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### Cover Page Footnote

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# The Trophic Status of the Lubuk Lampam Floodplain in South Sumatera, Indonesia

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## Abstract

The Lubuk Lampam floodplain's ecosystem is naturally affected by the fluctuation of the water surface. This ecosystem also receives anthropogenic substances such as nutrients and other chemicals, especially from the oil palm plantation and its industrial processing activities. The main objective of this research was to determine the trophic status of the floodplain using the trophic level index (TLI) and Carlson's trophic state index (TSI). The water quality and the fish samples were collected and analyzed from 7 stations representing various types of floodplain habitat. The results showed that the trophic status of Lubuk Lampam was hypereutrophic (very nutrient-rich). This was also supported by the high increase of the body weight ("b" value more than 3) and the high gonadosomatic index (GSI) of the studied fishes, i.e. *Osteochilus vittatus* 2.53-6.81% (male) and 3.00-15.86% (female); *Helostoma temminckii* 0.28-3.33% (male) and 1.30-10.43% (female); and *Channa striata* 0.33-0.59% (male) and 0.21-2.73% (female).

## Abstrak

**Status Trofik Rawa Banjiran Lubuk Lampam di Sumatera Selatan, Indonesia**. Rawa banjiran Lubuk Lampam merupakan ekosistem yang secara alamiah dipengaruhi oleh fluktuasi tingkat muka air. Ekosistem ini juga menerima bahan masukan antropogenik berupa nutrien dan bahan kimia pertanian terutama dari perkebunan kelapa sawit dan industri pengolahannya. Penelitian ini bertujuan untuk menentukan status trofik untuk rawa banjian menggunakan *trophic state index* (TSI) dari Carlson dan *trophic level index* (TLI). Pengambilan dan analisis kualitas air dan ikan pada 7 stasiun yang mewakili berbagai tipe habitat rawa banjiran. Hasil penelitian menunjukkan bahwa berdasarkan dua metode tersebut, Lubuk Lampam berada dalam status hypereutrofik (sangat subur). Hal ini juga didukung oleh pertambahan berat ikan yang tinggi (nilai "b" lebih besar dari 3) dan indeks kematangan gonad ikan (*Gonado Somatic Index*, GSI) yang cukup besar dari 3 jenis ikan sampel yaitu ikan *Osteochillus vittatus* 2,53-6,81% (jantan) dan 3,00-15,86% (betina); *Helostoma temminckii* 0,28-3,33% (jantan) dan 1,30-10,43% (betina); *Channa striata* 0,33-0,59% (jantan) dan 0,21-2,73% (betina)

*Keywords: floodplain, trophic status, Lubuk Lampam*

## Introduction

There are many methods used to assess the trophic state of water bodies, from single- to multiple-parameter models [1-2]. The most commonly used method was introduced by Carlson [2], i.e. the trophic state index (TSI), in which the calculation is determined by the quantities of total phosphorus, chlorophyll-a, and water transparency. Later, the TSI index was modified by adding total nitrogen to the equation to create the trophic level index (TLI) [3-5].

Both Carlson's TSI and TLI are applicable in determining the trophic status of stagnant waters, including lakes and reservoirs. However, TSI was also appropriate to be used for flowing bodies of water such as rivers [4]. In comparison with lakes and rivers, water bodies in floodplains are characterized by both lotic and lentic components [6]. The oscillation between the terrestrial and aquatic phases resulted from the fluctuation of the water level. Therefore, these areas are periodically inundated by the lateral overflow of rivers [7].

Since floods originate from three sources, i.e. overspill from the river channels, local rainfall, and tides, the fluctuation of these sources will cause changes in flood-plain water quality, which in turn will affect the trophic status of the floodplain. According to Welcomme [6], the great fluctuation in water levels causes a seasonal cycle of flood and drought over much of the area. Extreme changes in water chemistry and primary production also occur throughout the cycle. Determining the trophic status of floodplains is important because the indexes can be used as a predictive tool for effective water management programs [2,5].

Lubuk Lampam is one of the important floodplains situated in the Ogan Komering Ilir district. The main river in this area is Lempuing River, a tributary of the Komering River. This area is a natural floodplain that is important for ecological balance. Meanwhile, this area is also important for local economic growth, especially from fisheries and agricultural activities [8]. The government has designated several sites within the area as fishery reserves, such as Lebung Proyek, Suak Buayo and Kapak Hulu, as shown in Figure 1.

The greatest potential threat to this floodplain is land conversion for agriculture, i.e. deforestation and land clearance for the oil palm plantation and its industrial processing activities. Those activities affect the water quality due to the leaching of pesticides, fertilizers and other agrochemicals [9].

