Dynamics Water Quality in Koto Panjang Reservoir, Indonesia

B Budijono1*, I Suharman2, A Hendrizal1

1Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Riau University, Pekanbaru 28293, Indonesia
2Department of Aquaculture, Faculty of Fisheries and Marine Science, Riau University, Pekanbaru 28293, Indonesia

*budijono@lecturer.unri.ac.id

Abstract. Riau Province has the Koto Panjang reservoir which is generated from the damming of the Kampar River flow for hydroelectric power generation and other utilization activities. The increase in community activities in reservoir waters and on land causes water quality dynamics that can affect fish farming activities. The purpose of this study was to determine the dynamics of reservoir water quality. The survey was conducted in March – August 2021 at seven sampling points, where water samples at each sampling point were taken at a depth of 1 m as much as 1 liter using a van dorn water sampler and preserved and analyzed according to standard methods. Data from measurement and analysis were tabulated and analyzed descriptively including temperature, pH, turbidity, TSS, TDS, DO, nitrate, ammonia, total nitrogen, BOD5, COD, and total phosphate. The results obtained indicate that the values of temperature, turbidity, TDS, TSS, pH, DO, ammonia, nitrate, and phosphate are still below the quality standard, except in the range of BOD values of 4.30 – 5.75 mg/L and COD of 17.90 – 23.73 mg/L is an indication of organic matter originating from other activities on the reservoir land, such as plantations, agriculture, settlements, tourism, apart from floating net cage cultivation activities.

1. Introduction
Koto Panjang Reservoir is the largest national reservoir in Riau Province and the second largest in Southeast Asia with an area of ±12400 ha which has an adequate capacity of ±1.545 million km³ and a functional water capacity of ±1,040,000,000 m³ [1] which is used for power generation, hydroelectric power. The main water supply of this reservoir comes from the Kampar Kanan and Mahat rivers and small tributaries such as the Kapau, Tiwi, Takus, Gulamo, Osang, Cunding, Arau Kecil, and Arau Besar rivers [2]. This reservoir is a gathering place for various types of fish from the river and recorded around 24 – 44 species [1], [3]–[5]. The diversity and abundance of this fish has become a source of livelihood for 400 fishermen [1] with fishing locations in the waters of Batu Bersurat, Muara Takus, Gunung Bungsu, and Rantau Berangin [3], even in recent years. There is a floating net chart in the waters of Koto Tuo.
This reservoir is also used for cultivation of floating net cages (FNC), with the current number reaching 1204 plots and an increase in the number over the last five years as many as 304 plots [6] with the production of carp (*Cyprinus carpio*) Rajadanu variety. In a year, FNC production reaches 4816 tons. This fish farming activity has been going on for 18 years, especially FNC in the dam location area which is one of the water tourism destinations and fishing activities are carried out by dozens of water taxis, as well as two floating stalls and settlements. On the other hand, land in lacustrine and transition areas occurs when land is converted into agriculture, plantations, settlements, and tourism; even in the watershed there are also sand and gravel mining activities.

Since development reservoirs until now, there has been no development of the use of public waters and the Koto Panjang Reservoir area which is legally and formally determined by the local government which is the policy for the management and utilization of the reservoir so that it has the potential to become a big problem in the future. The main problem in the development of fisheries in reservoir waters in general is the decline in water quality due to the increasing pollution load, both organic and inorganic from community activities in the upstream area and the reservoir itself as well as changes in aquatic habitat from lotic (river) waters to lentic waters (river) reservoir. According to [7], reservoir pollution comes from activities in the watershed due to activities in the industrial sector, settlements, agriculture, livestock, and human activities in the waters of the reservoir itself, such as intensive fish farming activities, in floating net cages. Which does not consider the carrying capacity of water bodies.

Reservoir water quality decline is often associated with FNC activities which are significant contributors to reservoir pollution. The results of research in the Koto Panjang Reservoir showed that 19.28% of fish feed was wasted [8], while in other studies, 25-30% of wasted feed was found [9]. This means that in aquaculture activities there is a large amount of wasted feed residue and fish metabolism products that enter the waters, which have the potential to pollute the aquatic environment. The increase in the number of operating cages and the high activity of people on land around the reservoir, such as plantations and agriculture, have contributed to increasing the fertility of the waters. Increased water fertility causes problems of decreasing water quality which in turn has an impact on the unsustainability of fishery resources, and the production of cultured fish in cages. [10] stated that the activities of floating net cages produce inedible food waste and metabolic waste (faeces and urine), if in large quantities it will reduce reservoir water quality such as depletion of dissolved oxygen content and increase the concentration of toxic elements. The purpose of this study was to determine the dynamics of water quality as an indicator of the health of the waters in the Koto Panjang reservoir.

