5	Cups	108	1.5	74	1.2	91	1.4
6	Bottle caps	86	0.5	83	1.4	84	1.0
7	Plastic food wrapper	122	1.5	37	0.5	79	1.0
8	Others (Plastic)	57	1.7	98	1.4	78	1.6
9	Packaging	41	0.6	90	1.6	66	1.1
10	Cardboard cartons	37	2.0	65	2.1	51	2.0

## Debris Source

The proportion of debris sources reflected the abundance of debris items in Kosuhoi beach was seasonal (Figure 3). Overall, common source represented the majority of items collected (52%), followed by terrestrial (32%) and marine (16%) sources. The highest debris items found in this study was associated with household trash such as detergent plastic bottles, cooking oil plastic bottles, food wrappers, plastic shopping bags, plastic drinks straws, cosmetic plastic bottles, aluminum beverages cans, broken plastic toys and ketchup glass bottles. A study by Jayasiri *et al.*, (2013) and Walker *et al.*, (2006) also concluded land-based debris source was the highest debris items found on the beaches. Similar results obtained during this study were possibly due to the close proximity of coastal villages and inhabited islands with study sites since municipal did not provide waste disposal service to the islands and villagers (Daily Express Newspaper online, 2014).



**Figure 3:** Percentage of debris by sources according to monsoon seasons at the study sites.

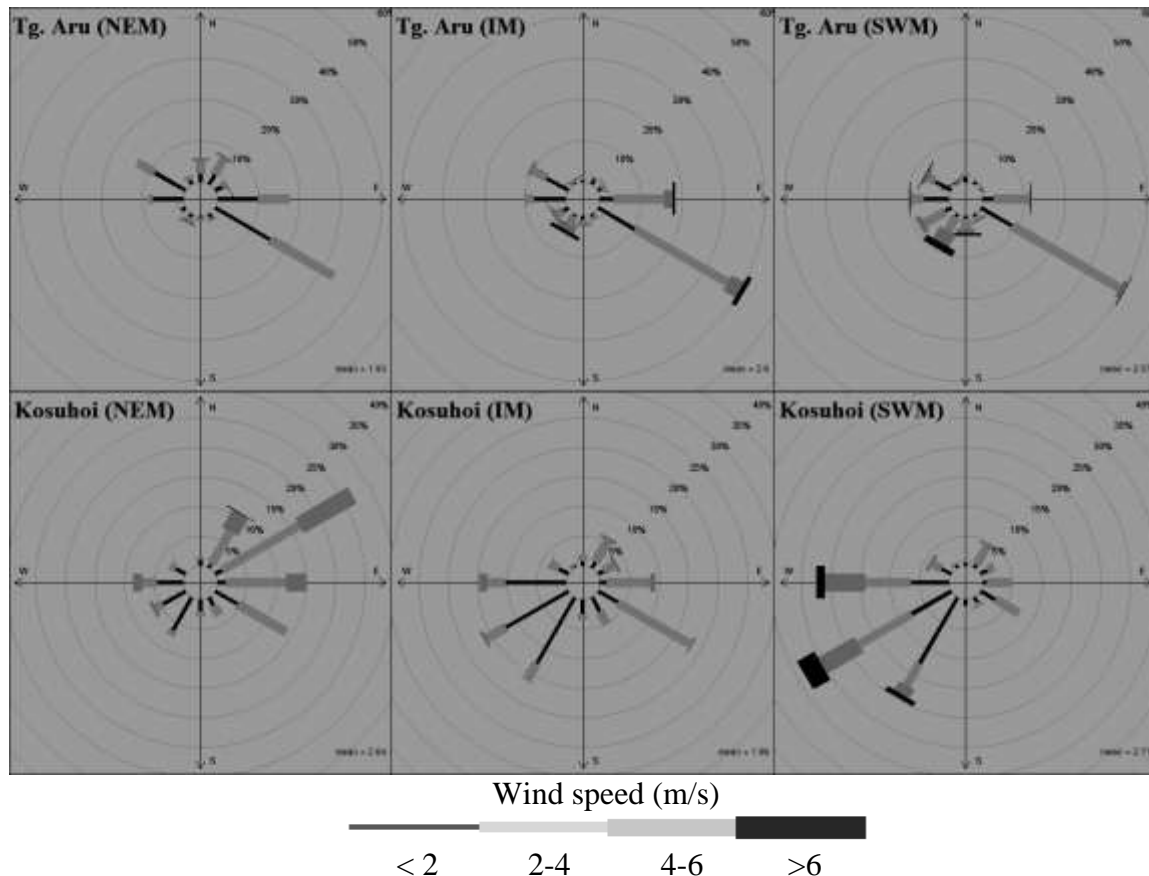
A paired samples *t*-test result showed that there was a significant difference ( $-363 \pm 153$  items/km;  $p < 0.01$ ,  $n = 6$ ) of total debris items between marine ( $174 \pm 142$  items/km) and common ( $537 \pm 236$  items/km) sources. This provided indication that the amount of debris and pollutant increased after rain events as a result of runoff flows along the ground in the urban area, rubbish eventually entered into river and the ocean (Gasim *et al.*, 2013; Waters *et al.*, 2011; Silva-Cavalcanti *et al.*, 2009; Golik & Gertner, 1992). The other possibility was the effect of longshore drift (Taffs & Cullen, 2005; Sonu *et al.*, 1966), since the coastal villages along Putatan river located within 2 km from Tg. Aru beach. For the villagers, throwing garbage into the water was an easy alternative method for rubbish disposal. Relatively high amount of plastics had been recorded, possibly because plastic were cheaply available.

Despite high volume of vessel traffic within Sabah coastal state water, the amount of debris items from marine source were less abundant, which included; clear and colored plastic bottles from other country, used navigational light bulbs and plastic lubricating oil bottles. Similar studies (Barnes *et al.*, 2009; Walker *et al.*, 2006; Otley & Ingham, 2003) also observed an inverse relationship between number of vessel and debris items accumulation. Although, these results suggested that illegal discharge occurred infrequently, however, the presence of debris items associated with shipping activities indicated that not all vessels complied to the new revised Annex V of the MARPOL 73/74 (International Maritime Organization, 2012) which prohibited discharge of all types of plastics material and required a port to provide facilities to receive shipborne garbage from any vessel that required garbage disposal service.

Analyzing debris objects origin, only 20% were still affix with labels indicating country of origin. Malaysia (82%) was the major sources, followed by Indonesia (7%), Singapore (2%), Thailand (2%), China (1%), Australia (1%) and Vietnam (1%). The highest objects affix label indicating the country origin were clear plastic bottles (45%), food wrappers (24%) and colored plastic bottles (17%). Kosuhoi beach accumulated the most objects for clear plastic bottles (68%) and colored plastic bottles (63%), while, Tg. Aru beach accumulated for food wrappers (56%) object. These objects were the highest during SWM seasons. The result showed that the 94% of the clear plastic bottles originated from Malaysia. Although domestic regulations and conventions might be in place for the prohibition of ocean dumping of waste materials, the temptation to ignore the regulation was obvious, particularly when enforcement was relaxed. Thus, monitoring national regulation compliance and efficient enforcement measures were necessary.

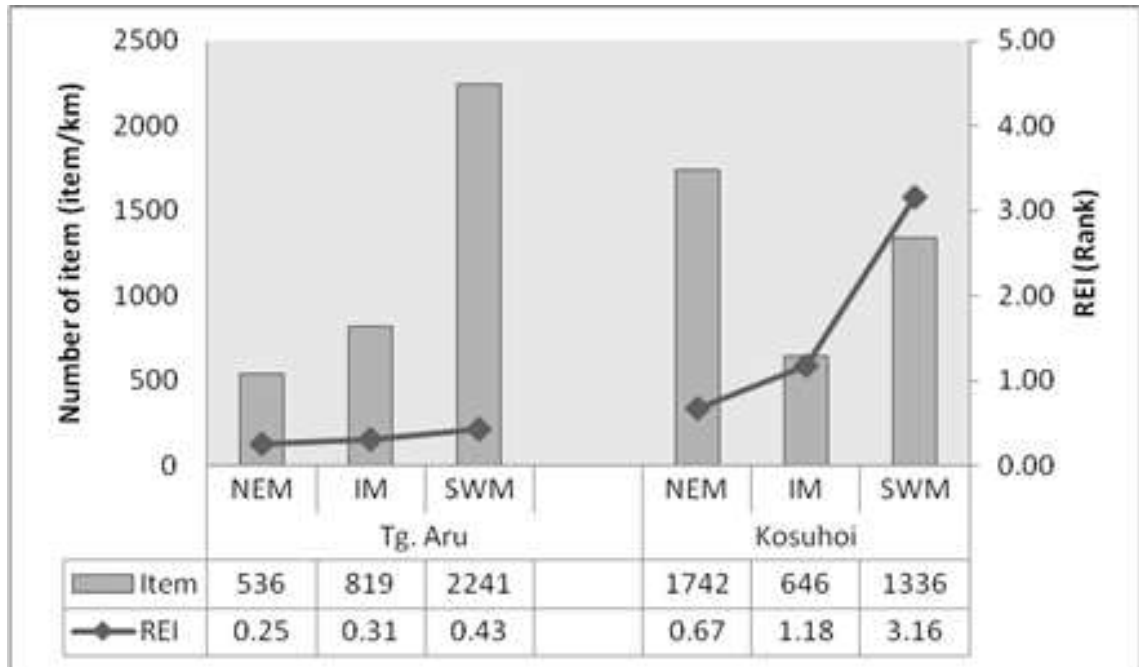
### **Relative Exposure Index**

Although the study sites faced west, the prevailing winds at Tg. Aru beach were from the southeast during the monsoon seasons, whereas, Kosuhoi beach corresponded with the monsoon seasons prevailing winds (Figure 4). The frequency of southwest wind during SWM season in Kosuhoi beach was 48% at maximum wind speed of 8.75 m/s, while, the frequency of northeast wind was 38% with maximum wind speed of 6.69 m/s during NEM season. From wind exposure analysis, the REI rank value during the monsoon seasons was higher at Kosuhoi beach compared to Tg. Aru beach (Figure 5). This result corresponded with the total debris items accumulated at  $1,241 \pm 554$  items/km ( $57.0 \pm 29.6$  kg/km) and  $1,199 \pm 914$  items/km ( $48.4 \pm 27.7$  kg/km) at Kosuhoi and Tg. Aru beaches respectively. Although, Kosuhoi beach showed a positive relationship between REI value and total debris items during IM and SWM seasons (Figure 5), statistical analysis showed no significant correlation ( $p > 0.05$ ,  $r = 0.06$ ,  $n = 6$ ). This analysis explained, a higher total debris items accumulated during NEM compared to SWM season when REI value ranked lower at Kosuhoi beach. In contrast, Tg. Aru beach received substantially higher total debris items when the REI value ranked very low wind exposure during the monsoon season.



