Journal of BIOLOGICAL RESEARCHES
ISSN: 08526834 | E-ISSN:2337-389X
Volume 21| No. 1| December | 2015

Review Article

SPECIATION AND ZOOGEOGRAPHY OF AMPHIBIAN IN SUNDALAND

Nia Kurniawan[1*], Driyana Rike Ahmadlia[2], Day Shine Nahari[3], Anggun Sausan Firdaus[1]

[1]Biology Department, Faculty of Mathematics and Natural Sciences, University of Brawijaya
[2]Biology Department, Faculty of Sciences and Technology, Islamic State University Maulana Malik Ibrahim
[3]Chemistry Department, Faculty of Sciences and Technology, Islamic State University Maulana Malik Ibrahim
Veteran Street, Malang 65145, East Java, Indonesia

ABSTRACT

Sundaland is an interesting area to be explored based on its geological history, topography, and climate. Sundaland consists of Penisular Malaysia, Sumatra, Borneo, and Java which experienced some emergence and submergence process in the past. During 1981-2015, most of research in Sundaland found that amphibian family in Sundaland was dominated by Bufonidae, Ranidae, Microhylidae, Megophrydae, Rachophoridae, and Dicroglossidae which experienced lot of speciation in its history. Among of 4 major islands in Sundaland, Borneo has the highest number of species diversity, then Peninsular Malaysia, Sumatra, and Java. During those years, Sumatra and Java got least concern by researcher. Therefore, it is suggested for further study to explore more in Sumatra and Java.

Keywords: *Sundaland, amphibian, speciation, zoogeography.*

INTRODUCTION

The history of Sundaland has begun at the Early-Cenozoic (approximately 65 mya). It was merged with the southern end of Eurasia continent (Hall, 1996). During Pliocene and Pleistocene period, Sundaland was a large single landmass. Since the rise of sea level in glacial period, Sundaland dispersed into Java, Borneo, Sumatra, Malay-Peninsula, and some adjacent islands (Molengraaff, 1916).

Sundaland has dispersed along the equator line with mountains and rivers on it. Sundaland has tropical climate and seasonal wind. During glacial Pleistocene, the climate has predicted to be cooler and drier, except in Sumatra, West Borneo, and North Borneo which have wet climate. Most of Sundaland included to monsoon climate area and the rest northern area with equatorial climate. The difference is on its rain cycle in the monsoon climate region. Climate in Sundaland is fluctuative between cooler-drier periods and warm-wet periods. Both of the periods has influenced the occurrence of tropical forest area as habitat of Sundaland amphibian in the past. On the other side, warmer climate in Sundaland causes it has high biodiversity. Warmer climate provide more food and constant temperature in a year. Thereby, Sundaland has high biodiversity than other subtropical regions (Lohman et al., 2011).

* Corresponding Author:
Nia Kurniawan
Biology Department, Faculty of Mathematics and Natural Sciences, Brawijaya University
Jl. Veteran, Malang 65145, East Java, Indonesia
phone : +6282142452370
e-mail : wawan@ub.ac.id

Amphibian composition in Sundaland is the result of amphibian exchange at Plio-Pleistocene period (Wilting et al., 2012; Brandon and Jones, 1996). There were several factors which influenced amphibian composition in Sundaland, they are geological history of Sundaland and tropical climate which affected on the other geological factors, such as ancient river system and climate. Beside that, supervulcanic eruption also gave some influence (Woodruff, 2003; Lohman et al., 2008). This chapter will discuss about speciation and zoogeography of amphibians in Sundaland, despite on its geological history and amphibian diversity (especially amphibians).Amphibian composition in Sundaland is the result of amphibian exchange at Plio-Pleistocene period (Wilting et al., 2012; Brandon and Jones, 1996).

SPECIATION OF AMPHIBIAN IN SUNDALAND

Speciation in Sundaland was predicted has begun when the process of land connecting and separating as the result of sea-level fluctuation since Eocene until Pleistocene period (Wilting et al., 2012; Ruedi, 1996). Both of these processes end with allopatric speciation which caused by physical barrier (such as topography, water, and landmass), it leads to the formation of genetic reproduction barrier. Futuyama (2005) explained in his book "*Evolution*" that natural selection and genetic drift have caused the divergence in genetic composition. When a region is separated in a long period of time (geographically) it will form new species as the result of allopatric speciation.

Amphibian research in Sundaland has started since the 18th until 20th century (today) and has completed the database of amphibian. There are 6 families which found in Sundaland (Bufonidae, Ranidae, Megophrydae, Microhylidae, Dicroglossidae, and Rhacophoridae) with the high similarity on their characters and high species diversity in every island. During the 18th until 20th century some studies showed that Sundaland has 301 species of amphibian (from 6 large families) approximately which some of them are endemic species. Each family was estimated have some species resulted from speciation in their developmental process. Percentage of each family in Sundaland (total species in Sundaland) since 18 century was Rhacophoridae 25%, Ranidae 20%, Bufonidae 18%, Microhylidae 14%, Megophrydae 12%, and Dicroglossidae 11% (Figure 1.a).