2. Methodology

2.1. Location point

The location points of this study consisted of seven locations, namely: location I (N=0.311532; E=100.639296), II (N=0.284061; E=100.708111), III (N=0.356076; E=100.272727), IV (N=0.312861; E=100.777395), V (N=0.29948; E=100.774048), VI (N=0.286321; E=100.875428) and VII (N=0.294164; E=100.884990) as shown in Figure 1, which represent the riverine zone, transition, lacustrin and reservoir outlets. This survey was carried out in March-August 2021. The samples were analyzed at the Laboratory of the Faculty of Fisheries and Marine Affairs, University of Riau, and the Regional Health Laboratory of Riau Province.

2.2. Data type

The water quality parameters observed were temperature, turbidity, pH, DO, BOD5, COD, nitrate, total nitrogen, and phosphate. In situ parameter measurements, including temperature (Hg thermometer), pH (HANNA HI 98107), turbidity (Martini Mi415), and DO (JPB-70A). Meanwhile, BOD5, COD, nitrate, total nitrogen, and phosphate were analyzed at the UPT Construction Materials Laboratory of the Bina Marga Office, Riau Province. In addition to primary data, secondary data obtained from various literatures are also used.

2.3. Measurement, Sampling and Analysis
Measurements and sampling were carried out at seven locations that have been determined with the physical and chemical parameters of water in Table 1. One liter of water sample was taken at a depth of 1 m with a Van Dorn water sampler and put into a sample bottle that was stored in a cool box at 4°C for analysis in the laboratory. Sampling procedures, preservation, and sample analysis were carried out by referring to the standard method of Water and Wastewater Examination Method [11].

2.4. Data analysis
The water quality measurement data obtained were analyzed comparatively with water quality standards [12], except for the nitrate value based on [13] for the last six years (2016 – 2021).

![Figure 1. Map of research location](image)

**Table 1.** Types of Water Quality Parameters, Sample Analysis Methods and Locations for Measurement or Analysis of Samples

| No. | Parameters | Unit     | Method          | Measurement |
|-----|------------|----------|-----------------|-------------|
| 1.  | Temperature| °C       | Expansion       | In-situ     |
| 2.  | Turbidity  | FTU      | Light scattering| In-situ     |
| 3.  | TDS        | mgL⁻¹    | Electrometric   | In-situ     |
| 4.  | TSS        | mgL⁻¹    | Gravimetric     | Laboratory  |
3. Results and Discussion

The range of the average temperature is between 27.25 - 29.70 °C. Turbidity values ranged from 2.48 to 4.23 FTU. TDS values ranged from 27.35 - 35.43 mg L⁻¹. TSS values from seven sites ranged from 8.25 to 13.25 mg L⁻¹. The pH value of the water ranged from 6.58 - 7.03. DO content was high in each location with a range of 6.38 - 6.68 mg L⁻¹. The concentration ranges of BOD₅ and COD were 4.13 - 5.75 mg L⁻¹ and 15.5 - 26.40 mg L⁻¹, respectively. The nitrate concentration ranged from 0.47 - 0.55 mg L⁻¹. The range of total nitrogen concentration is between 1.18 - 1.34 mg L⁻¹. Meanwhile, the total phosphate concentration ranged from 0.18 to 0.30 mg L⁻¹. From this water quality data, when compared with water quality data in the 2016 – 2020 period, a picture of the dynamics of reservoir water quality is obtained (Figure 2).
Figure 2. Dynamics of Water Quality in the Koto Panjang Reservoir

The temperature of the reservoir inundation waters at stations 1 – 6 was relatively stable for 6 years, including at station 7 with a deviation of < 3°C. The value of changes in turbidity is relatively tiny for 6 years with a high concentration at station 7, but the value of turbidity is still lower than in 2016. The
The concentration values of TDS and TSS are not much different for 6 years at all stations, and the concentration is higher in areas that are not. There are floating net cage activities such as at stations 1 – 4 compared to stations 5 – 6 as the location of FNC. The pH value was relatively stable for 6 years, with the lowest pH value at station 7. The DO value for 6 years at each station remained high, namely: above 6 mg/L, while the BOD$_5$ and COD concentrations were significantly different for 6 years. Years and the concentration of both parameters have exceeded the threshold at stations 1 – 4 as a non-FNC area and is slightly high at stations 5 – 6 as a FNC location but is still low compared to its concentration at station 7.