**Figure 4:** Distribution of wind speed and direction according to study sites and monsoon seasons sampling. Concentric circles represent percent frequency of occurrence during monsoon season.

Previous studies suggested that REI was a possible indicator to determine marine debris accumulation, besides providing a summary of the wind exposure on the beach (Garcon *et al.*, 2010; Walker *et al.*, 2006; Rodil & Lastra, 2004; Keddy, 1984). Although, wind exposure might have influenced the abundance of debris items in Kosuhoi beach, the REI analysis in this study was statistically inconclusive. Therefore, comprehensive and long-term monitoring along the coastline of Sabah should be carried out to identify relationship between debris item abundance and wind exposure.



**Figure 5:** Relationship between relative exposure index (REI) and number of debris items at the study sites according to monsoon seasons.

## CONCLUSION

The abundance of marine debris was determined in this study. Debris accumulation was higher during SWM seasons ( $1,789 \pm 640$  items/km). Plastic category ( $1,057 \pm 569$  items/km) was the most abundant item which may derived from land-based sources. The general public, villagers, beach visitors, vessel crews, garbage collection contractors, local government authorities and other stakeholders had the ability to reduce marine debris problem, by improving waste reduction, practicing effective waste management and introducing recycling initiatives. At local authority level, municipalities we required to provide waste disposal services to the coastal community to reduce or eliminate garbage disposal into the rivers or the sea. Although, marine environmental education can play an important role in mitigating ocean dumping, this process may take time for successful results. However, instilling the love of marine environment and awareness on the younger generation could mould them into responsible adults. For that reason, it was important to target the appropriate groups such as coastal villagers and vessels crews to initiate mitigation program. Nevertheless, identifying the root cause and introducing solutions to mitigate each garbage categories and sources were essential to ensure total eradication of illegal discharge at sea.

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## A REVIEW ON THE IMPACT OF ANTHROPOGENIC NOISE ON BIRDS

Emily A. Gilbert, Jephthe Sompud\*, Cynthia B. Sompud

Faculty of Science and Natural Resources,  
Universiti Malaysia Sabah, 44800 Kota Kinabalu, Sabah  
E-mail: jefty2003@gmail.com

**ABSTRACT.** *This review addresses the impacts of noise, the vital role of acoustic communication and the response of birds in overcoming the increased anthropogenic noise. The rapid development in human activities nowadays induce the noise that interrupt the acoustic communication of birds. Disturbance of the signals transmission causes detrimental impact on the birds as they are highly depending on the acoustic communication for their survival, territory defense and reproduction. Continuous exposure of the noise then results in the declination of species richness of which have been stated by several past studies. Although most of the studies stated that the negative impact as a consequence from the anthropogenic noise, however there is positive effect contributed by the noise of which are also recorded in other studies. Moreover, the impacts of other variables such as vegetation density that cause major changes to the bird population as compared to noise have also been highlighted in several studies. This indicates that several influencing factors are important in measuring impact that lead to the changes which occur within the bird population. Thus, in depth studies on the impacts of anthropogenic noise towards the species of birds by taking into account other contributing variables are important to enable that noise management to be conducted effectively especially in developing areas as a way in conserving the biodiversity of the bird population.*

**KEYWORDS.** Anthropogenic noise, avian community, bird's population, acoustic communication

### INTRODUCTION

Anthropogenic noise can affect a large scale of natural habitat (Barber *et al.*, 2009). It is not only seen as a highly potential disturbance in affecting the wildlife across the global landscape (Blickley and Patricelli, 2010) but also being regards as one of the factors that causes serious impact on the ecology (Forman and Alexander, 1998) of which arises the concern towards the biodiversity of the avian community.

Birds play vital roles as the agents for seed dispersal and pollinator (Peh *et al.*, 2005). Apart from that, this taxa is also a biological indicator (Sodhi *et al.*, 2005) that are widely used by other researchers and is capable in determining the health of the habitat's ecosystem (Miller *et al.*, 2004). Most of the previous studies that have been done focus on the impact of the noise on species level and the response of the birds in mitigating this effect. This review will address the impacts of the noise towards the bird, the significant role of acoustic communication to the birds and the response of the birds to overcome the noise.

## **The Impact of Anthropogenic Noise on Bird**

Anthropogenic noise is a current phenomenon that disturbs the acoustic communication of wildlife (Chan *et al.*, 2010; Luther and Baptista, 2010; Diaz *et al.*, 2011). This type of noise is one of the factors that has a significant effect on the habitat quality of birds (Habib *et al.*, 2007; Bayne *et al.*, 2008). The serious impacts of the anthropogenic noise toward the bird population have been documented in several studies that of which not only looking on the effect at species and population level, but also on the aspect of restricting the ability of the bird itself. Most of the published studies about anthropogenic noise are done in Europe and American countries, however it is still very scarce in Asian countries, such as Malaysia.

The impact of the noise from the population level perspective shows negative changes in the avian population behaviour based on study done by (Brumm, 2004). Several studies such as (Bottalico *et al.*, 2015; Dutilleux, 2012) have found that the increase of noise causes a decrease in the population density of bird. On the contrary, this finding is opposite from study conducted by (Wiacek *et al.*, 2015) as their result shows that there is no impact received by the bird population from the anthropogenic noise as the bird population is majorly affected by the forest edge effect. This has shown that the availability of various food source along forest edge has outweighed the effect of noise by attracting the birds to forage at that area (Helldin and Seiler, 2003).

To date, the effect of noise at species level have been documented in previous studies such as by (Kight *et al.*, 2012; Arroyo-Solis *et al.*, 2013; Hana *et al.*, 2011; Nordt and Klenke, 2013; Polak, 2014). Goodwin and Shriver (2010) stated that noise derived from human activities is a significant factor that cause the reduction of the number bird species in a habitat. The inability of some species to adapt their acoustic communication in an environment that contain high level of anthropogenic noise has resulted in the decreasing of individuals for that particular species (Francis *et al.*, 2011). Interestingly, the result from the study done by (Summers *et al.*, 2011) shows that the noise exposure does not seem to show any threats towards the species of bird that are being experimented in their study.

There are a few effects that are caused by the extreme anthropogenic noise on the birds' social behaviour. These passive effects such as psychological stress through the increasing of bird heart rate is among the consequences received by the avian in dealing with the high anthropogenic noise level (Slabbekoorn, 2012). According to Herrera-Montes and Aide (2011), the ability of the birds in nurturing and navigating were affected by the extensive noise. Apart from that, the noisy background also hinders them from detecting their predators (Dooling and Popper, 2007) due to the loss of hearing ability (Rabin *et al.*, 2003) as well as impaired them in selecting their mating partner (Bayne *et al.*, 2008).

A study done by Slabbekoorn and Ripmeester (2007) shows that both birds that exhibit high and low frequencies songs received the masking effect of the anthropogenic noise. The masking of the male bird's song that is used to attract female bird can lead to the reduction of pairing (Habib *et al.*, 2007; Swaddle and Page, 2007) and reproduction success (Halfwerk *et al.*, 2011; Reijnen *et al.*, 1996) of that species. However, the result from Meillere *et al.*, (2015) shows that anthropogenic noise is not the main factor that affect the reproduction success of birds. Apart from that, (Francis *et al.*, 2009) discussed that the disturbance on the prey-predator interaction has indirectly causes positive effect to reproduction especially the adaptive species. In addition, (Gonzalez-Orejo *et al.*, 2012) also found that the noise also support the nesting of birds in urban areas.

The interference of the transmission of acoustic signals also affect the fitness of the birds (Nemeth and Brumm, 2010) as it will force them to acquire more energy in overcoming the masking of the anthropogenic noise. Tragically, the declination of the survival rate of the young birds during their early development stage (Schroeder *et al.*, 2012) and the tendency of misdetection towards their parents call (Leonard and Horn, 2012) are also due to the increase of the noise in their surrounding environment. This indicates that birds face extreme challenges to survive in areas that have high level of anthropogenic noise (Diaz *et al.*, 2011).

### **The Roles of Acoustic Communication**

The avian community depends heavily on acoustic signals as their tool of communication for the success in selection of mating partner (Brumm, 2004). The vocal communication is very important to the birds as acoustic signals that are transmitted to receive contained messages about the birds' identity and their ability (Slabbekorn and Ripmeester, 2007). According to (Riebel, 2003; Verziden *et al.*, 2010), these signals are used by the male bird in attracting the female birds during the period of mate selection. The signals are needed to be transmitted well as (Legnage and Slater, 2002) states that birds depend on the transmission of their acoustic signals in order to successfully find their suitable mating partner.

Acoustic communication plays significant role for the survival of the birds as it is part of their defence system to avoid the predators (Brumm, 2004; Santana, 2011) through projection of alarm calls (Potvin *et al.*, 2014). In addition, the birds use the acoustic signals in search for food (Herrera-Montes and Aide, 2011). Hence, it shows that the acoustic communication is important for the survival of the birds particularly in areas that have scarce food.

