

## DOWNSTREAM MIGRATION OF TROPICAL ANGUILID SILVER EELS FROM LAKE POSO, CENTRAL SULAWESI, INDONESIA

Hagi Yulia Sugeha<sup>\*</sup>, Jun Aoyama<sup>\*\*</sup>, Katsumi Tsukamoto<sup>\*\*</sup>

### ABSTRAK

Penelitian tentang aktifitas migrasi menghilir sidat (silver eel) banyak dilakukan di daerah lintang tinggi, tapi tidak dengan silver eel di wilayah tropis. Untuk itu, telah dilakukan penelitian menyangkut aktifitas migrasi menghilir dari silver eel yang menghuni Danau Poso, Sulawesi Tengah, Indonesia. Penelitian ini bertujuan untuk mengetahui fluktuasi kelimpahan silver eel yang bermigrasi meninggalkan Danau Poso menuju hilir serta keterkaitannya dengan kondisi lingkungan. Studi ini dilaksanakan dari Januari hingga Desember 2001 melalui observasi aktifitas penangkapan silver eel oleh para nelayan pada tujuh trap yang membujur di depan mulut Danau Poso. Jumlah (individu) dan total berat tangkapan (kg) silver eel per trap yang didaratkan oleh nelayan dicatat secara sistematis dari hari ke hari disertai dengan pencatatan kondisi perairan, kondisi cuaca, serta fase umur bulan. Dari penelitian ini didapati bahwa total jumlah tangkapan silver eel saat bermigrasi menghilir mencapai 1660 individu pertahun dengan total berat tubuh sebesar 7710,5 kg pertahun. Aktifitas migrasi silver eel yang turun menuju hilir terjadi selama Januari hingga pertengahan Agustus (dari musim penghujan hingga awal musim kemarau) dan hanya sedikit yang teramati selama pertengahan Agustus hingga Desember (akhir musim kemarau hingga musim penghujan). Berbeda dengan species sidat lintang tinggi yang cenderung bermigrasi downstream sepanjang musim gugur dengan periode migrasi yang singkat, maka species sidat tropis bermigrasi menghilir hampir setiap bulan di hampir sepanjang tahun berjalan. Aktifitas migrasi menghilir oleh silver eel tropis dari Danau Poso memiliki keterkaitan dengan perubahan tingkat permukaan air danau dan tidak terkait dengan fase umur bulan.

**Kata kunci:** migrasi menghilir, sidat, *Anguilla*, fluktuasi muka air, Danau Poso

### ABSTRACT

Freshwater eels undergo metamorphosis into "silver eels" as they begin sexual maturation at the start of their catadromous spawning migration into the ocean. The downstream migration of silver eels has been studied mainly for temperate species, especially the American eel *Anguilla rostrata*, European eel *A. anguilla*, and Japanese eel *A. japonica*, but no study in the tropic. Therefore, we started an ecological study on the downstream migration of tropical anguillid silver eels in the Poso Lake, Central Sulawesi, Indonesia. The aim of the study is to know the fluctuation in abundance of the downstream migrant silver eels and its association with environmental conditions. The study was conducted in the outlet of Poso Lake from January to December 2001. There were seven commercial weirs located at the outlet of Lake Poso that was used for the study. Arrangement were made to systematically record the catch data of silver eels fished by the weirs through collaboration with local fisheries officers. The individual number and total weight (kg) of eels collected by each weir was recorded every day. Weather condition, water level, and moon phase were also recorded daily. From the study it was found that the total number of migrating silver eels fished by the weirs was 1,660 individuals and the total weight reached 7,710.5 kg. Downstream migrating eels were mostly observed from January to mid-August (from the rainy season to the middle of dry season) while only a few eels were found from mid-August to December (the later half of dry season to the middle of rainy season). Compared to that temperate eels species that migrate downstream only during the fall season and not prolonged, the tropical eel species have a tendency to migrate downstream most of the months throughout year. Furthermore, it was found that downstream migrating of tropical silver eels was strongly affected by the water level but no relation with lunar phase

**Key words:** downstream migration, silver eel, *Anguilla*, water level, lunar phase, Lake Poso

<sup>\*</sup> Researcher of RC Oceanography - Indonesian Institute of Sciences

<sup>\*\*</sup> Researcher of Ocean Research Institute, The University of Tokyo

## INTRODUCTION

Silver eel stage of tropical anguillid eels begin when the yellow eel start the process of reproductive maturation and initiate their migration to the spawning area (Sugeha, 2001; 2003). For eel in freshwater, this spawning migration consists of downstream migration within a river and an offshore migration from the estuary to a spawning area in the open ocean. The downstream migration of silver eels of temperate species was reported to be triggered by various environmental factors such as time of day and light, wind, turbidity, and lunar phase (Tesch, 1977). Hydrological factors such as water level, river current, as well as increasing rainfall affect the activity of downstream migration (Burnet, 1986).

