Sains Malaysiana 51(12)(2022): 3897-3907
http://doi.org/10.17576/jsm-2022-5112-03

Evaluating the Tropical Reservoir Health by using the Index of Biotic Integrity as a Management Tool for Resource Conservation Planning

(Menilai Kesihatan Takungan Tropika menggunakan Indeks Integriti Biotik sebagai Alat Pengurusan untuk Perancangan Pemuliharaan Sumber)

XEAI LI CHAI[1], H. ROHASLINEY[1,*] & I.S. KAMARUDDIN[2]

[1]*Department of Environment, Faculty of Forestry and Environment, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia*
[2]*Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia*

Received: 17 March 2022/Accepted: 15 August 2022

ABSTRACT

Biotic Integrity index (IBI) is widely utilized for biomonitoring in aquatic ecosystems, especially in assessing aquatic ecosystem health worldwide. Environmental changes significantly impact the aquatic ecosystem's health of Subang Reservoir, which consequently affects the aquatic biodiversity. This study was conducted to determine its ecosystem's health by assessing the IBI of freshwater fish in Subang Reservoir. In this study, thirty-four metrics were firstly selected as candidate metrics, and later, these thirty-four metrics underwent several statistical tests such as range, responsiveness, redundancy, and metrics scoring to screen and select the most appropriate metrics. A final eight metrics were selected after the statistical analysis, and a total score of 24 indicated that the Subang Reservoir's ecosystem shows some stress due to an imbalanced fish guild. This showed that the ecosystem's health of Subang Reservoir is in fair condition. This is because of the limitation of fish entering Subang Reservoir. The implementation of biomonitoring can be improved by modifying and selecting the most appropriate techniques, and the usage of biomonitoring can be increased in Malaysia's freshwater ecosystems. The result reported in this study can be used as a scientific base data for implementing biomonitoring.

Keywords: Fish assemblages; freshwater ecosystem; Index of Biotic Integrity (IBI); tropical reservoir

ABSTRAK

Indeks Integriti Biotik (IBI) digunakan secara meluas untuk pemantauan biologi dalam ekosistem akuatik terutamanya dalam menilai kesihatan ekosistem akuatik di seluruh dunia. Perubahan alam sekitar mempunyai kesan yang ketara terhadap kesihatan ekosistem akuatik Takungan Subang dan memberi kesan kepada kepelbagaian biologi akuatik. Kajian ini dijalankan untuk menentukan kesihatan ekosistemnya dengan menilai IBI ikan air tawar di Empangan Subang. Dalam kajian ini, tiga puluh empat metrik telah dipilih sebagai calon metrik. Tiga puluh empat metrik ini menjalani beberapa ujian statistik seperti ujian julat, ujian responsif, ujian redundansi dan pemarkahan metrik telah dijalankan untuk memilih metrik yang paling sesuai. Lapan metrik terakhir telah dipilih selepas analisis statistik dan jumlah markah metrik IBI ialah 24 yang menunjukkan bahawa ekosistem Empangan Subang mengalami beberapa tanda tekanan akibat kelompok ikan yang tidak seimbang. Empangan Subang didapati dalam keadaan sederhana sihat. Hal ini demikian kerana kemasukan ikan ke dalam Empangan Subang adalah terhad. Pelaksanaan pemantauan biologi boleh dipertingkatkan dan penggunaan pemantauan biologi boleh ditingkatkan dalam ekosistem air tawar Malaysia. Hasil kajian ini dapat digunakan sebagai data asas saintifik untuk pelaksanaan pemantauan biologi.

Kata kunci: Ekosistem akuatik; Indeks Integriti Biotik (IBI); perkumpulan ikan; takungan tropika

INTRODUCTION

According to Rocha, Andrade and Lopes (2015), the analysis of the physical and chemical parameters for water quality monitoring has been conducted in Malaysian inland water bodies. Monitoring water quality is vital for future management because the current, ongoing, and emerging problems can be detected earlier, and the beneficial uses of water can be protected. Furthermore, changes in physicochemical water parameters such as temperature, total dissolved oxygen, and turbidity can affect fishes' growth, survival, and reproduction (Dodds & Whiles 2010). Physicochemical water parameters such as pH, temperature, turbidity, biochemical oxygen demand (BOD), dissolved oxygen (DO), total phosphorus, total ammonia, nitrate, magnesium, sodium, potassium, bicarbonate, and phosphate are commonly used to determine water quality characteristics (Xiao et al. 2016). The results of water characteristics were compared with the National Water Quality Standard (NWQS) and National Lake Water Quality Criteria and Standard (NLWQS) to determine the suitability of water resources for different usage such as agriculture, industrial and domestic usage (Naubi et al. 2016). In Malaysia, the major pollutants in lakes and rivers are BOD, ammoniacal nitrogen (NH_3N), and suspended solids (Huang et al. 2015).