### **The Response of Birds toward Noise**

There are several studies that have recorded on the response of birds toward anthropogenic noise. However, the response can be different among species from the same family (Francis and Blickley, 2012). Francis *et al.*, (2010) found that differences of the response can be seen through the vocal song features and also their preference in selecting a habitat to mitigate the restriction of anthropogenic noise.

Shifting the time of calling activity is one of the strategy that is used by the birds to avoid the noisy period that interfere their communication (Nemeth *et al.*, 2013; Cartwright *et al.*, 2013). Meanwhile, vocal plasticity exhibited by birds are also found to be effective in adapting in noisy areas (Francis *et al.*, 2011). Parris and Schneider (2008) explains that vocal adjustment is usually used especially for birds that sing in low frequency to communicate in high-traffic site areas. Apart from changing the song frequency, studies by (Slabberkoorn and Ripmeester, 2007; Brumm and Zollinger, 2011) documented that birds also rise the amplitude of their song known as the Lombard effect to mitigate being masked by anthropogenic noise. However, the consequence of this mechanism consumes a lot of energy on the bird (Patricelli and Blickley, 2006). In addition, Cardoso *et al.*, (2011) state that some species of birds increase both amplitude and frequency to overcome the disturbance of their signals transmission by the noise.

The increase of noise in the environment led to the tendency of the birds in abandoning their habitat (Francis *et al.*, 2010; Bayne *et al.*, 2008). According to McClure *et al.*, (2013), the extreme noise can cause birds especially migratory species to move away. This indicates that the migratory birds prefers quieter environment that will enable the communication signals to be transmitted well (Rabin *et al.*, 2003).

## CONCLUSION

In conclusion, anthropogenic noise does cause impacts on the avian community through the disturbance on their acoustic communication. Although most of the reviewed studies reveal the negative impact of the noise, yet there is also positive relationship of the noise toward the birds. Moreover, other factors have also been identified that cause major impact as compared to the noise. Hence, it is recommended that future studies needed to take into account on other variables, such as vegetation density and vehicle in measuring the degree of impact of noise towards the birds, in order to fill the gap of understanding about the effect of this disturbance that will be very useful for noise management especially in the developing areas.

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## BIRD POPULATION IN TWO-YEAR OLD *Acacia mangium* PLANTATION, SABAH FOREST INDUSTRIES SDN BHD

Kee Sze Lue, Jephthe Sompud\*, Lee Woon Jah, Cynthia Boon Sompud, Emily Gilbert

Faculty of Science and Natural Resources, Universiti Malaysia Sabah,  
Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA.  
E-mail: jefty2003@gmail.com

**ABSTRACT.** *Large areas of tropical forest worldwide have been converted rapidly into forest plantation. Plantation can play an important role in restoring productivity, ecosystem stability, and biological diversity to degraded tropical lands. However, the conversion of forest areas to plantation rapidly resulting birds to lose their natural habitat. Therefore, Acacia mangium plantations have the potential as the refuges for birds. As such, this study was conducted to investigate the bird population in a 2-year Acacia mangium plantation, Sabah Forest Industries (SFI), Sabah to determine the bird population density and diversity of 2-year mangium plantation in SFI. There is no published information of the detailed status of birds in SFI yet. Bird survey was done by using point count method. The bird population density was analyzed by using distance 6.2 and bird diversity was calculated by using Shannon-Wiener diversity index. A total of 343 birds belong to 53 species from 21 families were detected. The bird population in this 2-year mangium plantation was 17.71 individuals per hectare, and Shannon-Wiener diversity index for bird diversity was 3.24. This study shows that the bird population density and diversity in SFI were higher as compared to other past studies in Borneo plantation areas.*

**KEYWORDS.** Forest plantation, population density, bird diversity, Acacia mangium, Sabah

### INTRODUCTION

Birds are classified into Aves class, sub Phylum Vertebrata and Phylum chordate (Pettingill, 1985). Birds can act as biological indicators to measure forest health and environmental condition (Gregory & Strien, 2010). Malaysia is rich in biodiversity which contain more than 815 species of birds including water birds and terrestrial birds (Zakaria & Rajpar, 2013). There are about 643 species of bird and 53 of endemic recorded in Borneo, Sabah (Wong, 2012).

The driving force of the world deforestation trend is the conversion of tropical forests to agricultural land that has increased over the past ten years, resulting in birds losing their habitat. Due to increasing world population, the demand for natural resources have become increasingly high, most tropical forest were converted to farmland or plantation (Morelli, 2013). The reason for the conversion of forested areas to plantations was to provide steady and sustainable stream of raw timber material for industries, such as pulp and paper, furniture and construction.

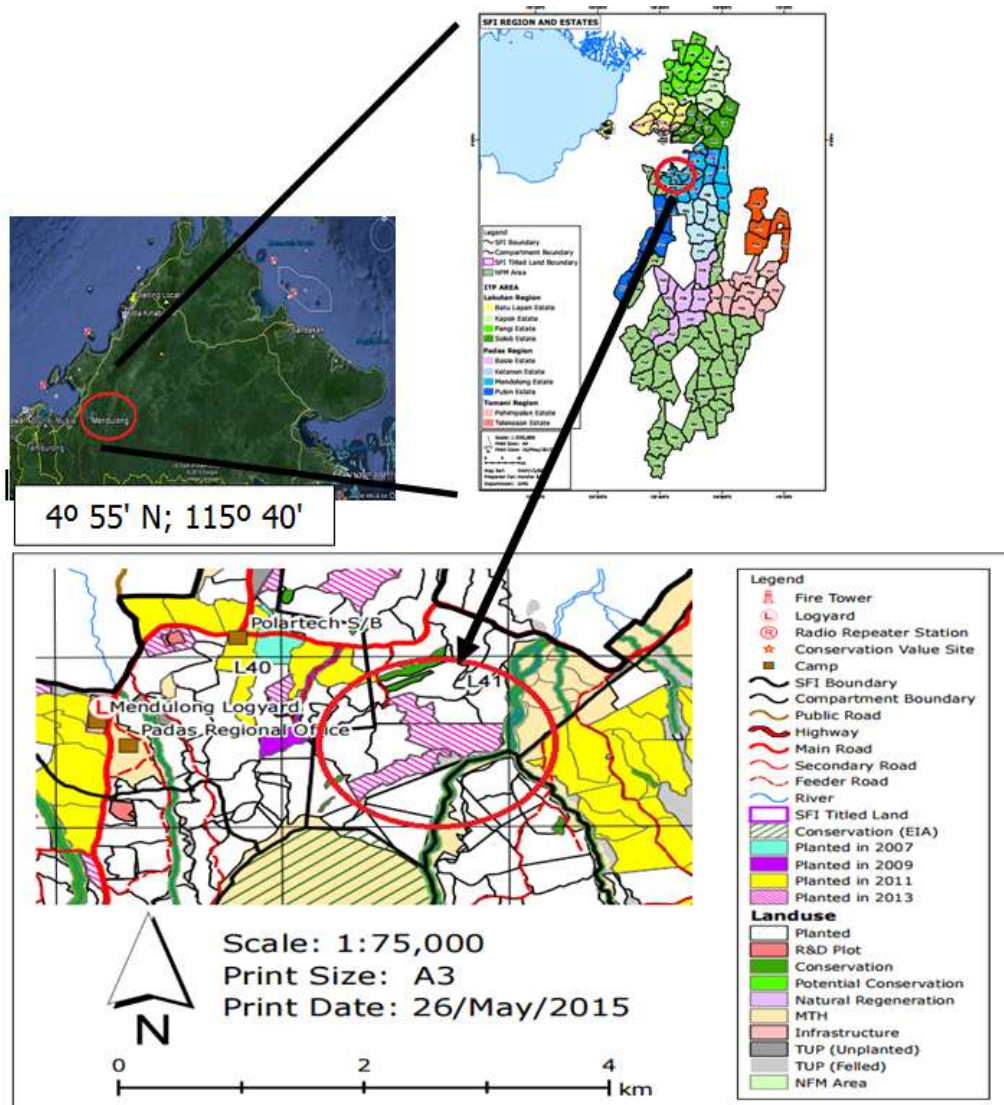
Therefore, industrial plantation was the key to produce timber supply quickly via fast growing tree species (Styring *et al.*, 2011). *Acacia mangium* grows well in Sabah and is recommended for planting in a plantation.

Plantations play an important role in restoring productivity, ecosystem stability, and biological diversity to degraded tropical lands (Parrotta, 1992). *Acacia mangium* plantations can act as secondary habitat or refuges for tropical organisms and aid in the conservation of biodiversity (Lindell *et al.*, 2003). However, there is unpublished information of the status of birds in Sabah Forest Industry (SFI) plantation. Published information regarding bird community in plantation is very scarce. Limited past studies will result poor management plan in plantation and less concern to the environmental impact. Considering the potential of a plantation as an alternative habitat to decreasing areas of natural habitat, the aim of this study is to determine bird population and species in two-year old *Acacia mangium* plantation in SFI is clearly of importance for better management in following age.

## METHODOLOGY

### Study site

The study site was in Mendulong region, Sabah Forest Industries (4° 54' 56.5'' N; 115° 42' 27.6'' E) in the compartment L41 with elevation 342 which is located in the Sipitang district of south-western part Sabah (Figure 1). The area covers 183,316 ha and including Mendulong plantation area. Mendulong Estate of two-year old *Acacia mangium* plantations cover 617.11 ha and two-year old *Acacia mangium* plantation in compartment L41 is covering about 44.18 ha (SFI, 2015). The elevation of compartment L41 Mendulong approximately 415 m above from the sea level. The annual rainfall was approximately 3,757 mm (SFI, 2015). The maximum and minimum temperatures in July to August 2014 are 30°C and 19°C respectively (SFI, 2015).