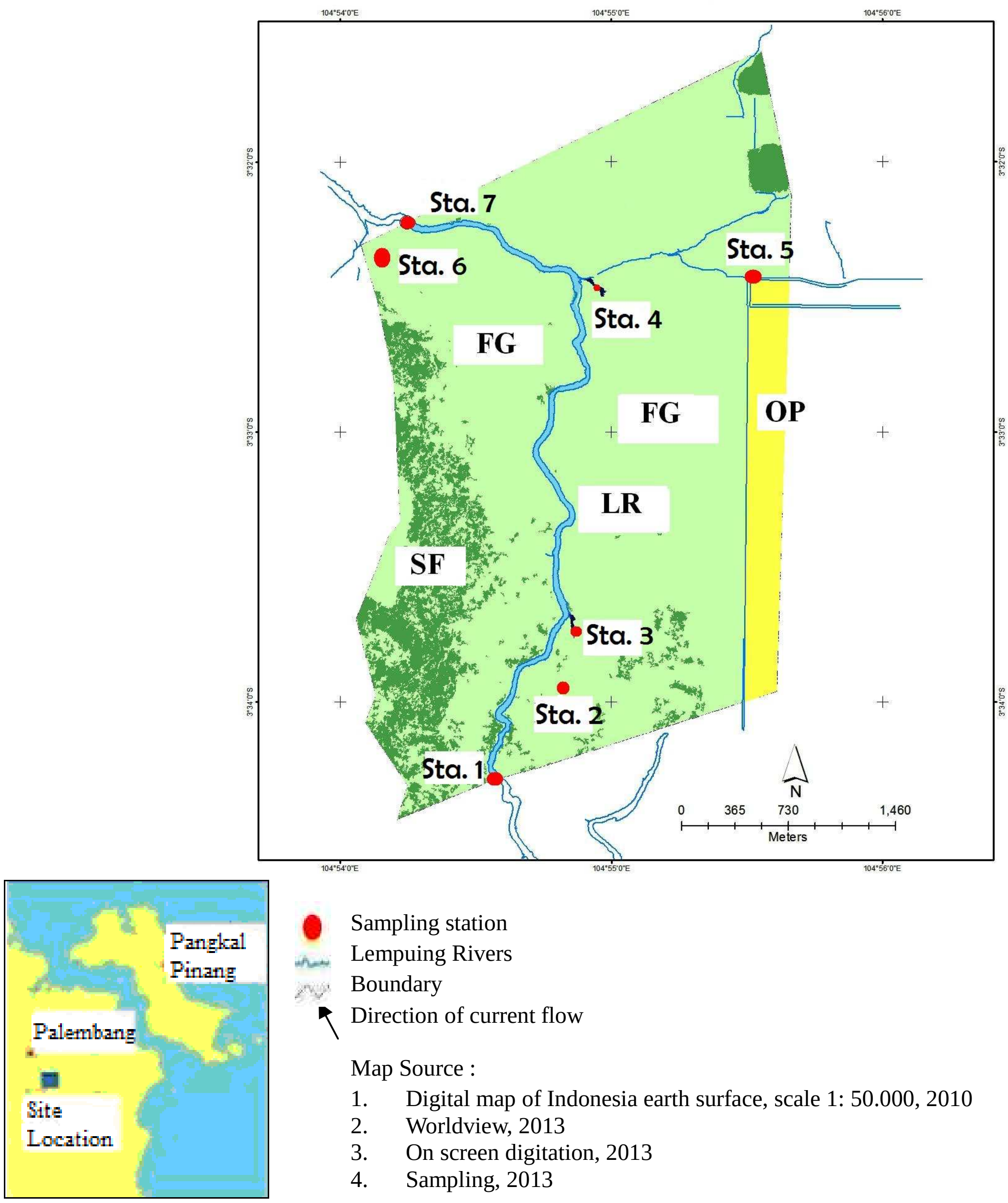



**Figure 1. Study Area and Sampling Sites (Stations): Kapak Hulu (Sta. 1), Flooded Grassland 1 (Sta. 2), Suak Buayo (Sta. 3), Lebung Proyek (Sta. 4), Channels of Oil Palm Plantations (Sta. 5), Flooded Grassland 2 (Sta. 6), and Lempuing Hilir (Sta. 7), Flooded Grassland (FG), Flooded Forest (SF), Lempuing River (LR), and Oil Palm Plantation (OP)**

There is limited information about the trophic state of the Lubuk Lampam floodplain (LLF). This study, therefore, aims to reveal the trophic status of this floodplain in relation to water level fluctuation and anthropogenic substances, mainly from the oil palm plantation.

## Material and Methods

Seven sampling sites were established upstream, inside and downstream of LLF (Figure 1), i.e. 1) Kapak Hulu, at the upper course of the main river (station 1); 2) flooded grassland 1 (station 2); 3) Suak Buayo, a natural flood-plain pool (station 3); 4) Lebung Proyek, a man-made floodplain pool (station 4); 5) drainage channels from the oil palm plantation (station 5); 6) flooded grassland 2 (station 6); and 7) Lempuing Hilir, downstream of LLF (station 7). Sampling was done monthly at all sites except for the flooded grasslands (station 1 and station 6), at which samples were collected only during flood season.

Fish sampling and water quality data were collected from December 2012 to November 2013, while the anthropogenic substances (detergent, herbicide, and oil and grease) were sampled only during the flooding, highest water level, and dry seasons. The water samples were collected, preserved, kept cooled at 4 $^oC$, and analyzed based on standard methods [10]. Measurements on total nitrogen (TN) and total phosphorus (TP) were performed by using a spectrophotometric analyzer. Chlorophyll-a (Chl a) was collected, preserved with $MgCO_3$ and determined using the spectrophotometric method. Oil and grease levels were analyzed using the gravimetric method, detergent was analyzed using a spectrophotometric analyzer, and herbicide was measured using gas chromatography.

