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Research Article

Length-Weight Relationship Analysis and Condition Factor of Fish in Lake Chini: Reason For Population Depletion

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ABSTRACT

Lake Chini's fish are important as a pool of ichthyodiversity of the Pahang River drainage and a natural food resource for the native community nearby. However, the fish population was shrinking after a disastrous flood in 1995, and it is still a puzzle as to the cause of the decline of the fish population. This study aims to estimate the fish growth pattern using the length–weight relationship (LWR) analysis and condition factor. The study evaluated b and K values from the LWR analysis equation. B value is the slope of the LWR, which indicates the growth pattern (e.g., isometric or allometric), while K value refers to the condition factor, which shows the overall health of fish. Fishes were sampled using a gill net and identified to species level, and water quality was analysed using standard methods. Lake Chini was found to have a good to moderate water quality status, ranging from category A to category C according to the Malaysian Lake Water Quality Standard (NLWQS). The Carlson trophic index has classified the lake water bodies into an early eutrophic status. The LWR analysis on four selected fish species showed the mean b value ranged between 2.07 and 4.02, implying negative isometric growth for most of the species and isometric and positive growth for one species, which is *K. cryptopterus* and *C.rapasson* respectively. Fish length significantly influenced weight, with coefficients of determination ranging from 69% to 98%. The K value ranged from 1.00 to 1.08, indicating that the fish is in a moderate condition of well-being. This study indicates that water quality, food sources, and habitat are not the significant factors that cause fish depletion in Lake Chini.

Key words: Environmental condition factor, fish diversity, fish growth pattern, lake ecosystem

INTRODUCTION

In fisheries, the length-weigh relationship (LWR) is a crucial evaluation technique, particularly in aquaculture (Ayoade & Ikulala, 2007; Chayajit *et al*., 2024). Information gathered from the length-weight relationship (LWR) can provide valuable insights into a fish stock's biomass, growth patterns, breeding rates, and mortality, all of which are essential for effective fisheries management and conservation planning (Kumar *et al*., 2014; Al Nahdi *et al*., 2016). The LWR also helps in assessing the ecological dynamics of fish populations and stock management (Froese, 2006). In addition, the application of the LWR has been extended to the assessment of fish populations in natural river or lake systems. Fish weight will increase with length, and this three-dimensional relationship function gives an idea of the growth status of fish by providing the average weight of fish through mathematical formulation. The relationship formed through the equation can estimate fish environmental factors and fish bioenzymes of that species (Sánchez-González *et al*., 2020). Indirectly, the assessment of environmental factors allows the estimation of interactions among biotic and abiotic factors to be done. The original hypothesis of the equation stated that heavier fish at a given length indicate better physiology and can be an index for fish growth rate monitoring (Ujjania *et al*., 2012).

The LWR has been expanded in use to assess the quality of fisheries and environmental factors affecting the growth and development of fish (Pauly, 1993). The length-weight equation used is as;

$$W=aL^{b}\ldots \qquad – \quad \text{Equation 1}$$

That is W = fish weight (g), L = fish length (cm), a = initial growth coefficient, b = growth coefficient

The b-value plays a fundamental role in fisheries research, aiding in the management of fish populations and contributing to ecological and conservation studies. The b-value reflects the nature of fish growth in terms of weight relative to length. It provides insight into the type of growth the fish exhibits, which depends on many environmental factors like food availability,

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habitat quality, and pollution. In addition to the LWR equation, the condition factor is widely used to assess many facets of fish populations, such as effects of environmental conditions (Pope & Kruse, 2007). The Fulton condition factor (K) is amongst the widely used, comparing the relative conditions of individuals within the sample and is useful for monitoring fish stress in the population (Pope & Kruse, 2007). It indicates the relative robustness or plumpness of a fish, which can be related to its health, reproductive potential, and habitat quality.

The fish population in Lake Chini was reported to decline significantly over the last 20 years (Kutty *et al*., 2009; Hashim *et al*., 2014). Several factors may influence fish growth, including genetics, interaction with abiotic factors such as food availability and habitat suitability, population density, pollution, and prey-predator relationships (Dudgeon *et al*., 2006; Carrizo *et al*., 2017). The composition of several species that are important in contributing to the ecosystem services of Lake Chini, such as tinfoil barb (*Barbonymus schwanenfeldii*), tiny scale barb (*Thynnichthys thynnoides*) and kissing gourami (*Helostoma teminkcii*), were decline (Hashim *et al*. 2014). Most previous studies on Lake Chini were conducted before the major flood event that damaged the ecosystem of Lake Chini, focusing on the diversity of fish in the lake. Although there have been several studies after the event, they have also only focused on diversity studies because the population decline incident has only occurred in recent years. In addition, the absence of predator fishes or fishing game species such as snakehead (*Channa micropeltes*) and hampala barb (*Hampala macrolepidota*) has had very significant implications for the tourism industry in Lake Chini. We hypothesise that the reduction of the fish population in Lake Chini is due to the disastrous flood event in 1995 that caused habitat changes in the lake. To our knowledge, there are no studies on fish growth patterns and habitat conditions in Lake Chini, and therefore, an assessment of fish growth conditions was conducted using the LWR equation to determine whether the habitat change, including alterations in water quality (e.g., temperature, dissolved oxygen, etc.) were key environmental factor contributing to fish population decline in Lake Chini.