The present study was conducted at the outlet of Lake Poso into the Poso River where fishing on downstream migrant silver eels has been done for many years and now has become the main activity of the community. Fishing activity for silver eels occurs throughout the year. Fisherman used

fishing gears such as weirs, spears, hook and long lines, and small boats to collect silver eels in the lake and its outlet. Weirs are operated in the outlet of Lake Poso while spear, hook and long line are operated inside the lake.

Water from Poso Lake flows into Poso River, which is a major river system in Sulawesi Island after Lake Towuti (Figure 1). Lake Poso is the second biggest tectonic lakes on the island. Its water flow through Poso River into the Bay of Tomini. This is the largest bay in Indonesian waters and is over 2000 m deep. Lehmusluoto *et al.* (1999) explained that Lake Poso is 400 m in depth and is weakly stratified. The lake seems to be oligotrophic with a transparency of 4.8 m. Soeroto (1996) suggested that the lake is different from other lakes in Indonesia, which are usually volcanic and are inhabited by primary freshwater fishes, but Lake Poso is tectonic and inhabited by secondary freshwater fishes.

Ecological studies on silver eels of temperate species have provided detail information about seasonal pattern and some aspects of their physiology and behavior

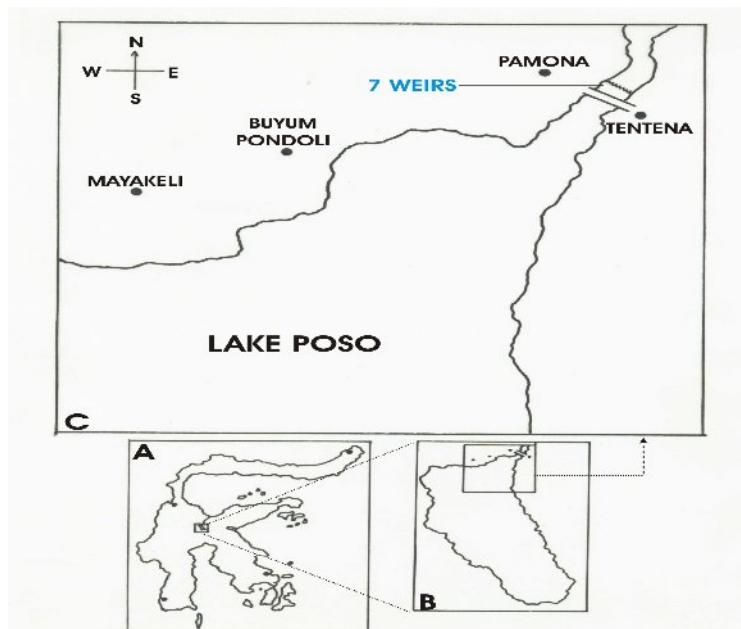


Figure 1. Map of Lake Poso, Central Sulawesi, Indonesia. A) Sulawesi Island ; B) Lake Poso ; C) Position of the 7 Weirs that Used for this Study

during downstream migrations. In contrast, there has been almost no research on the silver eel phase of tropical anguillid species. Therefore, an ecological study of the silver eels of *Anguilla* in the tropical central of Sulawesi Island, Indonesia was carried out. The objective of the study is to know the fluctuation in abundance of the downstream migrant silver eels leaving Lake Poso in central of Sulawesi Island and its association with environmental conditions.

## MATERIAL AND METHOD

There were seven commercial weirs (W1 to W7) located at the outlet of Poso Lake, they stretch out across the entire width of the river. Silver eels catch by the weirs are landed and weighed every day by local fisherman for commercial purpose. A life silver eel has strongly movement and their silky skin texture makes them difficult to measure individually for both body weight and total length.