The fish community is a common bioindicator that is used to determine the condition of the watershed because (1) they have extensive life history information for most species; (2) they consist of different trophic levels; (3) they are easily identified up to the species level, and (4) living in a broad-scale of habitat (Ganasan & Hughes 1998; Karr 1981; Stojković, Milošević & Simić 2011). The IBI metrics are strongly correlated to the fish assemblage characteristics (e.g., trophic composition, fish abundance, and richness) (Johnson & Ringler 2014).

Assessing the lake's health must involve regular monitoring of the biological condition of lakes and reservoirs to overcome several environmental issues such as water pollution and habitat degradation. The application of biomonitoring tools has been evidenced in many journals for the last twenty years, as mentioned in the study of Prabhakaran et al. (2017).

The environmental degradation assessment and ecosystem health can be determined by utilizing fish as a bioindicator (Fausch et al. 1990). However, there is a low number of studies conducted in Subang Reservoir by utilizing fish as bioindicators. A higher number of studies have been conducted on determining the fish diversity, whereas the study of the lakes' health status using ecological and fisheries indices such as the index of biotic integrity (IBI) of fish is deficient in lakes of Malaysia. Besides, biomonitoring has been widely introduced globally, and the biomonitoring technique in Malaysian aquatic ecosystems has mainly focused on bioaccumulation (Prabhakaran et al. 2017). In contrast, other biomonitoring techniques in the Malaysian aquatic ecosystems are limited (Prabhakaran et al. 2017). Hence, the development of biomonitoring practice is essential to protect and manage the current condition and ongoing ecosystem changes. Biomonitoring practices also can be applied to different studies in the future.

Subang Reservoir in Selangor, Malaysia, is an endorheic lake with no surrounding inlet streams, and there is no outflow to the sea. Precipitation and surface runoff from the watershed is the significant input for Subang Reservoir. The outputs of Subang Reservoir are evaporation and intermittent stream. Being an endorheic lake, Subang Reservoir is considered a unique ecosystem to study, primarily concerning the health of the fish and its surrounding habitats. The trophic state of Subang Reservoir is currently acidic-mesotrophic (Umi Wahidah et al. 2020). Therefore, it is crucial to determine the condition of Subang Reservoir's ecosystem based on fish assemblages and the water quality, whether Subang Reservoir is under intense pressure from human activities or otherwise. Fish is a vital bioindicator that can determine the changes in Subang Reservoir's environment, further demonstrating the lake's water quality. Fish diversity measures have typically disregarded the composition of sampled communities, whereas the fish index of biotic integrity is an assessment assumed to represent the entire fish community.

Hence, biomonitoring practice, especially fish indices, is essential to protect and manage the current condition and ongoing reservoir ecosystem changes. Therefore, this study aims to determine the health of tropical reservoirs, focusing on freshwater fishes using improved IBI at the endorheic lake of Subang Reservoir, Malaysia.

Materials and Methods

SITE DESCRIPTION

The state of Selangor has fourteen lakes and reservoirs with a total area and volume of 27.25 km^2 and 531.56 mm^3, respectively. Subang Reservoir is located in Petaling District, Selangor, Malaysia, with a latitude of 3°10'2.04" and a longitude of 101°28'47.1". Subang Reservoir was built in 1950, and the capacity of Subang Reservoir is about 777.00 milligram (mg). Pengurusan Air Selangor Sdn. Bhd. supplies water from Subang Reservoir to North Hummock Water Treatment Plant for water treatment before release to the industrial, and it is a restricted area under the protection of Lembaga Urusan Air Selangor (LUAS). The study site was divided into seven sampling points to ensure its coverage of the study site (Figures 1 & 2).

