Water quality, plankton community, and pollution index in the spawning habitat of longtail shad (*Tenualosa macrura*) in the waters of Bengkalis, Meranti Island and Siak Regencies, Riau Province

V Seygita¹*, Sulistiono², C Kusmana³ and G Yulianto²

¹ Study Program of Natural Resources and Environmental Management Science, Postgraduate School, IPB University (Bogor Agricultural University), Kampus IPB Baranangsiang Jl. Raya Padjajaran Bogor 16151. Kota Bogor. Indonesia
² Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University (Bogor Agricultural University), Jl. Agatis, Kampus IPB Dramaga, Bogor 16680, Indonesia
³ Department of Silviculture, Faculty of Forestry, IPB University, Bogor 16680, Indonesia

*Corresponding author: vivinseyygita@gmail.com

Abstract. The waters of Bengkalis (as the estuary of Siak River) in Meranti and Siak Regencies of Riau Province is known as longtail shad (*Tenualosa macrura*) spawning area. This study aims to describe the condition of the waters of the fish spawning habitat. Sampling was conducted for three months from September to November 2019. The physical, chemical, and biological parameters were observed i.e. temperature, depth and transparency, salinity, TSS, pH, DO, nitrate (NO₃), phosphate (PO₄), BOD, lead (Pb), and mercury (Hg), plankton abundance, and diversity. The result showed the waters temperatures, depth, transparency, salinity, TSS, pH, and DO varied i.e., 26.7-30.3 °C, 4-30 m, 0.27-0.835 m, 7, and 5.9-7.9 mg/l, respectively. The nitrate, phosphate, BOD, Pb, and Hg were 0.617-2.196 mg/l, 0.006-1.666 mg/l, 0.80-11 mg/l, 0.002-0.094 mg/l and <1 mg/l respectively. The most common genera of phytoplankton were *Trichodesmium* sp. (37.293 to 596.688 cells/m³), while the most abundant zooplankton was *Tintinnopsis* sp (8.421-54.135 cells/m³). According to the study, it is known that the water condition of the fish habitat was reasonably good. However, the nitrate and phosphate in the waters passed the quality standard threshold for fisheries.

Keywords: conservation; spawning ground; water condition

1. Introduction
Longtail shad (*Tenualosa macrura*), locally known as *ikan terubuk*, is classified as an endemic fish and found in the waters of Riau province. *Tenualosa macrura* is one of five species of the Genus *Tenualosa* in the world. Another species is *Tenualosa ilisha* which is found in eastern North Sumatra and western Kuwait, *Tenualosa reevesii* is found on the coast of South China to the Yangtze, Pearl, and Qiantang Rivers. *Tenualosa thibaudeau* is found in Mekong River and *Tenualosa toli* is found in Sarawak, Malaysia [1]. *Tenualosa macrura* is known for possessing high economic value and
considered as a celebrated icon by people of Riau. Ikan terubuk is a migrating fish, which lives in the salt water but has its spawning ground in brackish waters [2]. Its population has been depleting considerably, indicated by low catch and shrinking size [3]. The International Union for Conservation of Nature has declared *Tenualosa macrura* as a ‘near threatened’ species. Besides, Decree No 59/2011 of Minister of Marine and Fisheries of Republic Indonesia has regulated ikan terubuk (*Tenualosa macrura*) as a protected yet limited species of fish.

Several studies have been conducted to determine the causes of the decrease of the population of this clupeid, among which has been the deterioration of the spawning habitat. The spawning ground of ikan terubuk includes sub-areas of Bengkalis Strait, Padang Strait, Lalang Strait, and the estuary of Siak River [4]. On administrative basis, the migration and spawning pathway of this species are across coastal waters of Bengkalis, Meranti Islands, and Siak Regencies of Riau Province. An increase of human population and social-economic development in coastal areas put more ecological pressure on the ecosystem and its resources. Various activities take place along the coastal waters including households, farms, plantations, industries, and transportation producing various wastes entering coastal waters. The excessive addition of pollutants either organic or inorganic to water body has deteriorated water quality physically, chemically, and biologically. Poor water quality will also lower its stability, productivity, support, and capacity of a body of water. Waters quality declining due to anthropogenic activities will harm the habitat of fish and other organisms [5].