For collecting data of body weight, total body weight of silver eel trapped in each weir was measured using balance (kg) after landed. Arrangement were made to systematically record the catch data of silver eels at these seven weirs everyday through collaboration with a local fisheries officer. Both data sheet and data collection proce-

dures were designed carefully in order to avoid miss measurement and specimens loose during landed and handling specimens.

Data collections were made from January 1 to December 31 in 2001. The number and total body weight of silver eels collected by each weir were recorded everyday as well as observation of weather conditions, water level, and moon phase.

## RESULTS

Downstream migrating eels were mostly caught from December to mid-August from the rainy season to the middle of the dry season, while only a few eels were found from mid-August to mid-November during later half of the dry season to the middle of the rainy season. Water level inside the lake also changed in correspondence to these seasons, and showed a decreasing flow until under the average level from July to December (Figure 2). During the drastic decrease in water discharge from July to December, a complete absence of silver eels was found from 11 August to 9 November, suggesting the possibility that the downstream migration period of tropical silver eels was strongly affected by the amount of water discharge from the lake.

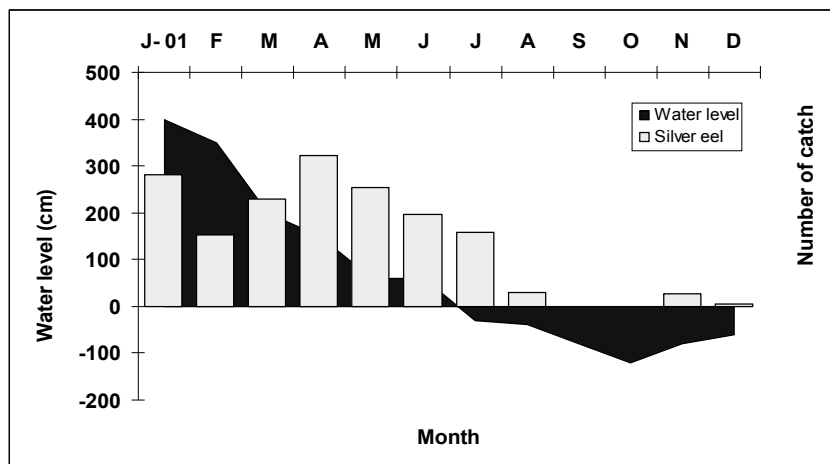


Figure 2. Monthly Catch of the Tropical Downstream Silver Eels in the Outlet of Poso Lake (Central Sulawesi) from January to February 2001 and Its Association with Water Level.

The total number of migrating silver eels fished by the weirs was 1,660 individuals, and the total weight of these eels reached 7,710.5 kg. Based on the analysis of mean individual body weight of migrant eels collected by weirs in Lake Poso from January to August 2001, it was found that the tropical silver eel start to migrate downstream from 4.1 to 7.2 kg body weight in average (Figure 3) following the increasing rainfall and water discharge. The smallest silver eel (1.7 kg in body weight)

was collected in January 2001 while the biggest silver eel (22.5 kg) was collected in June 2001 that affect the wide range of mean body weight of silver eels collected on that month. Silver eels were collected in the weirs almost every day except from August to November and there was seemingly no periodicity. The number of silver eels collected at each moon phase suggest that no relationship between downstream migration and lunar phase (Figure 4).

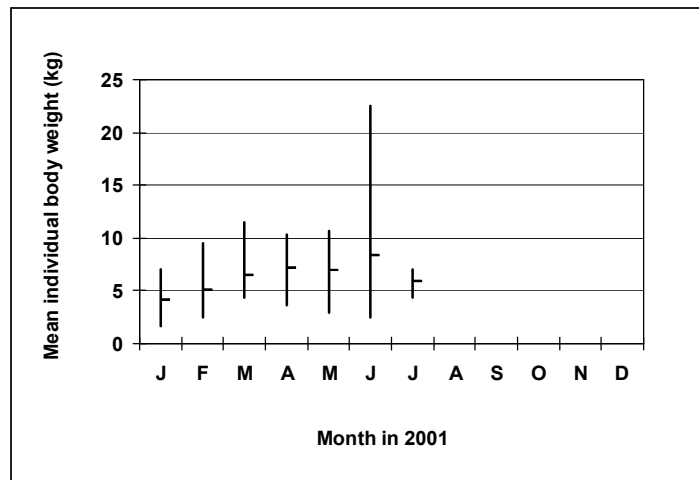


Figure 3. Mean Body Weight (kg) of Individual Silver Eels that Migrate Downstream Leaving the Poso Lake (Central Sulawesi), from January to July 2001.

