Recruitment Status of Coral Reefs (Scleractinian) after Earthquake and Tsunami in North Pagai Island of Mentawai Islands Regency

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Abstract

Recruitment of coral is marked by the appearance of reef colonies that are still juvenile. Coral recruitment data after the earthquake and tsunami are very few either in Indonesia or in other part of the world. The purpose of this study is to analyze the level of recruitment and to analyze recruitment diversity of coral reef Scleractinian in the waters affected by tsunami (west coast) and not affected by tsunami (east coast) of North Pagai Island. The observation on coral recruitment used benthic quadrate sampling method with a size of 1x1m^2 and the diameter of colony taken measured between 0.5–10 cm. The result of the study shows that the average of recruitment density at the west coast (affected by tsunami) ranged between 0.78–3.67 colonies.m^{-2} and at the east coast (not affected by tsunami) ranged between 5.11–11.67 colonies.m^{-2}. Coral recruitment level of the east coast is within the category of medium to very high while coral recruitment level of the west coast is in very low to low category. Diversity index (H') of east coast and west coast ranged between 1.55–2.54 with medium category, evenness index (E) of east coast and west coast ranged between 0.87–0.97 with stable category, and dominance index (C) with values ranging from 0.10–0.13 with low category.. Types of coral *Porites cylindrica* is growing rapidly and has the highest level of recruitment after the tsunami.

Keywords: recruitment reef, tsunami, coral, North Pagai Island

Introduction

Earthquake and Tsunami of Mentawai Islands Regency occurred on October 20, 2010.The earthquake with a magnitude of 7.7 (USGS, 2010) shook most of the coastal areas of West Sumatra to Bengkulu. The earthquake then aroused a tsunami that destroyed almost the entire village in the western coastal area of the southern part of Sipora Island, North Pagai Island, and South Pagai Island. Data of National Disaster Management Agency (BNPB) per-November 9, 2010 stated that the victims died as a result of the tsunami were 448 people, leaving 7,328 people who live until now refugee camps (Dinas ESDM Sumatera Barat, 2011). Massive destruction in the coastal areas as well as a relatively large loss of life occurred on the west coast with the tsunami height of 5-8 meters.

Coral reefs biota is the main benthic biota that affected directly by the earthquake and tsunami. Mass death of corals and other biota were visible due to long exposure on the surface of the water and some of them washed ashore by the tsunami. Recovery of coral reefs can be seen from several aspects, including aspects of recovery back to the original state (resilience) and aspects of coral recruitment. Recovery of coral communities are very dependent on the arrival of coral larvae which is a major factor in the relationship between reefs (van Moorsel, 1988; Smith *et al.,* 2001; Wilkinson *et al*., 2006)

Measurement of the abundance of coral recruitment is based on the number of coral juvenile defined as coral colonies measuring of ≤5 cm (Van Moorsel, 1985; Golbuu *et al*., 2007), colony size of 2–5 cm (Miller *et al*., 2000), colony size of 0.5–5.0 cm (McClanahan *et al*., 2005; Dunstan and Johnson, 1998). Meanwhile, recruitment of coral colonies is measured in the longest diameter of ≤10 cm (Obura and Grimsditch, 2009). Bachtiar *et al*. (2012) classify the size of juvenile into three categories: small (<3 m), medium (3-6 cm), and large size (>6 cm and ≤10 cm). This coral colony size limitation has no meaning biologically and ecologically, but can indicate the presence or absence of coral recruitment process.

The data about the condition of coral reefs and coral recruitment after the earthquake and tsunami is very little or rarely both in Indonesia and

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ijms.undip.ac.id
DOI: 10.14710/ik.ijms.21.4.161-168
Received : 01-08-2016
Accepted : 06-09-2016

in the world. Although the tsunami has often happened in Indonesia, the last tsunami in the Mentawai Islands regency, the condition of the reef and the recruitment has not been recorded yet. After the tsunami, the coral suffered major damage, especially in the waters of the bay and the beach. The damage to the reef are generally serious on 3-10 meters depth.

