ISSN 1907-0322

THE RATE OF ^{45}Ca UPTAKE BY TWO CORALS SPECIES AT WATERS OF PULAU BURUNG, BANGKA-BELITUNG PROVINCE

Zulkifli Dahlan[1)], Gusti Diansyah[2)], T. Zia Ulqodry[2)], and Ania Citraresmini[3)]

[1)] Department of Biology, Faculty of Natural Science, Sriwijaya University
E-mail : zulkiflidahlan@yahoo.com
[2)] Department of Marine Science, Faculty of Natural Science, Sriwijaya University
[3)] Centre for Application of Radiation and Isotope Technology,
National Atomic Energy Agency (BATAN)

Diterima 27 Oktober 2010; disetujui 04 Februari 2011

ABSTRACT

THE RATE OF ^{45}Ca UPTAKE BY TWO CORALS SPECIES AT WATERS OF PULAU BURUNG, BANGKA-BELITUNG PROVINCE. Coral reefs transplantation is the most technique used for coral reefs rehabilitation, at the present. Recently the ^{45}Ca technique has been using for determining growth appearances in corals because of its ability to calculate the calcification process. For this reason, the study on the rate of ^{45}Ca uptake by natural corals *Acropora formosa* and *Acropora nobilis* was carried out between June and December 2009 at the waters of Pulau Burung Island, Bangka-Belitung Province. The coral fragments of about 5 cm were harvested and put into a PVC container filled with 2 liters of fresh sea water, then incubated with $^{45}CaCl_2$ solutions with an activity of 11.04 µCi/ml for 8 hour under fluorescent light. After the incubation, the "labeled" coral fragments were transplanted to where they have been taken from, and after such period will be re-harvested to determine their ^{45}Ca uptake content. The results showed that the ^{45}Ca technique was a reliable method to calculate the rate ^{45}Ca uptake by coral fragments, which were studied in different depths and time periods of light exposure. There was a significant difference in the ^{45}Ca uptake by the two different coral species. *A. formosa* up took more ^{45}Ca than *A. nobilis* did. The highest ^{45}Ca uptake was shown by *A. formosa* at 5 m. This was true for all the lengths of time to light exposure (1, 3, 5 and 7 hours). Different pattern of ^{45}Ca uptake showed by *A. nobilis* at 10 m depth, where it could be recognized that after a drop of ^{45}Ca the uptake increase continuously until the end of the light exposure (7 hours). The difference in ^{45}Ca uptake between the coral fragments is assumed to be influence by light and the algae species living symbiotically with the coral species that will further influence the CO_2-fixation. This process will influence the calcification process, which is expressed in ^{45}Ca uptake. Further studies should be carried out to exactly gathered data of all the factors which could influence the calcification process by coral reefs, the factors could be CO_2-fixation, flow of sedimentation, etc.

Keywords : coral, ^{45}Ca, calcification, *Acropora formosa*, *Acropora nobilis*, Pulau Burung

ABSTRAK

TINGKAT SERAPAN ^{45}Ca OLEH DUA SPESIES TERUMBU KARANG DI PERAIRAN PULAU BURUNG, PROVINSI BANGKA-BELITUNG. Transplantasi terumbu karang adalah teknik yang paling banyak digunakan untuk perbaikan terumbu karang pada saat ini. Akhir-akhir ini teknik radioisotop ^{45}Ca banyak digunakan untuk menentukan pertumbuhan terumbu karena mampu menghitung proses kalsifikasi yang terjadi. Dengan menggunakan teknik tersebut dilakuan pengkajian terhadap tingkat serapan ^{45}Ca oleh terumbu alami *Acropora formosa* dan *Acropora nobilis.* Percobaan dilakukan pada bulan Juni sampai Desember 2009 di perairan Pulau Burung, Provinsi Bangka-Belitung. Terumbu karang dipanen seukuran 5 cm dan direndam dalam 2 liter air laut pada wadah PVC, kemudian diinkubasi dengan larutan $^{45}CaCl_2$ aktivitas 11.04 µCi/ml selama 8 jam. Sebagai pencahayaan sinar matahari digunakan lampu pendar. Setelah inkubasi, terumbu karang "bertanda" ditransplantasikan pada terumbu karang asalnya berada, dan setelah periode waktu tertentu dipanen kembali untuk menentukan kandungan serapan ^{45}Ca. Hasil percobaan menunjukkan bahwa metode radioisotop ^{45}Ca dapat menghitung laju serapan ^{45}Ca oleh bagian-bagian

ISSN 1907-0322

terumbu, yang dipelajari pada kedalaman dan panjang waktu penyinaran matahari yang berbeda. Terdapat perbedaan yang nyata pada serapan ^{45}Ca oleh kedua spesies terumbu. Secara keseluruhan spesies *A. formosa* memperlihatkan serapan ^{45}Ca yang lebih baik dibanding *A. nobilis*. Serapan ^{45}Ca tertinggi ditunjukkan oleh *A. formosa* pada kedalaman 5 m, dibandingkan terhadap spesies yang sama pada kedalaman 10 m, dan juga dibandingkan terhadap *A. nobilis* pada kedalaman 5 dan 10 m. Kondisi ini berlaku pada seluruh panjang waktu penyinaran matahari (1, 3, 5 dan 7 jam). Adanya perbedaan serapan ^{45}Ca pada percobaan ini diduga dipengaruhi oleh sinar matahari dan alga yang hidup bersimbiosis dengan terumbu karang. Keduanya mempengaruhi fiksasi CO_2 sehingga berpengaruh terhadap proses kalsifikasi. Penelitian lebih lanjut dibutuhkan untuk memperoleh data yang benar-benar menyeluruh berkenaan seluruh faktor yang dapat mempengaruhi proses kalsifikasi terumbu karang, seperti faktor fiksasi CO_2, laju sedimentasi, dan sebagainya.