MATERIALS AND METHODS

Study area

Lake Chini is located in the southeast of Pahang (3°22'30" N to 3°28'00" N & 102°52'40" E to 102°58'10" E) and is one of the natural lakes in Peninsular Malaysia (Figure 1). Lake Chini was once one of the main tourist destinations in Pahang. Besides, Lake Chini is accorded as a Biosphere Reserve under UNESCO due to its rich biodiversity and unique freshwater ecosystem. Maintaining its status requires protecting the surrounding environment and biodiversity through sustainable development, pollution control, and conservation efforts to ensure ecological balance and community well-being. Lake Chini is surrounded by several hilly areas, such as Bukit Ketaya (209 m) in the southeast, Bukit Tebakang (210 m) in the north, and the highest is Bukit Chini (641 m) (Arafat *et al*., 2016). The lake is characterised by 12 open water bodies locally known as *laut* that are connected and the drained into Sungai Pahang via the Sungai Chini all year. Lake Chini receive water from seven major feeder streams (Figure 1) with surface water of 202 ha and 700 ha of swamp forest, providing a unique habitat for many aquatic and swamp species. In addition, this ecosystem has also been reported to have 25 species of aquatic plants and 323 species of lowland forest plants (Sharip & Jusoh, 2010).

Sampling and analysis of water quality

Water quality measurements were taken every month for a period of six months, starting from August 2021 to January 2022. A total of six sampling sites were selected to represent the entire lake. The locations and coordinates of the sampling sites are shown in Table 1 and Figure 1. Water sampling was carried out using a Van Dorn sampler, in which 1000 mL of water was sampled for nitrite, nitrate, ammonia, total suspended solids (TSS) and chemical oxygen demand (COD) analysis and measurements

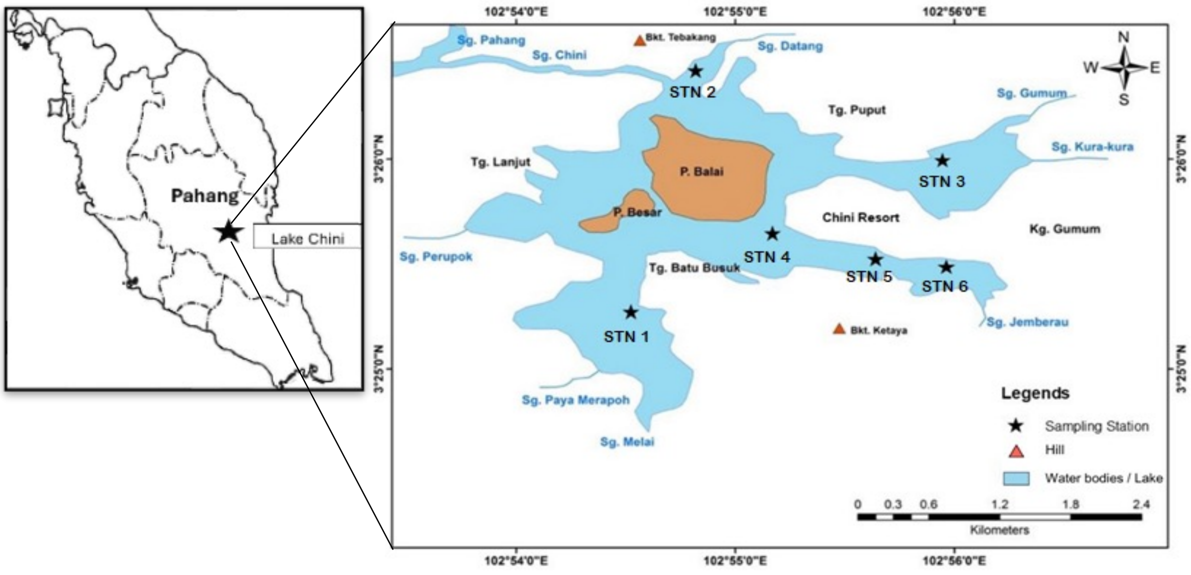


Fig. 1. Lake Chini and water sampling locations. (STN – station)

A total of 300 mL of water samples were taken using a black-coated BOD bottle for biochemical oxygen demand (BOD_5) measurements. Three replicates of water samples were taken from the sampling site. The list of parameters analysed and methods performed is shown in Table 2. The entire water quality sampling and analysis procedure was carried out according to standard methods (APHA 2012).

The in-situ measurements were done for dissolved oxygen, conductivity, Total Dissolved Solids (TDS) and temperature parameters using a pre-calibrated YSI model Professional Plus meter. The lake acidity measurements were done using a HANNA pH meter model H18424, while the YSI 650 meter was used for chlorophyll measurement. Before statistical analysis, data distribution was confirmed using Kolmogorov – Smirnov and Shapiro-Wilk. Water quality variation temporally and spatially was examined using a one-way ANOVA test at a 95% significant level.