After the tsunami, reef restoration concept is needed. Natural reef restoration is dependent upon the arrival of coral larvae. Understanding the coral recruitment is very important to make the concept of the reef ecosystem restoration. Coral recruitment studied are the number of colonies of coral recruitment, the number of types of coral recruitment, conditions of the substrate, water quality and coral succession observations on hard substrates. Coral recruitment research in 2014 or after the recruitment of corals had been aged over 3 years tsunami occurred October 20, 2010) is the right moment to take the data of abundance and diversity of coral recruitment. Assuming the reef has reached a diameter of more than 5 cm and has a good survival. Stated the growth of juvenile corals of the genus Acropora reach a diameter of 1–2 cm, and 2–5 cm within 2 years. Baird and Babcock (2000) stated that 3–6 cm is the size of the vulnerable for coral recruitment in Pari Island, Kepulauan Seribu. Stated that the size of coral fragments good to be transplanted is 3–6 cm and has a high survival rate. Mean while, the abundance and diversity of coral recruitment between 1–2 years old is still unstable and coral deaths frequently happened due to predation and competition with other biota. The condition in which the population is stable is the right time to retrieve the data of coral recruitment after tsunami. The coral population that has been stable can be used as the basis of post-disaster restoration of coral reefs in which the living coral reflects the coral that resilient and having high graduation life.

The purpose of this research is to analyze the level of Scleractinian recruitment based on the coral reefs abundance and to analyze the diversity of Scleractinian coral recruitment both in the waters affected by tsunami (west coast) and in the waters not affected by the tsunami (east coast) of North Pagai Island.

Materials and Methods

The study was conducted on June-August 2014 in North Pagai Island, Mentawai Islands Regency, West Sumatra Province. The coral recruitment sample was taken from six stations, *i.e.* the eastern part including S1 (Gosong Tubagok), S2 (Karang Tepi Mapinang) and S3 (Mapolak Beach) which are not affected by tsunami, and the western part affected by tsunami, namely S4 (Sabeogunggung Beach), S5 (Munte Baru-Baru) and S6 (Bulak Mongga).

In each research station,3 transect lines of 10 meters long each are made by using squared transect In each transect line, there were 3 squares: in the first meter, fifthmeter, and tenth meter. The observation on these coral recruitments used benthic quadrate sampling method with the size of 1 x 1 meter with the coral diameter measured between 0.5-10 cm. Therefore, there were 9 transect squares at a depth of 5-7 meters (Figure 1).The identification of coral recruitment were up to the species level by referring to Baird and Babcock (2000), Veron and Pichon (1976), Veron (2000a, b and c) as well as other identification books and literature. The density of coral recruitment based on the data collected by the transect square of 1x1 m^2 was calculated along 70 meters transect by nine times repetition. The coral recruitment level in the total density of coral reefs in the squares were grouped according to Engelhardt (2000). See Table 1. Coral recruitment data analysis used to draw the community structure by diversity index, evenness index, and dominance index. To analyze the differences in the abundance of coral recruitment west and east coasts performed with the student t test.

Diversity index that describes the richness and abundance of taxa in the community obtained by using Shannon-Wiener diversity index. Evenness index which represents the deployment balance (evenness) of each individual species in a community is calculated by comparing the obtained diversity index with the maximum diversity index . To see the dominance of a certain type within the community, Simpson index was calculated by Kreb equation (1989).

Table 1. The level of coral recruitment in the total density of coral reefs in the squares of 1x1 m^2 according to Engelhardt (2000).

Coral recruitment level	The density of coral in 1x1 m^2
Very low	0-2.5
Low	2.6 – 5
Medium	5.1 –7.5
High	7.6 – 10
Very High	>10

Result and Discussion

Coral recruitment level

The observation on six stations at east and west coast found the coral recruitment as much as 15 genera and 25 species. At the east coast (not affected by tsunami), there were 15 genera and 25 species while at the west coast (affected by tsunami) there were 8 genera and 14 species (Figure 2, Figure 3 and Appendix 1) Compared with the research conducted by Abrar and Yempita (2002) in the Tuapeijat Waters, Sipora Island, Mentawai Islands Regency, the juvenile coral genus was found as many as 25 species far more than those found in the waters of Pagai Island. It is caused by the location of research having more relatively calm waters in Tuapejat waters of Sipora Island while on Pagai Island the waters have relatively strong currents that affect the attachment of juvenile corals. The growing juvenile corals will greatly need calm waters to stick to the base substrate.

