

**BIOLOGICAL ASPECTS OF THE ENDEMIC EELS, *Anguilla borneensis*,  
FROM LAKE SEMAJANG, MAHAKAM WATERSHED  
(EAST KALIMANTAN, INDONESIA)**

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**Abstract**

*In order to study biological aspects of the endemic eels from Indonesian Waters, 30 specimens of anguillid eels were collected by gill nets from Lake Semajang, Mahakam Watershed, East Kalimantan (Indonesia) from January to February 2007. The specimens were successfully identified as the endemic species of *Anguilla borneensis* from Kalimantan Inland Waters, based on morphology and genetic analyses. The endemic species was about 320~780g (Mean  $\pm$  SD; 519.17 $\pm$ 122.26) in BW and 55~74cm (64.20 $\pm$ 5.60) in TL, and belong to the long-finned eels with 11.11~15.87 (12.97 $\pm$ 1.13) in ADL/%TL. Based on PCR-RFLP analyses, genetic character of the species could be detected by the appearance of double fragment DNA performed by restriction enzymes *Alu I* (400bp and 500bp), *BbrP I* (300bp and 500bp), and *EcoT14 I* (700bp and 600bp) and single fragment DNA performed by restriction enzymes *Hha I* (500bp), *Mva I* (700bp) and *Bsp1286 I* (250bp). Species adjustment was done using DNA mitochondria sequence of the 16S ribosomal RNA gene with specific primer set of the tropical anguillid eels species. Gonado Somatic Index and Eye Index of *A. borneensis* were about 1.8~10.3 (Mean  $\pm$ SD; 3.6 $\pm$ 2.1) and 3.8~15.9 (8.7 $\pm$ 3.1), respectively. It is suggesting that the species were in yellow and silver eel stages when collected. However based on gonad morphology, most specimens (80%) was belong to female immature eels while remain specimen was separated into 10% female mature eels and 10% intersex eels. Positive linear relationship was detected between TL and BW of *A. borneensis* suggesting the species still in growth phase when collected. The study had proven that Lake Semajang as upper side of Mahakam Watershed was inhabited by the endemic eels *A. borneensis*. Management and conservation are require in order to keep sustain *A. borneensis* in the nature since the species also promoted as one ancestor of genus *Anguilla* in the world.*

**Keywords:** *Anguilla borneensis*, Lake Semajang, Mahakam Watershed, biologicalaspect, endemic eel

**INTRODUCTION**

About 18 species and subspecies of anguillid eels has been reported to distribute around the world (Ege, 1939; Jespersen, 1942; Aoyama and Tsukamoto, 1997; Tsukamoto and Aoyama, 1998; Aoyama *et al*, 2001) and 9 species among them was reported to inhabit in the Indonesian Waters (Aoyama *et al*, 2003, 2007; Watanabe *et al*, 2004 and 2005; Minegishi *et al*, 2005; Sugeha *et al*, 2008). Nine species and subspecies of tropical eels were including *Anguilla borneensis*, *A. marmorata*, *A. celebesensis*, *A. interioris*, *A. bicolor bicolor*, *A. bicolor pacifica*, *A. nebulosa nebulosa*, *A. obscura*, and *A. megastoma*. The tropical area of Indonesian Waters reported as the center for

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biodiversity of the anguillid eels in the world (Sugeha *et al*, 2008) and were inhabit by the endemic and the ancestor eels of *A. borneensis* (Aoyama *et al*, 2001).

The endemic eels, *A. borneensis* Popta, were firstly reported as *A. latirostris* (Popta 1906 cited in Ege, 1939). In 1916, the species were reported as *A. celebesensis* by Weber & Beaufort (see Ege 1939). But in 1924, Popta revised his work and renamed *A. latirostris* as *A. borneensis*. No information about sampling location of the two adult specimens of *A. borneensis* identified by Popta in 1906 but her specimens were keep in the Leyden Museum and were used by Ege for his historical taxonomic study on the anguillid eels around the world (see Ege, 1939). Together with Popta's two co-types, Ege (1939) reported the taxonomy of *A. borneensis* based on his observation on the one adult specimen and large number of elvers of *A. borneensis* collected from Muara Muntai, Sungai Belajan, and Kuala Tenggarong of Mahakam River, Central Borneo (now Kalimantan) from 1926 to 1930.