TN:TP criteria are classified into three categories: nitrogen limited (TN/TP < 10:1), phosphorus limited (TN/TP > 30:1), and balanced (10:1≤ TN/TP ≥30:1) [4-5]. Trophic state of Lubuk Lampam was calculated by using the Carlson's TSI value [2, 11]. The TSI formulas were:

$$TSI_{SD} = 10x[6-(\ln SD/\ln 2)] \quad (1)$$
$$TSI_{Chl\ a} = 10x[6-((2.04-0.68 \ln Chl\ a)/\ln 2)] \quad (2)$$
$$TSI_{TP} = 10x[6-\ln(48/TP)/\ln 2] \quad (3)$$
$$TSI = [TSI (P)+TSI (chl\ a)+TSI (SD)]/3 \quad (4)$$

Where SD = Secchi depth (m); Chl a = chlorophyll-a (µg/L); P = total phosphorus (µg/L)

The modified TSI formula, namely the Trophic Level Index (TLI) [12], was calculated by:

$$TLI_{Chl-a} = 2.22+2.54\log_{10}(Chl\ a) \quad (5)$$
$$TLI_{SD}=5.10+2.60\log_{10}(1/S-1/40) \quad (6)$$
$$TLI_{TP}=0.218+2.92\log_{10}(TP) \quad (7)$$

**Table 1. TSI and TLI Classification Values**

| Trophic state | TSI level*) | TLI level**) |
|---|---|---|
| Oligotrophic (O) | <40 | <3.0 |
| Mesotrophic (M) | 40< TSI ≤50 | 3.0< TSI ≤4.0 |
| Eutrophic (E) | 50< TSI ≤70 | 4.0< TSI ≤6.0 |
| Hyper-eutrophic (HE) | >70 | >6.0 |

*) TSI Level adopted and modified from some references [3, 11-14]
**) TLI level based on Castellano [13]

$$TLI_{TN}=-3.61+3.10\log_{10}(TN) \quad (8)$$
$$TLI = \Sigma(TLI_{Chl\ a} + TLI_{SD} + TLI_{TP} + TLI_{TN})/4 \quad (9)$$

where TN = total nitrogen (µg/L).

The classification values based on TSI and TLI are shown in Table 1. Both TSI and TLI were analyzed based on stations and season. The mean of TSI and TLI was tested by t-test at the 0.05 significance level.

In this study, 3 species of fishes i.e. *Osteochilus vittatus* (n=805), *Helostoma temminckii* (n=793) and *Channa striata* (n=397) were caught in Lubuk Lampam. The samples were collected by using gillnet (0.5. 0.75, 1.0, 1.5, 2.0, 2.5, 3.0- mm mesh size) and portable traps. Then the samples were measured for their total length (TL) and total wet weight.

The length of the fish was measured to the nearest 0.5 mm, and the weight to the nearest 0.01 mg. The length-weight relationship (LWR), $W=aL^b$,was converted to a logarithmic expression: log W = log a + b log L. In this formula, W is weight in gram, and L is total length in mm. The "a" and "b" parameters were determined according to the power regression model. The "b" value for each species was tested by t-test at the 0.05 significance level to verify if it was significantly different from 3 [15-16].

The sex of the fish samples was determined through macroscopic gonad morphology examination (45). Later, the gonads were weighed and subsequently preserved in Gilson's solution. Seasonal changes in gonad mass for both sexes were determined by using the gonadosomatic index (GSI). The GSI is calculated as GSI (%) = 100 x (weight of gonad / weight of fish) [15-16].

## Results and Discussion

As shown in Figure 2, the study's measurement of water level fluctuation divides the 12 months of the research into 3 seasons, i.e. first flood or inundation season (FS1), low water level or dry season (DS), and second flood or nundation season (FS2). This grouping, then, is used to compare seasonal trophic state index values in the floodplain area.

The ratios of TN:TP for all sampling stations and seasons are shown in Table 2. The TN:TP values during the second flood season (FS2) are higher than those for the first flood season and dry season. The actual concentration values of both TN and TP were high for each season and station (Table 3).

The trophic status of the Lubuk Lampam floodplain based on Carlson's TSI and TLI values for each station and season are shown in (Figure 3 and 4). The mean values of TSI and TLI both showed that LLF was hypereutrophic. The TSI and TLI levels for nutrients (TP and TN) were higher than the TSI and TLI for Secchi