![Figure 1. Research location.](image-url)
Based on the facts above, more comprehensive efforts are required which begins by managing spawning habitat of ikan terubuk. Therefore, complete and accurate information regarding the characteristics of their reproduction site is vitally required for better management. The study was aimed at determining the physical, chemical, and biological characteristics of habitat preference for ikan terubuk spawning ground in the coastal waters of Bengkalis, Meranti Islands and Siak regencies of Riau Province.

2. Methods
The study was conducted in the waters of Bengkalis, Meranti Islands, and Siak regencies of Riau Province from September to November 2019 with two replications. The research was situated at seven sampling spots spreading over the migration and spawning paths of this fish. A purposive sampling method was applied to decide those sampling locations. Some sampling sites were located inside Terubuk Fishery Sanctuary mentioned in Riau Governor Decree No. 78 Yesar 2012 on Terubuk (*Tenualosa macrura*) Fishery Sanctuary in Riau Province, while the rests were outside the sanctuary. The distribution of sampling locations is shown in figure 1 and table 1.

Table 1. Distribution of sampling stations within the research area.

| Sampling Station | Sub-District | District | Regency         |
|------------------|--------------|----------|-----------------|
| Station 1        | Meskom       | Bengkalis| Bengkalis       |
| Station 2        | Sei Alam     | Bengkalis| Bengkalis       |
| Station 3        | Ketam Putih  | Bengkalis| Bengkalis       |
| Station 4        | Tanjung Padang| Tasik Putri Puyu | Meranti Island  |
| Station 5        | Sungai Apit  | Sungai Apit | Siak          |
| Station 6        | Lalang       | Sungai Apit | Siak          |
| Station 7        | Sungai Rawa  | Sungai Apit | Siak          |

Activities during the study comprised direct observation, in situ measurement, and laboratory analysis. Water quality analysis was conducted at Aquaculture Environment Laboratory, Department of Aquaculture, while analysis on composition and abundance of plankton was conducted at Bio Macro Laboratory 1, Division of Ecobiology and Conservation of Aquatic Resources, Department of Aquatic Resources Management. Both were administered by Faculty of Fisheries and Marine Science, IPB University.

2.1. Materials and tools
There were several materials used in this study: H$_2$SO$_4$ (used for preserving nitrate samples, HNO$_3$ (used for preserving heavy metal samples), and distilled water. In addition, some tools used were sample holders, large-sized plastic bags, cool boxes, Secchi disks, litmus papers, DO meter, refractometer, measuring pipettes, 100 mL Erlenmeyer flasks, and Atomic Absorption Spectrophotometry (AAS).

2.2. Research procedures
Water samples were taken from every sampling spot and placed inside bottles that had previously been filled with H$_2$SO$_4$ and HNO$_3$ solutions, and later they were brought to the laboratory and analyzed using Atomic Absorption Spectrophotometry. The parameters observed in this study as well as the measurement units, methods of analysis, and locations of analysis are all presented in table 2.
Table 2. Observed parameters, measurement units, tools, methods, and locations of analysis.

| Parameter       | Unit   | Tool/Method         | Note   |
|-----------------|--------|---------------------|--------|
| **Physical**    |        |                     |        |
| Temperature     | °C     | DO meter            | in situ|
| Transparency    | m      | Secchi disk         | in situ|
| **Chemical**    |        |                     |        |
| Salinity        | ‰      | Refractometer       | in situ|
| DO              | mg/L   | DO meter            | in situ|
| L for degree BOD| mg/L   | Spectrophotometer   | laboratory|
| Nitrate (NO₃)   | mg/L   | Spectrophotometer   | laboratory|
| Phosphate (PO₄) | mg/L   | Spectrophotometer   | laboratory|
| Lead (Pb)       | mg/L   | Spectrophotometer   | laboratory|
| **Biology**     |        |                     |        |
| Plankton        | ind/m³ | Enumeration         | laboratory|
|                 |        | (Census - SRC)      |        |