According to Ege (1939) *A. borneensis* Popta was an anguillid eel species without variegated marking and with long dorsal fin. The author reported that the body coloration of the species was similar with *A. anguilla* (European eel), *A. rostrata* (American eel), and *A. japonica* (Japanese eel) with a skin type shows on the body a marked contrast between an upper dark part and a lower lighter part. Complete body proportion of *A. borneensis* was not reported by Popta since their adult eel specimen was very limited. However, recent study on the re-examination of taxonomy of genus *Anguilla* conducted by Watanabe *et al* (2004) reported the similarity of morphological characters of *A. borneensis* from their studied with from Ege's study. The authors also suggest that the senior synonym *A. malgumora* after Kaup (1856), Bauchot *et al* (1993), and Smith (1999) for the name of *A. borneensis* was in doubt so they were used the traditional name *A. borneensis* in the published paper.

Except for the taxonomic studies conducted by Ege (1939) and Watanabe *et al* (2004 and 2005), there was no other biological study applied for the tropical eel of *A. borneensis*. In contrast, impact of environmental degradation, infrastructure development, human daily activities, and climate change was gradually affecting environmental condition of the Kalimantan Inland Waters as natural growth habitat of the endemic and the ancestor eel. Based on this problem we conducted both field and

laboratory study on the anguillid eels from Kalimantan inland waters. The objective of this study was to carry out basic biological information on the endemic eels of *A. borneensis* from Lake Semajang, Mahakam Watershed, East Kalimantan (Indonesia).

## **MATERIAL AND METHOD**

Eel specimens was collected in the Lake Semajang, (00.24157 °S; 116.65623 °E), upper part of Mahakam Watershed, East Kalimantan, Indonesia (Figure 1). Sampling was done in January and February 2007 using gill nets and traps. Eels that trapped in the fishing gears were kept alive in the fish container and directly landed using small boat in order to avoid specimen failed. After landed, specimens were anaesthetized with phenoxy-ethanol for external morphological observation and dissecting organs.

Body weighing was done to the nearest 1gr. Body length measurements were done including total length (TL), pre-dorsal length (PDL), pre-anal length (PAL), body depth (BD), head length (HL), head width (HW), head depth (HD), inter-orbital width (IOW), and pectoral fin length (Pf-L) to the nearest 1cm. Other body part measurements such as horizontal and vertical eye diameter were measured to the nearest 0.1mm. The morphological characters of ADL/%TL (Sugeha *et al*, 2001; Watanabe *et al*, 2004) and the dentition structure (Watanabe *et al*, 2004) were used as first confirmation for species identification.

Thereafter, specimens were dissected to pick up a piece of liver tissue for crossing check with genetic species identification using PCR-RFLP analyses (Sugeha *et al*, 2006 and 2008) and DNA mitochondria sequence analyses of 16S ribosomal RNA gene (Aoyama *et al*, 2001, 2003 and 2007; Watanabe *et al*, 2005). Gonad morphology and development were observed and described based on Satoh *et al* (1962). After observation, gonad were removed and weighed for adjustment the GSI of the specimen. The Gonad Somatic Index (GSI) was calculated as: Gonad Somatic Index = (gonad weight/body weight)\*100. The eye index (EI) was also calculated as: Eye Index =  $\{((A+B)/4)^2 * \pi / L\} * 100$  (Pankhurst, 1982), where A is the horizontal eye diameter, B is the vertical eye diameter and L is the total length.