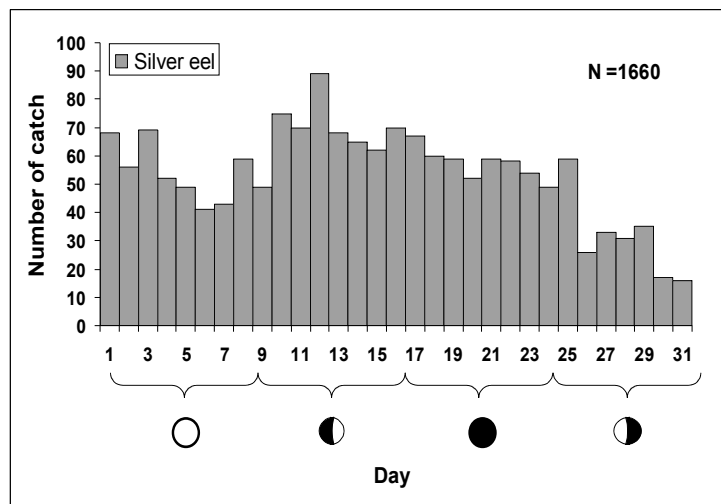


Figure 4. Cumulative Daily Catch of the Tropical Downstream Silver Eels in the Outlet of Lake Poso (Central Sulawesi) Recorded from January to December 2001 and Its Association with Lunar Period.

Among the 360 days of the study period, there were 102 rainy days (28.3 %) and 258 fine days (71.6 %) (Table 1). The silver eels collected during each weather condition were 596 individuals on rainy days and 1,064 individuals on fine days. However, the average number of specimen collected per day was significantly larger on rainy days (5.8 individuals) compared to fine days (4.1 individuals) during the study period. This suggests that silver eels preferably migrate on rainy days, clearly corresponding to the large number of

migrants during the rainy season or high water discharge.

Although the size and design of the weirs used in the study were the same, silver eels tend to be caught more in the weirs located in the middle of river flow (Table 2). Detailed examination of the riverbed depth has still not been done, but the middle flow area is relatively deeper than that of the bank. This suggests that silver eels prefer to migrate downstream in an area with deeper water and strong currents.

Table 1. The Number of Days of the Two Categories of Weather Conditions Record at Poso Lake (Central Sulawesi) and the Number and Percentage of Silver Eels Collected During the Two Weather Conditions.

Weather	Day	No. of specimens	No. of specimens/day
Rain	28.30 % (102 days)	35.90 % (n = 596)	5.8
Fine	71.60 % (258 days)	64.10 % (n = 1064)	4.1

Table 2. The Number of Silver Eels Collected at Each Weir in the Outlet of Poso Lake (Central Sulawesi) from January to December 2001 with the Grey Shading Showing the Higher Catches of Eels.

Month	W1	W2	W3	W4	W5	W6	W7	Total
January, 2001	29	41	25	39	57	46	45	282
February	12	16	36	27	29	10	23	153
March	34	39	29	32	39	33	22	228
April	38	41	47	65	60	43	29	323
May	30	31	43	49	43	32	26	254
June	22	28	31	40	30	31	15	197
July	10	27	25	49	23	15	10	159
August	3	2	4	8	2	7	4	30
September	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0
November	0	7	5	7	5	2	2	28
December	1	0	2	1	1	1	0	6
Total	179	232	247	317	289	220	176	1660

## DISCUSSION

The data on the tropical eels downstream migration timing at the outlet of Lake Poso is the first for tropical anguillid eels and provide new information about the reproductive migration of tropical anguillid species. This study succeeded to obtain a total of 12 months of downstream migration records of tropical anguillid species that inhabit the area, including *A. marmorata*, *A. celebesensis*, *A. bicolor pacifica*, *A. interioris*, and *A. borneensis* (Sugeha *et al.*, 2001c). Therefore, It begins a new era of research on the reproductive ecology and migration of tropical anguillid eels. Future research on the downstream migration pattern of each species is required in order to help manage the important tropical eel resources for both economic and conservation purposes.