2.3. Data analysis

The analysis of data retrieved from both in situ measurement and laboratory result was conducted using a descriptive method, which compared the result of water standard quality threshold regulated in State Minister for the Environment Decree No. 51 of 2004 on Salt Water Quality Standard for Marine Biota [6]. To determine the contamination status, the Pollution Index by Sumiotomo and Nerow (1970) as in State Minister for the Environment Decree No. 51 of 2004 was applied as follow:

\[ PI_j = \sqrt{\left( \frac{C_i}{L_i} \right)_M^2 + \left( \frac{C_i}{L_i} \right)_R^2} \]

Noted:
- \( L_i \): Concentration level of water quality parameter as in quality standard threshold (j)
- \( C_i \): Concentration level of water quality parameter from the survey
- \( PI_j \): Pollution Index (j)
- \( (C/L_i)_M \): Maximum value of \( C/L_i \)
- \( (C/L_i)_R \): Average value of \( C/L_i \)

The correlation between level of contamination and pollution index criteria based on State Minister for the Environment Decree No. 115 of 2003 on Determining Water Quality Status is expressed as follow [7]:

1. \( 0 \leq PI_j < 1.0 \): good
2. \( 1.0 < PI_j < 5.0 \): slightly polluted
3. \( 5.0 < PI_j < 10 \): fairly polluted
4. \( PI_j > 10 \): heavily polluted

3. Results and discussion

The existence of fish living in certain water body waters is dynamic depending on its natural movement and migration in seeking suitable habitat. Therefore, water quality where fish live in terms of physical, chemical, and biological characteristics affects a variety of eco-physiological aspects of fishes including growth, metabolism, reproduction, and spawning. In the following, those habitat characteristics for *T. macrura* are presented. The range of physical and chemical parameters at the sampling station are shown in table 3.
Table 3. Summary of physical and chemical measurements at the sampling station.

| Parameters             | Unit   | St.1   | St.2   | St.3   | St.4   | St.5   | St.6   | St.7   |
|------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Temperature            | °C     | 28.9   | 26.7   | 30     | 30.3   | 30.3   | 29.0   | 29.0   |
| Water transparency     | m      | 0.50   | 0.83   | 0.40   | 0.27   | 0.52   | 0.63   | 0.49   |
| Salinity               | %      | 28     | 28     | 30     | 27     | 25     | 27     | 30     |
| Dissolved Oxygen (DO)  | mg/L   | 7.6    | 7.9    | 6.8    | 7.8    | 5.9    | 7.4    | 7.3    |
| Biochemical Oxygen Demand (BOD) | mg/L | 10     | 11     | 0.8    | 10     | 3      | 10     | 10     |
| Nitrate (NO₃)          | mg/L   | 0.683  | 0.818  | 2.196  | 0.617  | 1.935  | 0.731  | 0.649  |
| Phosphate (PO₄)        | mg/L   | 0.016  | 0.010  | 1.666  | 0.006  | 1.442  | 0.008  | 0.020  |
| Lead (Pb)              | mg/L   | 0.002  | 0.003  | 0.094  | 0.003  | 0.056  | 0.002  | 0.003  |

3.1. Temperature
Temperature is an important physical parameter affecting fish physiology such as growth and reproduction. Therefore, fluctuation in temperature condition may influence fishery productivity. This is likely to occur as temperature increased due to global warming leads to stock declining in global fishery [8]. Horizontal distribution of temperature in the study area shows (figure 2) that the temperature ranging from 26.7 °C-30.3 °C is the common temperature in the terubuk habitat [9].