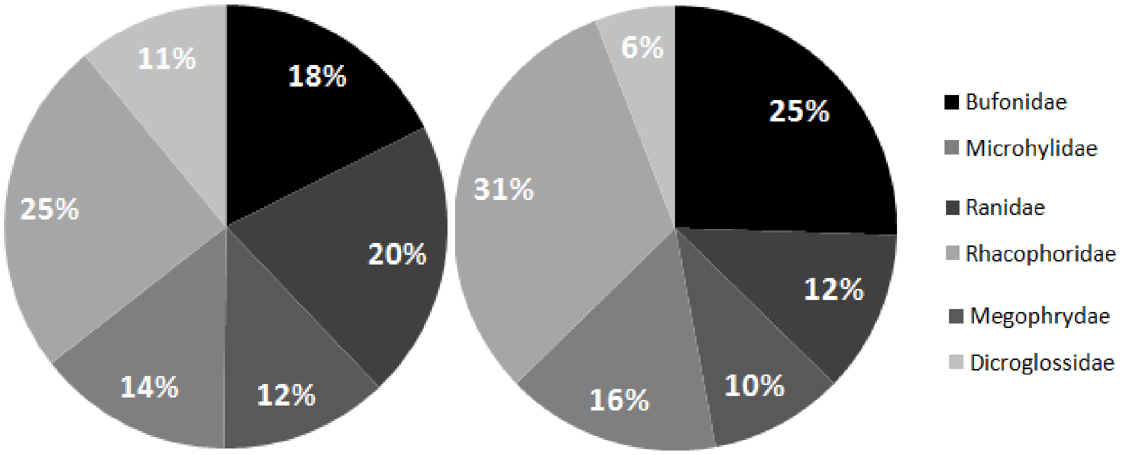

Figure 1. a) Percentage of amphibian species based on distributed family in Sundaland; b) Percentage of new species which distributed in Sundaland.

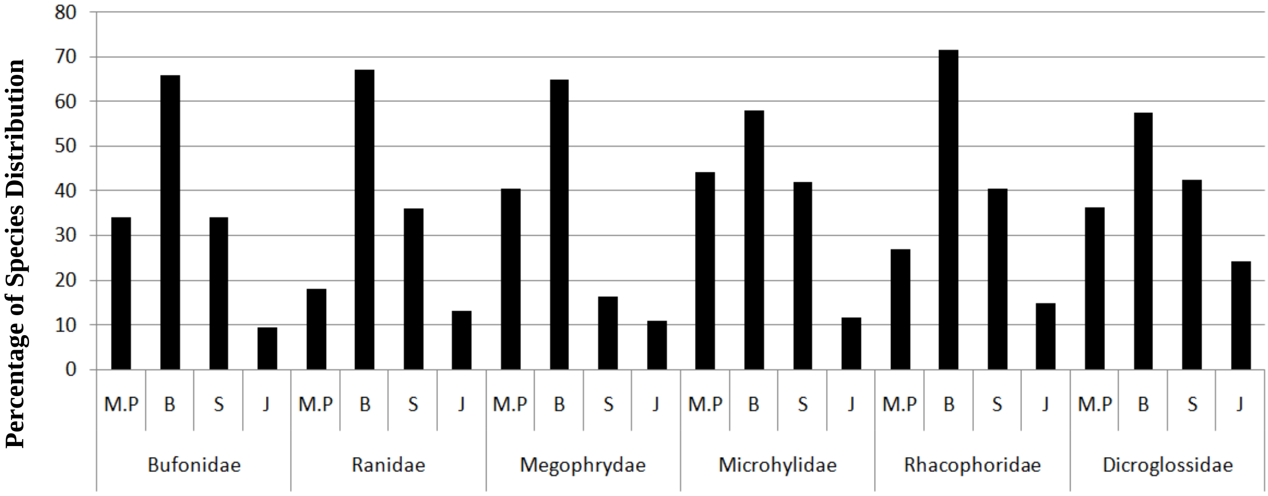

Figure 2. Percentage of species distribution in amphibian based on 6 main family (Bufonidae, Ranidae, Megophrydae, Microhylidae, Rhacophoridae, and Dicroglossidae) in 4 major islands (Malay Peninsular, Borneo, Sumatra, and Java) and adjacent island.

Rhacophoridae

Rhacophoridae family has the highest species diversity in Sundaland compared with five other families (see Figure 1.a). It consists of ±6 genera (*Nyctixalus*, *Phlautus*, *Polypedates*, *Rhacophorus*, *Theloderma*, and *Chiromantis*) with total ±74 of species. Some species in Rhacophoridae have been predicted as endemic species in Sumatra and Java. Species which predicted as endemic in Java were *Philautus jacobsoni*, *Philautus pallidipes*, *Philautus vitiger*, and *Rhacophorus javanus* (Kurniati, 2006), while Sumatra has *Rhacophorus achantharrena*, *Rhacophorus barisani*, *Rhacophorus bifasciatus*, *Rhacophorus bengkuluensis*, *Rhacophorus catamitus*. *Rhacophorus*, *Polypedates*, and *Theloderma* genera have wide distribution area in Sundaland, because they are distributed almost in all 4 major islands (Teynie et al., 2010; Streitcher et al., 2014; Harvey et al., 2002).

Philautus and *Rhacophorus* were genera with the highest number of densityin Sundaland compared with other genera (Teynie et al., 2010). Rhacophoridae has highcharacter similaries among its species member which predicted as the result of geological condition of Sundaland that led to speciation. *Philautus ingeri* is one of the example speciation results which found at Sarawak (Borneo) and predicted as *P. hosei* by Dring (1987). Another example is *Philautus mjobergi* which identified by Smith (1925) from Borneo, it first known as *P. aurifasciatus* (Bossuyt and Dubois, 2001). High similarityof their morphological characters sometimes cause misidentification. Morphological similarities of the species were predicted as the result of speciation process, as described by Darwin that evolution was originated from the ancestor which have changed and developed (Coyne, 2009).