An important finding of the present study is that tropical eels in Lake Poso were found to migrate downstream during most of the months throughout the year, which is in distinct contrast to temperate anguillids. Eels were collected in the weirs as they attempted to migrate downstream into the Poso River almost throughout the year from January to December 2001, except for about a three month period during the dry season, from mid-August to mid-November 2001. This pattern of migrating eel during most of the year is in contrast with the downstream migration patterns of temperate anguillid species in both the northern and southern hemispheres where the downstream migration of silver eels occurs only during the fall season and is not as prolonged (Haraldstad *et al.*, 1985; Vollestad & Jonsson, 1986; Jessop, 1987; Poole *et al.*, 1990; Boubee *et al.*, 2001).

In fact, there has been speculation about the apparent year-round spawning of tropical eels based on the back-calculated hatching dates of glass eels. This study provides the first direct confirmation that silver eels of tropical species appear to be

initiating their spawning migrating over a period of many months. Arai *et al.* (1999) and Sugeha *et al.* (2001a) suggested year round spawning of tropical eels of *A. marmorata* and *A. celebesensis* inhabiting northern Sulawesi Island based on their glass eel recruitment patterns. Data from the back-calculating hatching dates of glass eels also supported the idea of spawning throughout much of the year by the tropical eels in the Indonesian seas (*e.g.* Arai *et al.*, 2001; Marui *et al.*, 2001). A study in the Poigar River estuary in Northern Sulawesi Island have shown the same result where glass eels were found to recruit at various times throughout the year over a five years period (Sugeha, 2003). It seems that the gaps in the recruitment of glass eels in the Poso River estuary from August to November (Sugeha, 2003) and gap of spawning season of *A. marmorata* in the Poso River estuary (February to May) based on the back-calculated hatching dates (Sugeha, 2003) are related to the temporal gap in the downstream migration of silver eels leaving Lake Poso observed in the present study. Otherwise, they are simply due to seasonal transport factors of the leptocephali into the semi-enclosed Tomini Bay and then into the Poso River. Additional data on the downstream migration of silver eels in different years and different areas are needed to evaluate the seasonal pattern of downstream migration in order to determine the behavior of these eels whether regulated by annual biological rhythm or simply environmental factors such as rainfall and water discharge.

A short timing of downstream migration within the migration season of temperate anguillid eels was suggested to be strongly influenced by rain events and increased water flow in streams or rivers (Burnet, 1969; Deelder, 1954; Todd, 1981; Vollestad & Jonsson, 1986). Observation on the lack of movement of tropical eels from Lake Poso during the period of decreasing water discharge is interesting. During rainy season (October to April) the water level in

Lake Poso gradually increasing and reach its peak around January. When the water level is higher than 150 cm (February), the number of migrating eels gradually increased until it reached the peak of abundance in April (>300 individuals catch). Its then gradually decreased following the decreasing water level. The activity of downstream migration of silver eel was not detected from September to October, and at that time the water surface were in the lowest level (>100 cm below the average). This study suggested the possible influence of water discharge to the downstream migration of tropical anguillid eels. This study also found that more eels were collected on rainy days compared to fine days, so rainfall or cloudy conditions may have an influence on triggering the downstream movement of eels during their migration season.

In contrast to the effects of water discharge or rainfall, this study did not find any apparent influence of lunar cycle to the downstream migration of silver eels as has been suggested for temperate anguillid species. Boetius & Boetius (1967) and Edel (1976) reported that European silver eel showed an inner rhythm which affected their movement that was synchronized with moon phase, even when they were kept in the dark and under stable laboratory conditions. However, this relationship was rarely found in field observation. Numerous authors have suggested that light derived from the moon might affect the number of eels migrating downstream (Jonsson, 1991; Vollestad *et al.*, 1986; Haraldstad *et al.*, 1985). The result of the present study, least suggested that the downstream migration of tropical silver eels has no apparent relationship with moon phase.

#### ACKNOWLEDGEMENTS

This study was supported by Ministry of Education, Science and Culture of Japan in form of a Research Student Fellowship from 1999 to 2003 to H.Y.

Sugeha. We wish to provide our gratitude to the Fisheries Government Office of Poso, who supported and helped us during the field research.