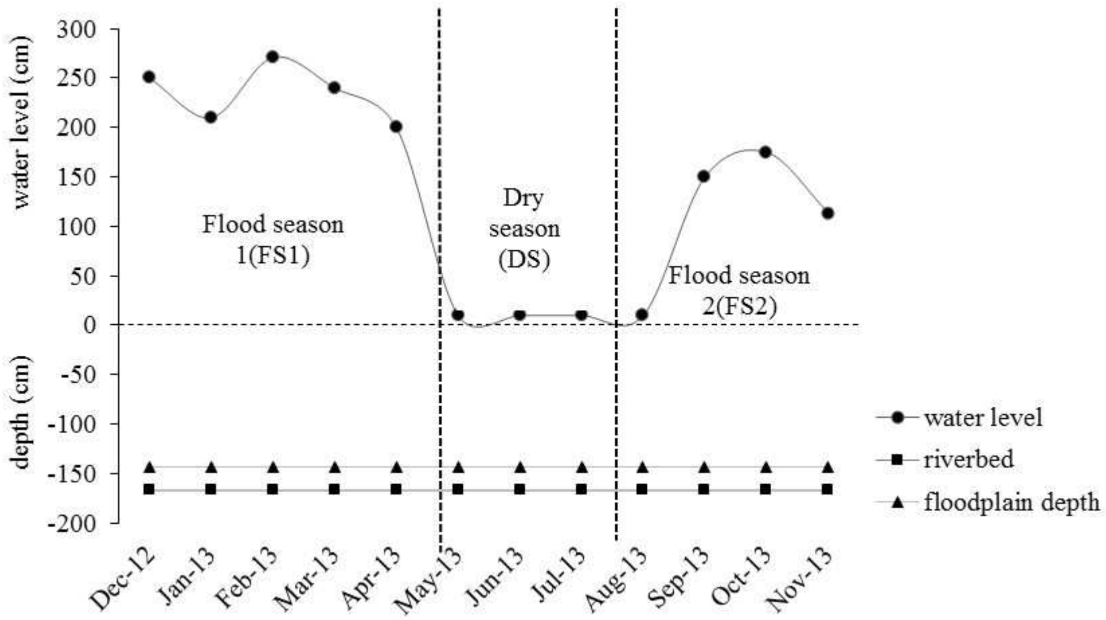



**Figure 2. Water Level Fluctuation and Seasonal Pattern**

**Table 2. Ratio TN : TP (mol)**

| Station | TN/TP (mol/mol) | | |
|---|---|---|---|
| | Flood season 1 | Dry season | Flood season 2 |
| Sta. 1 | 16 | 27 | 56 |
| Sta. 2 | 19 | - | 43 |
| Sta. 3 | 25 | 33 | 176 |
| Sta. 4 | 28 | 30 | 90 |
| Sta. 5 | 19 | 17 | 155 |
| Sta. 6 | 22 | - | 58 |
| Sta. 7 | 24 | 42 | 56 |

- : no observation at dry season

**Table 3. Mean of Concentration of TN, TP, Nitrite, Nitrate and Orthophosphate (mg/L)**

| Station | TN | | | TP | | | Nitrite | Nitrate | Ortho-phosphate |
|---|---|---|---|---|---|---|---|---|---|
| | FS1 | DS | FS2 | FS1 | DS | FS2 | | | |
| Sta. 1 | 39.92 | 38.74 | 56.03 | 5.40 | 3.23 | 2.20 | 0.30 | 2.67 | 0.08 |
| Sta. 2 | 42.02 | - | 50.43 | 4.86 | - | 2.60 | 0.02 | 1.96 | 0.11 |
| Sta. 3 | 43.14 | 37.70 | 47.62 | 3.77 | 2.52 | 0.60 | 0.25 | 3.07 | 0.07 |
| Sta. 4 | **51.54** | 42.64 | **72.84** | 4.04 | 3.33 | 1.80 | 0.20 | 2.76 | 0.10 |
| Sta. 5 | 49.30 | **45.22** | 70.03 | **5.80** | **5.85** | 1.00 | **0.30** | **4.53** | **0.16** |
| Sta. 6 | 50.98 | - | **72.84** | 5.21 | - | **2.80** | 0.02 | 1.70 | 0.07 |
| Sta. 7 | 43.70 | 40.79 | 56.03 | 4.08 | 2.17 | 2.20 | 0.17 | 2.88 | 0.12 |

Season : flood season 1 (FS1), dry season (DS), and flood season 2 (FS2)
Bold characters are the highest value
- : no observation at dry season

depth and chlorophyll-a (Figure 3-4). The mean values of TSI and TLI tend to be higher in the dry season compared to the flood season. Meanwhile, based on the mean of TSI and TLI values among stations (Figure 3-4), the highest TSI and TLI values were found in the drainage channels of the oil palm plantation (Station 5). Based on a two-tailed t-test, there was no significant mean difference in TSI and TLI among stations (t-value 1.95) or among seasons (t-value 1.36).