Ranidae

Ranidae consists of ±7 genera which spread widely in Sundaland (*Amolops*, *Huia*, *Hylarana*, *Staurois*, *Meristogenys*, *Odorrana*, and *Rana*) with ±61 species. *Rana* has the highest species diversity compared with other genus and spread in Peninsular Malaysia, Borneo, Sumatra, and Java. As the genus with the highest species diversity and the widest distribution, *Rana* has some species which resulted from speciation (Lim and Leong, 2004; Tjong et al., 2012). For example *Rana siberu* which formerly distributed in Sumatra, including Aceh, Bengkulu, and West Sumatra (Iskandar and Coljin, 2002), species also found in Peninsular Malaysia recently (Lim and Leong, 2004).

Rana siberu firstly described as *R. signata* complex because of their similarities. *R. siberu* male then known has no nuptial pad. The differences of their morphological character were predicted as the result of the difference between Sumatra and Peninsular Malaysia land mass (Lim and Leong, 2004). Mentawai Island, Sumatra, and Peninsular Malaysia connected through Batu Island (Northern Siberu) (Heaney, 1986; Hall, 1996; Voris, 2000). The land mass difference allowed genetic flow between Siberut, Sumatra, and Peninsular Malaysia.

Rana siberu was geographically isolated and experienced allopatric speciation. Simulation of geographical isolation was begun by the increase of seawater level that caused the ocean depth between Eastern Siberut and Western Sumatra reached 400 m (Heaney, 1986; Hall, 1996; Voris, 2000). During the last 250.000 years, sea surface was predicted to decreased into 120 m and caused the separation of Siberut and Batu Island that resulted in high level of speciation and endemism (such as *R. siberu*) (Lim and Leong, 2004).

The other genus that experienced speciation is *Hylarana*. *H. rufipes* from West Sumatra known as the result of sympatric speciation of *H. chalconota* based on Tjong et al. (2012) research. Recent studies found that there are differences on the number of chromosomes between them. Djamhuriyah (2000), clarifies that *H. chalconota* has 13 chromosome pairs which consists of 5 pairs of large chromosome and 8 pairs of small chromosome. Whereas, *H. rufipes* has 6 pairs of large chromosome and 7 pairs of small chromosome, 1 pair submetasentric and 12 pairs metasentric chromosome (Tjong et al., 2012).

Bufonidae

Bufonidae family (True Toads) consists of ±9 genera (*Ansonia*, *Bufo*, *Ingerophrynus*, *Duttaphrynus*, *Leptophryne*, *Nectophryne*, *Pedostibes*, *Pelophryne*, and *Phrynoides*) with ±53 species in Sundaland (Grismer, 2007; Grismer *et al*., 2006; Grismer, 2006; Marx, 1976; Marx, 1958; Chan *et al*., 2010; Teynie *et al*., 2010; Wood *et al*., 2008; Dring, 1983; Inger *et al*., 2001). Bufonidae in Sundaland was dominated by genus *Ansonia* which distributed in Malay Peninsula, Borneo, and Sumatra (Marx, 1976; Matsui, 2006; Teynie *et al*., 2010). Limited distribution in Malay Peninsula, and Borneo predicted caused by the geological history of Sundaland.

Ansonia breeds in stocky stream which facilitated by land mass of Riau-Bangka-Karimata arcs and Anambas-Natuna arcs. Genetical exchange of *Ansonia* was predicted occurred when Borneo and Peninsular Malaysia were separated from Sumatra and Javathen caused allopatric speciation (Inger and Voris, 2001). Some species of *Ansonia* have been clustered and only distributed in Peninsular Malaysia or Borneo. The predicted scenario for this condition is the vicariance event, the increasing of sea level that caused the separation of area distribution between Peninsular Malaysia and Borneo which occurred at Early-Miocene (24 – 13 Mya) (Bohlen et al., 2011; Woodruff, 2003). *Ansonia* then fragmented by mountain and sea barriers which lead to the natural selection and genetic drift.

Microhylidae

Microhylidae is a group of small-sized frog which has 14% number of total species in Sundaland. This family consists of ±6 genera (*Calluella*, *Gastrophrynoides*, *Kalophrynus*, *Kaloula*, *Microhyla*, and *Metaphrynella*) with ±43 of total species. *Kalophrynus* and *Microhyla* have the highest total species in Sundaland compared with other genus. Most of *Kalophrynus* species are spread in Borneo, and some are spread in 3 other major islands (Das and Haas, 2003; Teynie et al., 2010; Chan et al., 2010; Das et al., 2007; Matsui, 2009). Each of Microhylidae genera experienced some speciation process which caused by many factors.

Kalophrynus experienced some speciation processes which lead to the formation of new species, for example *Kalophrynus eok* which found at high land on Kalabid, Serawak, and Borneo. It can be distinguished with other *Kallophrynus* which found at other parts of Borneo by their morphological characters. *K. eok* is different from *K. baluensis* which found at Sabah, Western Malaysia by the presence of weak subarticular tubercles on its toe and one subarticular tubercle located on its fifth toe. It is different with *K. eok* which has subarticular tubercle on its third toe. Beside that, *K. baluensis* have unwebbed toes which different with *K. eok* that have toes webbed basally to below. Despite on its skin, *K. baluensis* has bright brownish color on dorsal, which differ with *K. eok* that has granul and maroon color on its dorsal (Kiew, 1994; Das and Haas, 2003). Those differences are predicted as the result of adaptation on their habitat where they live and lead to sympatric speciation between *Kalophrynus* in Borneo.