Table 1. Fish and water quality sampling locations

Station	Location	Geographical Coordinates
1.	Laut Melai	3˚ 24.9780'N, 102˚ 55.510' E
2.	Laut Tg. Jerangking	3˚ 26.5080'N, 102˚ 55.7650' E
3.	Laut Gumum	3˚ 25.9380'N, 102˚ 55.5110' E
4.	Laut Batu Busuk	3˚ 25.5870'N, 102˚ 55.1520' E
5.	Laut Labuh	3˚ 25.4450'N, 102˚ 55.3750' E
6.	Laut Jemberau	3˚ 25.3540'N, 102˚ 55.6990' E

Table 2. Water quality parameters and the method used

No.	Parameters	Unit	Methods
1.	Temperature	°C	*In situ*
2.	pH		*In situ*
3.	Conductivity	µS/cm	*In situ*
4.	Dissolved oxygen	mg/L	*In situ*
5.	*Chlorophyll a*	mg/L	*In situ*
6.	Water clarity	m	*In situ*
7.	Depth	m	*In situ*
8.	Nitrate	mg/L	HACH (Method 8192)
9.	Nitrite	mg/L	HACH (Method 8507)
10.	Orthophosphate (Phosphate Active)	mg/L	HACH (Method 8048)
11.	Ammonia Nitrogen	mg/L	HACH (Method 8038)
12.	Chemical oxygen demand (COD)	mg/L	HACH (Method 8000)
13.	Biochemical oxygen demand (BOD_5)	mg/L	APHA (Method 5210)
14.	Total suspended solids (TSS)	mg/L	APHA (Method 2540 D)

The Carlson's trophic state index (TSI) (Carlson,1977) was assessed using Secchi clarity (m), total phosphorus (µg/L) and chlorophyll *a* (µg/L) to assess the fertility of Lake Chini's ecosystem.

$$\text{Carlson TSI} = \frac{\text{TSI(SD)} + \text{TSI(CHL)} + \text{TSI(TP)}}{3} \quad - \quad \text{Equation 2}$$

Where TSI(SD) = 60-14.41ln(SD), TSI(CHL) = 9.81ln(CHL) + 30.6, TSI(TP) = 14.42ln(TP) +4.15.
TSI = tropical state index, SD = Secchi clarity, CHL = *chlorophyll a*, TP = total phosphorus
Carlson standard: Oligotrophic = <30 – 40, Mesotrophic = 40 – 50, Eutrophic = 50 – 70, Hypereutrophic = 70 – 100+

Fish sampling and LWR analysis

Fish sampling was conducted across the entire lake using three-layer Apollo gill nets. Three sets of gill nets with mesh sizes of 42 mm and 140 mm were set up for the 48-hr sampling period. The fish was sampled at the same event as the water sampling. The trapped fish was inspected twice daily, during dusk and dawn, respectively. Caught fish were counted, sorted according to species and measured for length (cm) and weight (g) individually. Fish identification was done according to Froese & Pauly (2025), Rainboth and Vidthayanon (2012) and Kottelat (1998).

Data analysis

Before the LWR assessment, fish samples were separated according to their body shape representative, which was elongate, oblong, and ovate. The species in the representative group growth pattern was assessed according to Le Cren (1951) as shown in Equation 1.

The equation was then transformed using a log transformation to simplify it into a linear regression technique. The natural logarithm transformation for both sides of the equation is given below:

$$\log(W) = \log(a) + b\cdot\log(L)\ldots \quad - \quad \text{Equation 3}$$

where: log(W) = (log-transformed weight), log(L) = (log-transformed length), log(a) = intercept, b = slope (exponent in the original equation)

The similarity of the growth pattern of the studied species to isometric was assessed using a one-sample t-test, and all analyses were tested at 95% confidence level (α=0.05). The confidence interval (CI) for b values in each representative group was calculated according to Egbal *et al*. (2011) using the formula shown below:

$CI = b \pm (t_{v,0.05} \times SE) \ldots$ – Equation 4

Where CI = confidence interval, t = Student t-test, SE = Standard error of the mean

The Le Cren's condition factor (Kn) was used to assess the general well-being or "fatness" of fish. This condition factor is the most suitable for comparing individuals within the population, which is assumed for allometric growth by utilising the actual length-weight relationship of the population or species. The condition factor within the representative group was calculated using the formula shown below:

$K_n = W/\hat{W} \ldots$ – Equation 5

(W = weight observed, Ŵ = predicted weight based on LWR equation)

RESULTS AND DISCUSSION

Water quality

Natural processes such as climate and hydrological changes are difficult to control and potentially affect the ecosystem (Yang *et al*., 2021a). However, changes in the lake's water quality are more affected by anthropogenic activities such as the impact of agriculture, industry and mining (Arafat *et al*., 2016). The water quality of Lake Chini for the 6-month study period is shown in Table 3. The physical parameter values illustrate that the lake is in natural condition, with a mean water body temperature of 29.27 ± 0.17°C, and the water is slightly acidic (pH 5.49 ± 0.23). Most of the open water bodies that make up the lake ecosystem are characterised by peaty conditions, which are naturally represented by high organic components. This is evidenced by the relatively high mean value of the lake water conductivity of 109.43 ± 2.91 µS/cm. A study by Noraini *et al*. (2010) on several peat swamps in Sarawak showed that the pH of peat water ranged between 3.03 and 4.07. However, Lake Chini water pH is less acidic compared to those values, which may be an effect of the incoming water from the Sungai Pahang during the wet season. Arafat *et al*. (2017) also reported variations in pH values in Lake Chini, which ranged from 4.93 to 6.70. The low pH value recorded in Lake Chini could be due to the presence of organic acids that are released during the decomposition of plant materials. With 202 ha of open water and 700 ha of swamp, Lake Chini may contribute to naturally acidic water from several key processes related to the environment and chemistry of peatlands. However, pH value characterises Lake Chini in Category A, which means the water is to be used for recreational purposes, such as for primary body contact as referred to the Malaysian National Lake Water Quality Standard (NLWQS) (Department of Environment, 2009).