3.2. Water transparency
Waters transparency in the research location ranged from 0.27-0.83 m. The highest transparency was observed in Station 2; on the contrary, the lowest one was recorded in Station 4. The reason for lower transparency level that might be related to sampling site position is transportation paths and is influenced by Siak River estuary. In reference to Ministerial Decree No. 51/2004, water transparency in spawning habitat of T. macrura was below allowable quality standard specific to marine biota [6].

Transparency is defined as the level of light penetration into a water column. The transparency level is the opposite of the turbidity level. A low level of transparency will limit light penetration into waters. Low transparency will reduce photosynthesis by aquatic plants. Figure 3 shows the distribution pattern of this parameter.

3.3. Salinity
Salinity conditions varied between 25-30 %, and the highest was found at Stations 3 and 7, whereas the lowest was at Station 5 (figure 4). The lowest value was measured at the closest to Siak River, where water body is influenced by freshwater. Based on the standard quality of Ministerial Decree No. 51/2004, salinity is still appropriate for marine biota [6]. Salinity is an amount of salt dissolved in waters and is expressed per thousand. In water column, salt content in water is affected by water circulation, evaporation, precipitation, and supply of fresh water from rivers [10]. Ikan terubuk spawns in the coastal waters of Bengkalis, Meranti Island dan Panjang Strait where sea water from Malaka Strait meets fresh water from Siak River estuary.

3.4. Dissolved Oxygen (DO)
The values of dissolved oxygen (DO) observed in several sites varied between 5.9-7.9 mg/L (figure 5). The highest was found at Station 2, while the lowest was at Station 5. A lower DO level might be linked to the high inputs of organic materials brought by Siak River. However, its lowest value remains to meet quality standard for marine biota. Marine biota can tolerate DO to 2 mg/L [11]. Oxygen is one key parameter determining water quality as it is required by living things for respiration and aerobic metabolism. Therefore, oxygen decreases due to these two activities. Sources of oxygen in waters are derived from diffusion from air and photosynthesis by aquatic autotroph [12]. Low oxygen levels in waters can cause stress in fish due to lack of oxygen supply to their brain, and it can also lead to death due to oxygen deficiency (hypoxia) [13].
Figure 2. Temperature distribution pattern in the spawning habitat of T. macrura.

Figure 3. Horizontal distribution of waters transparency in the spawning habitat of T. macrura.

Figure 4. Salinity distribution pattern in the spawning habitat of T. macrura.

Figure 5. Dissolved Oxygen (DO) conditions in the spawning habitat of T. macrura.

3.5. Biochemical Oxygen Demand (BOD)
Based on the measurement, BOD ranged from 0.80-11 mg/L, where the highest was found at Station 2, while the lowest was at Station 3 (figure 6). In comparison to the national standard, BOD values were all below the pollutant level (20 mg/L). The measurement of BOD is extremely important to find pollution flow from the upstream to the estuary [14]. The value of BOD is the amount of oxygen needed by waters to biologically oxidize organic materials [15], which is identified as pollution status and may affect fishery productivity [16]. A higher BOD concentration indicates an elevated condition of organic materials [17]; therefore, this parameter also functions as biodegradation activity in water. The distribution pattern of BOD in the study area is presented in figure 6.
3.6. Nitrate (NO$_3$) and Phosphate (PO$_4$)

Nitrate (NO$_3$) concentration in the research location ranged from 0.617-2.196 mg/L. The highest concentration was observed in Station 3, while the lowest was in Station 4. The distribution pattern of nitrate concentration is shown in Figure 7. Concentration of phosphate (PO$_4$) in the spawning habitat of *T. macrura* varied between 0.006-1.666 mg/L, where the highest concentration was measured at Station 3, while the lowest was at Station 4. Phosphate concentration level in seven sampling stations in the research location is presented in Table 3 and the distribution pattern can be seen in Figure 8.

Based on the State Minister for the Environment Decree No. 51 Year 2004 [6], it is shown that nitrate and phosphate concentration in terubuk spawning habitat was considerably high and passed the minimum limit quality standard for marine biota. The high concentration might be derived from man-made activities including agriculture, plantations, industries, and households along the coast. According to Wattayakorn who stated that those anthropogenic activities are decomposed to become nutrients [18]. Nutrients are one of the limiting factors of water quality. They trigger phytoplankton growth and fish production; however, an excess of nutrients will facilitate the growth of harmful phytoplankton known as Harmful Alga Blooms [19].