The coral colonies were most commonly found on the genus Acropora as many as 7 species. This was because the juvenile corals of the genus Acropora could stand with extreme environmental conditions and could easily attach to the new substrate. Munasik (2008) stated that the Acropora is coral pioneer species that can easily attach to the new substrate. Siringoringo (2009) stated that coral recruitment is a process of colonization and occupation of a new place. Coral communities that far from the location and coral reproduction characteristics are very influential on coral recruitment and its ability to shape the coral community.

The average of recruitment density of the east coast (not affected by tsunami) ranged between 5.11–11.67 colonies.m^{-2} and at the west coasts (tsunami) ranged from 0.78–3.67 colonies.m^{-2}. Student t test results showed there were significant differences between the abundance of coral recruitment locations west coast and the east coast ($p < 0.05$). Based on the level of recruitment by Legendre and Legendre (1983); English *et al*. (1997); Engelhardt (2000) the coral recruitment rate in the east coast waters is in the category of medium to very high and the west coast waters has very low category.

The average density of the total density rukruitmen reef on the East Coast (not affected by the tsunami), the highest found in the type *Pocillopora damicornis*, followed *Acropora digifera* and coral species *Acropora humilis* (Figure 2). While the average density of the total density of coral recruitment on the West Coast (tsunami) is the highest found in the type of *Porites cylindrica,* followed by the type of *Acropora intermedia*, *Acropora carduus,* and *Acropora protrata* (Figure 3). Results of research consistent with research Siringoringo (2009) that the types of coral *Porites cylindrica* dominated after the earthquake and tsunami Nias in 2004, 2005, 2006 and 2007. This is due to the type of coral *Porites cylindrica* is a form of branching coral belonging to the group growing fast.

Coral recruitment density in the waters affected by several factors such as currents, light intensity, recruitment willingness and recruitment positions. Pitasari *et al.* (2011) stated that differences in conditions and topography of benthic reef waters largely determine the success of juvenile corals to be able to develop into adult corals. The low density of coral recruitment in the west waters due to a very strong current and the changes of base substrate after the tsunami that disturbing the coral larval settlement. In addition, the good condition of the coral also affect the juvenile density. Siringoringo (2009) states that adult corals will inhibit the growth of juvenile corals in terms of space competition, food competition, and availability of substrate for coral larval settlement. In addition to live coral cover, the low density of juveniles associated with soft corals and other fauna. Coral recruitment pattern like this is similar to the result of the research conducted by Bachtiar *et al.* (2012) in Pantar and Marisa Island, NTT. Furthermore, Bachtiar *et al.* (2012) mentioned that there is a tendency that after passing a certain threshold, the higher the live coral cover is, the smaller the number of juvenile corals will be. It is related to the space competition between juvenile and adult corals as well as lack of space for the attachment of a new coral larvae. Something similar was found by Pitasari *et al.* (2011) in the study at Pasir Putih Beach, Situbondo. The study said that the highest recruitment levels were found at locations in which dead coral (DC) were found, while in the coral reefs with good condition, recruitment was low.

Community structure of coral recruitment

The community structure observed in this study are the diversity index (H'), evenness index (E), the dominance index (C), and the similarity index (S) (Table 3). Evenness index and dominance index reflects the presence or absence of the dominant species. The value of evenness index and dominance index ranges from 0–1. If the evenness index is close to 0, it indicates an imbalance between the proportion of individuals between types or in other word there are certain types that