## **RESULT AND DISCUSSION**

A total of 30 specimens of freshwater eels were collected by gill nets from Lake Semajang, Mahakam Watershed, East Kalimantan (Indonesia) from January to February 2007, in order to study biological aspects of anguillid eels from the waters. The specimens were successfully identified as the endemic species of *Anguilla borneensis* from Kalimantan, based on morphology and genetic analyses.

The endemic species was about 320~780g (Mean  $\pm$  SD; 519.17 $\pm$ 122.26) in BW, 55~74cm (64.20 $\pm$ 5.60) in TL, and about 17.12~34.55 (29.85 $\pm$ 2.93) (Table 1). The species belong to long-finned eels with 11.11~15.87 (12.97 $\pm$ 1.13) in ADL/%TL (Figure 2). All the specimen of *A. borneensis* was non-spotted of skin type, blackish brown in dorsa-lateral and yellowish to silvering in ventral side coloration, with narrow maxillary of teeth-structure.

Based on PCR-RFLP analyses, genetic character of the species could be detected by the appearance of double fragment DNA performed by restriction enzymes *Alu* I (400bp and 500bp), *Bbr*P I (300bp and 500bp), and *Eco*T14 I (700bp and 600bp) and single fragment DNA performed by restriction enzymes *Hha* I (500bp), *Mva* I (700bp), and *Bsp*1286 I (250bp). Species adjustment was done using DNA mitochondria sequence of the 16S ribosomal RNA gene with specific primer set of the tropical anguillid eels species.

Gonado Somatic Index (GSI) and Eye Index (IE) of *A. borneensis* were about 1.8~10.3 (Mean  $\pm$ SD; 3.6 $\pm$ 2.1) and 3.8~15.9 (8.7 $\pm$ 3.1), respectively (Figure 3). It is suggesting that the species were in yellow and silver eel stages when collected. However based on gonad morphology, most specimens (80%) was belong to female immature eels while remain specimen was separated into 10% female mature eels and 10% intersex eels.

Positive linear relationship was detected between TL and BW (Figure 4).

Here in the present study, we report the existence of *A. borneensis* in Kalimantan Island based on morphology and genetic study. Aoyama *et al* (2001) was the first to report the occurrence of *A. borneensis* in the Kalimantan inland waters based on molecular genetics analysis and the authors proposed the species as the ancestor of genus *Anguilla* in the world. Further, Watanabe *et al* (2004 and 2005) was conducted

taxonomic study on the genus *Anguilla* around the world based on morphology and genetic analysis and the authors also reported the occurrence of *A. borneensis* in the Kalimantan inland waters. After studies by Kaup (1856), Ege (1939), Aoyama *et al* (2001), Watanabe *et al* (2004 and 2005), and the present study, it was no doubt that the species was an endemic species or just grow up in the waters of Kalimantan Island.

Taxonomy study on the species by Popta (cited in Ege, 1939) and Ege (1939) was using limited number of adult specimen so difficult to carry out other important biological information such as reproductive characters. This study is the first to report basic biological information on the reproductive character of the endemic species, *A. borneensis*. Relatively highest in GSI and eye index of *A. borneensis* suggesting that the specimens collected in the present study were in young and adult eel stages. Mostly specimens were in the growth stage or belong to immature eels but some specimen just entering maturation or reproductive stage as mature eels which soon would be initiative to migrate downstream for reach their spawning area.

Jespersen (1942) is the first who proposed the spawning ground *A. borneensis* based on his collecting specimens of eel larvae (leptocephalus) of the endemic species in around Sulu and Sulawesi Seas. Recent study on the distribution and dispersal of tropical anguillid eel leptocephali in the Indonesian Waters (Aoyama *et al*, 2003; Sugeha *et al*, 2006) reported the occurrence of *A. borneensis* leptocephalus in the Sulu Sea, Sulawesi Sea, Maluku Sea, and Makassar Strait. Based on collection of relatively small *A. borneensis* (8.5mm in TL) in the Celebes Sea, then the species were proposed to spawn on that sea. However, the occurrence of larvae of the species in the other areas suggested that the species may have multiple spawning areas including around Makassar Strait and Sulu Sea near their growth habitat in the Kalimantan inland waters. Interestingly, Sugeha *et al* (2001) reported the occurrence of glass eel *A. borneensis* in the Poso River Estuary. Therefore, it is possible to find *A. borneensis* in the Maluku Sea (Aoyama *et al*, 2003), and the sea would be one proposed area for spawning ground of the species. In fact, it is important to review the endemic status of *A. borneensis* using more advance genetic study of cryptic species. Future intensive research cruise on those areas as well as continues study on the tropical eels from Poso River system were also important to do in order to proof the hypothesis.