The BOD_5 concentration was found in low concentrations (1.76 – 2.67) and classified the lake into Category – A as referred to the NLWQS. The BOD_5 value below 5 mg/L indicates good water quality, suitable for supporting diverse aquatic life and recreational activities. The BOD_5 is closely related to dissolved oxygen (DO), and a chemical oxygen demand of water (COD), and all these parameters classify Lake Chini in Category B, which can be used for recreational purposes as secondary body contact. Overall, water quality results illustrate that Lake Chini water body is not facing any serious contamination threat and is still between Category A and B. Chlorophyll *a* was found in uniform concentration (3.92 – 5.67) across the lake and classified the lake in category B according to the NLWQS. Although oil palm plantation activities occur surrounding the lake, no significant organic or chemical pollution has been detected in the lake water. Apart from that, mining activities are happening near the lake, yet no obvious pollution loads are found. The TSS in the lake ranged from a mean of 7.61 ± 6.20 to 13.40 ± 6.98 and are in Category A.

The quality of a lake ecosystem is more closely referred to the trophic status of the lake, a factor that can be measured based on organic contents, especially the amount of phosphorus and nitrate. Phosphorus is a limiting parameter to an aquatic ecosystem and is particularly significant for assessing the fertility of the lake. A various method is being used for lake trophic assessment, but nitrogen, phosphorus, pH, turbidity and water colour are widely used. Assessment on a single criterion was calculated to estimate Lake Chini's fertility status. The measured orthophosphates from this study were multiplied by a factor of 0.3261 to represent the total phosphorus value (Hach, 2010). Results show Lake Chini is classified as an oligotrophic state by phosphorus, mesotrophic by chlorophyll *a* (treated with pheophytin), and eutrophic by water clarity. Apart from evaluation by mathematical formula, TSI can also be evaluated according to a single parameter, and the result shows that Lake Chini is in a large range of quality (oligotrophic to eutrophic) and difficult to interpret. Therefore, the use of formulas is more relevant.

Indices based on a single criterion could potentially be unambiguous and sensitive to change. Using a single criterion may cause difficulty in the classification interpretation. Therefore, Carlson has combined the three parameters using statistical formulas to produce a more realistic classification. Carlson's trophic state index (TSI) is one of the most widely used indices for assessing lake trophic status. It describes more extreme water conditions compared to the water quality parameters. The calculated TSI of Lake Chini for the six-month study period ranges from 58.79 to 63.60, with an average of 61.48 ± 4.27 and classifies the lake into the eutrophic category (Table 4). Natural lakes generally contain high nutrient content due to their rapid biodegradation process compared to artificial lakes. After being flooded in 1995, most of the important aquatic macrophytes, especially floating leaves (*Nelumbo nucifera*) and lotus (*Nymphea lotus*), were inundated and decayed cause nutrients enrichment in the water body (Wan Julian *et al*., 2010). The lake, once famous because of its lotus plant (*N. nucifera*) species composition, has been replaced by a submerged non-native macrophyte (*C. furcata*) (Shuhaimi-Othman *et al*., 2007). Some of the riparian wetland vegetations were also inundated during the flood event, resulting in the death of many plants and swamps. This could be the best reason for the increase in TSI values in Lake Chini. Previous studies have indicated changes in Lake Chini's trophic state from oligotrophic

(Mohamed *et al*., 1994) to mesotrophic (Shuhaimi-Othman *et al*., 2007) and subsequently to a eutrophic lake (Sharip & Zakaria, 2007).

Length-weight analysis

Due to the low specimen number collected during this study, only four species were considered for the discussion, even though the LWR analysis was undertaken for all collected species, as shown in Table 5. A larger sample size could have provided better results, but low fish density in the lake made sampling is limited sampling. Froese (2006) recommends a minimum of 30 to 50 individuals for reliable LWR analysis, emphasising the importance of capturing variability, even though Ricker (1975) suggests that while smaller samples can be used, larger samples (50-100) provide more accurate and stable estimates of LWR parameters. With the difficulty of obtaining sufficient samples due to low fish diversity in the lake, this study used 30 as the minimum number for LWR analysis. All species used in this study are between the pre-mature and mature stage based on a study done by Mohsin & Ambak (1983). Bronze featherback (*N. notopterus*) (n = 135 indivdu, range = 10 cm – 22.2 cm, SL = 18.05 ± 2.13 cm), river carp *(Thynnichthys thynnoides)*, ray-finned *(Kryptoterus cryptopterus)* (n = 45 individu, range = 10.6 cm – 13.45 cm, SL= 12.27 ± 0.65 cm) and beardless barb *(Cyclocheilichthys apagon)* (n = 68 individu, range = 17.7 cm - 21.9 cm, SL = 19.87 ± 1.02 cm) are the four species recorded with more than 30 individuals and their LWR equation were used for further explanations.