Kata kunci : terumbu karang, ^{45}Ca, kalsifikasi, *Acropora formosa*, *Acropora nobilis*, Pulau Burung

INTRODUCTION

In Indonesia, the demolishing of coral reefs is mostly attributed to the development of the coastal areas namely the sea sand exploitation, industrial wastes consisted of heavy metals and toxic materials, using of bombs and cyanides for fishing [1]. More recently the global warming which has increased sea temperatures has been one of the important factors declining growth of the coral reefs and could be end by the dying of them. This could be observed by whitening of corals as happened in Australia at The Great Barrier Reef and in Indonesia [2,3].

According to SUHARSONO [4] in Indonesia there are about 50.000 km^2 coral reefs areas at 841 locations, of which about 5.23% are in very good, 24.2% in good, 37.34% in medium (between good and bad), and 33.17% bad condition could increase when no efforts to save the coral reefs are carried out.

There are several ways of rehabilitating condition of the coral reefs, i.e. by building artificial reefs, by transplanting coral, and by using of electricity to stimulate coral growth [4,5,6,7,8]. At present, coral reefs transplantation is the most technique used for coral reefs rehabilitation, especially when materials for building artificial reefs are not available [8,9]. Coral transplantation is done by cutting of fragments of healthy corals, considered as donors, and transplanting it to the rehabilitation area [1]. After a period of time the transplanted coral is tested if it survives, meaning that the method could work on coral reefs rehabilitation.

In the early days of coral reefs studies, the measurement of corals growth was by using red alizarin, a color substance, to determine the volume and weight of the coral [1]. This method was not accurate. The method where volume and weight were involved, especially weight, often face serious difficulties. Weighing of the corals after a period of time rarely showed increasing numbers, and sometimes it looks like the corals have lost weight. This is due to the manifestation of the holes in the coral after a period of time. These holes obviously are responsible for the weight lost. It was assumed that these holes were made by small sea creatures, which symbiotically live with the corals. Recently the method used for determining growth appearances in corals is the ^{45}Ca technique. By using the ^{45}Ca technique the calcification process in the corals could be calculated. The calcification process is used to proof that there is growth in the coral. The ^{45}Ca in the calcification process would form $^{45}CaCO_3$, where the ^{45}Ca could be calculated qualitatively and quantitatively.

Calcification is a complex process that takes place outside the epidermical calcicoblas of the corals. Metabolism processes in the corals will produce and

ISSN 1907-0322

secrete organic substances which are the main substance used in the calcification process. The calcium of the seawater is bound by the organic substances to form $CaCO_3$ which is then deposited into the coral constituents. Physical environmental factors which greatly influence the corals growth are obviously light and temperature. Other environmental factors which play a role in the calcification process are salinity, depth of the water, sedimentation and acidity (pH) [1]. Another environmental factor which could improve coral growth is a biological factor, in the form of Zooxanthellae (algae) which frequently live symbiotically with the corals. According to GOREAU and GOREAU [10] the algae plays a very important role in the calcification process. When the algae is inhibited or taken from the coral, the photosynthesis process could be terminated and it will result in very slow $CaCO_3$ formation. Corals capable of reef building are invariably inhabit by Zooxanthellae, and their growth is dependable on light to execute their CO_2-fixation capability. This was shown by GOREAU and GOREAU [10] and GOREAU [11], where several coral reefs will decrease their Ca uptake when the light decrease from bright to cloudy and end at darkness. For example *Acropora palmate* showed 33.79 – 53.41 µg Ca/N/hour in bright light. This will decrease to 18.80 – 33.80 µg Ca/N/hour in semi-darkness and the lowest Ca uptake was at complete darkness which was 2.56 – 3.84 µg Ca/N/hour.

Why the rebuilding and the maintenance of coral reefs is important, could be summarized by quoting SUPRIHARYONO [12] who forwarded the advantages of preserving the coral reefs which are for increasing and maintaining fish production; as a source of food; source of medicine; tourist industry; ornamental sea fish aquariums; and as a barrier for great waves.

The purpose of this study is to determine the calcification ability of the coral fragments by using ^{45}Ca. If calcification process happened then it means that there is growth in the coral fragments which have been transplanted.