Study on the early life history of *A. borneensis* leptocephali based on otolith microstructure and microchemistry analyses (Kuroki *et al*, 2006) suggested that the species has to spawn at a variety of times throughout the year, and have to reach their maximum size of leptocephali around 50mm in TL and about 80days old. At that time the leptocephali start to metamorphosis to be glass eels while migrate inshore to reach their recruitment area in the estuary. The author also proposed that the species has a small-scale local migration from spawning area to growth area, so *A. borneensis* may spawn near their growth habitat. Unfortunately, no study has ever been done for the glass eel recruitment of *A. borneensis* that would be help answer the question about recruitment season and duration of oceanic migration of the remarkable species from spawning area to recruitment area. Some difficulties related to the widest and deepest of Mahakam River and recruitment area of Delta Mahakam that completely covered by a great mangrove forest has rising up a big problem for collecting specimens of glass eels and elvers. In addition, environmental degradation, development of infrastructure, water transportation, and forest fired become the next indirect problems that may cause the endemic species to be an endangered species in the future.

In conclusion, the study had proven that Lake Semajang, as the upper side of Mahakam Watershed, inhabited by the endemic eels of *A. borneensis*. Management and conservation are required in order to keep sustain *A. borneensis* in the nature since the species also promoted as one ancestor of genus *Anguilla* in the world.

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## REFERENCES

- Aoyama J and Tsukamoto K. 1997. Evolution of the freshwater eels. *Naturwissenschaften*, 84:17-21
- Aoyama J, Nishida M, Tsukamoto K. 2001. Molecular phylogeny and evolution of the freshwater eel, genus *Anguilla*. *Molecular Phylogenetics and Evolution*, 20:450-459
- Aoyama J, Wouthuyzen S, Miller MJ, Inagaki T, Tsukamoto K. 2003. Short-distance spawning migration of tropical freshwater eels. *Bio Bull*, 204:104-108
- Aoyama J, S Wouthuyzen, MJ Miller, Y Minegishi, M Kuroki, SR Suharti, T Kawakami, OK Sumadhiharga, K Tsukamoto. 2007. Distribution of leptocephali of the freshwater eels, genus *Anguilla*, in the waters off Sumatera in the Indian Ocean. *Environ Bio of Fish*, 80:445-452
- Bauchot ML, M Desoutter, and PHJ Castle. 1993. Catalogue of type specimens of fishes in the Museum national d'Histoire naturelle, Paris. Anguilliformes and Saccopharyngiformes. *Cybiurn* 17:91-151
- Ege V. 1939. A revision of the genus *Anguilla* Shaw. A systematic, phylogenetic and geographical study. *Dana Report*, 16:1-256
- Jespersen P. 1942. Indo-Pasific leptocephali of the genus *Anguilla*. *Dana Rep* 22:1-128
- Kaup JJ. 1856. Catalogue of apodal fish in the collection of the British Museum, London. British Museum, London. 163 p., 19 pls
- Kuroki M, Aoyama J, Miller MJ, Arai T, Wouthuyzen S, Tsukamoto K. 2006. Contrasting pattern of growth and migration of tropical anguillid leptocephali in the western Pacific and Indonesian Seas. *Mar Ecol Prog Ser*, 309:233-246
- Minegishi Y, J Aoyama, JG Inoue, M Miya, M Nishida, K Tsukamoto. 2005. Molecular phylogeny and evolution of the freshwater eel genus *Anguilla* based on the whole mitochondrial genome sequence. *Molecular Phylogenetic and Evolution*, 34:134-146
- Pankhurst NW. 1982. Relation of visual changes to the onset of sexual maturation in the European eel *Anguilla anguilla* (L.). *J Fish Biol*, 21:127-140
- Smith DG. 1999. Anguillidae. Freshwater eels. Pages 1630-1636 in KE Carpenter and VH Niem eds. *FAO species identification guide for fisheries purposes. The living marine resources of the western central Pacific*, 3.
- Sugeha HY, Watanabe S, Arai T, Aoyama J, Limbong D, Tsukamoto K. 2001. Inshore migration of tropical glass eels (*Anguilla* spp) to the Poso River, Central Sulawesi Island, Indonesia. In: K. Aida, K Tsukamoto, K Yamauchi (eds). *Proceedings of the International Symposium on Advances in Eel Biology*. The University of Tokyo. Pp. 122-125
- Sugeha HY, Arai T, Miller MJ, Limbong D, Tsukamoto K. 2001. Inshore migration of the tropical eels *Anguilla* spp recruiting to the Poigar River estuary on north Sulawesi Island. *Mar Ecol Prog Ser*, 182:283-293