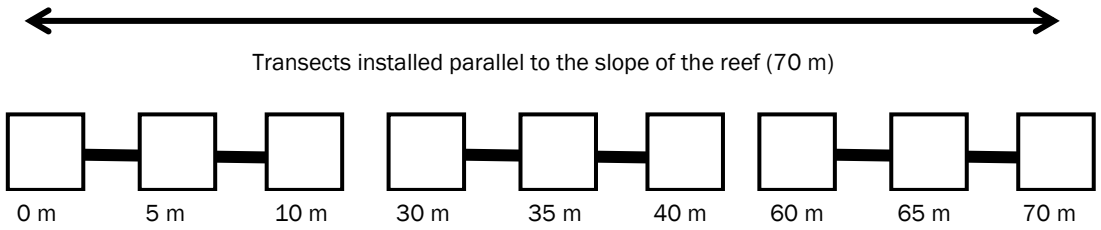

Figure 1. Observation by transect squares

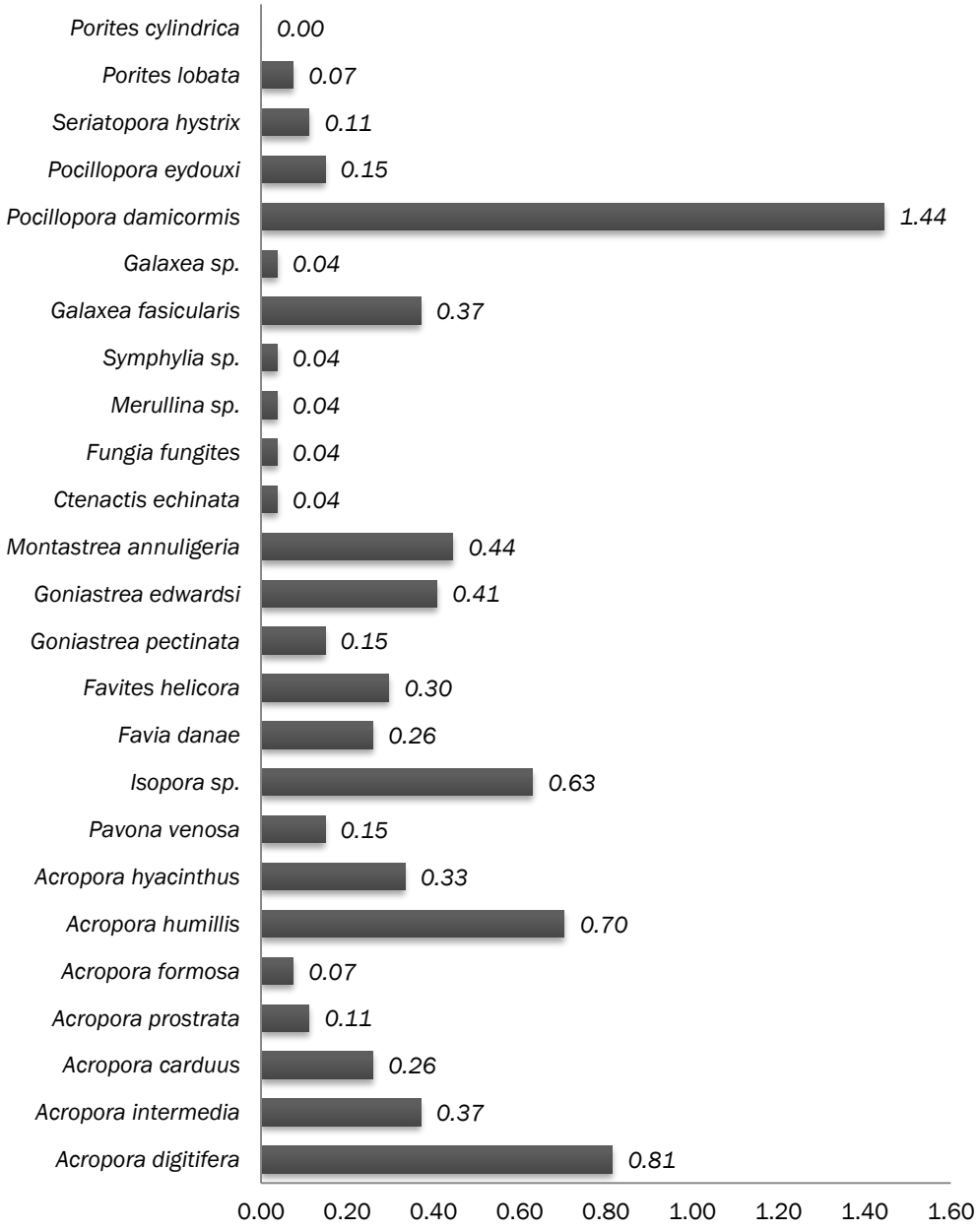

Figure 2. The average of coral recruitment density on the East Coast (non-tsunami)
Note: ■ = Density (colony.m^{-2})