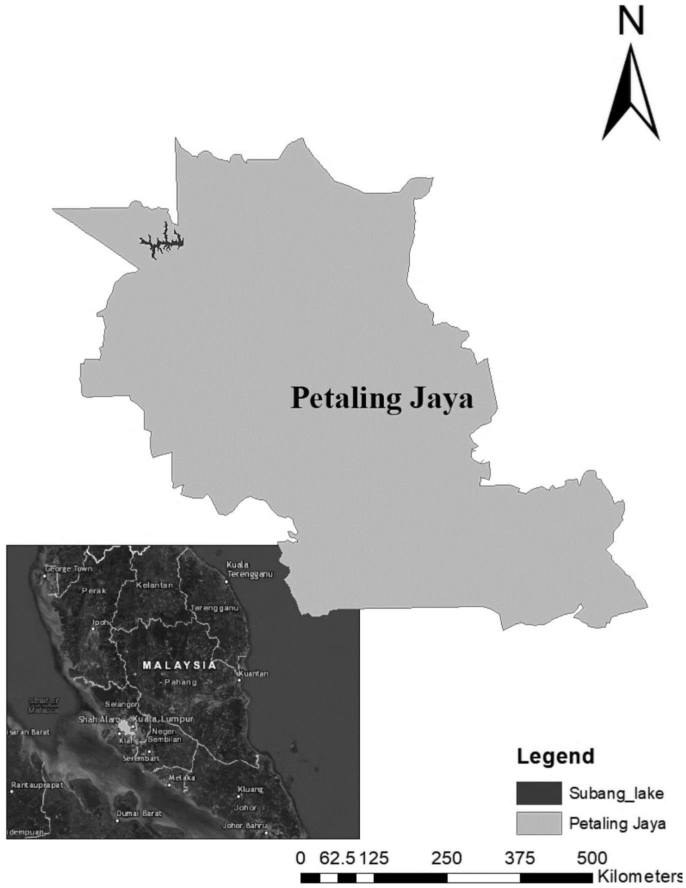

FIGURE 1. The location of Subang Reservoir in Selangor, Malaysia

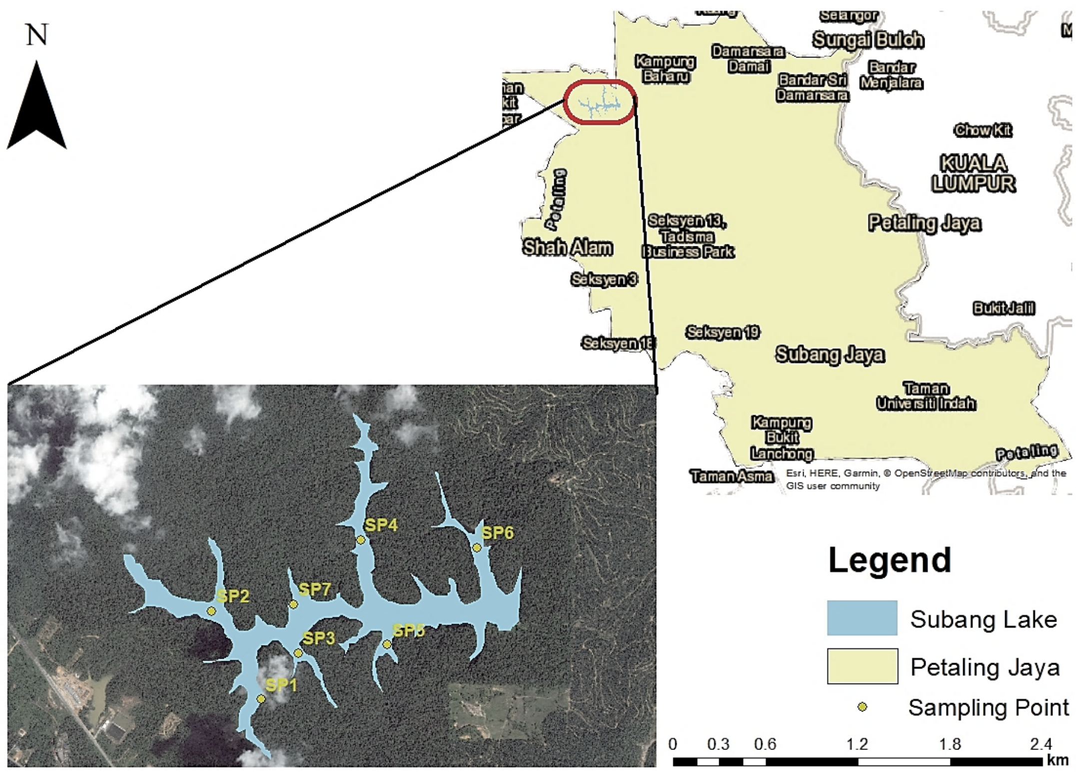

FIGURE 2. Subang Reservoir's location and sampling locations' distribution

FISH SAMPLING

This study used passive capture techniques (i.e., gill nets and fish traps) to ensure enough sampling duration and capture the most fish species. Thus, several mesh sizes of gill nets were used to ensure sampling efficiency. According to Bjordal (2002), gill nets and fish traps have moderate to good catch quality. Therefore, five-gill nets with different mesh sizes (3.81 cm, 5.08 cm, 7.62 cm, 10.16 cm, and 12.70 cm) and two fish traps were set at each sampling point. The gill nets (N = four sampling days X five-gill nets X seven sampling points X three months = 420 samples/lake) and fish traps (N= four sampling days X two fish traps X seven sampling points X three months = 168 samples/lake) were both set overnight for four consecutive days. The fishing equipment was set up at the limnetic and littoral zone to ensure different sizes of fish could be collected. The sampling periods were conducted in June 2019, August 2019, and October 2019. Fish samples were placed into a bucket containing water from the lake, then identified using the taxonomic keys of Kottelat (2013) and Zakaria-Ismail, Fatimah and Khaironizam (2019). The species and number of individuals landed from each sampling point were recorded for further data analysis. Some species were preserved using 10% of formalin, labelled, and stored as voucher specimens in the laboratory at the Department of Environment, Faculty of Forestry and Environment, Universiti Putra Malaysia, Malaysia.

WATER PARAMETERS COLLECTION

The water sample collection was conducted in June, August, and October 2019, and the sampling months were randomly selected during the fish sample collection. Three replicates were collected through random sampling at each sampling point and were kept at approximately ± 4°C to reduce water degradation and avoid bias concurrently (N = five sampling days X three replicates X seven sampling points X three months = 315 samples/lake). Therefore, five *in-situ* and six *ex-situ* water parameters were collected concurrently during fish samplings, such as temperature, pH, turbidity, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3N), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4).