- Sugeha HY. 2003. Life history of the tropical eel *Anguilla marmorata* (Quoy & Gaimard) in the Indonesian Waters. Doctoral dissertation, The University of Tokyo, Japan
- Sugeha HY, S. Wouthuyzen, O.K. Sumadhiharga, and Katsumi Tsukamoto. 2006. Distribution and dispersal of anguillid leptocephali in the Indonesian Throughflow and Tomini Bay revealed by morphology and genetic analysis. Proceeding on the Annual Scientific III - ISOI, UNDIP Semarang, 19-20 September 2006.
- Sugeha HY, Sasanti RS, Wouthuyzen S, Sumadhiharga OK. 2008. Biodiversity, Distribution, and Abundance of the Tropical Anguillid Eels in the Indonesian Waters. *Marine Research in Indonesia*, 33(2):129-138
- Satoh H, Nakamura N, and Hibiya T. 1962. Studies on the sexual maturation of the eel. Part I. On the sex differentiation and the maturing process of the gonads. *Bull. Japan Soc Scient Fish*, 28:579-584
- Tsukamoto K, Aoyama J. 1998. Evolution of the freshwater eels of the genus *Anguilla*: a probable scenario. *Environmental Biology of Fishes*, 52:139-148
- Watanabe S, J Aoyama and K Tsukamoto. 2004. Reexamination of Ege's (1939) Use of Taxonomic Characters of the Genus *Anguilla*. *Bull Mar Sci*, 74:337-351
- Watanabe S, J Aoyama, M Nishida and K Tsukamoto. 2005. A molecular genetics evaluation of the taxonomy of eels of the genus *Anguilla* (Pisces:Anguilliformes). *Bull Mar Sci*, 76(3):675-690