MATERIALS AND METHODS

These works were carried out at the waters of Pulau Burung, District of South Bangka, Bangka-Belitung Province. The location in details is presented in Fig. 1. The experiment was carried out from June until December 2009 on two species of natural

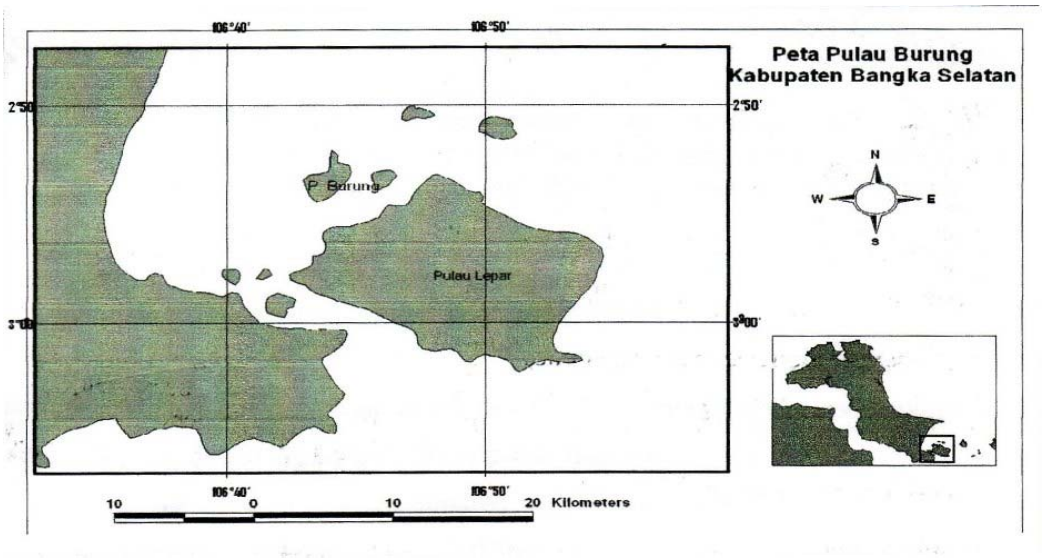

Fig 1. The study site at Pulau Burung, South Bangka Province.

ISSN 1907-0322

coral *Acropora*, namely *Acropora formosa* and *Acropora nobilis*, at coral reef area of Burung Island water, Bangka. From June to October 2009 Survey to determine the location where the coral reefs grow, was done by continuously observing the coral every month visually. On October 2009 the corals and each coral reef were determined and ready to be studied for their calcification process by using ^{45}Ca.

In October 2009, coral fragments of about 5 cm were taken from top of natural coral beds. The harvested coral fragments were put in glass vials with fresh sea water. The sea water was change every one hour. This was done for acclimatizing the coral fragments prior to incubation with ^{45}Ca.

After acclimatization the coral fragments were put into a PVC container filled with 2 liters of sea water, and one hour later $^{45}CaCl_2$ solutions with an activity of 11.04 µCi/ml was added. At the given time, 10 p.m., the ^{45}Ca solution was added to the seawater and was stirred gently for about 20 minutes. After stirring it was considered that the ^{45}Ca has dissolved completely in the sea water. The container was then placed under fluorescent light for eight hour, from 10 p.m. to 6 a.m. The light was put 50 cm above the container. During the incubation period oxygen supply was done by putting an aerometer in the container. All this activity took placed in a fishing boat near the locations where the coral fragments were taken from. The incubation process was conducted using the method of VAN DER MEULEN and MUSCATINE [13] with some modification.

After about eight hour of incubation period, the coral fragments were put into small transparent PVC bags and transplanted from where they have been taken from, which was at 5 and 10 m depths at around 8 a.m. After 1, 3, 5 and 7 hours the coral fragments were re-harvested to determine their ^{45}Ca uptake content. The time applied in this study is to exposure the coral fragments to daylight. As mentioned before the light will induce CO_2-fixation by the algae living symbiotically with the corals and play an important role in the calcification process. In this study the calcification process is expressed in ^{45}Ca uptake.

The harvested coral fragments were put into PVC bags, sealed off and then taken to the isotope lab at the Agricultural Division of PATIR (Pusat Aplikasi Isotop dan Radiasi), Pasar Jumat, Jakarta Selatan. The samples were oven dried at 105°C. After reaching a constant dry weight, they were grinded to pass a 2 mm sieve. The grinded coral samples were put into porcelain cups and ashes by placing them into a furnace at 650°C for around 12 hours. The ashes were dissolved in 17 ml concentrated HCl and heated by hot plate at 100°C, until the solution become clear. A one ml clear solution was taken and put into counting vials and 14 ml distilled water and 1 ml liquid scintillation was added and stabilized around one hour before counting them by liquid scintillation counter (LSC). To describe more clearly about the ^{45}Ca analysis process, a diagram is presented in Figure 2.

The calcification process assumed would have taken place in the constituent of the corals in the coral reefs, represented by the coral fragments used. After coral fragments were incubated in ^{45}Ca, they were transplanted onto their original site and left for 1, 3, 5, 7 hours. During this time it is assumed that the coral fragments carried out the calcification process, and the ^{45}Ca will be deposited as $^{45}CaCO_3$ in their constituent.