**Figure 1:** The location of the study site in compartment L41 (Source: SFI, 2015).

## Data Collection

Twenty-one days were spent in the two-year old *Acacia mangium* plantation, Mendulong from 1<sup>st</sup> August to 21<sup>st</sup> August 2015 to obtain reliable estimates and increased precision of result data (Rajpar & Zakaria, 2010). Standard point count method was carried out and species of birds were identified through direct observation from 0630 hr to 1130 hr by using a pair of binoculars (10 X 40) because the best time for the bird observation was morning (Zakaria *et al.*, 2009). When it was raining, birds were not to be surveyed because cold weather shut down bird activity (Ralph *et al.*, 1993). During each point count survey, each individual of bird detected by sighting were recorded in point count data form and identified on the spot

using field guide “Birds of Borneo” (Wong, 2012) and “Field Guide to The Birds of Borneo” (Phillipps & Phillipps, 2014). Only birds that perched in a tree were recorded for standard survey and birds on flight were recorded as opportunities survey (Zakaria & Rajpar, 2010).

A total of 25 point count stations were established for bird survey in two-year old *Acacia mangium* plantation, Mendulong. Five point counts were set in one transect line with five replicates. The length of transect line was set as 250 m. A 20 m distance was established before start the first point count station to avoid forest edge. Transect lines were parallel to each other, which were established using mapping compass. The interval between points counts stations were 50 m. The distance between the transect line was 50 m. Points were spaced closely together to provide a comprehensive inventory (Styring *et al.*, 2011). At least four transect lines or 1000 m was done by a day. The observation last exactly for 5 minutes at each point count station (Mojiol *et al.*, 2008). Five minute observation in each point count enables to record sufficient number of individuals with minimal efforts and disturbance (Rajpar & Zakaria, 2010).

### Data Analyses

Distance 6.2 software was used to estimate the population density of bird (Buckland *et al.*, 2009). All data were truncated at 20 m to remove any outlying records and also improve model fit (Mallari *et al.*, 2011).

The Shannon’s Index of Diversity ( $H'$ ) is a mathematical statistic index to determine the evenness and species richness in a region. The value of Shannon’s Index of Diversity ( $H'$ ) normally falls between 1.5 and 3.5, and it is only rarely over 4.5. A value near 4.6 would indicate that the numbers of individuals are evenly distributed between all the species (Bibi & Ali, 2013).

$$\text{Shannon's Index of Diversity } (H) = - \sum_{i=1}^s p_i \ln p_i$$

Where  $n_i$  = The individual in species  $i$

$N$  = Total number of individual

$\Sigma$  = Summation

$P_i$  = proportion ( $n/N$ ) of individual of one particular species

Simpson’s Index of Diversity (1-D) is a tool to measure the diversity of the birds and used to quantify the biodiversity of a habitat. The Simpson’s Index of Diversity (1-D) was be used as desirable statistical properties (Wilsey & Stirling, 2007). The range value of Simpson’s Index of Diversity (1-D) is 0 when there is no diversity in the sample area whereas 1 is indicated the sample area is diverse.

$$\text{Simpson's Index of Diversity } (1 - D) = 1 - \sum p^2$$

Where,  $P$  = Proportion ( $n/N$ ) of individual of one particular species

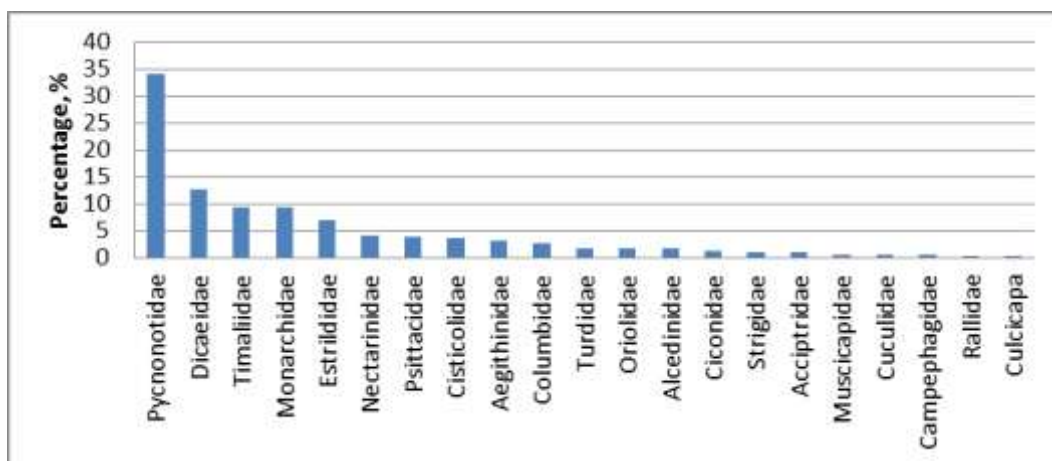
## RESULTS

There were 480 point counts of bird surveys that were conducted for this study. A total of 53 species with 21 families (343 individuals) were recorded in the 2-year mangium plantation L41. Some of the bird families were observed only once as shown in Table 1. The family of Pycnonotidae and Dicaeidae was found to form a considerable proportion of bird species in 2-year mangium plantation. They were almost 50% of the total species observed in the 2-year mangium plantation (Figure 2). The results indicated that the family Pycnonotidae, Dicaeidae and Timaliidae were mainly comprised of this species such as Yellow-Vented Bulbul (*Pycnonotus goiavier*), Bold-striped tit-babbler (*Macronous bornensis montanus*) and Orange-Bellied Flowerpecker (*Dicaeum trigonostigma*). However, the top five highest numbers of bird species were Yellow-vented bulbul (*Pycnonotus goiavier*), Orange-bellied flowerpecker (*Dicaeum trigonostigma*), Pied fantail (*Rhipidura javanica*), Black-headed bulbul (*Pycnonotus atriceps atriceps*) and Chestnut-munia (*Lonchura atricapilla*). This is because they are either omnivores or insectivores which can survive with wide range of habitat and favour in open area and forest edges (Styring *et al.*, 2011; Fujita *et al.*, 2014). There were several families that were observed by only single species or individuals including Ciconidae, Strigidae, Campephagidae, Rallidae, and Culicicapa. These groups either belonged to the migratory species or their natural habitats were not in plantation (Zakaria *et al.*, 2005).

**Table 1:** Number of species and individuals by family in 2-year mangium plantation (L41) recorded in 21 days continuously.

Family	L41
Accipitridae	1 (3)
Aegithinidae	3 (11)
Alcedinidae	2 (6)
Campephagidae	1 (2)
Ciconidae	1 (4)
Columbidae	2 (9)
Cuculidae	2 (2)
Culicicapa	1 (1)
Dicaeidae	3 (43)
Estrildidae	3 (24)
Cisticolidae	3 (12)
Monarchidae	1 (32)
Muscicapidae	2 (2)
Nectarinidae	6 (14)
Oriolidae	1 (6)
Psittacidae	1 (13)
Pycnonotidae	10 (117)
Rallidae	1 (1)
Strigidae	1 (3)
Timaliidae	7 (32)
Turdidae	1 (6)

Note: The first number refer to the number of species; the one number in bracket refer to the number of individual



**Figure 2:** Relative abundance of bird families in 2-year mangium plantation L41, SFI.

The Shannon's diversity index value ( $H'$ ) is 3.24. This result shows that the bird in the 2-year mangium plantation L41 was diversified. The Simpson's diversity index value was estimated at 0.94, indicating that the bird species were equally diversified. The Simpson's diversity index hence fully supported Shannon's diversity index.

Point estimate population density is 17.71 individuals per hectare ( $SE=1.63$ ; % of  $CV=9.25\%$ ; D LCL=14.76; D UCL=21.23) in the 2-year mangium plantation.

## DISCUSSION

The bird population density and diversity in this study was compared with other past studies as shown in Table 2 and Table 3. Sabah Forest Industries (SFI) shows the highest bird population density and diversity that is 17.71 individuals per hectare and 3.24 respectively compared to Sabah Softwood Berhad (SSB) and Sarawak Planted Forest (SPF).

**Table 2:** Comparison of bird population density of bird in SFI, SSB and SPF.

Study Site	Bird Population Density (individual/ha)	Age Group	Type of Vegetation	Studies
SFI	17.71	2-years	<i>Acacia mangium</i>	This study
SSB	15.9	2-years	<i>Acacia mangium</i>	Sheldon & Styring (2011)
SPF	9.3	2-years	<i>Acacia mangium</i>	Sheldon & Styring (2011)



**Table 3:** Comparison of diversity of bird in SFI, SSB and SPF.

Study Site	Diversity of bird (Shannon's Diversity Index)	Age Group	Type of Vegetation	Studies
SFI	3.24	2-year	<i>Acacia mangium</i>	This study
SSB	1.48	2-year	<i>Acacia mangium</i>	Sheldon & Styring (2011)
SPF	1.29	2-year	<i>Acacia mangium</i>	Sheldon & Styring (2011)

The 2-year old *Acacia mangium* plantation in SSB was surrounded by logged native forest and the area had left uninhabited 45 years ago (Sheldon & Styring, 2011). But, the remaining stands of logged forest at SSB are managed for sustained use and retained as original tree diversity until 25 years ago (Sheldon & Styring, 2011). In contrast, the 2-year old *Acacia mangium* plantation of SFI is surrounded by conservation forest, stream and timber harvest. These varieties of habitats promote diversity and density of bird population (Sheldon and Styring, 2011). According to the Sheldon and Styring (2010), human disturbance is one of the factors that affect the bird population density and diversity in the region. The bird population density and diversity in SFI is higher than SSB due to the undisturbed conservation forest in SFI. In addition, the 2-years mangium plantations of SFI might provide adequate food source that draws the movements of the birds from the surrounding habitats to the plantation area.

Sarawak Planted Forest (SPF) has the lowest bird population density and diversity as compared to others. This is because the logged native forest nearby the SPF is poor in soil conditions that resulted in low food sources productivity, such as lack of fruiting season (Sheldon & Styring, 2011). Besides that, the forest near to the SPF has been disturbed for much longer time which caused the loss of variety of food source (Sheldon & Styring, 2011). The study site in SFI was located nearby two conservation areas and several riparian conservation areas as shown in Figure 1. There were also many conservation areas that exist as small forest islands. These conservation areas may be the factor that causes higher population density and diversity observed in the study site.