DEVELOPMENT OF IBI METRICS

The IBI was used to determine the community structure and the water quality of a natural habitat based on fish assemblages. In this study, 34 candidate metrics were selected primarily according to previous studies (Table 1). In addition, these candidate metrics were selected from previous studies that responded to the anthropogenic pressure and description of fish assemblage (Jia, Sui & Chen 2013; Terra et al. 2013).

The candidate metrics were then selected using the range, responsiveness, redundancy, and metric scoring to determine the most suitable metrics for this study (Table 2). The statistical analysis was conducted following range, responsiveness, redundancy, and metric scoring sequences. The statistical analysis was conducted by using IBM SPSS Statistics software version 25. The range test underwent frequency analysis for each candidate, and the value of each metric was accumulated for the whole sampling times and sampling sites of the whole reservoir. The metrics results of the range test with a range below 4, or more than 75 % of values, were eliminated (Vile & Henning 2018). Meanwhile, Spearman's rank coefficient with physicochemical water quality parameters was used to determine the metrics' responsiveness. The metrics were considered to respond if the value of the metrics correlated with the water parameters ($\alpha = 0.05$, r more than 0.70), such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3N), nitrite (NO_2), nitrate (NO_3), phosphate (PO_4), temperature, pH, turbidity, electrical conductivity (EC), and dissolved oxygen (DO). The physicochemical water parameters data were collected during the sampling months. Therefore, the highest significant responsiveness in each class was retained ($\alpha = 0.05$). Finally, the candidate metrics' redundancy was evaluated by using Spearman's rank coefficient. If the metrics showed a coefficient value, r more than 0.70, the metrics were considered redundant because the metrics were assumed to be closely related to each other (Krause et al. 2013; Terra et al. 2013). Therefore, the redundant metrics with the highest significant responsiveness were eliminated (Krause et al. 2013).

Eight metrics that passed the redundancy test remained on the metric list after the redundancy test. These metrics included the number of native species, number of benthopelagic species, number of benthopelagic intolerant native species, the proportion of benthopelagic intolerant native individuals, the proportion of herbivore individuals, number of omnivore species, proportion of carnivore individuals, and the number of native individuals per day of sampling (Table 2).

Based on the boxplot for each final metric, the metrics score fell below 25 percentiles was scored 1, whereas the metrics score within 25 to 75 percentiles was scored 3, and the scoring metric above 75 percentiles was scored 5 (Li et al. 2018). The final metrics were used to determine the total metrics score by the sum of the score of the final metrics. The sum of all metrics scores was rated according to Table 3.

TABLE 1. Candidate metrics and the metric classes for each metric

Metrics	Metrics class
Number of species	Species diversity
Number of native families	Species diversity
Number of native species	Species diversity
The proportion of native individuals	Species diversity
Number of non-native species	Species diversity
The proportion of non-native individuals	Species diversity
Number of native fish species, family Cyprinid (excluding tolerant taxa)	Species diversity
Number of native Cyprinid species	Species diversity
Shannon-Wiener Diversity Index	Species diversity
Number of demersal species	Habitat
The proportion of demersal species individuals	Habitat
Number of benthopelagic species	Habitat
The proportion of benthopelagic species individuals	Habitat
Number of demersal native species	Habitat
The proportion of demersal native species individuals	Habitat
Number of benthopelagic native species	Habitat
The proportion of benthopelagic native individuals	Habitat
Number of demersal intolerant native species	Habitat
The proportion of demersal intolerant native individuals	Habitat
Number of benthopelagic intolerant native species	Habitat
The proportion of benthopelagic intolerant native individuals	Habitat
Number of intolerant species	Tolerance
The proportion of intolerant individuals	Tolerance
Number of tolerant species	Tolerance
The proportion of tolerant individuals	Tolerance
Number of herbivore species	Trophic function
The proportion of herbivore individuals	Trophic function
Number of omnivore species	Trophic function
The proportion of omnivore individuals	Trophic function
Number of carnivore species	Trophic function
The proportion of carnivore individuals	Trophic function
Number of fish per day sampling	Abundance and condition
Number of native individuals per day sampling	Abundance and condition
Number of non-native individuals per day sampling	Abundance and condition

TABLE 2. Candidate metrics and the expected response to environmental changes and the stage of the metrics screening process