In this study the ^{45}Ca technique is used as a method to evaluate the probability of the calcification process in the coral fragments from two coral species, namely *A. formosa* and *A. nobilis.* All the works prior to ^{45}Ca analysis involving coral fragments harvest; transplantation after soaking in ^{45}Ca + seawater; and re-harvesting after certain hours, were done from and at a fishing boat near the location of reef corals. The diving involved in this work was done by licensed divers.

ISSN 1907-0322

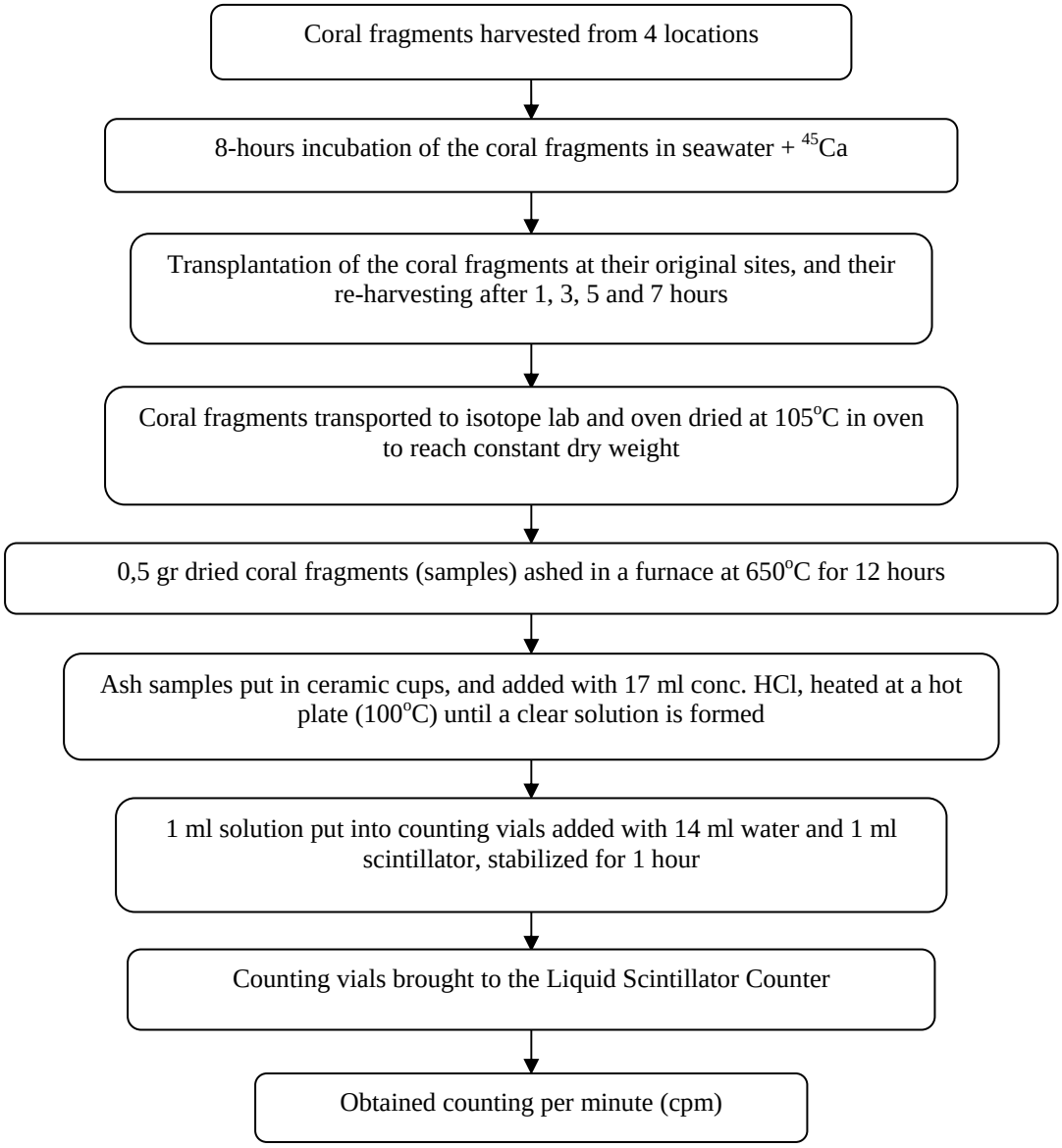

Fig. 2. Scheme of ^{45}Ca counting from harvest to cpm in coral fragments samples.

RESULTS AND DISCUSSION

The base data to calculate the ^{45}Ca uptake is the counts per minute (cpm), which is acquired through Liquid Scintillation Counter. Further the values of ^{45}Ca uptake could show the rates of calcification process. The radioactivity measurement was done on December 30, 2009, about two months after the incubation in ^{45}Ca and followed by transplanting, and terminated by harvesting the coral fragments on October, 20, 2009. The cpm values were then transformed to dpm values, by dividing the cpm values with the counting efficiency of the Liquid Scintillation Counter (LSC). The dpm values on December 30, 2009 (Table 1) were then calculated to the date of October 20, 2009 (the date when the transplantation and harvest were carried out, see Table 2) as shown by L'ANNUNZIATA [14] with a decay factor of 0,697.

ISSN 1907-0322

Table 1. Counts per minute (cpm) and disintegration per minute (dpm) number of two different natural corals, at 30 Desember 2009.