The top five dominant bird species of this study were compared to the past study of Sheldon and Styring (2011) as shown in Table 4. Both of the dominant bird species of Sabah Forest Industries (SFI) and Sabah Softwood Berhad (SSB) is Yellow-vented bulbul while the dominant bird species at Sarawak Planted Forest (SPF) is Bold-stripes tit-babbler.

**Table 4:** Comparison of top five bird species in SFI, SSB and SPF of 2-year mangium plantation

	SFI (This Study)	SSB (Sheldon & Styring, 2011)	SPF (Sheldon & Styring, 2011)
1	Yellow-vented bulbul	Yellow-vented bulbul	Bold-striped tit-babbler
2	Orange-bellied flowerpecker	Bold-striped tit-babbler	Rufous-tailed tailorbird
3	Pied fantail	Yellow-bellied prinia	Fluffy-backed tit-babbler
4	Black-headed bulbul	Rufous-tailed tailorbird	Little spiderhunter
5	Chestnut munia	Ashy tailorbird	Yellow-vented bulbul

Exotic plantation tree species generally suffer lower pest damage compared to indigenous plantation tree species because the planted environment is different and native pests were not present. However, exotic plantation tree species do not resist pests for long period due to the attracting of indigenous pests as new food sources such as termite, bagworms, caterpillar plusia, grasshopper, mosquito bug, pinhole borers, and stem borer. Therefore, these pests attracted the insectivorous or omnivorous birds to feed on them such as Yellow-vented bulbul, Orange-bellied flowerpecker, Pied fantail, Black-headed bulbul, Bold-striped tit-babbler, Yellow-bellied prinia, Rufous-tailed tailorbird, Ashy tailorbird, Fluffy-backed tit-babbler and Little spiderhunter (Wee, 2009; Sodhi *et al.*, 2005; Phillipps & Phillipps 2014).

Yellow-vented bulbul was the only one of the dominant bird species that can be found in all three studies. This species was well adapted to human creation habitat, such as cultivated areas, plantation and open woods and less found in deep forests (Wee, 2009). Yellow-vented bulbul is generalist in term of food, taking flowers, nectar, fruits, insects, and even carrion (Wells, 2007; Wee, 2009). Chestnut munia was not the dominant bird species in SSB and SPF but it was the top five dominant bird species in SFI. The favourable habitat for chestnut munia is grassy area, field, paddy land and rice agriculture (Well, 2009; Phillipps & Phillipps, 2014). This bird species was dominant in 2-year mangium plantation in SFI due to the bushy and grassy bund condition of study site.

The top five dominant bird species in SFI is different from SSB and SPF may be due to the differences of environment condition. Based on the value of bird diversity and bird population density, SFI has the highest value of bird diversity and bird population density. SFI contributes a comparative different plantation environment condition with the existence numerous conservation areas distributed throughout the plantation. This may this influence the observed bird species difference recorded in top five dominant bird species.

In short, the main factor that influenced the observed high bird population density and diversity in SFI, as compared to other 2-year mangium plantations may be due to the high availability of food source that was supported by the presence of nearby conservation areas. It is as expected since the bird diversity in Primary Forest and Steep Forest were higher as compared to SFI due to the pristine habitat that provide abundant food sources and the varieties of habitat. Food sources may be the key factor that influenced the dominant bird species observed in this study.

## CONCLUSION

The bird population density and diversity in two-year old mangium plantations in SFI were higher as compared to those reported in past studies in SSB and SPF. This observed result may be due to the existence of numerous adjacent conservation areas and several riparian reserves that provides habitats and food sources, influencing the bird population found in the adjacent 2-year mangium plantation. A further study is recommended to be conducted in the adjacent conservation area with the mangium plantation at SFI to examine the mutual influence of adjacent plantation with the conservation area.

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## GEOTOURISM POTENTIAL AT SILAM COAST CONSERVATION AREA (SCCA), SILAM, SABAH

**Zulherry Isnain<sup>1</sup>, \*Junaidi Asis<sup>1</sup>, Hazerina Pungut<sup>2</sup>, Sanudin Tahir<sup>2</sup>, Baba Musta<sup>1</sup> and  
Hardianshah Saleh<sup>2</sup>**

<sup>1</sup>Small Island Research Centre (SRIC)

Faculty of Science and Natural Resources (FSSA)

Universiti Malaysia Sabah (UMS)

<sup>2</sup>Geology Programme

Faculty of Science and Natural Resources (FSSA)

Universiti Malaysia Sabah (UMS)

\*junaidi@ums.edu.my

**ABSTRACT.** *A research has been conducted at Silam Coast Conservation Area (SCCA) to evaluate the geotourism potential of the geological heritage resources. The study area is located at Silam, Lahad Datu, in the eastern part of Sabah. The SCCA and surrounding area are made up of igneous and sedimentary rocks of ultramafic, gabbro, amphibolite, basaltic dykes, plagiogranites and basaltic rocks capped by red radiolarian chert. It is also known as the Darvel Bay Ophiolite Complex which represents the ophiolitic sequence of oceanic crust that formed during Jurassic to Cretaceous around 150-80 million years ago. In SCCA area, only pillow basalt, lava basalt, chert and minor occurrence of basalt dyke are present. Mid-Miocene tectonic event has deformed and uplifted the rock unit. SCCA is a coastal area which also covers few small islands namely Tabun Island and Saranga Island to the northeast of the conservation area in Darvel Bay. The geomorphology and geologic features contribute to the aesthetic values of the area that enhance the scientific values. Two potential geosites have been identified which are Tabun-Saranga islands and Pandanus-Ara beaches that hold unique features of remnant cliff, wave-cut cliff, faults, caves, stacks, tafoni, headland, pocket beach, colluvial beach deposit and remnant of raised coral colonies. Development of this geosites could lead to conservation for sustaining the geological heritage resources as well as contributing to the state's economy and tourism industry.*

**KEYWORDS:** Geotourism, Silam Coast Conservation Area, SCCA, Tabun, Island, Saranga Island.

## INTRODUCTION

The SCCA is surrounded by many landscapes, areas and sites treasured consisting of series of pocket beach along the coastal area, beautiful river, lowland topography, Silam mountain and geological resources such pillow basalt, chert, peridotite and serpentinite. Silam Coast Conservation Area (SCCA) is situated on the south east foothills of Silam Range or Silam Mount. The terrain is characterized by NE-SW trending ridges with gentle slopes. Several streams have drained the undulating terrain of the site which formed a dendritic and parallel drainage pattern. The main river of the area is Sg. Silam. To the east and southeast of SCCA

lies Darvel Bay. There are several small islands located nearby namely Tabun Island and Saranga Island.

The developments of the main topographic features appear in general to be controlled by lithology and geologic structures. The hilly to undulating region to the Northwest is underlain by crystalline basement and ultramafic rocks. The undulating hill slopes to low lying areas to the southwest is underlain by basalt and chert association or formerly known as the Chert Spilite Formation. The north-northeast elongation of the ridges is coincident with the direction of elongation of the ultramafic rock mass. The dendritic drainage pattern may be controlled by the bedrock fracture pattern. The research site is also covered by recent alluvium mainly on the valleys and coastal area.

There are no significant studies focus on geotourism potential have been done so far in Silam Coast Conservation Area (SCCA). Hence, it is very significantly important to carry out a research on this area. The objectives of this research are to provide the knowledge and information about the geological aspect regarding the petrography of the rock, beach morphology, historical geology and geotourism potential for geological heritage resources at the SCCA.

### **Geological Background of SCCA**

The geological map of the Silam Coast Conservation Area (SCCA) was illustrated in Figure 1. Based on the figure, the rocks in the study area comprised of volcanic-sedimentary rock (Chert-Spilite Formation) and Ultramafic-serpentinite rock of the Darvel Bay ophiolite complex (DBOC). Leong (1974, 1977) had done an extensive work on geology of igneous and sedimentary rock of the Upper Segama Valley and the Darvel Bay. Leong (1974) has reported the occurrence of Crystalline Basement at Upper Segama area consist of amphibolite, hornblende schist and gneiss, granodiorite, tonalite, granite and had been dated in range Cretaceous to Triassic (Kirk, 1962; Leong, 1974, 1998; Hutchison 1997). The Chert Spilite formation of Early Cretaceous age at Upper Segama area comprised complex extrusive igneous rock such as basalt, spilites, volcanic breccia, agglomerates and associated with radiolarian chert, limestone and clastics (Leong 1974, 1977). The Darvel Bay Ophiolite Complex (DBOC) proposed by Shariff *et al.*, (1992) was composed of ultramafic, gabbro, amphibolite, basaltic dykes, plagiogranites, and basaltic rocks capped by red radiolarian chert. This complex was formerly known as Chert-Spilite Formation and other igneous rock association in (Fitch, 1955) and (Leong, 1974). The complex was also categorized as ophiolite sequence which was a terminology for a group of metamorphic, igneous ultramafic and igneous mafic rocks. The complex was surrounded by melange and overlain by Neogene and Quaternary sediments.