Metrics	Metrics class	Expected response	Range test	Responsiveness test	Redundancy test	Final metric
Number of species	Species diversity	Decrease	+	+	-	
Number of native families	Species diversity	Decrease	-	-	-	
Number of native species	Species diversity	Decrease	+	+	+	Final metric
Proportion of native individuals	Species diversity	Decrease	+	-	-	
Number of alien species	Species diversity	Increase	-	-	-	
Proportion of alien individuals	Species diversity	Increase	+	-	-	
Number of native fish species, family Cyprinidae (excluding tolerant taxa)	Species diversity	Increase	-	-	-	
Number of native Cyprinidae species	Species diversity	Increase	-	-	-	
Shannon-Wiener Diversity Index	Species diversity	Decrease	-	-	-	
Number of demersal species	Habitat	Decrease	-	-	-	
Proportion of demersal species individuals	Habitat	Decrease	+	-	-	
Number of benthopelagic species	Habitat	Decrease	+	+	+	Final metric
Proportion of benthopelagic species individuals	Habitat	Decrease	+	-	-	
Number of demersal native species	Habitat	Decrease	-	-	-	
Proportion of demersal native species individuals	Habitat	Decrease	+	-	-	
Number of benthopelagic native species	Habitat	Decrease	+	-	-	
Proportion of benthopelagic native individuals	Habitat	Decrease	+	-	-	
Number of demersal intolerant native species	Habitat	Decrease	-	-	-	
Proportion of demersal intolerant native individuals	Habitat	Decrease	+	-	-	
Number of benthopelagic intolerant native species	Habitat	Decrease	+	+	+	Final metric
Proportion of benthopelagic intolerant native individuals	Habitat	Decrease	+	+	+	Final metric
Number of intolerant species	Tolerance	Decrease	+	-	-	
Proportion of intolerant individuals	Tolerance	Decrease	+	-	-	
Number of tolerant species	Tolerance	Increase	-	-	-	
Proportion of tolerant individuals	Tolerance	Increase	+	-	-	
Number of herbivore species	Trophic function	Decrease	-	-	-	
Proportion of herbivore individuals	Trophic function	Decrease	+	+	+	Final metric
Number of omnivore species	Trophic function	Increase	+	+	+	Final metric
Proportion of omnivore individuals	Trophic function	Increase	+	-	-	
Number of carnivore species	Trophic function	Decrease	-	-	-	
Proportion of carnivore individuals	Trophic function	Decrease	+	+	+	Final metric
Number of fish per day sampling	Abundance and condition	Decrease	+	-	-	
Number of native individuals per day sampling	Abundance and condition	Decrease	+	+	+	Final metric
Number of non-native individuals per day sampling	Abundance and condition	Increase	-	-	-	

+ denoted positive response to the test and passed the test and - denoted failure of response to the test

TABLE 3. Selected metrics and score interval for the final metrics of Subang Reservoir

	Metric scores		
Metrics	1	3	5
Number of native species	<5	5-7	>7
Number of benthopelagic species	<4	4-6	>6
Number of benthopelagic intolerant native species	<2	2-4	>4
Proportion of benthopelagic intolerant native individuals	<36	36-81	>81
Proportion of herbivore individuals	<0	0-9	>9
Number of omnivore species	>5	4-5	>4
Proportion of carnivore species	<4	4-15	>15
Number of native individuals per day sampling	<7	7-15	>15

The total IBI score was calculated based on all metrics scores. Li et al. (2018) have reduced the IBI values that ranged from 0 to 60 to 0 to 40 (Table 4) due to lesser metrics used in their study, which was only eight metrics, a lesser number of metrics compared to the previous study (Karr 1981) with 12 metrics. Therefore, this study used an IBI value range based on eight metrics from Li et al. (2018). The metrics selected in this study were similar to the study of Karr (1981).

TABLE 4. The fish IBI class boundaries and general description of their attributes

Class	Attributes	IBI value
Excellent	Comparable to the best situations without the influence of man; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with a full array of age and sex classes; balanced trophic structure	35-40
Good	Species richness is somewhat below expectation, primarily due to loss of most intolerant forms; some species with less-than-optimal abundances or size distribution; trophic structure shows some signs of stress	28-34
Fair	Signs of additional deterioration include fewer intolerant forms, more skewed trophic structure (e.g., increasing frequency of omnivores); older age classes of top predators may be rare	21-27
Poor	Dominated by omnivores, pollution-tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present	14-20
Very Poor	Less fish present, primarily introduced or very tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular	6-13
No fish	Repetitive sampling fails to turn up any fish	0-5

Source: Li et al. (2018)

RESULTS AND DISCUSSION

The metric scoring of Subang Reservoir was scored 24 (Table 3). The IBI's metrics score showed that the Subang Reservoir has a more skewed trophic structure, significantly increasing the frequency of omnivores (Table 4). This is because Subang Reservoir is endorheic; therefore, the fish were primarily stocked or released by humans. Furthermore, the omnivore species primarily structured fish assemblages in Subang Reservoir (i.e., including tolerant and intolerant species). Therefore, based on the IBI score, the Subang reservoir's trophic structure might indicate some sign of stress due to the imbalance of trophic structure. Nevertheless, the effects depend on introducing fish species to the reservoir.