Depth (m)	Transplantation time (hours)	*Acropora formosa*					*Acropora nobilis*				
		cpm		dpm		Ro-dpm**	Cpm		dpm		Ro-dpm
		a*	b*	a	b		a	b	a	b	
5	1	9971	4466	15340	6871	11106	643	1524	989	2345	1661
	3	9690	8871	14908	13648	14278	1428	4719	2212	9438	5825
	5	14948	3669	22997	5645	14321	3867	1204	5949	1852	3901
	7	6865	2009	10562	3091	6827	1015	1213	1562	1866	1714
10	1	4403	4559	6774	7014	6894	1031	2699	1586	4149	2868
	3	1202	1465	1849	2254	2052	1069	1329	1645	2044	1845
	5	1846	450	2840	692	1766	3074	nd	4729	nd	4729
	7	418	914	645	1406	1025	3095	4862	4761	7210	5986

*a and b are two different samples from the same species
**Ro-dpm is the mean value of a and b

Table 2. Disintegration per minute (dpm) numbers of two different natural corals at Desember 30th back dated to October 20th 2009 after incubated with ^{45}Ca.

Depth (m)	Transplantation time (hours)	*Acropora formosa*					*Acropora nobilis*				
		dpm (30-12-2009)		dpm (20-10-2009)		Ro-dpm	dpm (30-12-2009)		dpm (20-10-2009)		Ro-dpm
		a	b	a	b		a	b	a	b	
5	1	15340	6871	22009	9858	15934	989	2345	1419	2187	1803
	3	14908	13648	21388	19581	20485	2212	9438	3174	13541	8357
	5	22997	5645	32944	8099	20522	5949	1852	8535	2657	5596
	7	10562	3091	15154	4435	9795	1562	1866	2241	2677	2459
10	1	6774	7014	9719	10063	9891	1586	4149	2275	5953	4114
	3	1849	2254	2653	3234	2944	1645	2044	2360	2933	2647
	5	2840	692	4075	2534	3305	4729	nd	6785	nd	6785
	7	645	1406	925	1471	1198	4761	7210	6830	10344	8587

Table 3. Content of radioactivity ^{45}Ca (µCi/sample) in two different natural corals determined at the date of October 20, 2009.

Depth (m)	Transplantation time (hours)	*Acropora formosa*			*Acropora nobilis*		
		a	b	Ro-µCi/0.5 g samples	a	b	Ro-µCi/0.5 g samples
5	1	0.05218	0.02337	0.03778	0.00336	0.00519	0.00428
	3	0.05071	0.04643	0.04857	0.07530	0.01982	0.01982
	5	0.07811	0.01920	0.04866	0.02024	0.00630	0.01327
	7	0.03593	0.01052	0.02323	0.00531	0.00634	0.00583
10	1	0.02304	0.02836	0.02345	0.00539	0.01411	0.00875
	3	0.00629	0.00767	0.00698	0.00559	0.00695	0.00627
	5	0.00966	0.00601	0.00784	0.01609	nd	0.01609
	7	0.00219	0.00349	0.00284	0.01619	0.02453	0.02031

ISSN 1907-0322

Table 4. The ^{45}Ca uptake (µg) by two different natural corals fragment.

Depth (m)	Transplan-tation time (hours)	*Acropora formosa*			*Acropora nobilis*		
		a	b	Ro-µg	a	b	Ro-µg
5	1	0.02007	0.00899	0.01453	0.00129	0.00200	0.00165
	3	0.01950	0.01786	0.01868	0.00290	0.01235	0.00763
	5	0.03004	0.00738	0.01817	0.00778	0.00244	0.00510
	7	0.01382	0.00405	0.00894	0.00204	0.00244	0.00224
10	1	0.00886	0.00918	0.00902	0.00207	0.00543	0.00375
	3	0.00242	0.00295	0.00269	0.00215	0.00267	0.00241
	5	0.00372	0.00231	0.00302	0.00619	nd	0.00619
	7	0.00084	0.00134	0.00109	0.00623	0.00843	0.00783
	Ro-to			0.00952			0.00461

After obtaining the dpm values at October 20, 2009, the dpm were then transformed to µCi (Table 3) as shown by L'ANNUNZIATA [14] and the ^{45}Ca uptake could be calculated according to this data (Table 4).

Data in Table 3 (µCi/ 0.5 g samples) is the transformation of the dpm data in Table 2. Table 1 to 3 all showed differences between the different two coral species, *A. formosa* and *A. nobilis*, where the first mentioned had much higher cpm, dpm and µCi than the second species at the 5 m depth. For the 10 m depth both species has small cpm, dpm and µCi values.

For the time of light exposure *A. formosa* has an increase in cpm, dpm, and µCi values up to 5 hours exposure at the 5 m depth, while at the 10 m depth all these values dropped after only 1 hour of exposure. *A. nobilis* showed a different pattern than *A. formosa*. At the 5 m depth, the highest cpm, dpm, and µCi values were reached at 3 hours after exposure and then dropped. Meanwhile at the 10 m depth there was a drop in the values of cpm, dpm and µCi after 3 hours of exposure and then increased to reach their highest values at 7 hours of exposure. These values for ^{45}Ca are all in line with the values of cpm, dpm, and µCi as shown in Table 4. To simplify the data for discussion, the data of Table 4, which is ^{45}Ca uptake has been drawn and presented in Fig. 3. The discussion will be focused in ^{45}Ca uptake due to the fact that they are quantitative data, which is reliable to represent the calcification process whether it has occurred or not.