Shariff *et al.*, (1992) categorised the sequence of the ophiolite in the Darvel Bay area into three rock units namely ultramafic unit (mantle peridotite through ultramafic cumulate), gabbro and dyke units and volcanic sedimentary unit. No sheeted dyke complex was found in

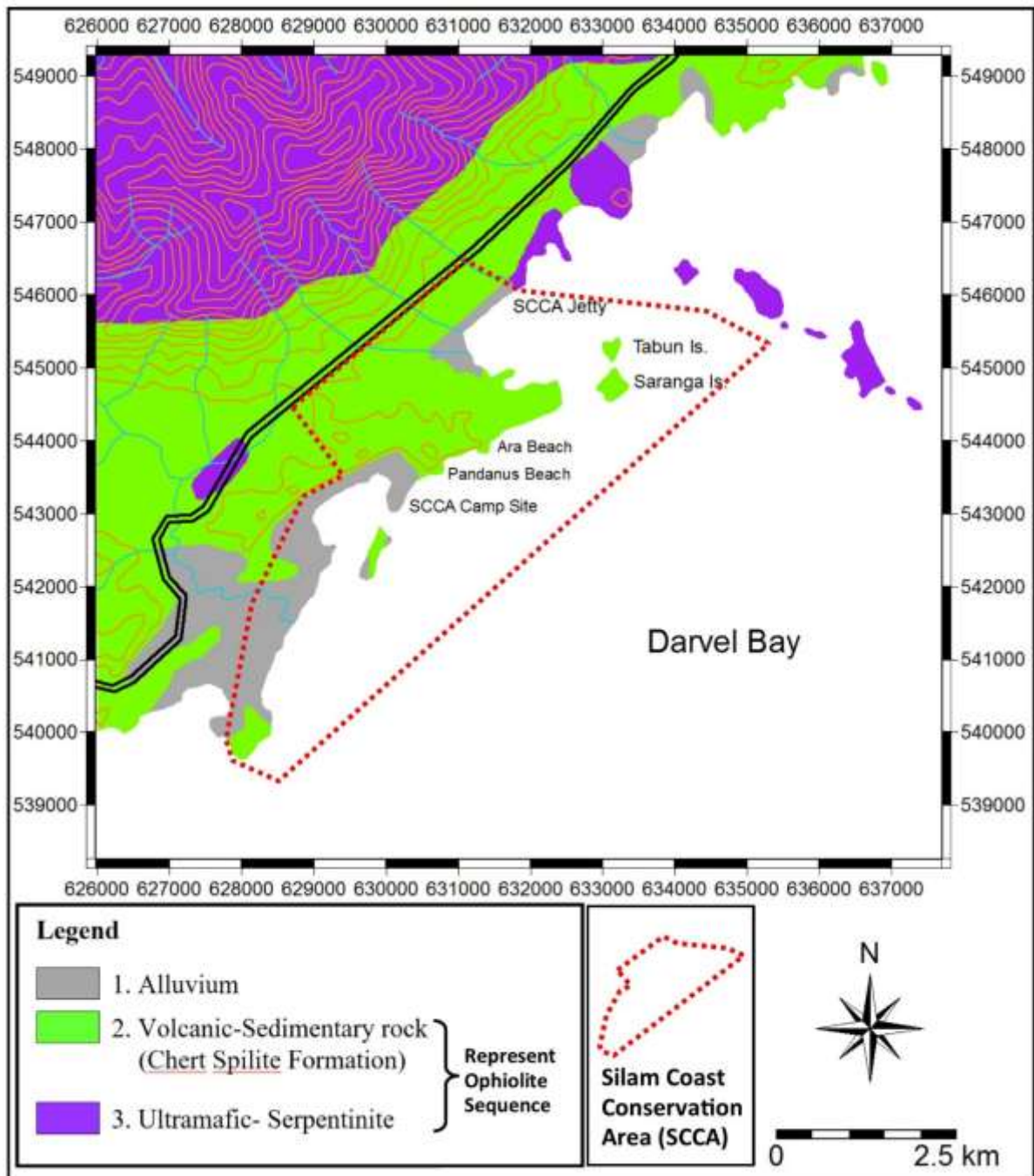
the study area. The ultramafic unit comprise largely of serpentinized peridotites, dunites and pyroxenites. The gabbro unit consisted of layered and massive gabbros, amphibolites and plagiogranites. Volcanic rock unit was represented by the lava basalt with minor layered basalt, metatuffs and volcanic breccia. Lava basalt was occasionally associated with red bedded radiolarian cherts. The age of chert sediment was thought to be Cretaceous ranging from Barremian to Valanginian (Leong, 1977), however the latest work of radiolarian chert at Kunak Area had resulted an age ranging from Aptian to Turonian (Junaidi & Basir, 2010; Junaidi & Basir, 2012; Junaidi & Basir, 2013). Hence we can conclude that the radiolarian chert at study area ranged from Valanginian to Turonian. The age of igneous rock underlain the radiolarian chert was older than chert perhaps Jurassic. The rock association at study area was considered as an ophiolite sequence which represented an oceanic crust (Shariff *et al.*, 1992; Shariff 1996a, 1996b; Basir, 1991, 2000; Hutchison, 2005).

The geological history of the study area started with the evolution of igneous and metamorphic rock known as the Darvel Bay Ophiolite Complex, also categorized as Ophiolite sequence. As mentioned earlier, the Darvel Bay Ophiolite Complex comprised of ultramafic unit, gabbro and volcanic clastic unit. During the middle Miocene, deep basin appeared to have been formed in a very unstable condition. Extensive uplifting, faulting and folding had brought up the rock to the surface of the ocean. This was due to the tectonic activities. Rock units those formed exotic blocks during the middle Miocene period which were now represented by mélangé (Kuamut Formation). This rock unit in melange was characterized by the highly deformed and fractured rocks of older formation. During the Quaternary period, active processes of weathering and erosion caused the breakdown of rocks into sediments which then followed by sedimentation process. This resulted in the alluvial deposits occurred in low land such as flood plain, valley and coastal areas. The remnants of raised coral colonies at the beach of all two geosites indicated that the area has undergone sea level changes during the age of Pleistocene-Holocene. Colluvial beach deposit or known as colluvium of ultramafic rock debris or scree deposits (Leong, 1974) formed terrace along the beach area. It contained fragments from the basalt rock cliff where some of it was mixed with coral remnants.

## **MATERIAL AND METHOD**

On 10 May 2015 to 20 May 2015, an extensive fieldwork focus on geotourism potential had been conducted at Silam Coast Conservation Area (SCCA). Field studies had included geological mapping and sampling for petrography analysis, geomorphological features and geotourism potential. Thin section preparation for petrographic analysis was based on Kerr (1977) by using polarize microscope. Method used for geotourism potential which includes identification, mapping and description of those geosites and the identification was based on the occurrences of important geological and geomorphological features of the sites.





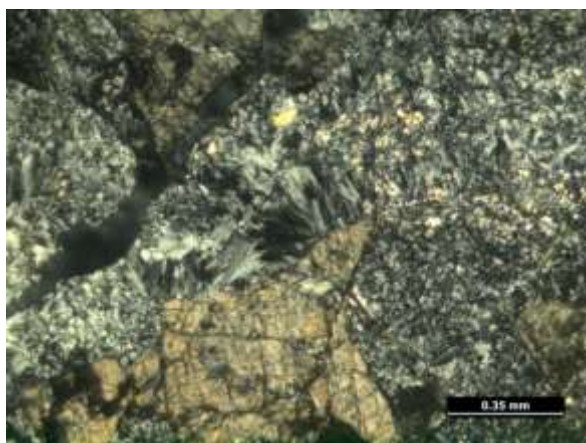
**Figure 1:** Geological map of study area (Modified from Leong 1974; Shariff *et al.*, 1992)

### Petrography

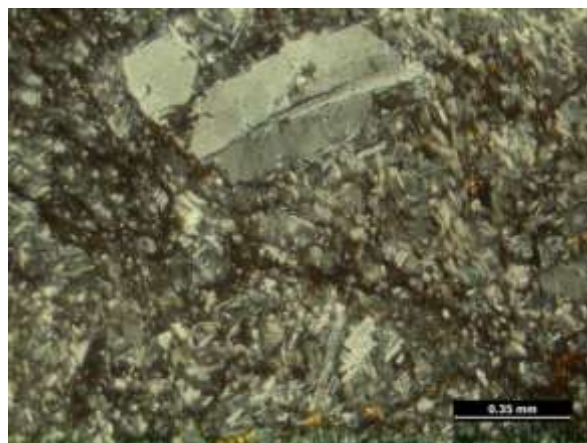
The geology of SCCA is mainly underlain by basaltic rocks. There are two types of basalt have been observed, namely pillow basalt and lava basalt. Basically this two rocks unit have same geochemical composition, but have different texture of mineral arrangement and structure of the rock.

Field observation shows that the pillow basalt has a clear pillow shape and layering while the lava basalt has plain surface with no apparent structure. Both types of basalt outcrops can be found along coastal area and Tabun-Saranga Island. The sizes of pillow basalt range from 40- 60 cm long. The petrography of pillow basalt shows larger phenocrysts of subhedral clinopyroxene in groundmass of finer crystals of plagioclase and pyroxene (Figure 2). Lava basalt of the study area is observed as brownish in colour and sometimes greenish. Some of the rocks have been brecciated, probably due to tectonism. Thin section of lava basalt (Figure 3) shows the grain size of minerals is fine to medium. Commonly it has interstitial textures of plagioclase laths. Minerals of plagioclase and pyroxene are made up mostly both the massive and pillow basalt.

Chert of the study area occurs as block and can be found in several locations away from the beaches. The Chert exists as block and has undergone high deformation. They are reddish-brown in colour and associated with lava basalt. Thin section shows the abundance of radiolarian fossils or known as radiolarite identified as spherical spumellarids along with quartz veins (Figure 4).