From the selected final metrics, all eight metrics covered most of the metric class: Species diversity, habitat, trophic function, and abundance and condition (Li et al. 2018; Petesse et al. 2014; Zhang, Shan & Ao 2014). According to Petesse et al. (2016), the environment with less degradation was expected to have more species. The Subang Reservoir (19 species) has more species compared to the Pergau Reservoir (17 species) (Amir Shah Ruddin et al. 2017) and Bersia Reservoir (16 species) (Hamid & Mansor 2013), even though Subang Reservoir has a smaller area (0.7 km^2) and low volume (3.5 mm^3). Pergau Reservoir has a total area of 4.30 km^2 with a total volume of 62.5 mm^3, while Bersia has a total area and volume of 5.7 km^2 and 70 mm^3. Therefore, Subang Reservoir recorded higher species compared to Pergau Reservoir and Bersia Reservoir, although the area and volume of Subang Reservoir are lower.

Apart from that, the number of herbivorous, omnivorous, and carnivorous species (Froese & Pauly 2019) in Subang Reservoir was 1, 12, and 6, respectively. There was a higher number of omnivorous species in Subang Reservoir (Table 5), followed by carnivorous and herbivorous species. According to Petesse et al. (2016), omnivorous species are expected to increase in herbivorous and carnivorous species tend to decrease when the environment changes, such as water quality and habitat degradation. A record of a higher number of omnivorous species indicates that the trophic structure expresses some signs of stress (Li et al. 2018). According to Li et al. (2018), a higher number of omnivorous recorded when there was anthropic interference. Out of 12 omnivore species caught in the reservoir, eight omnivore species were considered intolerance fish species.

Through personal observation during the study period, the reservoir riparian and littoral zones could support herbivore and insectivore fish species. Furthermore, this reservoir is surrounded by permanent forest reserves, namely Bukit Cerakah Forest Reserves (Shah Alam Community Forest 2022), that can provide excellent natural vegetation to the lake's inhabitants. Besides that, this zone supplies food, shading, nursery, and feeding zones that benefit the fish and other aquatic organisms (Shah Alam Community Forest 2022).

Different fish species can adapt to natural and human-induced changes in water quality and other environmental conditions. These vary from species to species, but some baseline conditions must be met to ensure a healthy fish population. A healthy reservoir can accommodate more intolerant native fish species (Vile & Henning 2018). Ten intolerant native fish species and four tolerant native fish species were found in Subang Reservoir (Table 5). According to Zakaria-Ismail and Fatimah (2002), intolerant species are found mainly in the unpolluted stream in Malaysia, whereas tolerant species can be found in the polluted waterbody. Vile and Henning (2018) recorded a higher percentage of tolerant fish species with increasing anthropogenic disturbance in New Jersey's stream. The number of tolerance fish species occupies the most significant part of this study area. A higher number of intolerant species recorded indicated less anthropogenic disturbance in Subang Reservoir.

Nevertheless, the study's findings demonstrated that Subang Reservoir is considered fair class integrity based on the metric scoring. The reservoir class integrity can be enhanced if proper management planning is implemented, such as stocking native species and re-stocking different trophic structure fish species. Subang Reservoir can be one example of a healthy reservoir with self-sustaining fish populations (i.e., good fish assemblages, high diversity, fish with all age classes, no morphological anomalies, and normal behavior) when proper management planning is implemented.

A higher number of native species was recorded compared to non-native species. The number of native and non-native individuals per day of sampling represents disturbance and stress. There is an inverse relationship between native richness and anthropogenic disturbance (Vile & Henning 2018). Vile and Henning (2018) documented that the native richness decreased when the anthropogenic disturbance increased. The study of Vile and Henning (2018) found that native species richness was positively correlated to the forest area and negatively correlated with urban land. However, Subang Reservoir was surrounded by Bukit Cerakah Forest Reserve, which has a larger forest area. Thus, the native richness is not affected. This study concurred with Chai et al. (2021) findings concerning the length-weight relationships and fish condition of *Cyclocheilithys apogon* and *Notopterus notopterus.* Both fish species are in a healthy intermediate state (fair condition growth), with the K value greater than 1.4 (Chai et al. 2021), indicating that the dominant species were not affected.

Benthopelagic and demersal fish species provide essential information on the degradation of an ecosystem. According to Jia, Sui and Chen (2013), the benthopelagic and demersal fish species were sensitive to siltation and oxygen deficiency. In this study, a higher number of benthopelagic fish species were recorded (16 species) compared to demersal fish species (3 species) (Table 5). The reservoir depth ranged from three to five meters deep, with a mean depth of 9.1m (Umi Wahidah et al. 2020). Therefore, sunlight can penetrate the water surface to the bottom, especially in the littoral zones. In addition, vegetation at the littoral zones was observed in this lake and contributed to the normal range of water dissolved oxygen.