![Figure 6](image1)  
**Figure 6.** BOD distribution Pattern in the spawning habitat of *T. macrura*.

![Figure 7](image2)  
**Figure 7.** Nitrate distribution pattern in the spawning habitat of *T. macrura*.

![Figure 8](image3)  
**Figure 8.** Phosphate distribution pattern in the spawning habitat of *T. macrura*.

3.7. Lead (Pb)

The concentration of lead (Pb) ranged from 0.002-0.094 mg/L, and it is shown that Stations 3 and 5 had Pb concentration exceeded the quality standard for marine biota (0.008 mg/L). The high Pb concentration may be linked to human activities where these locations close to human settlements,
transportation channels, and industrial areas. In contrast, other stations showed a tolerable level of lead devoted to marine biota. The concentration level of Lead (Pb) in the research location is presented and its distribution pattern can be seen in figure 9.

![Figure 9. Lead (Pb) distribution pattern in the spawning habitat of T. macrura.](image)

High heavy metal Lead (Pb) content that exceed the quality standard has the potential to become toxic that contaminates water biota. High Lead (Pb) concentration in the body water will affect an individual’s growth, physiology function, reproduction, and even lead to death. Lead (Pb) enters the fish body via three entrances: gills, digestive tract, and body surface. Heavy metals in the fish body will be accumulated and flow into the food chain. Consuming fish that are exposed by heavy metal Lead (Pb) will affect human health [20].

### 3.8. Plankton

Phytoplankton compositions comprised *Trichodesmium* sp., *Coscinodiscus* sp., *Nitzschia* sp., *Chaetoceros* sp. and *Planktoniella* sp.. The most commonly found was *Trichodesmium* sp. ranged between 37.293-596.688 cell/m³ in abundance, while *Planktoniella* sp. was the least with 16.842 cell/m³ (figure 10). Zooplankton composition comprised *Tintinopsis* sp., *Nauplius*, *Leprotintinnus* sp., *Calanus* sp., *Oithona* sp., *Arcella* sp., *Oncaea* sp., *Eucalanus* sp., *Steenstrupiella* sp. and *Balanus* sp.. The most common type of zooplankton found was *Tintinopsis* sp. with the abundance level of 9.624-54.135 cell/m³, while the least was *Steenstrupiella* sp. with 1.203 cell/m³. Compositions and abundance level of zooplankton in the research location are presented in figure 11.

Planktons are a vital component in waters as the base link of a food chain. Phytoplankton is the primary producer that transform inorganic materials through photosynthesis. Organic materials produced by phytoplankton are used by both zooplankton and fish in the waters as a natural source of food. Some fish consuming phytoplankton are those from the family Mugilidae, Engraulididae, Clupeidae, and Gobiidae. Fish from the family Clupeidae consume not only phytoplankton but also zooplankton [21]. *T.macrura* belonging to the family Clupeidae that is plankton feeder, especially zooplankton. Phytoplankton and zooplankton abundance is directly proportional with the result of fish catch [22].
Figure 10. Compositions and abundance of phytoplankton in spawning habitat of *T. macrura*.

Figure 11. Zooplankton compositions and abundance in *T. macrura* spawning habitat.

3.9. Pollution Index

The Government Regulation of Republic Indonesia No. 19 of 1999 on Control Measures of Marine Pollution and/or Destruction regulates that marine pollution is defined as an inclusion or the entry of...
living organisms, substance, energy, and/or other components into the marine environment due to human activities leading to a certain level of quality declining that makes the marine environment less suitable with its quality standard and/or its functions [23]. In addition, quality standard is defined as measurement limit or rate of existing living organisms, substance, energy, or components or those that should exist and/or pollutants whose existence in the waters is somehow tolerable.