In this work the ^{45}Ca uptake by the coral fragments could be regarded as the rate of the calcification process. Here the environmental factors applied to the different coral species, *A. formosa* and *A. nobilis*, were exposure time to the light (1, 3, 5, and 7 hours) and the depth (5 and 10 m) of coral location. It is assumed that the calcification process occurs whenever was taken up by the coral fragments.

In order to make a simple description about the ^{45}Ca uptake, which is playing a role as a picture of the calcification process, the data in Table 4 is transformed into Fig. 3. The discussion is focused on ^{45}Ca uptake as a representation of the calcification process, which is the most important data in this study. By looking at the ^{45}Ca uptake data, the calcification process could be read. The high or low of ^{45}Ca uptake is the picture of high or low the rate of the calcification process. Although ^{45}Ca uptake are important data, it has to be taken into consideration that it could not be calculated without the determination of cpm, dpm, and µCi content of each sample (Tables 1, 2, 3).

ISSN 1907-0322

Actually the data of Tables 1 to 3 could already be used qualitatively as an indication of ^{45}Ca uptake. This was shown by VAN DER MEULEN and MUSCATINE [13], who showed high or low counts per minute (cpm) of *Pocillopora diomicornis* as a parameter of high or low calcification rates.

higher ^{45}Ca uptake than *A. nobilis* 0.00952 > 0.00461 µg ^{45}Ca/sample (Table 4, Ro-to). Does this mean that *A. formosa* has a better calcification rate compared to *A. nobilis*, could be further answered by looking at Fig. 3.

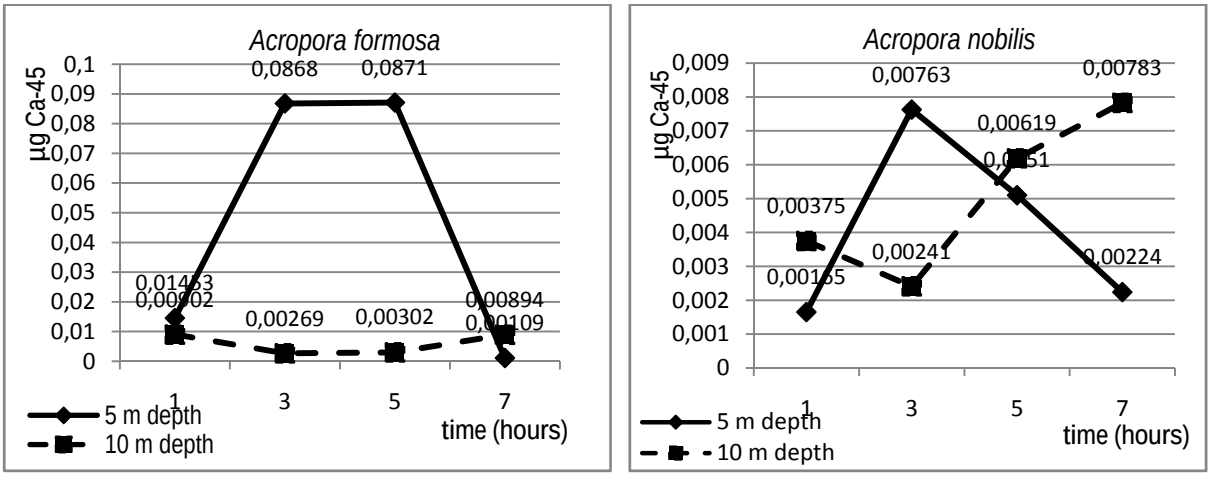

Fig. 3. ^{45}Ca uptake by two different corals (*A. formosa* and *A. nobilis*) at two different depth (5 m and 10 m) after 1, 3, 5, and 7 hours after transplanting.

In this work, the ^{45}Ca uptake by the coral fragments could be regarded as the rate of the calcification process as has been shown by several investigators [13]. Here the environmental factors which have been applied to test the ^{45}Ca uptake were two factors namely exposure to light at rate of 1, 3, 5, 7 hours and different depth of the coral reefs location, which were 5 and 10 m depth. While other factors which could influence the calcification process, such as temperature; salinity; sedimentation; and pH were considered as stable factors. The results of these two factors are presented in Fig. 3, which was transformed from data in Table 4. The main discussion concerning the data in this work is ^{45}Ca uptake.