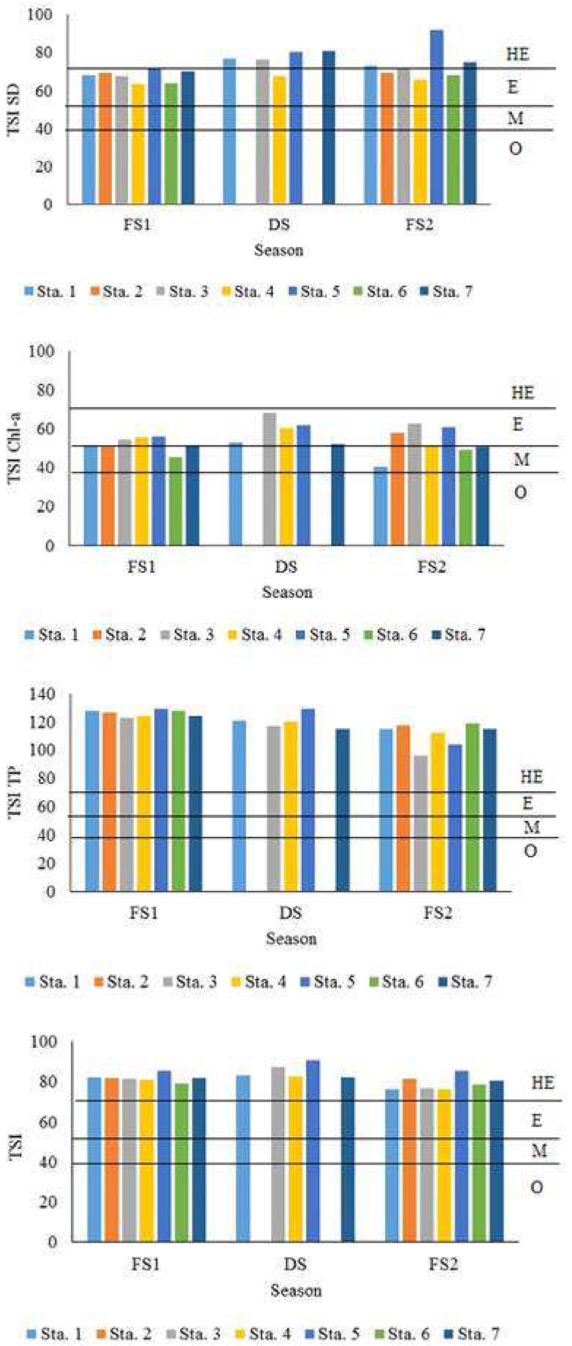



**Figure 3. TSI Values in each Stations and Season; Trophic Levels : HE (Hyper-eutrophic), E (Eutrophic), M (Mesotrophic), O (Oligotrophic)**

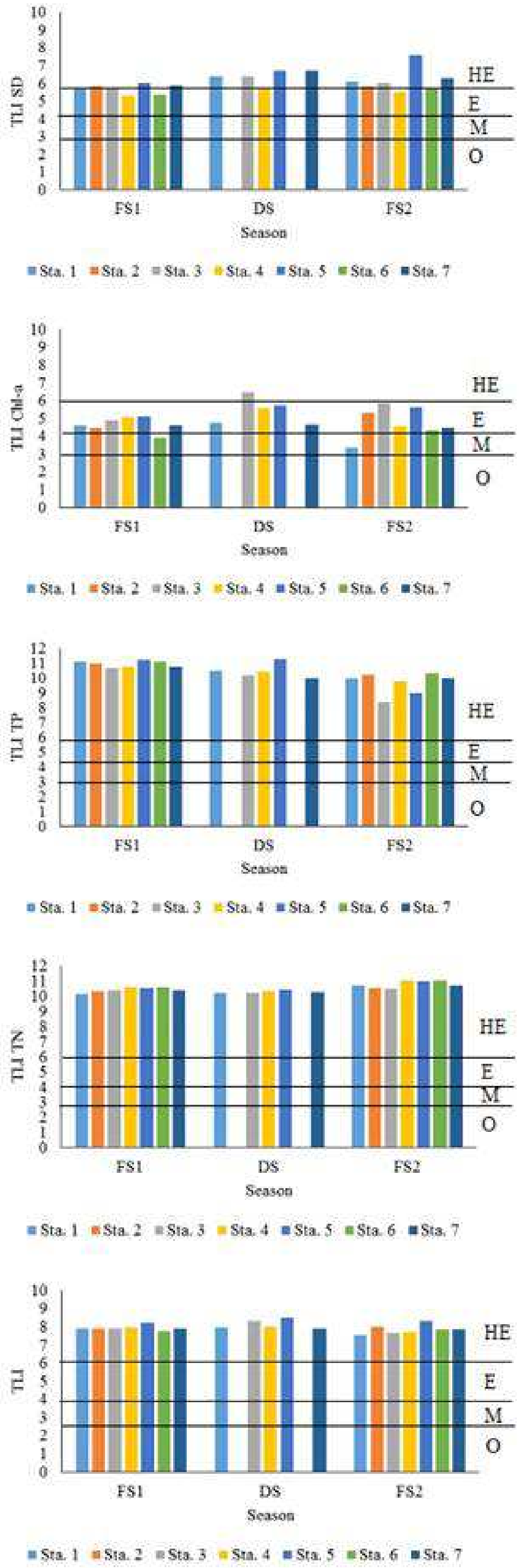
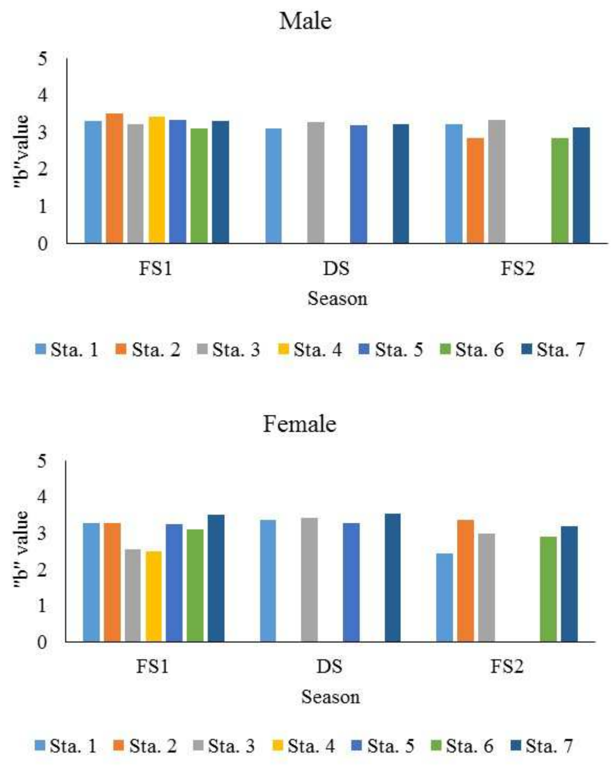