The average value of nitrate is slightly higher in the 2021 study with the highest concentration being at stations 5 – 6 which is the location of fish cages. The value of nitrate concentration every year is obtained to fluctuate slightly at each research location. This is in line with the highest total nitrogen concentration also at stations 5-6, even though the concentration is above the quality standard (0.75 mg L$^{-1}$) starting from stations 1 - 4 where there is no floating net cage activity, and the total nitrogen concentration per station did not differ much over the last 6 years (2016 – 2021). The total phosphate value is lower than the 2016 – 2020 value, and its concentration remains high at stations 5 – 6, but its concentration is above the quality standard of 0.03 mg L$^{-1}$ at all stations for the last six years. Based on [12] regarding the implementation of environmental protection and management for Class II Lake Water Quality Standards, it can be stated that this reservoir is still in good condition, except for parameters BOD$_5$, COD, total phosphate, and total nitrogen which have values above the water quality standards.

The ranges of BOD$_5$ and COD values in all locations ranged from 4.13 – 5.75 mg L$^{-1}$ and 19.3 – 26.3 mg L$^{-1}$, where the values for these two parameters were slightly lower than their concentrations in the previous period. 2016 – 2020. [12] For Lake Water Quality Standard Class II, the BOD$_5$ and COD values are set at 3 mg L$^{-1}$ and 25 mg L$^{-1}$, respectively, and are above the quality standard or BOD content above natural waters of 0.57 mg L$^{-1}$ [14]. These high BOD$_5$ and COD values indicate that the reservoir waters have decreased due to the entry of organic matter by human activities in the waters and in the land area of the reservoir [6]. High BOD$_5$ and COD values above the water quality standard are indicators of organic matter pollution [15].

BOD$_5$ shows the amount of dissolved oxygen needed by microorganisms to decompose or oxidize waste containing simple organic matter in water [16], which is influenced by the content and type of organic matter, temperature, abundance of plankton, dissolved oxygen availability, pH value, and the presence of microbes. If the concentration of BOD$_5$ is high, it will result in a decrease in dissolved oxygen due to the decomposition of organic matter under aerobic conditions, including a decrease in water pH [17]. Meanwhile, COD (Chemical Oxygen Demand) is defined as the amount of oxygen needed to break down all organic matter contained in water. In the COD test, the decomposition of organic matter is carried out chemically using potassium bichromate, under hot and acidic conditions with a silver sulfate catalyst, so that all types of organic matter, both easily decomposed and difficult to decompose, will be oxidized completely [18]. The biodegradation capacity can be seen from the ratio between BOD5 and COD and the ratio of the seven stations ranges from 0.208 to 0.266 or has a biodegradation index below 0.3 which is categorized as non-biodegradable. [19] divides 3 levels of biodegradation index, namely: (1) BOD/COD ratio value > 0.6 is categorized as biodegradable; (2) the BOD/COD ratio value of 0.3 – 0.6 is categorized as slow biodegradable; and (3) the BOD/COD ratio value < 0.3 is categorized as non-biodegradable.

Based on the concentration of BOD$_5$ and COD for 6 years which remained above the quality standard, it did not affect decreasing the DO concentration, which remained relatively high at all locations and, according to [20], had met the minimum DO limit for fish life of 4 mg L$^{-1}$. The availability of dissolved oxygen in the waters is critical to support fishery resources and the success of fish cultured. It indicates that the input of organic matter due to feeding and metabolic waste of cultured fish is still relatively low and can be tolerated by the waters, including those from land activities and settlements in non-FNC locations. This high DO concentration comes from the photosynthesis of phytoplankton and diffusion.
from the air that occurs on the surface of the large reservoir, and the penetration of light is still quite deep, and the surface temperature is relatively stable. In addition, the reservoir continuously receives water input from the river with a slow current from the upstream to the reservoir, which also carries O2 to reach the FNC location. High DO concentrations were also recorded in other studies at the exact location, namely: 4.23 – 6.62 mg L-1 [21]; 6.4–6.7 mg L-1 [8]; 6.20 – 6.70; and 4.23 – 7.17 mg L-1 [22] and when compared to the Jatiluhur Reservoir which has a DO range of 4.0 – 5.0 mg/L [23].