Figure 3 shows that there are differences in the two species of *A. formosa* and *A. nobilis* to their exposure to light and depth of their growth location. In general it could be shown in Fig. 3 that *A. formosa* has

The 5 m depth apparently was favorable to ^{45}Ca uptake by *A. formosa*, showing the highest ^{45}Ca uptake compared to the same species at a 10 m depth and to the different species *A. nobilis* for both 5 and 10 m depth. To make the statement clearer it could be put as follows ^{45}Ca uptake by *A. formosa* at 5 m depth > *A. formosa* at 10 m depth > *A. nobilis* at 5 and 10 m depth. This could be due to the penetration ability of the light, where at 5 m depth it has a higher penetration meaning higher light intensity compared to the 10 m depth. This conclusion was for *A. formosa* (Fig. 3) where obviously at the length of time to all light exposure (1, 3, 5, 7 hours) having the higher ^{45}Ca uptake than the same species at 10 m depth. For *A. formosa* at both depth, the lowest uptake was at 7 hours to light exposure, this might be due to the lowering of the light intensity at 7 hours of exposure which was at 3 p.m. The highest ^{45}Ca uptake

ISSN 1907-0322

by *A. formosa* was on 3 and 5 hours exposure to light at 5 m depth and on 1 hour exposure at 10 m depth, although again it can be observed that at 5 m depth, the 1 hour exposure to light still gives higher ^{45}Ca uptake than at the same exposure time at 10 m depth. The reason for low or high ^{45}Ca uptake which could be expressed in other words as low or high rate of calcification is due to the capability of the algae which have a symbiotic relation with the coral to carry out CO_2-fixation [10].

The CO_2-fixation by algae could increase the deposition of Ca. This could be seen on *A. formosa*, when taking into consideration that *A. formosa* at both depth has the same algae species grown in symbiotic relation, then the light intensity will be the main factor to lower or higher the CO_2-fixation. As it was said before the rate of CO_2-fixation will decrease or increase the calcification process and in this study is expressed in ^{45}Ca uptake. Obviously the ^{45}Ca uptake in *A. nobilis* was down below the *A. formosa* especially at the 5 m depth. The pattern of ^{45}Ca uptake done by *A. nobilis* at 5 m depth is similar to that of *A. formosa*, but then decrease earlier than that of *A. formosa*. After 5 hours of exposure to light, *A. nobilis* already showed a sharp decrease of ^{45}Ca uptake, while contrary in *A. formosa* which still show increase albeit at a very low rate. The reason might be that although on the same depth (5 m) the capability of the algae which is growing symbiotically with *A. nobilis* has lower CO_2-fixation capacity. This was then shown by decreasing ^{45}Ca uptake by *A. nobilis*. Of course this need more detailed studies. At the 10 m depth surprisingly *A. nobilis* demonstrate different pattern in ^{45}Ca uptake compared to *A. formosa*. Apparently at this depth *A. nobilis* has more ^{45}Ca uptake capacity at 5 and 7 hours of exposure. After a decrease in ^{45}Ca uptake at 3 hours to light exposure, the ^{45}Ca uptake increase at 5 and 7 hours to light exposure and reach it highest rate of ^{45}Ca uptake at 7 hours of exposure. This might be explained by several factors. First the light penetration, it could be that at the location of *A. nobilis* after 3 hours of light exposure, the light penetration increase resulting in greater light intensity. This greater light intensity could enhance the CO_2-fixation resulting in higher ^{45}Ca uptake by *A. nobilis*. This did not explain why at the 5 m depth *A. nobilis* could not reach ^{45}Ca uptake as high as at the 10 m depth. It is expected that at the shallower depth the coral fragments could do more CO_2-fixation activity than at deeper depth. This might be explained by the sedimentation. Visually the divers have spotted that at 10 m depth there was a stronger current than at 5 m depth bringing with it plenty sediment materials which consist of several nutrition. This nutrition could have been beneficial for the algae growth. More algae growth although at deeper waters could have resulted in higher CO_2-fixation activity. And this all could have resulted in higher ^{45}Ca uptake. It might be that at this particular spot there was high sedimentation. Again all this needs more detailed studies with more environmental factors to be involved.

In general from this study it could be concluded that the length of light exposure could increase or decrease ^{45}Ca uptake by both coral species. Different depth could influence difference in ^{45}Ca uptake, and when this is connected to light exposure again different ^{45}Ca uptake arouse. *A. formosa* could have benefit from the length of light exposure to a certain point at the same depth but a different pattern occurs at the 10 m depth expressed in ^{45}Ca uptake. On the other hand at the 10 m depth *A. nobilis* in connection with length of light exposure at 5 and 7 hours undergoes an enhancement of ^{45}Ca uptake.

The ^{45}Ca uptake by both coral species is an expression of the rate of the calcification process done. The high or low of the CO_2-fixation by algae living symbiotically with the coral species is assumed responsible for the high or low of the calcification process as mention by several researchers in the past. In this study this calcification process is expressed in the ^{45}Ca uptake by the coral species. In short the

ISSN 1907-0322

light penetration at different depth causing different light intensity is responsible for the different CO_2-fixation by the algae living symbiotically with the coral species. This fixation process could be expressed in ^{45}Ca uptake by coral species and could be calculated quantitatively. This quantitative calculating of ^{45}Ca uptake is able to estimate the calcification process carried out by the coral species.