Table 3. Water quality data based on six sampling stations

Parameter	Unit	Sampling Stations						
		1	2	3	4	5	6	
		Laut Melai	Laut Tg. Jerangking	Laut Gumum	Laut Batu Busuk	Laut Labuh	Laut Jemberau	Mean ± SD
Water temperature	°C	29.41 ± 1.22	29.06 ± 1.55	29.12 ± 1.79	29.44 ± 1.64	29.41 ± 1.79	29.20 ± 1.88	29.27 ± 0.17
pH	Unit	5.94 ± 0.60	5.43 ± 0.82	5.38 ± 0.82	5.56 ± 0.86	5.33 ± 0.97	5.32 ± 0.91	5.49 ± 0.23
Conductivity	μS/cm	114.5 ± 8.61	109.97 ± 6.50	107.9 ± 8.30	107.93 ± 4.79	109.1 ± 5.91	105.6 ± 4.17	109.4 ± 2.91
Dissolved oxygen	mg/L	5.22 ± 1.29	3.31 ± 0.67	4.99 ± 1.54	5.06 ± 1.19	4.46 ± 1.54	4.59 ± 2.02	4.60 ± 0.69
Chlorophyll a	μg/L	5.67 ± 1.60	4.62 ± 1.37	4.48 ± 1.45	3.92 ± 2.47	4.09 ± 2.80	4.31 ± 1.89	4.52 ± 0.62
Water clarity	m	0.92 ± 0.22	0.60 ± 0.17	0.66 ± 0.22	1.12 ± 0.36	1.26 ± 0.47	1.04 ± 0.36	0.93 ± 0.43
Depth	m	2.04 ± 1.00	1.99 ± 1.03	2.89 ± 0.83	2.41 ± 1.12	2.48 ± 0.92	2.68 ± 1.03	2.42 ± 0.35
Nitrate	mg/L	0.04 ± 0.05	0.07 ± 0.12	0.08 ± 0.17	0.06 ± 0.10	0.05 ± 0.11	0.08 ± 0.17	0.06 ± 0.02
Nitrite	mg/L	0.003 ± 0.002	0.002 ± 0.002	0.002 ± 0.002	0.002 ± 0.002	0.003 ± 0.004	0.001 ± 0.004	0.002 ± 0.001
Orthophosphate (Phosphate Active)	mg/L	0.37 ± 0.27	0.51 ± 0.19	0.79 ± 0.61	0.78 ± 1.32	0.43 ± 0.25	0.44 ± 0.42	0.55 ± 0.19
Ammonia Nitrogen	mg/L	0.41 ± 0.21	0.47 ± 0.27	0.47 ± 0.27	0.36 ± 0.31	0.37 ± 0.35	0.39 ± 0.43	0.41 ± 0.05
Chemical oxygen demand (COD)	mg/L	15.98 ± 2.57	10.45 ± 1.89	13.78 ± 1.42	12.53 ± 4.73	15.07 ± 10.83	16.47 ± 11.98	14.06 ± 2.25
Biochemical oxygen demand (BOD$_5$)	mg/L	2.67 ± 1.62	1.76 ± 1.30	2.46 ± 1.49	2.25 ± 1.37	2.57 ± 1.43	2.52 ± 1.39	2.37 ± 0.11
Total suspended solids (TSS)	mg/L	8.29 ± 3.34	13.40 ± 6.98	11.86 ± 4.83	8.09 ± 4.94	7.61 ± 6.20	8.40 ± 5.95	9.61 ± 2.41

The fish was categorised into three different body shape groups – oblong, elangate and ovate body shapes. Four species from Cyprinidae were grouped into oblong body shapes, three species from Notopteridae, Siluridae, and Channidae were in elongate shape, and Pristolepididae were in ovate shape (Table 5). The LWR analysis pattern for the eight studied species is presented in Figure 2. The graph is generated from all 317 individuals, and the growth pattern, regression coefficients, and a, b, and k values are shown in Table 5.

Table 4. Lake quality classification based on Carlson TSI and sub-index

Location	TSI (SD)	TSI (CHL)	TSI (TP)	TSI Carlson	Status
Laut Melai	61.17	47.62	73.51	60.76	Eutrophic
Laut Tg. Jerangking	67.32	45.62	77.86	63.60	Eutrophic
Laut Gumum	65.96	45.32	84.20	65.16	Eutrophic
Laut Batu Busuk	58.35	44.00	84.06	62.14	Eutrophic
Laut Labuh	56.66	44.43	75.27	58.79	Eutrophic
Laut Jemberau	59.46	44.92	75.71	60.03	Eutrophic
Mean	61.48±4.27	45.32±1.27	78.44±4.62	61.75±2.36	