**Figure 4. TLI Values in Each Stations and Clusters**

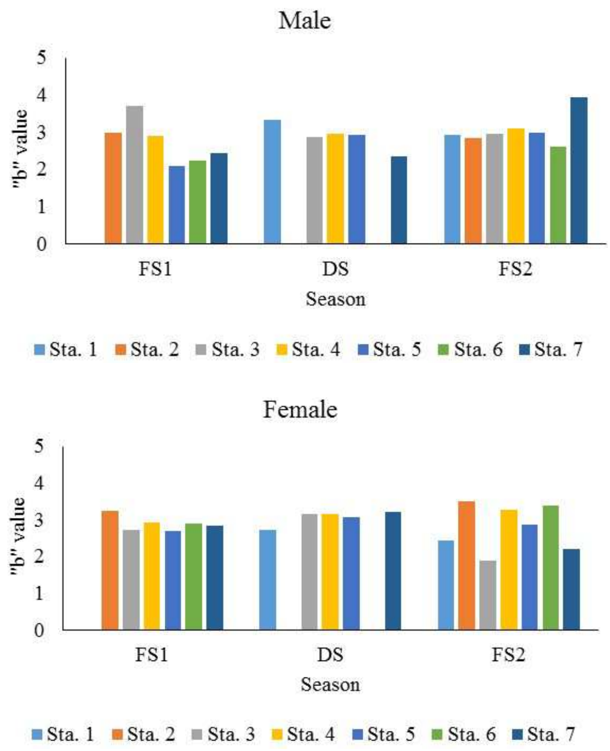
This results of this study showed that the "b" value from LWR (Figure 5) for most of the studied fish were more than 3. Meanwhile, the GSI values of the three species of fishes in Lubuk Lampam, as shown in Figure 6, were as follows: *O. vittatus* 2.53-6.81 (male) and 3.00-15.86 (female); *H. temminckii* 0.28-3.33% (male) and 1.30-10.43% (female); and *C. striata* (0.33-0.59% (male) and 0.21-2.73% (female).

The high concentrations of TN and TP in LLF were due to a high number of nutrients in this area. These results concurred with the study results of Yarbro *et al.* [17], who showed the importance of a floodplain as a nutrient retainer, mainly for nitrogen and phosphorus. However, in some stations the ratio of TN:TP suggests that phosphorus is functioning as a limiting factor (TN:TP>30), whereas at other stations the ratio was balanced (10:1≤ TN/TP ≥30:1).

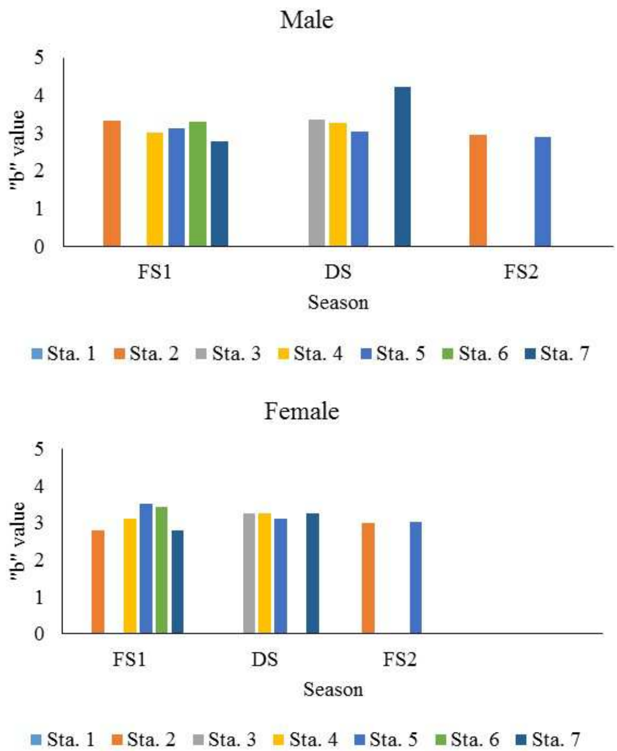
Based on TSI and TLI, all stations and seasons had hyper-eutrophic status. The hypereutrophic status of the Lubuk Lampam floodplain was affected by natural characteristics and anthropogenic substances. Naturally, a floodplain is a high productivity ecosystem [18]. The establishment of oil palm plantations in recent years could be the source of the anthropogenic substances found in Lubuk Lampam. According to Huibin [5], lakes that are categorized as eutrophic and hypereutrophic are mainly affected by natural conditions and anthropogenic activities such as domestic sewage, as well as industrial