CONCLUSION

Data obtained by this study would be concluded as follows;

- The ^{45}Ca method could be used satisfactorily to calculate the ^{45}Ca uptake by the coral fragments studied in different depth and several light exposures.
- There was a significant difference in the ^{45}Ca uptake by the two different coral species namely *A. formosa* and *A. nobilis*, in overall *A. formosa* showing a sufficient ^{45}Ca uptake than *A. nobilis.*
- Higher ^{45}Ca uptake was shown by *A. formosa* at 5 m depth compared to the same species at 10 m depth, and to *A. nobilis* at 5 and 10 m depth, this was true for all the time periods of light exposure (1, 3, 5 and 7 hours).
- The ^{45}Ca uptake showed difference patterns, when plotted against time periods of light exposure. *A. formosa* has the highest ^{45}Ca uptake at the 5 hours light exposure and then dropped sharply reaching its lowest ^{45}Ca uptake at 7 hours of light exposure, at 5 m depth. While at 10 m depth, this species showed the highest ^{45}Ca uptake at the earliest light exposure (1 hour) and then dropped at the further time periods of exposure.
- For *A. nobilis* at 5 m depth the ^{45}Ca uptake showed a similar pattern as shown by *A. formosa*, but here the highest ^{45}Ca uptake was at the 3 hours of light exposure, and to decrease sharply after 3 hours of light exposure. There was a different pattern of ^{45}Ca uptake at 10 m depth, where it was shown that after a drop of ^{45}Ca uptake there is a continuous increase up to the end of the light exposure (7 hours).
- The difference in ^{45}Ca uptake in the coral fragments is assumed to be influenced by light and algae species living symbiotic with the coral species.
- The ^{45}Ca uptake is evidence that the coral fragments transplanted has growth during this study.
- Further studies should be carried out to exactly gathered data of all the factors which could influence the calcification process by coral reefs, the factors could be CO_2–fixation, flow of sedimentation, etc.

ACKNOWLEDGEMENT

We would like to thank DP2M DIKTI for funding this study. The authors also wish to thank Mr. Amrin Djawanas and Prof. Riset Elsje L. Sisworo, Ir., MS., for their involvement in the field and laboratory assay. We also appreciate Prof. Riset Elsje L. Sisworo, Ir., MS., for editing this paper.

REFERENCES

1. IDRIS, Pendugaan laju kalsifikasi karang dengan menggunakan radioisotop $^{45}CaCl_2$ sebagai tracer (penanda) pada karang jenis *Euphyllia cristata* di Pulau Pari, Kepulauan Seribu, Skripsi, FPIK – IPB, Bogor (2004).

2. ANONIMOUS, Mesti Berjuang untuk Hidup, *KOMPAS,* Kamis 29 April 2010, 13 (2010).

3. SUHARSONO dan KISWARA, W., Kematian karang alami di Laut Jawa, *Oseana*, **9** (1), 31 – 40 (1984).

4. SUHARSONO, "Jenis-jenis Karang yang Umum Ditemukan di Perairan Indonesia, Proyek Penelitian dan Pengembangan Daerah Pantai",

ISSN 1907-0322

Pusat Penelitian Oseanologi, LIPI, Jakarta (1996).

5. CLARCK, S., and EDWARD, A.J., "Coral Transplantation as an Aid to Reef Rehabilitation, Evaluation of a Case Study in The Maldive Islands", University of New Castle, New Castle (1995).

6. BIRKELAND, A., RANDALL, G., and GRIMM, G., Three Methods of Coral Transplantation for Purpose of Re-establishing a Coral Community in Thermal Effluent Area of The Tanguisson Power Plant, Guam Marine Lab. Tech., Rep. No. 60, 1 – 24 (1979).

7. HILBERTZ, W., FLETCHER, D., and KRAUSSE, C., Mineral aeration technology, applications architecture and aquaculture, *Industrial Forum,* **8**, 75 – 84 (1977).

8. HERDIANA, Y., Respon pertumbuhan serta keberhasilan transplantasi koral terhadap ukuran dan posisi penanaman pada dua spesies karang *Acropora micropthalma* dan *Acropora intermedia* di Perairan Pulau Pari, Kepulauan Seribu, Skripsi, FPIK – IPB, Bogor (2001).

9. HARIOT, V.J., and FISK, D.A., Coral Transplantation as a Reef Management Option, Proc. Of the 6th Int. Coral Reef Symp., Australia, 2, 75 – 79 (1998).

10. GOREAU, T.F., and GOREAU, N.I., The Physiology of skeleton formation in corals. I. A method of measuring the rate of calcium deposition by corals under different conditions, *Biology Bulletin Marine, Biology Laboratory Woods*, **116**, 59 – 75 (1959).

11. GOREAU, T.F., Problem of growth and calcium deposition in reef coral, *Endeavor*, **20**, 32 – 40 (1961).

12. SOEPRIHARYONO, The Effect of sedimentation on a fringing reef in North Central Java, Indonesia, Thesis, Univ. of New Castle upon Thyne, New Caste Upon Thyne, (1976).

13. VAN DER MEULEN, J.H., and MUSCATINE, L., "Influence of Symbiotic Algae on Calcification in Reef Corals Critique and Progress Report, Symbiosis in the Sea", University of South Carolina Press, South Carolina, 1 – 19 (1974).

14. L'ANNUNZIATA, M.F., "Radiotracers in Agric. Chemistry", IAEA, Vienna, 425 – 428, (1979).