Based on the State Minister for the Environment Decree No. 115 of 2003, one method to determine water quality index is by using water pollution index (PI) [7]. Water pollution index can be used to evaluate the quality of the body of water and its appropriate allocation. The pollution index rate of all 7 sampling stations is presented in figure 12.

About the Pollution Index analysis, it is understood that the waters of ikan terubuk spawning habitat can be classified as in category ‘good’, except for Station 2 which can be classified as ‘slightly polluted’. Based on the State Minister for the Environment Decree No. 115 of 2003, the pollution index rate within the range of 0 ≤PIj≤1.0 is classified as ‘good’, while with the range of 1.0<PIj<5.0, it can be classified as ‘slightly polluted’ [7]. The high rate of pollution index in Station 2 is expected due to its location that is not far away from settlements and its function as a transportation channel.

In general, the water quality status in ikan terubuk spawning habitat was observed in a better condition compared to the result of the previous study by Amri et al stating that the DO distribution rate and low pH indicated that there was pollution in Bengkalis estuary waters [4].

![Figure 12. Pollution index rate in Ikan Terubuk spawning habitat.](image-url)

4. Conclusion

Based on the rate of waters quality summarized in the Pollution Index rate, it can be concluded that the ikan terubuk spawning habitat in the waters of Bengkalis, Meranti Islands, and Siak regencies of Riau province is in the ‘good’ and ‘slightly polluted’ categories with the Pollution Index rate ranging from 0.25 to 2.13.

Acknowledgments

This study was funded by Riau Provincial Government via Regional Civil Service Agency of Riau Province. Therefore, we, the researchers, deeply express our gratitude to Riau Provincial Government, especially to the Regional Civil Service Agency and Department of Maritime Affairs and Fisheries of Riau Province.
References
[1] Blaber S J M, Milton D A, Brewer D T and Salini J P 2003 Biology, Fisheries, and Status of Tropical Shads (Tenualosa spp.) in South and Southeast Asia American Fisheries Society Symposium 35:000–000
[2] Efizon D, Djunaedi OS, Dhahiyat Y and Koswara B 2012 Population abundance and exploitation rate of Terubuk Fish (Tenualosa Macrura) in Bengkalis Waters, Riau Jurnal Berkala Perikanan Terubuk 40(1): 52–65 [in Indonesian]
[3] Suwarso, Taufik M and Zamroni A 2017 Fisheries type and status of Terubuk (Tenualosa Macrura, Bleeker 1852) resources in the Estuarine of Bengkalis and Panjang Strait Indonesian Fisheries Research Journal. 23(4): 261–273 https://doi.org/10.15578/jppi.23.4.2017.261-273 [in Indonesian]
[4] Amri K, Winarso G and Muchlizar 2018 Water environment quality and fish potention production in Bengkalis Shads conservation (Tenualosa Macrura, Bleeker 1852). Indonesian Fisheries Research Journal 24(1): 37–49 https://doi.org/10.15578/jppi.1.1.2018.37-49 [in Indonesian]
[5] Ghofizadeh MH, Melesse AM and Reddi L 2016 A comprehensive review on water quality parameters estimation using remote sensing techniques Sensors b (8): 1298–1340 https://doi.org/10.3390/s16081298
[6] State Minister for the Environment Decree No. 51 of 2004 on Salt Water Quality Standard for Marine Biota (Link: http://www.menlh.go.id) [in Indonesian]
[7] Ministry of Environment Decree No 115/2003 on Guidelines for Determination of Water Quality Status [in Indonesian]
[8] Ezenwaji EE, Ahiadu HO, Nzoiwu CP and Ekolok AM 2014 An analysis of the relationship between temperature variation and fish production in Lagos, Nigeria IOSR Journal of Agriculture and Veterinary Science 11(3) : 38–43 https://doi.org/10.9790/2380-071133843
[9] Blaber SJM, Brewer DT, Milton DA, Merta GS, Efizon D, Fry G, and Van der Velde T 1999 The life history of protandrous tropical shad Tenualosa macrura (Alosinae: Clupeidae) : fishery implications Estuarine, Coastal and Shelf Science 49: 689–701 https://doi.org/10.1006/ecss.1999.0545
[10] Nontji, A 2002 Nusantara Sea Publish Djambatan Jakarta pp 59–67 [in Indonesian]
[11] SWINGLE, HS 1968 Standardization of chemical analysis for water and pond muds. FAO Fish, Rep 44(4): 379–406
[12] SALMIN. 2000. Dissolved oxygen levels in the waters of the Dadap, Goba, Muara Karang and Banten Bay rivers. in: foraminifera as pollution bioindicator, study result in estuarine waters of Dadap River, Tangerang (Djoko P Praseno, Ricky Rositasari and Hadi Riyono S, eds) P3O - LIPI pp 42–46 [in Indonesian]
[13] Tatangindatu F, Kalesaran O, Rompas R. 2013. Study on water physical-chemical parameters around fish culture areas in Lake Tondano, Paleloan Village, Minahasa Regency Journal of Aquaculture 1(2): 8–19 https://doi.org/10.35800/bdp.1.2.2013.1911
[14] Salmin. 2005. Dissolved oxygen (DO) and biological oxygen demand (BOD) as indicator to determine water quality Jurnal Oseana 30(3): 21–26 [in Indonesian]
[15] Nugroho AA, Rudiyanti S, and Haeruddin 2014 The effectiveness of Broom Fish (Hypostomus plecostomus) to Improve the quality of fish processing wastewater (based on BOD, COD, TOM Values) Diponegoro Journal of Maqueres 3(4): 15–23 [in Indonesian]
[16] Mukherjee S and Dutta M 2016 Biological oxygen demand in controlling fish production and cost of supplementary feed towards better sustainability of a sewage-fed aquaculture system: a case study of East Kolkata Wetlands, West Bengal, India International Journal of Waste Resources 6(2) https://doi.org/10.4172/2252-5211.1000209
[17] Yudo S. 2010. Kondisi Kualitas Air Sungai Ciliwung di Wilayah DKI Jakarta Ditinjau dari Parameter Organik, Amoniak, Fosfat, Deterjen dan Bakteri Coli. *Jurnal Akuakultur Indonesia* 6(1): 34–42 https://doi.org/10.29122/jai.v6i1.2452 [in Indonesian]