TABLE 5. The fish community structure and function

Species name	Tolerance	Trophic function	Habitat	Native
Barbonymus altus	Tolerance	Herbivore	Benthopelagic	Non-native
Barbonymus gonionotus	Tolerance	Herbivore	Benthopelagic	Non-native
Barbonymus schwanenfeldii	Tolerance	Herbivore	Benthopelagic	Native
Cyclocheilichthys apogon	Intolerance	Omnivore	Benthopelagic	Native
Cyprinus carpio	Tolerance	Omnivore	Benthopelagic	Non-native
Desmopuntius hexazona	Intolerance	Omnivore	Benthopelagic	Native
Rasbora caudimaculata	Intolerance	Omnivore	Benthopelagic	Native
Rasbora lateristriata	Intolerance	Omnivore	Benthopelagic	Native
Channa micropeltes	Intolerance	Carnivore	Benthopelagic	Native
Channa lucius	Intolerance	Carnivore	Benthopelagic	Native
Channa striata	Tolerance	Carnivore	Benthopelagic	Native
Clarias batrachus	Tolerance	Omnivore	Benthopelagic	Native
Notopterus notopterus	Intolerance	Omnivore	Demersal	Native
Trichopodus leerii	Intolerance	Omnivore	Benthopelagic	Native
Trichopodus trichopterus	Intolerance	Omnivore	Benthopelagic	Native
Oreochromis niloticus	Tolerance	Omnivore	Benthopelagic	Non-native
Pristolepis fasciata	Intolerance	Omnivore	Benthopelagic	Native
Oxyeleotris marmorata	Tolerance	Carnivore	Demersal	Native
Pterygoplichthys pardalis	Tolerance	Omnivore	Demersal	Non-native

Conclusion

IBI has been widely used to determine the environmental changes and fish community structure. Based on the IBI metric score of this study, Subang Reservoir's health is considered in fair condition. Nonetheless, the fair condition of Subang Reservoir does not indicate that the lake is an unhealthy ecosystem because Subang Reservoir is an endorheic reservoir where humans mainly contributed to the stocking of the fish species. A higher number of native fish richness showed that the reservoir does not experience significant disturbance because most of the native species are intolerant. Although more omnivores were found in this reservoir, stocking more herbivores and insectivore native species can improve the reservoir score to a healthy ecosystem. This pristine ecosystem should be optimized so that the ecological quality of the reservoir can be upgraded. The endorheic reservoir is highly sensitive to natural and anthropogenic disturbances. Hence, frequent monitoring of native species program in the long term is significant to protect the aquatic ecosystem's health status. Overall, the implementation of biomonitoring can further be improved, particularly in tropical reservoirs or lake environments, and biomonitoring can be fully utilized in Malaysia's freshwater ecosystems. Indeed, the implementation of biomonitoring can protect the biodiversity of the fish and fisheries resources and help improve lake management.

ACKNOWLEDGEMENTS

The authors wish to thank funding from Geran Putra Universiti Putra Malaysia (UPM) (GP/2017/9564500) for completing the study. Also, high appreciation to Mohd Sulkifly Ibrahim, Abdul Rahman Sokran @ Mohamad, and Dalina Jaafar for their assistance. Apart from that, high gratitude for Pengurusan Air Selangor Sdn. Bhd. and Lembaga Urusan Air Selangor (LUAS) for their approval for the authors to carry out their study smoothly in Subang Reservoir. Finally, thank you for the kindest cooperation given by the supervisor of Subang Reservoir, Mohd Rezza Haizad Abdullah, and all the staff (Rajuddin Hamid, Yusof Rohman, and Muhammad Fadzil Idris). The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript. The authors confirm that the data supporting the findings of this study are available within the article (and/or) its supplementary materials.

REFERENCES

Amir Shah Ruddin Md. Sah, Zarul Hazrin Hashim, Mohd Shafiq Zakeyuddin, Mohd Syaiful Mohamad, Mohd. Noh Ahmad, Azwin Abdul Razad & Wan Ruslan Ismail. 2017. Fish checklist of Pergau Reservoir, Jeli, Kelantan. *Kepelbagaian Biologi Gunung Basor dan Tasik Pergau Kelantan*, edited by Zahari, I., Mohd Radhi Chu, A., Razali, A.R., Najwa Dina, A., Suryani, M.N. & Latif, A. Jabatan Perhutanan Negeri Kelantan. pp. 74-79.

Bjordal, A. 2002. *A Fishery Manager's Guidebook – Management Measures and Their Application,* edited by Cochrane, K.L. Rome: Food and Agriculture Organization of the United Nations.

Chai, X.L., Rohasliney, H., Muhammad Nur Aiman, R., Mohamad Hamizan, K., Nur Ain, H., & Izharuddin, S.K. 2021. Length-weight relationship and relative condition factor of two dominant species (*Cyclocheilithys apogon* and *Notopterus notopterus*) at Subang Lake, Selangor, Malaysia. *Pertanika Journal of Science and Technology* 29(3): 1557-1566.

de Carvalho, R.D., Leal, C.G., Junqueira, N.T., de Castro, M.A., Fagundes, D.C., Alves, C.B.M., Hughes, R.M. & Pompeu, P.S. 2017. A fish-based multimetric index for Brazilian savanna streams. *Ecological Indicators* 77: 386-396.

Dodds, W. & Whiles, M. 2010. *Freshwater Ecology: Concepts and Environmental Applications of Limnology*. 2nd ed. Amsterdam: Elsevier.

Fausch, K.D., Lyons, J., Karr, J.R. & Angermeier, P.L. 1990. Fish communities as indicators of environmental degradation. *American Fisheries Society Symposium* 8(1): 123-144.