**(A)**

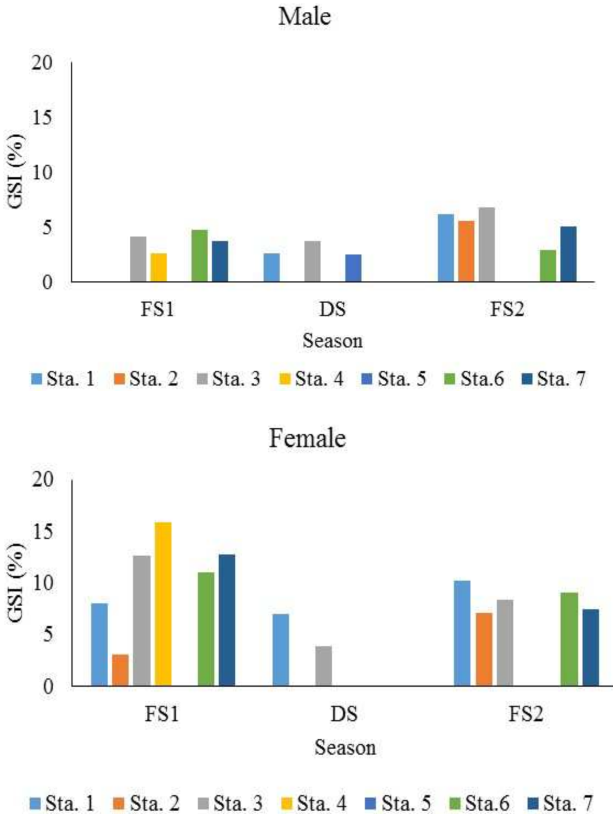



**(B)**

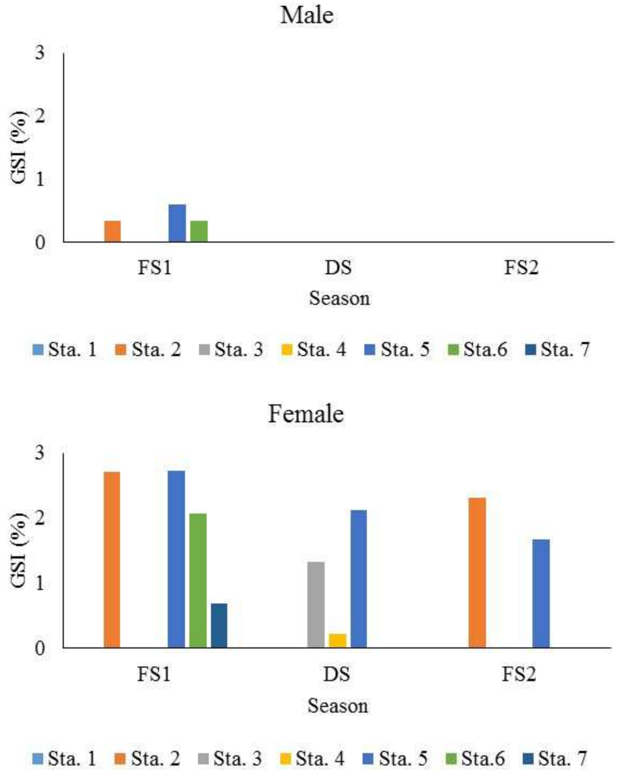



**(C)**

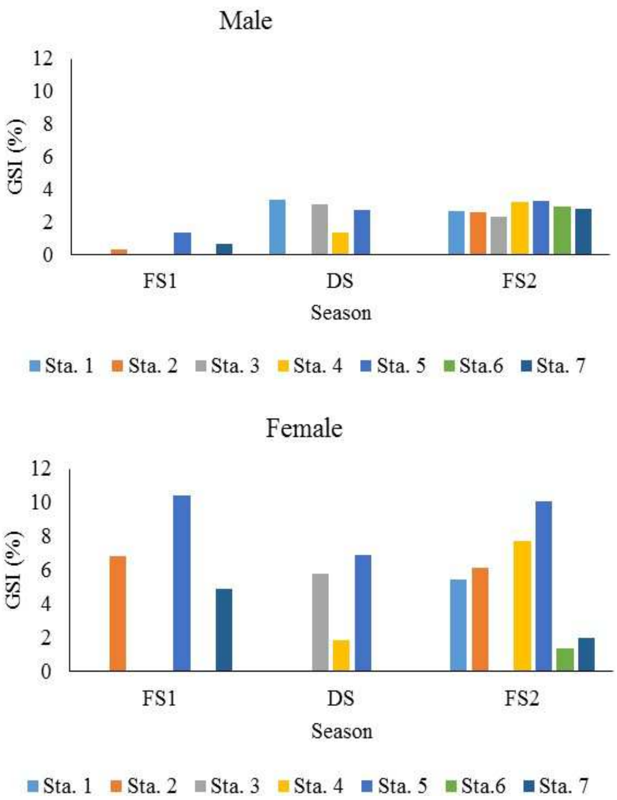
**Figure 5. "b" Values from Fish Lenght-weight Relationship: (A) *O. vittatus*, (B) *H. temminckii*, and (C) *C. striata***




**(A)**




**(C)**




**(B)**

**Figure 6. GSI: (A)** ***O. vittatus,*** **(B)** ***H. temminckii,*** **and (C)** ***C. striata***

and non-point source pollution. Organic pollutants, fertilizer-born nutrients (mainly nitrogen and phosphorus) and heavy metals can reach the watercourse through direct discharge, leaching or eroded soil particles [19].