Megophrydae

Megophrydae in Sundaland consists of ±5 genera (*Leptobrachella*, *Leptobrachium*, *Leptolalax*, *Megophrys*, and *Xenophrys*) with ±37 species. *Leptobrachium* and *Megophrys* are genera which contributed more species than the others (Teynie et al., 2010; Iskandar and Erdelen, 2006; Inger and Iskandar, 2005; Chan et al., 2010; Grismer et al., 2004; Inger et al., 1995; Matsui, 2006; Inger, 1966). Most of *Leptobrachium* spread on Borneo and least spreading on other main islands (Malaya Peninsular, Sumatra, and Java).

The divergence time of *Leptobrachium* predicted occured on early Eocene, whilethe speciation occurred on middle Eocene, then it simultaneously occurred on last Eocene or early Oligocene (Matsui et al., 2010; Zhao and Morgan, 1985; Chung et al., 1998). Based on the distribution, speciation of *Leptobrachium* predicted happened in on late-Miocene or early-Pliocene, when Borneo has lost connection with its mainland (Lloyd, 1978 cited in Wilson and Moss, 1999; Matsui et al., 2010). At that period of time, Peninsular Malaysia, Sumatra, and Java were connected with land, meanwhile Borneo was least isolated with sea (Inger and Voris; 2001; Chappell & Shackleton, 1986). That event affected on genetic flow of the islands, they lost connection with other main islands then allowed isolation for certain period of time. One of the example is the research of Matsui et al. (2010) which indicated that speciation of *L. nigrops* from its ancestor *L. hendricksoni* dan *L. hasseltii* with divergence time estimation at last-Oligocene until last-Miocene (30-14 Mya before present). The speciation has expected as the impact of land connection disruption between Borneo and Peninsular Malaysia which caused isolation between Borneo and Malayan peninsular population.

Megophrydae has wider distribution compared to *Leptobrachium*. It distributed on four main islands (Peninsular Malaysia, Borneo, Sumatra, and Java). The evenly distribution expected similar to Pliocene period and Pleistocene until the last 10.000 year which on that period there were repeating increasing and decreasing of sea level (Woodruff & Turner, 2009). As the consequence, when the increasing of sea level genus *Megophrys* could make a move, while when sea level decrease this genus is being isolated of geographic that caused allopatric speciation.

Dicroglossidae

Dicroglossidae in Sundaland consists of ±4 genea (*Fejervarya*, *Limnonectes*, *Occidozyga*, and *Ingerana*) with ± 33species. This family was dominated by *Limnonectes* which distributed in four major islands of Sundaland. *Limnonectes* became a good example for speciation despite on its high morphological similarity and genetic differentiation on its species (Djong et al., 2010). This genus consists of 2 species complex which have high morphological character similarity between each species, *L. blythii* and *L. kuhlii*. *L. blythii* was distributed in Myanmar, Thailand, Peninsular Malaysia, and Northern Sumatra only. This condition was predicted as the result of its lifestyle. Its reproduction occurs in low stream river and related to ancient river system in Northern Sumatra which connected to Peninsular Malaysia and end in Southern China sea and Andaman sea. During Pleistocene period, Northern Sumatra has 2 river systems, Malacca strait which flowed between Malay Peninsula and Sumatra then ended in Andaman sea,Siam river which ended in Southern China Sea. The river system of Malacca straits comprised river at Northern Sumatra, Riau, and some at Peninsular Malaysia. While Siam river system comprised of Riau and some at Peninsular Malaysia (Voris, 1153; Tjong et al., 2010). Both rivers system did not connected to the river system in Java. This condition allowed *L. blythii* to spread from Peninsular Malaysia to northern Sumatera and to develop sympatric speciation was occurred between *L. blythii* species.