The average nitrate obtained at all locations remained in accordance with the water quality standard set at <10 mg L-1 for 6 years [24], but was no longer determined based on [12]. However, the average value of nitrate at each observation location is categorized as quite high for reservoir waters and is still low compared to the results of research at the same location by [25] which obtained nitrate concentrations ranging from 0.326 to 1.467 mg L-1. In different reservoir locations such as the Jatiluhur Reservoir, the nitrate range is between 0.21 – 0.86 mg L-1 [26] and in the Saguling Reservoir, the nitrate range is 0.03 – 1.063 mg L-1 [27]. Compared with studies [25], [26], and [27], nitrate concentrations in this study and the previous five years were still in the same range. Based on the nitrate concentration data obtained above > 0.2 mg L-1 with a fertility level classified as eutrophic. According to [13], the division of water fertility levels based on nitrate concentration, are: (1) 0.0 - 0.1 mg L-1 (oligotrophic); (2) 0.1 - 0.2 mg L-1 (mesotrophic); and (3) > 0.2 mg L-1 (eutrophic).

According to [26] nitrate concentrations above 0.2 mg L-1 can cause eutrophication (nutrient enrichment) which will stimulate the rapid blooming of algae and aquatic plants. This is in accordance with the statement [28] that eutrophication will be experienced by all reservoir waters after being inundated within one to two years. Referring to the previous statement, the increase in the fertility of the reservoir waters is caused by the duration of inundation that has reached 23 years and the development of human activities in the waters and on land around the reservoir. According to [29], phytoplankton grow optimally in the nitrate range between 0.9 mg L-1 to 3.5 mg L-1. The nitrate concentration found in this reservoir is negatively correlated with the number of floating net cages operating as many as 1,204 FNC plots. This means that the addition of the number of cages does not increase the concentration of N in the water, so that the increase in N is a combination of cage activities with other activities, including agricultural and plantation activities and settlements. Usually fertilizers used in agricultural and plantation activities (rubber and oil palm) contain high concentrations of N. This is in accordance with the results of research [30] which found that around the land area of the Koto Panjang reservoir there is an agricultural area of ± 32,296 ha, plantations (oil palm and rubber) covering an area of ± 11,548.57 ha, and an area of ± 1,243.11 ha as residential land. .

Total nitrogen is a form of inorganic N that is soluble and organic N, in the form of suspended particles. Based on the total nitrogen concentration at all locations and for the last 5 years above the quality standard of 0.75 mg L-1 [12]. According to [31], nitrogen cannot be utilized directly by aquatic plants and must be first fixed to NH3, NH4+, and NO3-. The high N concentration at the FNC location was closely related to the N contained in fish feed protein (pellets) used with an average protein of 30%. The N content in the feed is estimated to be 4.86% [3], of which fish does not consume 30% of the feed do not consume 30% of the feed and added N from 25-30% of fish excretion into the waters [32]–[35]. The ratio between the total N:P obtained from FNC locations (locations 5 and 6) ranged from 2.87 – 3.70. According to [36], N:P ratio > 12 (P as limiting factor), N:P < 7 (N as limiting factor) and 7 < N:P < 12 (N and P do not act as limiting factor). This can illustrate that N is a limiting factor for the formation of composition, phytoplankton biomass, and water fertility.

Based on the phosphate value, the average phosphate value for all locations was above the acceptable water quality standard of 0.03 mg L-1 [12] and was classified as eutrophic to hypereutrophic. This is in accordance with the distribution of water fertility levels based on phosphate determined by [13] having phosphate levels of 0.101 – 0.200 mg L-1 (eutrophic) and above 0.200 mg L-1 (hypertrophic). [25]
obtained phosphate concentrations during the study in this reservoir in the rainy season ranging from 0.068 - 0.416 mg L\(^{-1}\) and in the dry season ranging from 0.131 - 0.352 mg L\(^{-1}\). Similar conditions were also found in the Djuanda Reservoir with a phosphate value range of 0.20-0.36 mg L\(^{-1}\) (eutrophic-super eutrophic) \[26\], while the results of the study \[37\] obtained a phosphate range between 0.098 - 0.27 mg L\(^{-1}\) at Gajah Mungkur Reservoir.