[18] Wattayakorn, G. 1988 Nutrient cycling in estuarine. *Paper presented in the project on research and its application to management of the mangrove of Asia and Pasific*. Ranong Thailand pp 17

[19] Gypens N, Borges AV and Lancelot C. 2009 effect of eutrophication on air-sea CO$_2$ fluxes in the coastal Southern North Sea: a model study of the past 50 years. *Global Change Biology* 15(4): 1040–56 https://doi.org/10.1111/j.1365-2486.2008.01773.x

[20] Afshan S, Ali S, Ameen US, Farid M, Bharwana SA, Hannan F and Ahmad R. 2014 Effect of different heavy metal pollution on fish. *Research Journal of Chemical And Environmental Sciences* 2(1): 74–79

[21] Andriani A, Damar A, Rahardjo MF, Simanjuntak CPH, Asriansyah A and Aditriawan RM. 2017 Abundance of phytoplankton and its role as fish food sources in Pabean Bay, West Java. *Indopasific Aquatic Resource Journal* 1(2): 133–144 [in Indonesian]

[22] Sihombing HP, Hendrawan IG and Suteja Y. 2018 Analysis of the relationship between surface plankton abundance and catching results of Lemuru (Sardinella lemuru) in the Bali Strait. *Journal of Marine and Aquatic Sciences* 4(1): 151–161 https://doi.org/10.24843/jmas.2018.v4.i01.151-161 [in Indonesian]

[23] Republic of Indonesia. (1999). Government Regulation No. 19 of 1999 on Control of Marine Pollution/ Destruction [in Indonesian]