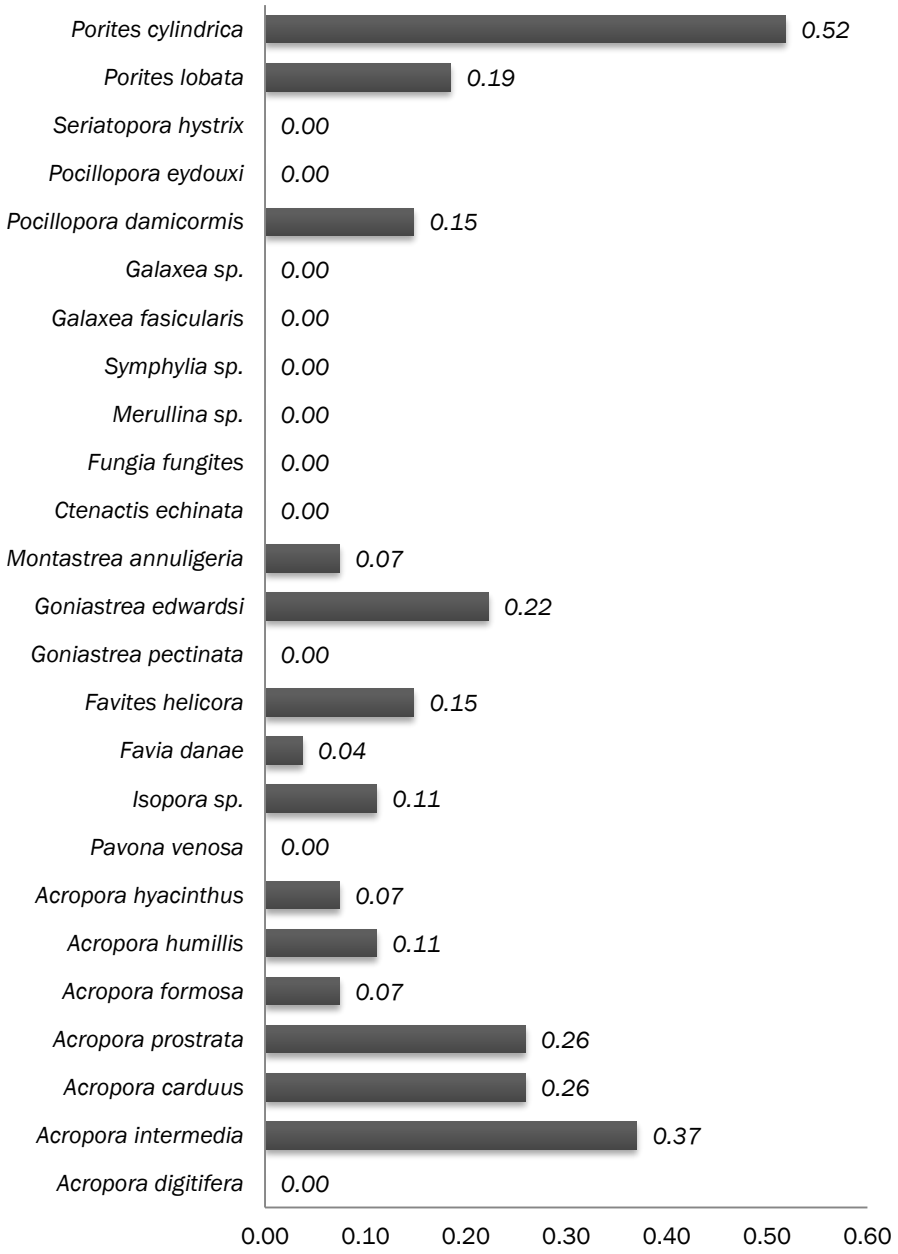

Figure 3. The average of coral recruitment density on the West Coast (tsunami)
Note: ■ = Density (colony.m^{-2})

Table 2. The value of the diversity index (H'), evenness index (E), and the dominance index (C)

Index	S1	S2	S3	S4	S5	S6
Diversity Index (H')	2,01	2,40	2,54	1,55	1,84	1,94
Evenness index (E)	0,87	0,91	0,90	0,97	0,95	0,96
Dominance Index(C)	0,16	0,11	0,10	0,28	0,17	0,13