Froese, R. & Pauly, D. 2019. *FishBase*. https://www.fishbase.de/. Accessed on 25 July 2020.

Ganasan, V. & Hughes, R.M. 1998. Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), India. *Freshwater Biology* 40: 367-383.

Hamid, M.A. & Mansor, M. 2013. The inland fisheries with special reference to Temengor and Bersia Reservoirs, Perak. *Malaysian Applied Biology Journal* 42(1): 73-76.

Huang, Y.F., Ang, S.Y., Lee, K.M. & Lee, T.S. 2015. Quality of water resources in Malaysia. *Research and Practices in Water Quality*, edited by Lee, T.S. IntechOpen. pp. 65-90.

Jia, Y., Sui, X. & Chen, Y. 2013. Development of a fish-based index of biotic integrity for wadeable streams in Southern China. *Environmental Management* 52(4): 995-1008.

Johnson, S.L. & Ringler, N.H. 2014. The response of fish and macroinvertebrate assemblages to multiple stressors: A comparative analysis of aquatic communities in a perturbed watershed (Onondaga Lake, NY). *Ecological Indicators* 41: 198-208.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. *Fisheries* 6(6): 21-27.

Kottelat, M. 2013. The fishes of the inland waters of Southeast Asia: A catalogue and core bibliography of the fishes known to occur in freshwaters, mangroves and estuaries. *Raffles Bulletin of Zoology* Suppl.27: 1-663.

Krause, J.R., Bertrand, K.N., Kafle, A. & Troelstrup, N.H. 2013. A fish index of biotic integrity for South Dakota's Northern Glaciated Plains Ecoregion. *Ecological Indicators* 34: 313-322.

Li, T., Huang, X., Jiang, X. & Wang, X. 2018. Assessment of ecosystem health of the Yellow River with fish index of biotic integrity. *Hydrobiologia* 814(1): 31-43.

Naubi, I., Zardari, N.H., Shirazi, S.M., Ibrahim, N.F.B. & Baloo, L. 2016. Effectiveness of water quality index for monitoring Malaysian river water quality. *Polish Journal of Environmental Studies* 25(1): 231-239.

Petesse, M.L., Siqueira-Souza, F.K., de Carvalho Freitas, C.E. & Petrere, M. 2016. Selection of reference lakes and adaptation of a fish multimetric index of biotic integrity to six amazon floodplain lakes. *Ecological Engineering* 97: 535-544.

Prabhakaran, K., Nagarajan, R., Merlin Franco, F. & Anand Kumar, A. 2017. Biomonitoring of Malaysian aquatic environments: A review of status and prospects. *Ecohydrology and Hydrobiology* 17(2): 134-147.

Rocha, F.C., Andrade, E.M. & Lopes, F.B. 2015. Water quality index calculated from biological, physical and chemical attributes. *Environmental Monitoring and Assessment* 187(1): 1-15.

Shah Alam Community Forest Society. 2022. *What Will Be Left of the Shah Alam Community Forest?* https://shahalamforest.org/wp/what-will-be-left-of-the-shah-alam-community-forest/

Stojković, M., Milošević, Đ. & Simić, V. 2011. Ichthyological integral indices, the history of development and possible application on rivers in Serbia. *Biologica Nyssana* 2(1): 59-66.

Terra, B.D.F., Hughes, R.M., Francelino, M.R. & Araújo, F.G. 2013. Assessment of biotic condition of Atlantic rainforest streams: A fish-based multimetric approach. *Ecological Indicators* 34: 136-148.

Umi Wahidah Ahmad Dini, Fatimah Md Yusoff, Ahmad Zaharin Aris, Zati Sharip & Sinev, A.Y. 2020. Planktonic microcrustacean community structure varies with trophic status and environmental variables in tropical shallow lakes in Malaysia. *Diversity* 12(9): 322.

Vile, J.S. & Henning, B.F. 2018. Development of indices of biotic integrity for high-gradient wadeable rivers and headwater streams in New Jersey. *Ecological Indicators* 90: 469-484.

Xiao, M., Bao, F., Wang, S. & Cui, F. 2016. Water quality and protection: Water-quality assessment of the Huaihe River segment of Bengbu (China) using multivariate statistical techniques. *Water Resources* 43(1): 166-176.

Zakaria-Ismail, M. & Fatimah, A. 2002. Fish index for classifying riverine ecosystem of Peninsular Malaysia. *Malaysian Journal of Science* 21(1&2): 1-7.

Zakaria-Ismail, M., Fatimah, A. & Khaironizam, M.Z. 2019. *Fishes of the Freshwater Ecosystems of Peninsular Malaysia*. Republic of Moldova: Lambert Academic Publishing.

Zhang, H., Shan, B. & Ao, L. 2014. Application of fish index of biological integrity (FIBI) in the Sanmenxia Wetland with water quality implications. *Journal of Environmental Sciences (China)* 26(8): 1597-1603.

*Corresponding author; email: rohasliney@upm.edu.my