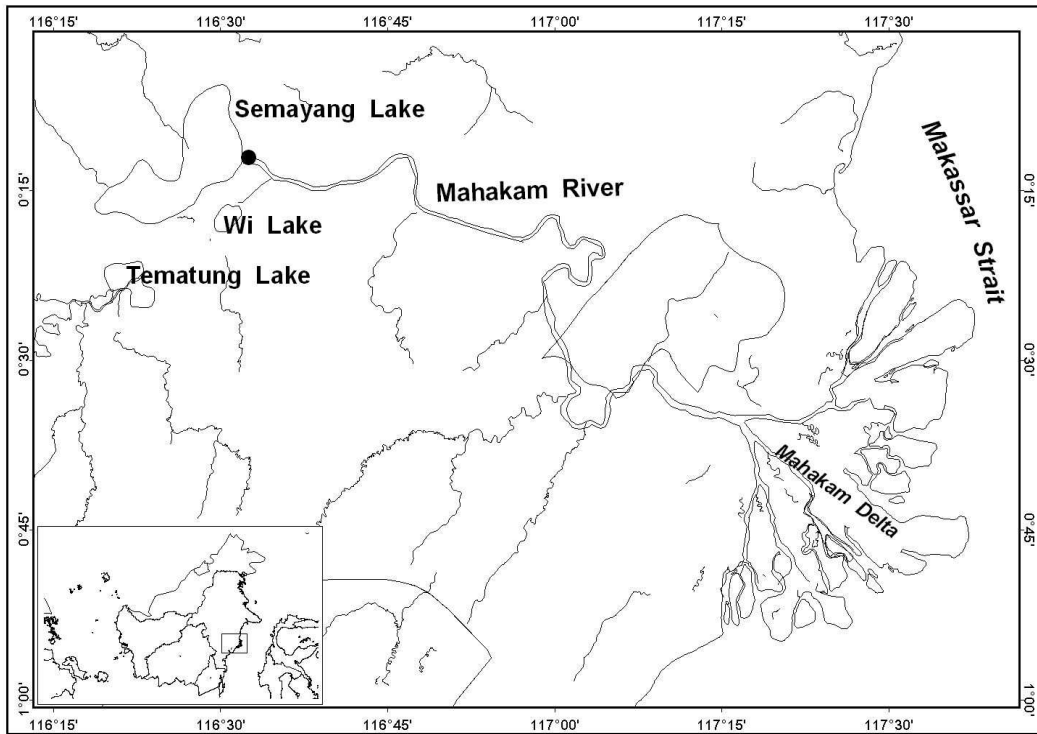


Figure 1. Map of sampling location in the Lake Semayang, Mahakam Watershed, East Kalimantan, Indonesia

Black circle indicating sampling site of the endemic eel, *Anguilla borneensis*.

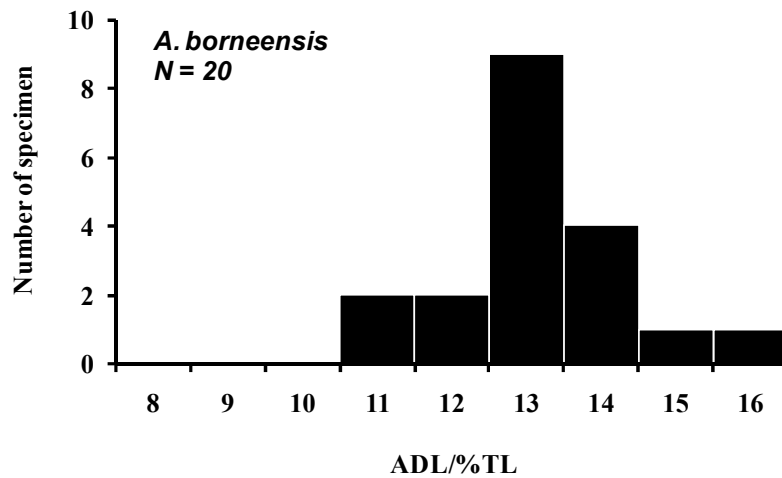


Figure 2. Distribution of ano-dorsal length in percentage of total length (ADL/%TL) of *Anguilla borneensis* collected in the Lake Semayang, Mahakam Watershed (East Kalimantan, Indonesia)