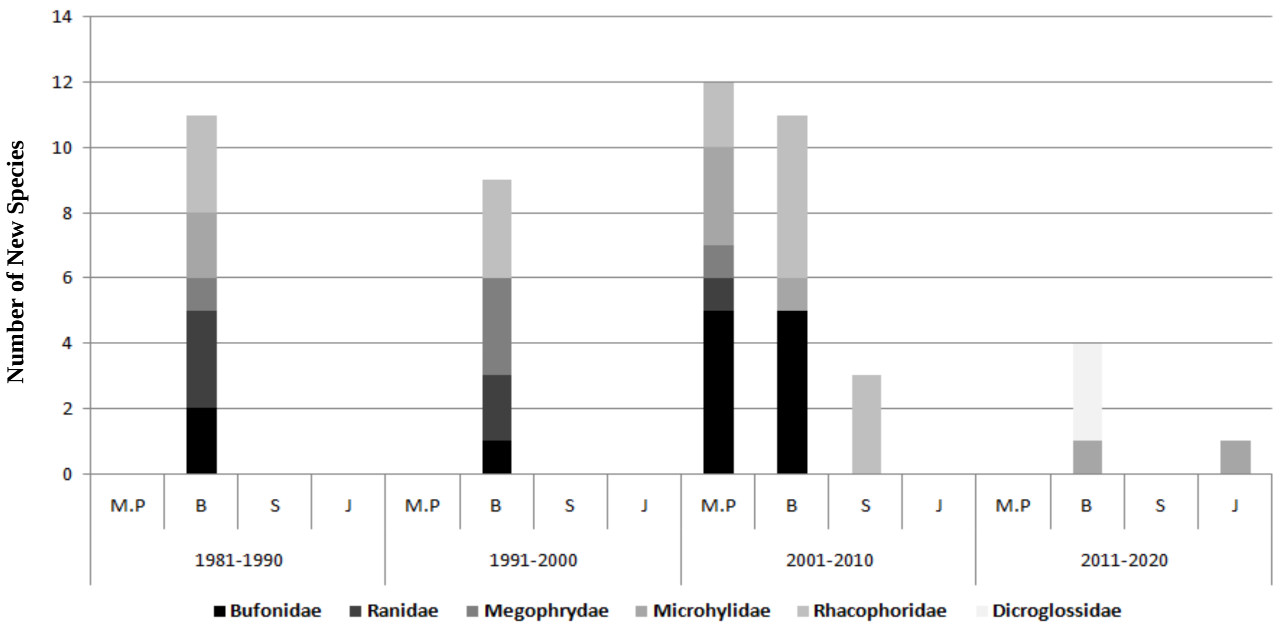

Figure 3. Total of new species discovered based on 6 main family (Bufonidae, Ranidae, Megophrydae, Microhylidae, Rhacophoridae, and Dicroglossidae) in 4 major islands (Malay Peninsular, Borneo, Sumatra, and Java) and adjacent Island since 1981 in a range of 10 years.

New Species in Sundaland

Zoogeographical history of Sundaland has drawn interest of some researcher to study about it. It was proven by some researchers about the high speciation level of amphibian which formed some new species in Sundaland. The total new species which found in Sundaland was approximately 51 species from family Bufonidae, Ranidae, Megophrydae, Microhylidae, Rhacophoridae, and Dicroglossidae. The new species which found in Sundaland was dominated by Rhacophoridae (25%), Ranidae (20%), Bufonidae (18%), Microhylidae (14%), Megophrydae (12%), and Dicroglossidae (11%). List of new species can be seen at Table 1.

Table 1. New species which found in Sundaland at year range 1981 – 2015.

No.	Taxa	Origin
	Bufonidae	
1	*Ansonia anotis* (Inger et all., 2001)	Borneo
2	*Ansonia echinata* (Inger and Stuebing, 2009)	Borneo
3	*Ansonia endauensis* (Grismer, 2006)	Peninsular Malaysia
4	*Ansonia jeetsukumarani* (Wood, Grismer, Ahmad, and Senawi, 2008)	Peninsular Malaysia
5	*Ansonia kraensis* (Matsui et al., 2005)	Peninsular Malaysia
6	*Ansonia latiffi* (Wood, Grismer, Ahmad & Senawi, 2008)	Peninsular Malaysia
7	*Ansonia torrentis* (Dring, 1983)	Borneo
8	*Ingerophrynus gollum* (Grismer, 2007)	Peninsular Malaysia
9	*Pelophryne api* (Dring, 1983)	Borneo
10	*Pelophryne linanitensis* (Das, 2007)	Borneo
11	*Pelophryne murudensis* (Das, 2008)	Borneo
12	*Pelophryne rhopophilius* (Inger and Steubing, 1996)	Borneo
13	*Pelophryne saravacensis* (Inger and Steubing, 2009)	Borneo
	Ranidae	
14	*Amolops amoropalamus* (Matsui, 1986)	Borneo
15	*Amolops macrophthalmus* (Matsui, 1986)	Borneo
16	*Amolops orphnocnemis* (Matsui, 1986)	Borneo
17	*Rana asperata* (Inger et all., 1996)	Borneo
18	*Rana banjarana* (Leong and Lim, 2003)	Peninsular Malaysia
19	*Rana rhacoda* (Inger et all., 1996)	Borneo
	Megophrydae	
20	*Leptobrachella palmate* (Inger and Steubing, 1991)	Borneo
21	*Leptolalax kajangensis* (Grimer et al., 2004)	Peninsular Malaysia
22	*Leptolalax maurus* (Inger et all., 1997)	Borneo
23	*Megophrys edwardinae* (Inger, 1989)	Borneo
24	*Megophrys dringi* (Inger, 1995)	Borneo
	Microhylidae	
25	*Calluella minuta* (Das et al., 2004)	Peninsular Malaysia
26	*Kalophrynus calciphilus* (Dehling, 2011)	Borneo
27	*Kalophrynus eok* (Das and Haas, 2003)	Borneo
28	*Kalophrynus nubicola* (Dring, 1983)	Borneo
29	*Kalophrynus yongi* (Matsui, 2009)	Peninsular Malaysia
30	*Microhyla orientalis* (Matsui, Hamidy, Eto, 2013)	Java (adjacent island)
31	*Microhyla maculifera* (Inger, 1989)	Borneo
32	*Microhyla mantheyi* (Das et al., 2007)	Peninsular Malaysia
	Rhacophoridae	
33	*Philautus aurantium* (Inger, 1989)	Borneo
34	*Philautus bunitus* (Inger et all., 1995)	Borneo
35	*Philautus davidlabangi* (Matsui, 2009)	Borneo
36	*Philautus disgregus* (Inger)	Borneo
37	*Philautus erythrophthalmus* (Steubing and Wong, 2000)	Borneo
38	*Philautus juliandringi* (Dehling, 2010)	Borneo
39	*Philautus refugii* (Inger and Steubing, 1996)	Borneo
40	*Polypedates chlorophthalmus* (Das, 2005)	Borneo
41	*Rachophorus norhayatii* (Chan and Grismer, 2010)	Peninsular Malaysia
42	*Rhacophorus achantharrhena* (Harvey et al., 2002)	Sumatra
43	*Rhacophorus barisani* (Harvey et al., 2002)	Sumatra
44	*Rhacophorus catamitus* (Harvey et al., 2002)	Sumatra
45	*Rhacophorus gadingensis* (Das and Haas, 2005)	Borneo
46	*Rhacophorus kajau* (Dring, 1983)	Borneo
47	*Theloderma licin* (Macleod and Ahmad, 2007)	Peninsular Malaysia
	Dicroglossidae	
48	*Ingerana rajae* (Iskandar, Bickford, Arifin, 2011)	Borneo
49	*Limnonectes cintalubang (*Matsui, Nishikawa, Eto, 2014)	Borneo
50	*Limnonectes hikidai* (Matsui and Nishikawa, 2014)	Borneo