When compared between research sites, this phosphate value is still in the same range for 6 years. According to \[38\], the selected cultivation sites in lakes and reservoirs have low to moderate fertility rates. The eutrophic condition of a waters is an indication that the carrying capacity of the water has been exceeded to support aquaculture activities. The highest concentration of total phosphate in this study and for the last 5 years was at the FNC location (locations 5 and 6). The main source of phosphorus in the reservoir damsite comes from cage activities, especially from uneaten feed and the metabolism of cultured fish. Fish need phosphorus to grow normally, and excess phosphorus is excreted from the body through feces and urine \[39\]. Phosphorus in cultured fish feed ranged from 1.27 - 1.66\% (1.50\%) and excess phosphorus was removed \[40\] and \[41\] found to be 0.89\% in commercial feed at the Koto Panjang FNC Reservoir. Generally, a high total phosphorus in feed will release dissolved phosphorus into the water. \[42\] stated that the release of phosphorus into water will be higher in line with the high total phosphorus in the feed and conditions of pH, temperature, DO, turbulence and activity of aquatic microorganisms affect the release of phosphorus. High temperatures cause an increase in the rate of nutrient release from the feed \[43\]. Another source of total phosphate is from domestic activities in the guard house on each FNC raft due to the use of detergent. The total P concentration was not much different at non-FNC locations. This means that in the part of the reservoir where there is no FNC activity, there is phosphate input into the reservoir waters, including phosphate carried by water flows from the main rivers that supply water to the reservoir. On the other hand, the total P concentration at the reservoir outlet was slightly lower or relatively the same as at the site without FNC. The high concentration of total P in this reservoir is negatively correlated with the number of operating floating net cages. This means that the total concentration of P does not increase with an increase in the number of FNC. Other P sources besides FNC are also agricultural activities, plantations, tourism, and settlements \[6\].

The distribution of cages in the reservoir is currently located at locations 5 and 6. When compared to locations without cages, they also have high concentrations of BOD\(_5\), COD, nitrate, total nitrogen and total phosphate so that there is a contribution of organic material, total N, and P originating from reservoir land activities, such as rainwater runoff that carries fertilizer residues from agricultural and plantation activities. Disposal of organic waste from tourism and residential activities that enter the reservoir waters through a series of physical, chemical and biological processes can increase the organic content, nitrogen and phosphate. Even agricultural and plantation activities (rubber, oil palm) generally use large amounts of fertilizer. This is in accordance with \[25\] that there is input of household waste from settlements around the Kampar River waters to the reservoir and waste from floating net cages in these waters.

4. Conclusion
The average values of BOD\(_5\), COD, total nitrogen and phosphate concentrations in this reservoir fluctuated for six years with the values of these four parameters at each research location not much different. The values of BOD\(_5\), COD, total nitrogen and total phosphate are above the water quality standard from activities on the reservoir land, in addition to floating net cage activities.

References
[1] Haryanto H, Sukendi, Thamrin 2013 J. Sains dan Mat. 18(4):158–169.
[2] Warsa A, Nastiti U S A, Nurfiarni A 2008 Bawal 2(3): 93-97.
[3] Nurdawati S, Nastiti U S A, Satria H, Suryandari A 2006 Prosiding Seminar Nasional IV Jatiluhur
29-30 Agustus 2006

[4] Mulia A 2006 Skripsi Universitas Riau Pekanbaru

[5] Harahap S, E Huri 2012 Berk. Perikan Terubuk 38(1):9-14.

[6] Budijono, Tang U M, Putra R M, Nofrizal 2021 Aquac. Aquarium, Conserv Legis 14(2): 965–975.

[7] Kartamihardja E S 2014 Badan Penelitian dan Pengembangan Kelautan dan Perikanan.

[8] Sumiarsih E 2014 Padjadjaran University Postgraduate Dissertation, Bandung.