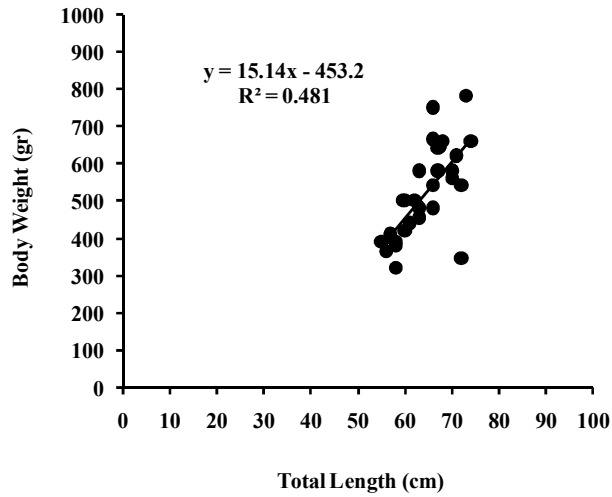


Figure 3. Relationship between total length (TL) and body weight (BW) of *Anguilla borneensis* collected in the Lake Semajang, Mahakam Watershed (East Kalimantan, Indonesia)

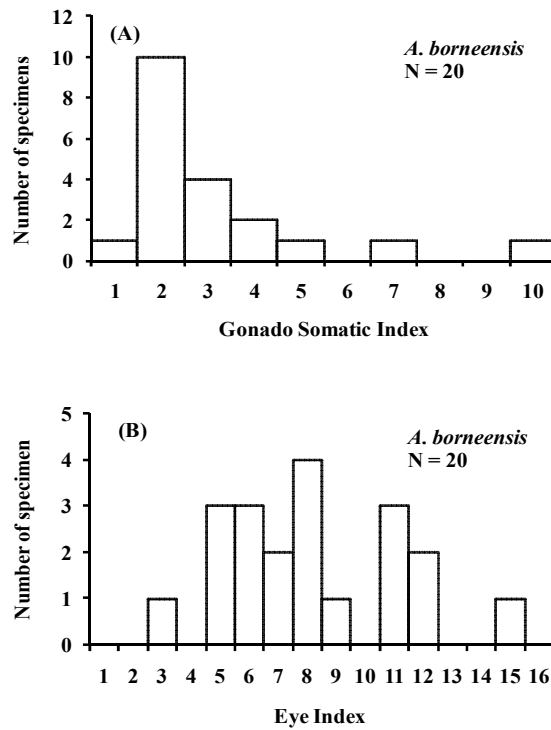


Figure 4. Distribution of (A) Gonad Somatic Index and (B) Eye Index of *Anguilla borneensis* collected in the Lake Semajang, Mahakam Watershed (East Kalimantan, Indonesia)

Table 1. Morphological characters of *Anguilla borneensis* collected in the Lake Semajang, Mahakam Watershed (EastKalimantan, Indonesia).

<b>Character</b>	<b>BW</b>	<b>TL</b>	<b>PDL</b>	<b>PAL</b>	<b>ADL</b>	<b>BH</b>	<b>LG</b>	<b>HL</b>	<b>HW</b>	<b>HD</b>	<b>IOW</b>
	<b>(gr)</b>	<b>(cm)</b>	<b>(cm)</b>	<b>(cm)</b>	<b>(cm)</b>	<b>(cm)</b>	<b>(mm)</b>	<b>(cm)</b>	<b>(cm)</b>	<b>(cm)</b>	<b>(mm)</b>
<b>N</b>	20	20	20	20	20	20	20	20	20	20	20
<b>Mean</b>	514.75	64.80	19.05	27.38	8.33	4.94	28.65	8.20	4.06	4.04	18.77
<b>Max</b>	780.00	74.00	23.00	33.00	10.50	6.00	34.60	9.50	5.00	5.00	22.70
<b>Min</b>	320.00	55.00	12.50	22.00	4.50	4.00	22.70	6.50	3.00	3.00	15.40
<b>SD</b>	123.79	5.94	2.39	2.73	1.26	0.43	2.98	0.86	0.52	0.46	2.07

BW : body weight,  
 TL : total length,  
 PDL : pre-dorsal length,  
 PAL : pre-anal length,  
 ADL : ano-dorsal length,  
 BH : body depth,  
 LG : length of gape,  
 HL : head length,  
 HW : head width,  
 HD : head depth,  
 IOW : inter-orbital width