The total new species which found in Sundaland was estimated during 1981-2015 shown in Figure 3. The data shows that most of new species was found in Borneo. It probably caused by geological history of Borneo which already explained in previous chapter. The highest discovery of amphibian new species was achieved at range of year 2001 – 2010 in Peninsular Malaysia, Borneo, and Sumatra with ±25 of total species. That probably caused by researcher interest on that year to explore Sundaland. Some of researchers which already explored Sundaland are Robert F. Inger, Masafumi Matsui, and Indraneil Das. The lack of new species discovery in Java and Sumatra probably was caused by the less concern from researchers.

ZOOGEOGRAPHY OF SUNDALAND

Distribution of Anura (Family Bufonidae, Ranidae, Megophrydae, Microhylidae, Rhacophoridae, and Dicroglossidae) in four major islands of Sundaland were measured by the total number of spesies which spread in that four major islands. The result shows that Borneo has the highest number of total species, meanwhile Java is the lowest one (Figure 2). Species distribution of Anura in four major islands, probably affected by amphibian distribution at Plio-Pleistocene period (Wilting et al., 2012).

Borneo has the highest number of total species (from family Bufonidae, Ranidae, Megophrydae, Microhylidae, Rhacophoridae, and Dicroglossidae) compared to the three other islands. It was predicted to be related to geological history of Borneo. Borneo was not included in the series of volcanic ring which related to the tectonic plate. Series of volcanic ring was stretched from Sumatra to Javawhich allowed supervolcanic eruptions which resulted in the extinction of species (Mayr, 1944). In geological history, Borneo has no volcano-mountain row which caused supervolcanic eruption and species extinction. These cases caused the gene flow that goes to Borneo is more stable and make the possibility the sympatric speciation to be occured. It was affected the total number of species in Borneo as the result of island stability and sympatric speciation which happened. Another factor was the fact that Borneo became main object on some research and has been explorated in almost all locations, so the amphibian's database is increased.

Sundaland has two volcanic rings: 1) Stretched from Sumatra through Java to Banda; and 2) stretched in the western end of North Maluku. The influence of the presence of volcanic rings is the volcanic activity (Mayr, 1944) in Sumatra and Java. Western Sumatra has experienced most powerful supervolcanic eruption in geological history (Toba supervolcanic eruption) about 73 kya (Ambrose, 1998; Rose and Chesner, 1987; Williams et al., 2009). That incident almost destroyed most of amphibian in the eruption area (Wilting et al., 2012) caused by volcanic dust spread in the stratosfer (Rampino and Ambrose, 2000). The effects of Toba supervolcanic eruption gave enormous impact to Sumatra, meanwhile Peninsular Malaysia got least impact (Wilting et al., 2012) after the incident, Sumatera recolonised and had warm condition and prosperous soil. This condition caused amphibians of Sumatra came back again to their habitat in Sumatra.

Peninsular Malaysia does not include in ring of fire, so it did not experienced natural disaster in its geological history which affected on its flora and amphibian. Peninsular Malaysia was the only Island of Sundaland which still connected with Asia mainland. Therefore, amphibian composition in Peninsular Malaysia was mostly influenced by Asia mainland. There were several factors which predicted interfere gene flow in Peninsular Malaysia. One of it is the seawater level fluctuation at Plio-Pleistocene period. When seawater level increased, amphibian could migrate to from Peninsular Malaysia or vice versa. On the other way, when seawater level decreased, amphibian would be isolated in it. As the time goes by, speciation will occurred within that process. One factor which leads to sympatric speciation was mountain range in Peninsular Malaysia.

Java island has 59 young volcanoes with more than 2000 m in height and volcano from Tertiary period. One of the most powerful supervolcanic eruption in Java island was Krakatau in 1883 (Self and Rampino, 1981). That eruption covered Java island with lava and dustwhich caused extinction of local species. In addition, Java island became drier and had poorer habitat for its organism compared to Sumatra and Borneo (Mayr, 1944).

CONCLUSION

Sundaland which located in equator line has interesting geological history and topography. Therefore, its zoogeography, ecological barrier, and diversity have drawn interest of many researchers. Meanwhile, during 1981-2015 most of researchers concern only on Peninsular Malaysia and Borneo. Therefore, further study about the exploration of amphibian in Sumatra and Java needed to increase amphibian database of Sundaland.