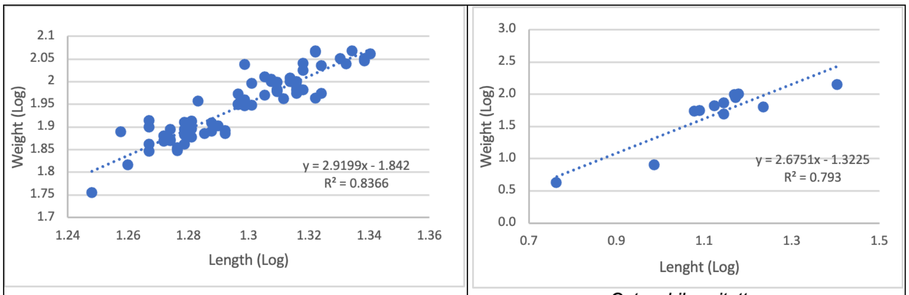
Results from the log-transform LWR showed little variation for all species except *Osteochilus vitattus, Pristolepis faciata* and *Channa lucius*, which may be due to the small n values (Table 5). This study found a strong degree of coefficient of determination (r^2) for all studied species, ranging from 69% to 98%, implying compliance with the stochastic law (Figure 2). Ahmed *et al*. (2011) reported a high coefficient of determination value, proving that fish weight can be estimated well using standard length. *Notopterus notopterus* (Notopteridae) and *K. cryptopterus* (Siluridae), which are from the elongate group, have b value 2.74 and 3.07, respectively, whereas *T. thynnoides* and *C. apagon,* which both are both from the Cyprinidae family and in the oblong shape group, have b value 2.92 and 2.61, respectively. No significant difference (*P*> 0.05) was found in well-being between elongate and oblong body shape (Figure 3).

Observations on four species that reached the minimum number recommended for LWR analysis show three species, *N. notopterus*, *T. thynnoides* and *C. apagon* showing a slight negative allometric growth, except for *K. cryptopterus* positive allometric growth. As the positive allometric growth occurs when the weight of fish is higher that the length of fish, resulting a more robust or heavier body shape while negative allometric growth happens when fish growth happen vice versa that leads to a more elongated or slimmer form as the fish grows (Riedel *et al*., 2007) The b values obtained (2.07 – 4.02) shows low fatness, which increase in body length is not proportionate in their body weight except for *K. cryptopterus*. Froese (2006) has confirmed that the expected range of b value is between 2.5 and 3.5. In addition, b values between 2.5 and 4 are considered to comply with the cube law (Beverton & Holt, 1957). The unusually low or high b value may be influenced by factors such as environmental conditions, feeding habits or habitat suitability within the ecosystem.

Different body shapes and growth patterns of each species can result in variations of LWR between species. Therefore, the b value can vary between species. The comparison of the b value from the same species was made. Isa *et al*. (2010) in their study at Pedu Lake reported that the b value for *N. notopterus* was 3.25, which is higher than the species from Lake Chini. Muzzalifah *et al*. (2015) reported that *Pristolepis fasciata* in Temenggor Lake experiences positive allometric growth (*b*=3.072). Zulkafli *et al* (2015) reported that *T. thynnoides* from the Pahang River was found to have the b value 2.92, which is similar to this study. One-sample t-test shows both elongate and oblong body shape have insignificant difference of their average b values from the isometric value (p>0.05, α=0.05), indicating those species in each group tend to have isometric growth conditions. This indicates that even though most species exhibited negative allometric growth, they did not vary significantly from the isometric score value. This result may indicate that alteration of the lake's habitat due to the disaster flood in 1995 does not significantly affect the aquatic food web in Lake Chini because result of the analysis show that the calculated b values are not significantly different from the isometric value, which indicates availability of sufficient food resources.

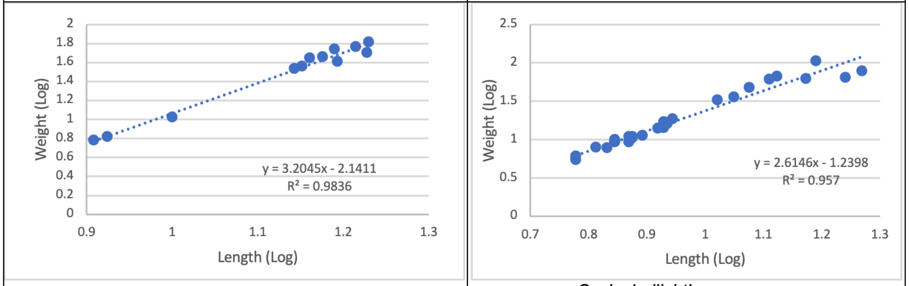
Even though the dominant lotus (*Nelumbo nucifera*) was replaced by the aquatic cat tail (*Cabomba furcata*), the studied fish species still exhibit a well- being growth even with slightly lower b value from isometric score, proven by positive allometric growth of *K. cryptopterus Cyclocheilichthys rapasson* in this study. As a natural lake, Lake Chini provides a complex food source chain, but the loss of several key species may affect fish food sources and cause them to lose their habitat. In natural aquatic environments, *N. nucifera* in the lake serves as a shelter and nursery ground for many fish species. Its dense foliage offers protection and reduces predation, supporting higher survival rates of juvenile fish (Yang *et al*., 2021b). Even *N. nucifera* disappeared from the lake ecosystem, other aquatic macrophytes such as aquatic pandan (*Pandanus* sp.) and bog bulrush (*Lepironia articulata)* still remain in dense stands and serve as habitat and roaming ground for fish.