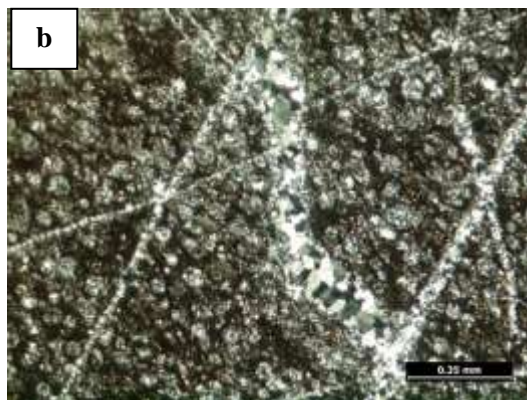
**Figure 2:** Photomicrograph of pillow basalt showing larger phenocrysts of subhedral clinopyroxene within finer crystals of plagioclase and pyroxene



**Figure 3:** Microphotograph of lava basalt showing carlsbad-albite twinning



**Figure 4.a:** Chert block found at SCCA Jetty area.



**Figure 4.b:** Photomicrograph of chert showing spherical spumellarids and quartz veins

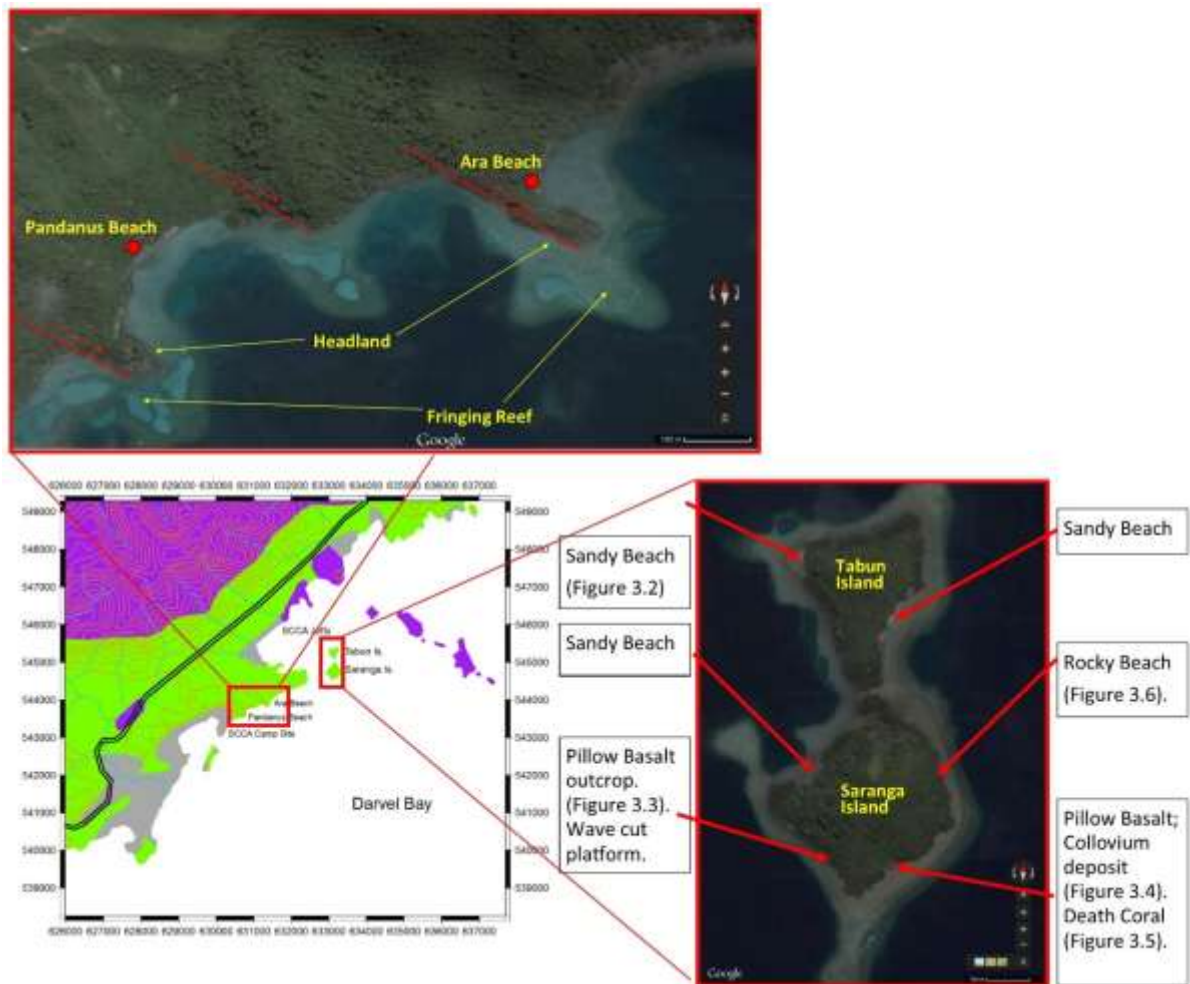
### Geotourism potential

Geopark is a territory encompassing one or more sites of scientific importance, not only for geological reasons but also by virtue of its archaeological, ecological or cultural value. The age of the Darvel Bay Ophiolite Complex at SCCA area probably ranges from Jurassic to Cretaceous (Hutchison 2005; Leong 1974). This rock unit is a part of ophiolite sequence of oceanic crust. In SSCA area only basalt or pillow basalt and chert are present and do not have a complete section of the ophiolite sequence. Other rock unit of ophiolite sequence such as gabbro, peridotite, dyke, are present at surrounding area e.g. Upper Segama, Danum, Tingkayu, Lahad Datu and Mount Silam. This rock unit are widespread in Sabah region, and has a unique and interesting geological characteristic which can only be found in Sabah and in several parts of Sarawak. This area will provide knowledge and information about the geological aspect of the study area. In this conservation area, two geosites have been identified to be having geotourism potential (Figure 5).

### Geosite 1: Saranga Island & Tabun Island

Geosite 1 represents by two small islands namely Saranga Island (southern part) and Tabun Island (northern part) (Figure 5 & 6). The geology of both islands are made up by pillow basalt, lava basalt (Figure 7), and volcanic breccia of volcanic unit of the Darvel Bay Ophiolite Complex. The distinct feature of pillow basalt is observed along the cliff of coastal area at the Saranga Island and Tabun Island (Figure 8 & 9). Geologic features that can be observed including, colluvial deposit that form flat terrace below the basalt cliff (Figure 10) and remnant of raised coral colonies located in the western part of Saranga Island (Figure 11). Coastal geomorphology feature such as pocket beach, rocky beach, sandy beach and cliff as a result from coastal erosion processes (Figure 12) can be observed in this geosite.





**Figure 5:** Geosites 1 and 2 identified as having geotourism potential at the study area.



**Figure 6:** During low tide both islands are accessible by foot



**Figure 7:** Cliff made up of lava basalt and pillow basalt at Saranga Island



**Figure 8:** Wave cut platform morphology of pillow basalt outcrop at Saranga Island.



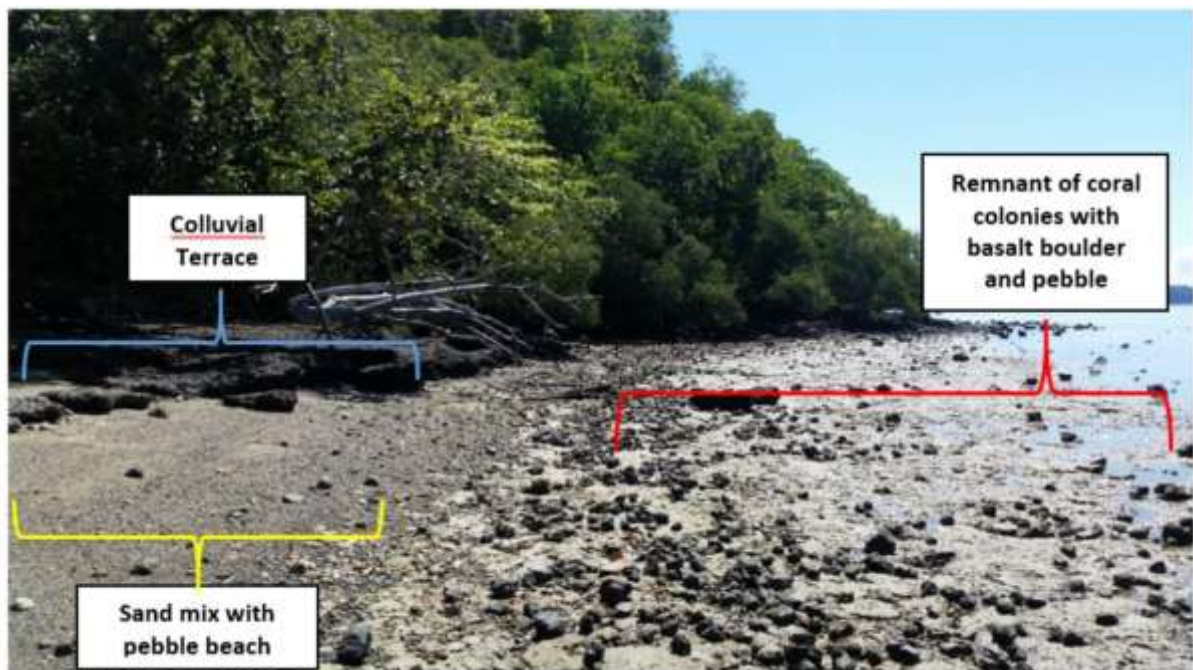
**Figure 9:** Different colour of pillow basalt indicates different degree of weathering process.



**Figure 10:** Colluvial terrace exposed below basalt cliff forming a flat platform at Saranga Island.



**Figure 11:** Remnant of Recent coral skeletal in colluvial deposit



**Figure 12:** Colluvial terrace and remnant of raised coral with basalt boulders and pebbles

### **Geosite 2: Pandanus & Ara Beach**

The Pandanus & Ara Beach is located approximately 1 km - 2 km from the Tumunong Hallu basecamp (Figure 5). Figure 13 shows the pocket beach and headland morphology of Pandanus Beach. The geology of the area is made up of lava basalt and some of the rock is highly deformed by tectonic event creating faulting and fracture (Figure 14). Basalt outcrop can be observed at headland of Pandanus-Ara beach. Erosional and depositional processes created beautiful geomorphologic features along the coastline. The beach is covered by dark coloured sand and rocky beach (Figure 15 & 16). Sand sample taken from the beach contains rock fragments of spillite, basalt and schist and quartz mineral with some coral and foraminifera (Figure 17-20). Other features such as colluvial deposit (Figure 21), raised coral remnant (Figure 22), wave cut platform (Figure 23) and pitholes (Figure 24) are also preserved along the coastline.