#### REFERENCES

- Arai, T., J. Aoyama, D. Limbong, and K. Tsukamoto. 1999, Species composition and inshore migration of tropical eels, *Anguilla* spp., recruiting to the estuary of the Poigar River, Sulawesi Island, Mar. Ecol. Prog. Ser. 188:299-303.
- Arai, T., M. Marui, M.J. Miller, and K. Tsukamoto, 2002 Growth history and inshore migration of the tropical eel *Anguilla marmorata*, in the Pacific, Mar Biol 140:309-316.
- Boetius, I. & J. Boetius, 1967, Studies in the European eel, *Anguilla anguilla* (L). Experimental induction of the male sexual cycle, its relation to temperate and other factors, Meddelelser Fra Denmark Fiskeri-og Havunderogelser 4:339-405.
- Boubee, J.A., C.P. Mitchel, B.L. Chisnall, D.W. West, E.J. Bowman, and A. Haro, 2001, Factors regulating the downstream migration of mature eels (*Anguilla* spp) at Aniwhenua Dam, Bay of Plenty, New Zealand, NZ J. Mar. Fresh Res. 35:121-134.
- Burnet, A.M.R., 1986, Migrating eel in a Centerbury River, New Zealand, NZ J. Mar. Fresh. Res. 3:230-244.
- Deelder, C.L., 1954, Factor affecting the migration of the silver eel in Dutch Island waters, J. Cons. Int. Explor. 20:177-185.
- Edel, R.K., 1976, Activity Rhythms of maturing American eels (*Anguilla rostrata*), Mar. Biol. 36:283-289.
- Haraldstad, O., L.A. Vollestad, and B. Jonsson, 1985, Descent of European silver eels *Anguilla anguilla* L., in a

- Norwegian watercourse. J. Fish. Biol. 26:37-41.
- Jessop, B.M., 1987, Migrating American eels in Nova Scotia, Trans Am. Fish. Soc. 16:161-170.
- Jonsson, N., 1991, Influence of water flow, water temperature and light on fish migration in rivers, Nordic J. Fresh. Res. 66:20-35.
- Lehmusluoto, P., B. Machbub, N. Terangna, F. Achmad, L. Boer, S.S. Brahmana, B. Setiadji, B. Priadie, K.H. Timotius, and F. Goeltenboth, 1999, Limnology in Indonesia. From the legacy of the Past to the Prospect for the future, *In*: Wetzel, R.G. & B. Gopal (Ed), Limnology in Developing Countries 2:119-234.
- Marui, M., T. Arai, M.J. Miller, D.J. Jellyman, and K. Tsukamoto, 2001, Comparison of early life history between New Zealand temperate eels and Pacific tropical eels revealed by otolith microstructure and microchemistry, Mar. Ecol. Prog. Ser. 213: 273-284.
- Poole, W.R., J.D. Reynolds, and C. Moriarty, 1990, Observations on the silver eel migrations of the Burrisshoole River System, Ireland, 1959 to 1988, Int. Revue. Ges. Hydrobiol. 75:907-815
- Soeroto, B., 1996, The inland fishes and the distribution of Adrianiichthyoidea of Sulawesi Island, with special comments on the endangered species in Lake Poso, Proc. First Int. Conf. East-Aus. Ver. Fau.: 1-5
- Sugeha, H.Y., T. Arai, M.J. Miller, D. Limbong, and K. Tsukamoto, 2001a, 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, H.Y., J. Aoyama, and K. Tsukamoto, 2001b, First Report on the silver eel of *Anguilla marmorata* (Quoy & Gaimard) from Central Sulawesi Island, Indonesia, Proceed
- Sugeha, H.Y., S. Watanabe, T. Arai, J. Aoyama, D. Limbong, and K. Tsukamoto, 2001c, Inshore Migration of Tropical Glass Eels (*Anguilla* spp) to the Poso River, Central Sulawesi Island, Indonesia. *In*: Aida K., K. Tsukamoto, and K. Yamauchi (eds), Proceeding of the International Symposium: Advance in Eel Biology, Tokyo, pp.122-124
- Sugeha, H.Y., 2003, Life history of tropical eel *Anguilla marmorata* in the Indonesian waters, Ph.D Disertation, The University of Tokyo, Jepang.
- Tesch, F.W., 1977, The Eel. Biology and Management of Anguillids eels, Chapman and Hall, London, 435 p.
- Todd, P.R., 1981, Timing and periodicity of migrating New zeland freshwater eel (*Anguilla* pp), NZ J. Freshw. Res. 1:227-235
- Vollestad, L.A. & B. Jonsson, 1986, Life-history characteristic of the Eiropean eel *Anguilla anguilla* in the Imsa River, Norway, Trans Am. Fish. Soc. 115:864-871