The overall results from the four species that met the minimum sample size for LWR analysis showed b values ranging from 2.61 to 3.07, which can be considered following the cube law as reported by Froese (2006). The lowest b value (2.07) was recorded for the predator species (*C. Lucius),* possibly due to difficulty in finding prey (smaller fish), resulting in the decline of the population. However, it is important to note that *C. Lucius* was captured in low numbers and did not meet the minimum sample size required for a valid LWR analysis.



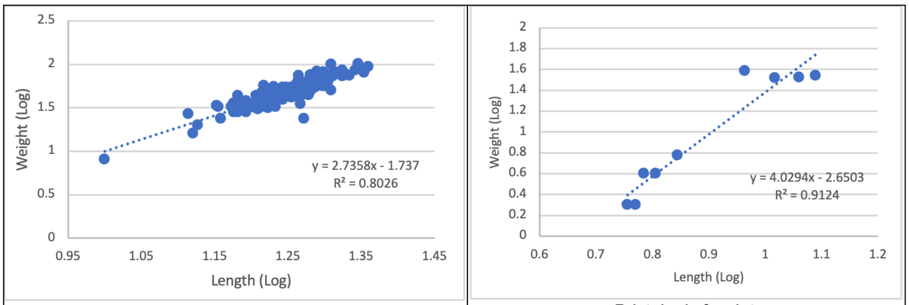
Thynnichthys thynnoides

Osteochilus vitattus



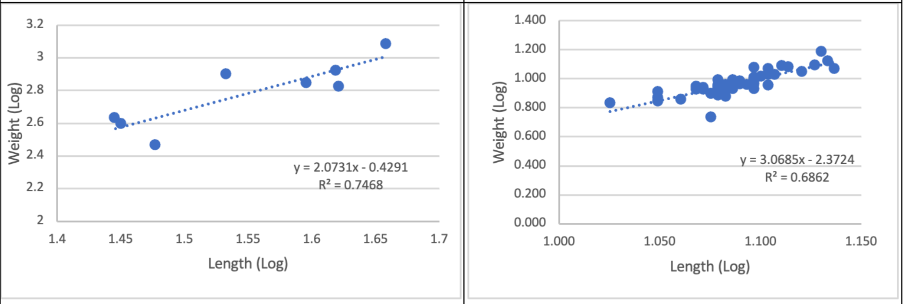
Cyclocheilichthys apogon

Cyclocheilichthys rapason



Notopterus notopterus

Pristolepis fasciata



Channa lucius

Kryptoterus cryptopterus

Fig. 2. Growth pattern for eight fish species in Lake Chini

Table 5. Physical characteristics, growth value and environmental factors for the eight studied species in Lake Chini

	Species	Group	length(cm)	Weight (g)	*n*	Length-weight equation constants				GP	W = aL^b
						a	b	r^2	k		
Notopteridae	*N. notopterus*	elongate	10.0 – 22.2	8 - 102	135	0.02	2.74	0.80	1.01±0.16	AL	$W = 0.0183L^{2.7358}$
Siluridae	*K. cryptopterus*	elongate	10.6 – 13.5	5.4 – 15.4	45	0.01	3.07	0.69	1.02±0.11	AP	$W = 0.0042L^{3.0685}$
Channidae	*C. lucius*	elongate	27.9 – 45.5	293 – 1214	8	0.37	2.07	0.75	1.02±0.23	AL	$W = 0.3723L^{2.0731}$
Cyprinidae	*T.s thynnoides*	oblong	17.7 – 21.9	56.8 – 116	68	0.01	2.92	0.84	1.00±0.07	AL	$W = 0.0144L^{2.9199}$
Cyprinidae	*O. vitattus*	Oblong	5.8 – 25.4	4.2 - 138	12	0.05	2.68	0.79	1.01±0.42	AL	$W = 0.0476L^{2.6751}$
Cyprinidae	*C. rapasson*	Oblong	8.1 – 16.4	6.0 – 57.7	12	0.01	3.20	0.98	1.00±0.42	AP	$W = 0.0072L^{3.2045}$
Cyprinidae	*C.apagon*	oblong	6.0 – 18.6	5.4 – 106.5	30	0.06	2.61	0.96	1.02±0.18	AL	$W = 0.0576L^{2.6147}$
Pristolepididae	*P. fasciata*	ovate	5.7 – 12.3	2.0 – 33.4	9	0.00	4.02	0.91	1.08±0.49	AP	$W = 0.0005L^{4.0294}$