The trophic state of a floodplain is affected by season. This study showed higher values of TSI and TLI in the dry season than during the flood season. According to Junk and Bayley [20], a floodplain is most productive during dry season. It is possible that this is because during the dry season, the optimal primary productivity is greatly influenced by the optimal light intensity and the availability of nutrients, which in turn affects the trophic status. However, Junk [7] stated that fertile sediments and dissolved nutrients carried by flood waters were the main cause of the high productivity in many floodplains.

The high values (TSI TP, TLI TP and TLI TN) are affected by the high concentration of nitrogen and phosphorus. According to Richardson [4], a large proportion of phosphorus in freshwater occurs as organic phosphates and cellular constituents in the biota or is absorbed as inorganic and dead particulate matter. The concentration of TP and TN in floodplains mainly occurs in particulate form. It shows from the composition values between TP and orthophosphate as dissolved form, and also between TN and dissolved nitrogen form, i.e. nitrate and nitrite (Table 3). Noe and Hupp [21] stated that the high TP and TN concentration is caused by the entering constituents to the floodplain through flowpath during the flood. The TP concentration of a floodplain is high and it is caused mainly by particulate P fraction. Meanwhile, high TN concentration during floods is caused by the decreasing 6% of dissolved organic nitrogen (DON) and increasing 5% of particulate organic nitrogen (PON).

The channel plantation (CP) had the highest TSI values, and this area was also categorized as highly polluted [8]. According to Dembkowski [22], runoff from agricultural fields may contain high concentrations of phosphorus and nitrogen-based pesticides and fertilizers, contributing to eutrophication. This station had a high concentration of nutrients, i.e. phosphorus and nitrogen (Table 3), and also tend to be contaminated by several anthropogenic sub-stances (Table 4). Interestingly, the concentration level of the contaminants was lower than that measured in several research studies and also lower than the limits required by many environmental and public health regulators [23-26]. However, oil and grease concentration was above the permissible value (PV) allowed by Indonesian Government Regulation No. 82/2001, i.e. 1 mg/L [27].

In spite of the two-tailed t-test of TSI and TLI values showed that significant mean difference among stations in season, but considering to the classification values criteria, all stations were in hyper-eutrophic state. Hence, we can use these two formulas. Wu *et al.* [28] suggested to use TLI because it is simpler, faster and more accurate. On the other hand, several other researchers [3-4] suggested to use TSI if TP is the limiting factor, and use TLI if TN is the limiting factor or if the nutrients are balanced.

The relationship between trophic state and length-weight relationship (LWR) was reported by Treer *et al.* [29]. The results of this study showed that the "b" value from LWR estimated for the three studied fish species represent floodplain fishes according to Welcomme [15].

**Table 4. Antrophogenic Substances Concentration(mg/L)**

| Stations | Oil and Grease | Detergent | Glyphosate | Paraquat |
|---|---|---|---|---|
| Sta. 1 | 1.725 | 0.056 | 0.003 | 0.003 |
| Sta. 2 | 0.750 | 0.041 | 0.002 | 0.003 |
| Sta. 3 | 2.500 | 0.061 | 0.003 | 0.003 |
| Sta. 4 | 2.125 | 0.065 | **0.005** | **0.011** |
| Sta. 5 | **4.250** | **0.071** | 0.002 | 0.004 |
| Sta. 6 | 0.500 | 0.028 | 0.001 | 0.002 |
| Sta. 7 | 3.125 | 0.046 | 0.005 | 0.003 |

Bold characters are the highest value

It represent also different food habit of the studied fishes (*O. vittatus* and *H. temminckii* tend to be herbivore, and *C. striata* is carnivore [6]). The "b" value of most fishes is more than 3, meaning the fishes become weightier and also showing the area offers favorable conditions to these populations. The TSI values is related to food availability for the fish [26]. Food supply and sufficient space area throughout the year were probably the main contributing factors to the steady increase in fish weight and length.

The GSI of fish, normally used as a reproductive indicator, can also be used to measure the influence of trophic state on the gonad growth of fish. The GSI of fish is higher in eutrophic water than in oligotrophic water, which may be a result of greater nutrient availability [30]. The GSI values for *O. vittatus* for each station and season were high (2.53-6.81% for male and 3.00-15.86% for female), though not nearly as high as the GSI values for cultured *O. vittatus* (21.25±4.41%) [31]. The GSI values for *H. temminckii* (0.28-3.33% for male and 1.30-10.43% for female), tend to be higher than those for *Anabas testudineus* as another Anabantidae showed the GSI values for female 0.13-9.84% [32]. The GSI values for *C. striata* for male (0.33-0.59%) and female (0.21-2.73%) were lower than the GSI values of matured *C. striata* from other studies (0.6-2.10% for male and 1.4-8.0% for female) [33], though still higher than the GSI values from *Channa marulius* (0.018-0.056 for male and 0.018-0.42% for female) [34].

## Conclusions

Based on the Carlson's TSI and TLI formulas, two methods that can be used to estimate the trophic status, it was indicated that the Lubuk Lampam floodplain is in a hyper-eutrophic state. The high trophic status of this aquatic ecosystem gave positive effect to the increase in body weight and GSI of the studied fishes.

## Acknowledgements

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