Description:
S1, S2, S3 are East Coast Stations (not affected by tsunami)
S3, S4, S5 are West Coast Stations (affected by tsunami)

dominate. Conversely, if the value is close to 1, it means that the proportion of the number of individuals among species is relatively balanced, or in other words there is no dominant species. In this case, dominance index is the opposite of evenness index. From Table 2, it can be seen that the diversity index (H') of east coast and west coast ranged between 1.55–2.54 with medium category (Krebs, 1989). Evenness index (E) of east coast and west coast ranged between 0.87–0.97 with stable category (Odum, 1989), and dominance index (C) with values ranging from 0.10–0.13 with a low dominance category (Odum, 1989). High or low diversity index of a community is affected by the species richness and individual equality making up the community. The higher species richness and uniformity, the higher the diversity index and vice versa, the lower species richness and evenness index, the lower the diversity of the community.

Diversity index of coral recruitment in western coasts are generally lower than the east coast. This is thought to be caused by environmental conditions that are not suitable for the growth of coral recruitment, relatively strong currents, and there is a change of substrate in this area causing not many juvenile corals can be attached to the waters base substrate. Odum (1998) said that the diversity of the community may decrease if the community is dominated by one or a few species.

Evenness index ranges from 0–1, the smaller the value of uniformity, the smaller the uniformity of the population in the community, meaning that the spread of the individual is uneven. Based on the community condition, the evenness index values are grouped into three categories, namely: community in depressed condition (E= 0–0.5), community is in unstable condition (E= 0.51–0.75), and community in distress (E= 0.76–1) (Odum, 1998).

It can be seen in Table 2 that the dominance index of coral recruitment is low. Simpson dominance index is divided into two categories, namely C<0.5 which means low dominance and C >0.5 which means high dominance (Odum, 1989). Dominance index is inversely proportional to the diversity index and evenness index. If the diversity and evenness index are high, the dominance index is low, and vice versa if the diversity and evenness indexis lower then the dominance index is high.

Conclusion

The average of recruitment density at the east coast (not affected by tsunami) ranged between 5.11–11.67 colonies.m^{-2} and at the west coast (tsunami) ranged between 0.78–3.67 colonies.m^{-2}. Coral recruitment level of the east coast is within the category of medium to very high while coral recruitment level of the west coast is in very low to low category. Types of coral *Porites cylindrica* is growing rapidly and has the highest level of recruitment after the tsunami.

Acknowledge

A big thank you goes to the Director General of Higher Education (DIKTI) Kemendikbud as the organizer of Fundamental Research 2014, Coordinator of Kopertis Region X, Rector and LPPM Chairman of the University of Bung Hatta which has facilitated the smooth running of this research.

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Appendix 1. Coral recruitment data of North Pagai Island

Spesies	S1	S2	S3	S4	S5	S6
Acropora digitifera	12	7	3			
Acropora intermedia	4		6		5	5
Acropora carduus	2		5			7
Acropora prostrata		2	1		5	2
Acropora formosa		2		2		
Acropora humillis	10	2	7		3	
Acropora hyacinthus	3		6		2	
Pavona venosa		1	3			
Isopora sp.		6	11			3
Favia danae	2		5	1		
Favites helicora		3	5	1		3
Goniastrea pectinata		4				
Goniastrea edwardsi	1		10	1	2	3
Montastrea annuligeria		5	7			2
Ctenactis echinata		1				
Fungia fungites		1				
Merullina sp.			1			
Symphylia sp.		1				
Galaxea fasicularis		5	5			
Galaxea sp.	1					
Pocillopora damicormis	5	9	25			4
Pocillopora eydouxi	4					
Seriatopora hystrix			3			
Porites lobata			2		5	
Porites cylindrica	0	0	0	2	8	4
Total Number of Colonies	46	49	105	7	30	33
Number of Colonies/m2	5.11	5.44	11.67	0.78	3.33	3.67
Diversity Index (H')	2.01	2.40	2.539	1.55	1.84	1.94
Evenness index (E)	0.87	0.91	0.90	0.97	0.95	0.96
Dominance Index (C)	0.16	0.11	0.10	0.28	0.17	0.13

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