REFERENCES

Ambrose SH. 1998. Late Pleistocene Human Population Bottlenecks, Volcanic Winter, and Differentiation of Modern Humans. *Journal of Human Evolution* 34: 623–651.

Bohlen J, Slechtova V, Tan HH, Britz R. 2011. Phylogeny of the Southeast Asian Freshwater Fish Genus *Pangio* (Cypriniformes; Cobtidae). *Molecular Phylogenetics and Evolution* 61: 854-865.

Bossuyt F, Dubois A. 2001. A Review of the Frog Genus *Philautus* Gistel, 1848 (Amphibian, Anura, Ranidae, Rhacophorinae). *Zeylanica* 6(1):1-112.

Chan KO, Belabut D, Ahmad N. 2009. A Revised Checklist of the Amphibians of Peninsular Malaysia. *Russian Journal of Herpetology* 17 (3): 202-206.

Chappel J, Shackleton NJ. 1986. Oxygen Isotopes and Sea Level. *Nature* 324: 137-140.

Chung SL, Lo CH, Lee TY, Zhang YQ, Xie YW, Li XH, Wang KL, Wang PL, 1998. Diachronous Uplift of the Tibetan Plateau Starting 40 Myr ago. *Nature* 394: 769–773.

Coyne JA. 2009. *Why Evolution is True*. Oxford University Press. New York.

Das I, Haas A. 2003. A New Species of *Kalophrynus* (Anura: Microhylidae) from the Highlands of North-Central Borneo. *The Raffles Bulletin of Zoology* 5(1): 109-113.

Das I, Yaakob N, Sukumaran J. 2007. A New Species of *Microhyla* (Anura: Microhylidae) from the Malay Peninsula. *Hamadryad* 31(2): 304-314.

Dring J. 1983. Frogs of the Genus *Leptobrachella* (Pelobatidae). *Amphibian-Reptilia* 4: 89-102.

Grismer LL. 2007. A New Species of *Ingerophrynus* (Anura: Bufonidae) from a Lowland Rain Forest in Southern Peninsular Malaysia. *Journal of Herpetology* 41(2): 225-230.

Grismer LL. 2006. A New Species of *Ansonia* Stoliczka, 1870 (Anura: Bufonidae) from a Lowland Rainforest in Southern Peninsular Malaysia. *Herpetologica* 62(4): 466-475.

Grismer LL, Grismer JL, Youmans TM. 2004. A New Species of *Leptolalax* (Anura: Megophrydae) from Pulau Tioman, West Malaysia. *Asiatic Herpetological Research* 10: 8-11.

Grismer LL, Youmans TM, Wood PL, Grismer JL. 2006. Checklist of the Herpetoamphibian of the Seribuat Archipelago, West Malaysia with Comments on Biogeography, Natural History, and Adaptive Types. *The Raffless Bulletin of Zoology* 54(1): 157-180.

Hall R. 1996. *Reconstructing Cenezoic South East Asia* In Hall, R & D. J Blundel (eds), Tectonic evolution Of Southeast Asia. Geological Society Publishing House, Bath, 153-183.

Harvey MB, Pemberton AJ, Smith EN. 2002. New and Poorly Known Parachuting Frogs (Rhacophoridae: *Rhacophorus*) from Sumatra and Java. *Herpetological Monographs* 16: 46-92.

Heaney LR. 1986. Biogeography of Small Mammals in SE Asia: Estimates of Rates of Colonization, Extinction and Speciation. *Biological Journal of the Linnean Society* 28: 127-165.

Inger RF, Iskandar DT. 2005. A Collection of Amphibians from West Sumatra, with Description of a New Species of *Megophrys* (Amphibian: Anura). *The Raffles Bulletin of Zoology* 53(1): 133-142.

Inger RF, Lian TF, Yambun P. 2001. A New Species of Toad of the Genus *Ansonia* (Anura: Bufonidae) from Borneo. *The Raffles Bulletin of Zoology* 49(1) 35-37.

Inger RF, Stuebing RB. 1996. Two New Species of Frogs from Southeatern Sarawak. *The Raffles Bulletin of Zoology* 44(2): 543-549.

Inger RF, Stuebing RB, Lian TF. 1995. New Species and New Records of Anurans from Borneo. *The Raffles Bulletin of Zoology* 43(1): 115-131.

Inger RF, Voris HK. 2001. The Biogeographical Relations of the Frogs and Snakes of Sundaland. *Journal of Biogeography* 28: 863-891.

Iskandar DT, Collin E. 2000. Preliminary Checklist of Southeast Asian and New Guinean Herpetoamphibian, *I Amphibians. Treubia* 31(3): 1-134.

Iskandar DT, Eredelen WR. 2006. Conservation of Amphibians and Reptiles in Indonesia: Issues and Problems. *Amphibian and Reptiles Conservation* 4(1): 60-87.

Kiew BH. 1984. A New Species of Sticky Frog (*Kalophrynus palmatissimus* n. sp.) from Peninsular Malaysia. *Malayan Nature Journal* 37: 145-152.

Kurniati H. 2006. The Amphibians Species in Gunung Halimun National Park, West Java, Indonesia. *Zootaxa Indonesia* 15(2): 107-120.

Leong TM, Lim BL. 2004. *Rana siberu* Dring, McCarthy and Whitten, 1990 – A First Record for Peninsular Malaysia (Amphibian: Anura: Ranidae). *The Raffles Bulletin Of Zoology* 52 (1): 261-263.