[9] Chen W, Ai Q H, Mai K S, Xu W, Liufu Z G, Zhang W B and Cai Y H 2011 Aquaculture 318(1-2):95–100.

[10] Purnomo K, Warsa A and Kartamihardja E S 2016 J. Penelit. Perikan. Indon 19(4):203–212.

[11] American Public Health Association (APHA) 2005 Washington, DC, USA

[12] Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 Tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup

[13] Goldman C R, Horne A J 1983 Limnology McGraw-Hill Book Co New York 464 p

[14] Setiari N M, Mahendra M, Suyasa I B 2012 ECOTROPIC 7(1): 40–46

[15] Atima W 2015 Jurnal Penelitian Science dan Pendidikan 4(1):83–93

[16] Nugroho R, Mahmud I 2005 Jurnal Air Indonesia 1(2):163-712

[17] Barus T A 2004 J. Mns. dan Lingkung 11(2): 64–72

[18] Boyd C E 1982 Elsevier Scientific Publishing Co. USA 318p

[19] Srinivas T 2008 Environmental biotechnology. New Age International Ltd., New Delhi. 113p.

[20] Lung W S 1993 Water Quality Modelling; Application to Estuaria Vol II CRC Press Florida

[21] Siagian M 2010 Jurnal Perikanan dan Kelaatun 15(1): 25–38

[22] Siagian M, Simarmata A H 2018 Aquac. Aquarium, Conserv Legis 11(1):1–9

[23] Anas P, Jubaedah I, Sudinno D 2017 J. Penul. Perikan. dan Kelaut. 11(1):35–47

[24] Peraturan Pemerintah Nomor 82 Tahun 2001 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air.

[25] Hasibuan I F, Hariyadi S, Adiwilaga E M 2017 J. Ilmu Pertan. Indon 22(3):147–155

[26] Sari H M, Sulardiono B, Rudiyanti S 2015 Manag. Aquat. Resour. J 4(3):123–131

[27] Kartamihardja E S, Krismono 2016 Marine and Fisheries Research and Development Agency.

[28] Kusriani M, Widjarnako P 2017 J. Fish. Mar. Res 1(2): 88–94

[29] Asriyana, Yuliana. 2012. Produktivitas perairan. Bumi Aksara. Jakarta 278p.

[30] Nurdin N, Bahri S, Zulkarnain, Sukendi. 2017. Analisis Indek Penutup Lahan Daerah Tangkapan Air Waduk PLTA Koto Panjang Menggunakan Aplikasi Sistem Informasi Geografis (SIG). Seminar Nasional 3 Strategi Pembangunan Infrastruktur (SPI-3) Institut Teknologi Padang. 3:219–227.

[31] Efeendi H 2003 Telah Kualitas Air Kanisius Yogyakarta 257p

[32] McDonald M E, Tikkenan C A, Axler R P, Larsen C P, Host G 1996 Aquac. Eng.15(4):243–259

[33] Beveridge M C M 1984 Food and Agriculture Organization. FAO Fish.Tech.Pap 255:131 p

[34] Avnimelech Y 2000 Advocate 3(2):23-24

[35] Pujiasutti P, Ismail B, Pranoto P 2013 Jurnal Ekosains 5(1):59-75

[36] Indrayani E, Nitimulyo K H, Hadisusanto S, Rustadi R 2015 J. Mns. dan Lingkung 22(2):217–225

[37] Utomo A D, Ridho M, Putranto D D A, Saleh E 2012 International Conference on Indonesian Inland Water III, 8-11-2012 Jakarta

[38] Sulaiman P S, Rachmawati P F, Puspasari R, Wiadnyana N N 2020 J. Kebijak. Perikan. Indon 12(2): 59–73

[39] Lestari NAA, Diantari R, Efendi E 2015 e-Jurnal Rekayasa dan Teknol Budid Perair 3(2): 367–374

[40] Ardi I 2013 Media Akuakultur 8(1): 23–30
[41] Warningsih T, Setiyanto D D, Fahrudin A, Adrianto L 2016 *Omni-Akuatika* **12**(2):49-57
[42] Sukadi M F 2016 *J. Ris. Akuakultur* **5**(1): 1–12
[43] Kibria G, Nugegoda D, Fairclough R, Lam P 1997 *Hydrobiologia* **357**(1-3): 165–171