**Figure 13:** Satellite image of Pandanus-Ara Beach showing pocket beach morphology.



**Figure 14:** Fault zone at tip of the beach with small stacks of rocks caused by coastal erosional process (Fault: 143/80).



**Figure 15:** Dark coloured sand and rocky beach.



**Figure 16:** Dark coloured sand exposed at Ara Beach.



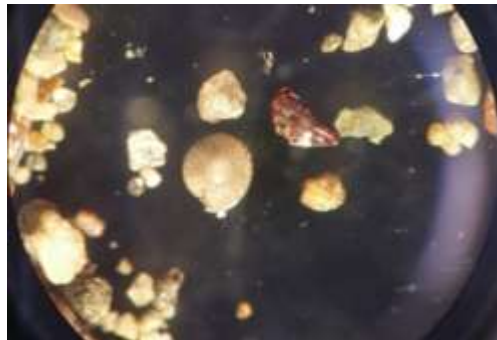
**Figure 17:** Sand sample showing mixture of rock and mineral fragments.



**Figure 18:** Coral skeletal.



**Figure 19:** Chert fragments.



**Figure 20:** Foraminifera.



**Figure 21:** Colluvial deposit exposed at the beach.



**Figure 22:** Remnant of raised coral.



**Figure 23:** Wave cut platform as a product of repeated wave erosion.



**Figure 24:** Pitholes in rocks at Pandanus Beach due to weathering and wave erosion.

Both geosites 1 and 2 have the potential to be developed as a geotourism attraction. The aesthetic and recreational values enhance the scientific value of the geological heritage resources in this area. Apart from the geological resources, the geosites hold its own flora and fauna both living in land and sea. Some recreational activities such as sight-seeing, picnic, camping, hiking and diving in the ocean can be done here. This geosites are important



to conserve as it is worth more than just preserving the beautiful geological and geomorphological features as it records the geological historic events that occurred in the past. Thus, it is suitable for future research and education. Table 1 shows the value of the geological heritage resources in the study area, while Figure 25-27 display the scenic view around the geosites.

**Table 1:** Valuation of geological heritage resources of the study area.

Geological Resources	Characteristics	Value
Rock units: lava basalt, pillow basalt and chert	Formed part of Darvel Bay Ophiolite Complex representing ophiolitic sequence of oceanic crust which had developed during Jurassic to Cretaceous. Outcrops observed in Tabun-Saranga Island and Pandanus-Ara Beach.	Scientific
Coral remnant	The remnant of raised coral colonies at the beach indicates that the area had undergone sea level changes during the age of Pleistocene-Holocene.	Scientific
Colluvial deposit	Colluvial deposit formed terrace along the beach containing basalt fragments derived from basalt cliff along with some coral skeletal.	Scientific
Wave cut platform	Gently sloping angle of basalt bedrock product of wave erosional process.	Scientific and Aesthetic
Pandanus and Ara Beach	Variety of geomorphologic features of pocket beach, headland, rock stacks, rocky beach with dark coloured sand, colluvial terrace, remnant of raised coral, abrasion platform and pitholes due to weathering, erosional and depositional processes.	Scientific, Aesthetic and Recreational
Tabun and Saranga Island	Islands that made up of basalt and chert representing ophiolitic sequence with other coastal geomorphologic features of cliff, pocket beach, rocky beach, sandy beach, colluvial terrace and remnant of raised coral.	Scientific, Aesthetic and Recreational



**Figure 25:** Panoramic view during sunrise from SCCA camp



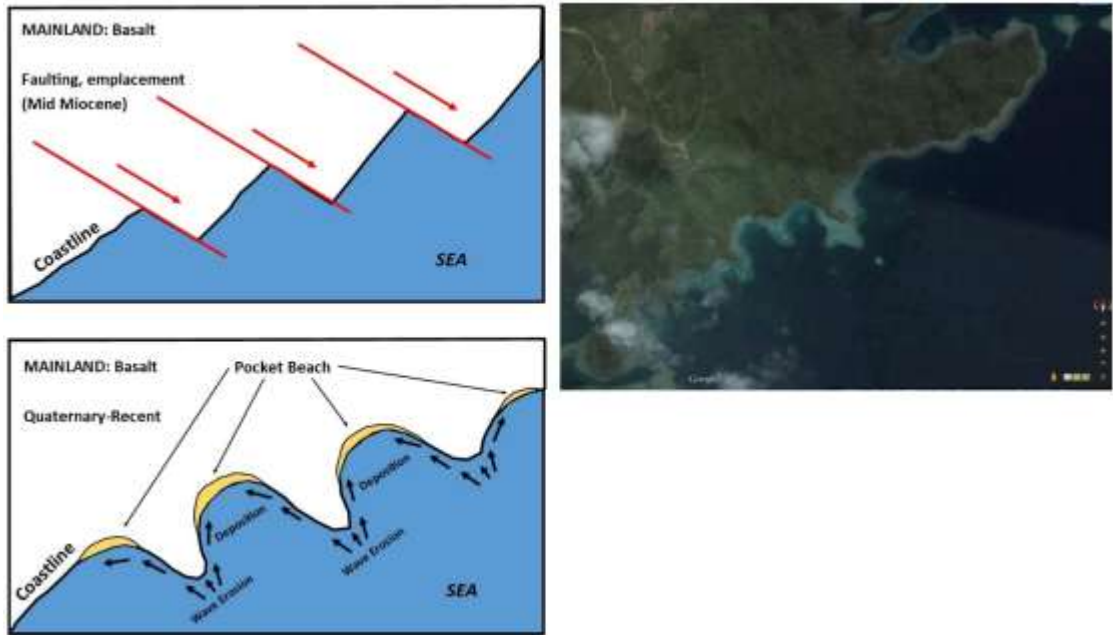
**Figure 26:** Geosite 1: Tabun and Saranga Island



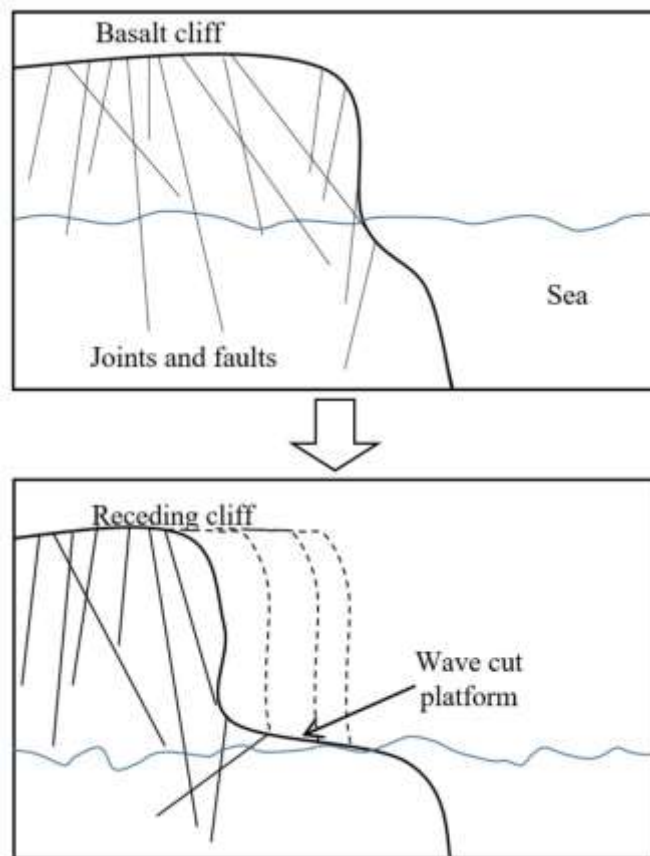
**Figure 27:** Coral reefs and sea urchin are visible under clear seawater

### **Evolution or structural control on beach morphology**

The location of study area is situated at island and along coastline makes it prone to weathering, erosional, and depositional processes producing variety of beautiful geomorphologic features. Figure 28 display the simplified diagram on the formation of pocket beach of Pandanus in SCCA area. The beach is underlain by basalt that formed during Pre-Cretaceous. During the Middle Miocene, tectonic event acted towards the area resulting in the uplifting and development of series of lateral fault trending NW-SE (143/80) in the bedrock. These fault lines were the weak zones in the bedrock which were highly prone to weathering and wave erosion. These processes repeated over time, and finally producing the pocket beach and headland morphologies in the SCCA area. Continual destructive wave acting towards the headland makes it vulnerable to erosion, as the wave's energy gets concentrated here and gradually will develop other coastal features such as rock stacks and pitholes. Development of wave cut platform (Figure 29) is also related to the geological structure of the study area. The rock cliff at the coastline is made of basalt that is deformed, creating joints and faults. Intense physical and chemical weathering acting towards these joint makes it vulnerable and easily eroded by wave erosion. Repeated weathering and wave erosion processes will finally produce wave cut platform with gently sloping angle of hard bedrock that are exposed during low tide. Colluvial deposit that form terrace along the beach is a product of basalt cliff weathering and depositional processes.



**Figure 28:** The formation of pocket beach.



**Figure 29:** Formation of wave cut platform is controlled by joints and faults.

## CONCLUSION

Two geosites have been identified namely Tabun-Saranga Island & Pandanus-Ara Beach. The geology of SCCA areas are mainly consist of Basalt (Pillow Basalt, Lava basalt) of the Darvel Bay Ophiolite Complex. This rock unit was a part of Ophiolite Sequence in the Oceanic Crust which was developed during Jurassic-Cretaceous age. The Quaternary Deposits also have been found as Alluvium, Colluvial deposit and coral remnant at the beach. The coastal area of SCCA area has geological, aesthetic, and recreational values and has potential to be developed for geotourism. It is recommended that the beaches at the Silam Coast Conserveation Area to be conserved in order to protect the beautiful landscapes. Geotourism activity could be promoted on some of the beaches at the Tabun-Saranga Island and Pandanus-Ara Beach. The study of geological aspect of beaches for geotourism development is an innovative way for value added to their existing aesthetic attraction in order to enhance and sustain the state's tourism industry.

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