Lohman DJ, Bruyn M, Page T, Rintelen K, Hall R, Ng PKL, Shih HT, Carvalho GR, Rintelen T. 2011. Biogeography of the Indo-Australian Archipelago. *Annual Review of Ecology, Evolution, and Systematics* 42: 205-226.

Lohman DJ, Peggie D, Pierce NF, Meier R. 2008. Phylogeography and Genetic Diversity of a Widespread Old World Butterfly, *Lampides boeticus* (Lepidoptera: Lycaenidae). *BMC Evol. Biol* 8:301.

Marx H. 1976. Supplementary Catalogue of Type Specimens of Reptiles and Amphibians in Field Museum of Natural History. *Fieldiana Zoology* 69(2): 1-72.

Marx H. 1958. Catalogue of Type Specimens of Reptiles and Amphibians in Chicago Natural History Museum. *Fieldiana Zoology* 36(4): 1-112.

Matsui M. 2009. A New Species of *Kalophrynus* with a Unique Male Humeral Spine from Peninsular Malaysia (Amphibian, Anura, Microhylidae). *Zoological Science* 26: 579-585.

Matsui M. 2006. Anuran Inventory in Sabah-Past and Future. *Current Herpetology* 25(1): 1-14.

Matsui M, Hamidy A, Murphy RM, Khonsue W, Yambun P, Shimada T, Norhayati A, Daicus MB, Jiang JP, 2010. Phylogenetic Relationships of Megophryid Frogs of the Genus *Leptobrachium* (Amphibian, Anura) as Revealed by mtDNA Gene Sequences. *Molecular Phylogenetics and Evolution* 56: 259–272.

Mayr E. 1944. Wallace's Line in the Light of Recent Zoogeographic Studies. *Quartery Review of Biology* 19: 1-14.

Molengraaff GAF. 1916. Het probleem der koraaeilanden ende isostasie. *Verslagen der Afdeeling Natuurkunde der Koninklijke Akademie van Wetenschappen.* 25. 1–217.

Rampino MR, Ambrose SH. 2000. Volcanic Winter in the Garden of Eden: the Toba Super-Eruption and the Late Pleistocene Human Population Crash. in: McCoy, F.W., Heiken, G. (Eds.), Volcanic Hazards and Disasters in Human Antiquity. *Geological Society of America Special Paper* 345: 71–82.

Rose WI, Chesner CA. 1987. Dispersal of Ash in the Great Toba Eruption, 75 ka. *Geology* 15: 913–917.

Ruedi M. 1996. Phylogenetic Evolution and Biogeography of Southeast Asian Shrews (Genus *Crocidura*: Soricidae). *Biological Journal of the Linnaean Society* 58: 197-219.

Self S, Rampino MR. 1981. The 1883 Eruption of Krakatau. *Nature* 294: 699–704.

Streitcher JW, Hamidy A, Harvey MB, Anders B, Shaney KJ, Kurniawan N, Smith EN. 2014. Mitochondrial DNA Reveals a New Species of Parachuting Frog (Rhacophoridae: *Rhacophorus*) from Sumatra. *Zootaxa* 3878(4): 351-365.

Teynie A, David P, Ohler A. 2010. Note on a Collection of Amphibians and Reptiles from Western Sumatra (Indonesia), with the Description of a New Species of the Genus *Bufo*. *Zootaxa* 2416: 1-43.

Tjong DH, Iskandar DT, Gusman D. 2010. Hubungan Filogenetik Spesies *Limnonectes* (Ranidae: Amphibian) Asal Sumatera Barat dan Asal Asia Tenggara Berdasarkan Gen 16S Ribosomal RNA. *Makara, Sains* 14(1): 79-87.

Tjong DT, Syaifullah, Indra S, Amelia A. 2012. Kariotipe *Rana chalconota* Kompleks yang terdapat di Sumatra Barat. *Biospecies* 5: 13- 19.

Voris HK. 2000. *Maps Journal Biogeography* 27.

Williams MAJ, Ambrose SH, van der Kaars S, Ruehlemann C, Chattopadhyaya U, Pal J, Chauhan PR. 2009. Environmental impact of the 73 ka Toba super-eruption in South Asia. *Palaeogeography Palaeoclimatology Palaeoecology* 284:295-314.

Wilson MEJ, Moss SJ. 1999. Cenozoic Palaeographic Evolution of Sulawesi and Borneo. *Palaeogeography, Palaeoclimatology, Palaeocology* 145: 303-337.

Wilting A, Sollmann R, Meijaard E, Helgen KM, Fickel J. 2012. Mentawai's Endemic, Relictual Amphibian: Is It Evidence for Pleistocene Extinctions on Sumatra. *Journal of Biogeography* 39: 1608-1620.

Wood PR, Grismer LL, Ahmad N, Senawi J. 2008. Two New Species of Torrent-Dwelling Toads *Ansonia* Stoliczka, 1870 (Anura: Bufonidae) from Peninsular Malaysia. *Herpetologica* 64(3): 321-340.

Woodruff, D.S. 2003. Neogene Main Transgressions, Palaeogeography and Biogeographic Transition in the Thai-Malay Peninsula. *Journal of Biogeography* 30: 511 – 567.

Woodruff DS, Turner LM. 2009. The Indochinese–Sundaic Zoogeographic Transition: A Description and Analysis of Terrestrial Mammal Species Distributions. *Journal of Biogeography* 36: 83–821.

Zhao WL, Morgan WJ. 1985. Uplift of Tibetan plateau. *Tectonics* 4: 359–369.