The Le Cren's condition factor (Kn) is also a measurement involving the length and weight of the fish, and therefore, it could be influenced by the same factors as the LWR. The value of the environment factor (Kn) for eight fish species ranged from 1.00 to 1.08 (Table 5). *Kryptoterus cryptopterus* and *C. apagon* exhibited the highest Kn value (1.02), and the dominant species, *N. notopterus,* has a Kn value of 1.01. A higher Kn value reflects better growth, but typical range values for conditions can vary depending on sex, species and environmental conditions. The K values from these four species that conform to the minimum sample size for LWR analysis fluctuate around 1.00 and demonstrate a similar growth condition. Some species naturally have higher or lower condition factors than others, and what constitutes "good growth" can vary widely between species. Barnham and Baxter (1998) suggested that a K value of 1 indicates poor fish condition, 1.20 as moderate condition and 1.4 and above as good and well-proportioned fish. This study shows fishes in Lake Chini have lower values of K compared to studies in Lake Temenggor by Muzzalifah *et al*. (2015), which mostly have values of K above 1. All Le Cren condition factors (Kn) recorded in this study are below 1.2, which typically indicates moderate fish condition. Differences in condition factor could be due to many factors, such as the availability of food, as well as the difference in gonad development stage (Gupta *et al*., 2011). However, even though low b and K values of fishes recorded, the one-sample t-test indicates insignificant differences from the good growth score 1.4 (P=0.866, α=0.05). This would imply that even though Lake Chini experiences hydrological and habitat change, it still has sufficient ecosystem services to support aquatic communities, especially fish.

The water barrage that was built in 1995 significantly altered Lake Chini's hydrological scheme and resulted in the degradation of the lake environment. The water barrage expanded the open water area, flooding the swampy forest and riparian zone and reducing water velocity (Sharip & Jusoh, 2010). The flood causes the extinction of the lotus plant (*N. nucifera*) due to the flood event and is replaced by a non-native submerged plant (*C. furcata*), and alters fish habitat. Anthropogenic biodegradation enhances nutrient enrichments and change trophic state toward eutrophication. The impacts of water quality alteration and physical changes are not a significant factor for fish depletion in the lake. Other factors, such as water weir structure and over-harvesting, need to be considered in fish depletion in the lake. According to Lizama *et al*. (2002), the study of environmental factors is important for understanding the life environment of fish. Imam *et al*. (2010) also agreed with the understanding that good environmental factors can help manage species well. In summary, negative allometric growth found in this studied species, as well as low condition factor, are not solely determined by food sources and could be due to the factors listed earlier or a combination of factors which require further investigation.

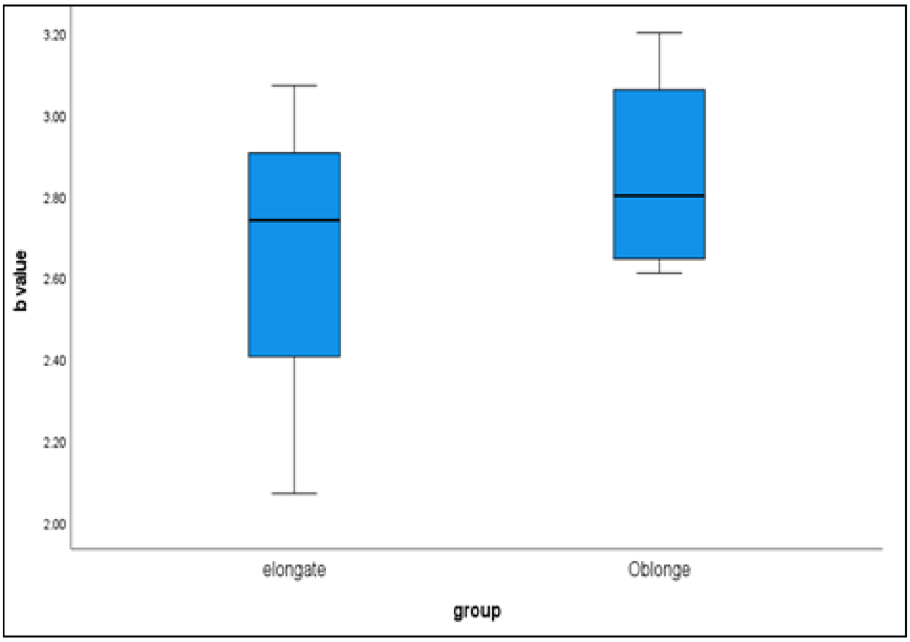


Fig. 3. Boxplots of LWR analysis for b value from elongate (188 ind.) and oblong (122 ind.) body shape groups.

CONCLUSION

The Lake Chini water quality is of moderate quality and does not vary significantly between dry and wet periods. The lake is in early eutrophic conditions for all water body sections. The results of the study show that the floods that occurred did not have a serious impact on the water bodies that remain in categories A and B. However, the value is only an indicator of a more broadly defined concept. The best indicator for trophic status may vary between lakes and seasonally and should be chosen on pragmatic grounds. This study provides important information on the LWR for four species that have conformed to the minimum size for the LWR analysis. The majority of studied fish have b and K values that insignificantly vary from the recommended value for well-being growth. This indicates that ecosystem change due to the disaster flood event only has a small effect on the development of the fish population. The result of the LWR analysis indicates that fish in Lake Chini may be affected by other anthropogenic factors, especially water barrage construction in the Chini River that imposes a significant hydrological change. The existence of the water barrage structure in the Chini River has interrupted fish migration. Since many other factors may affect fish growth, more studies are necessary for a better understanding of Lake Chini's ecosystem health and ecosystem services. An integrated approach needs to be undertaken to protect and conserve the fish population in the lake, such as physical interference (the existence of a water barrage) and overfishing by local aboriginal people.

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ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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