Maejo Int. J. Sci. Technol. **2021**, *15*(03), 261-272

Maejo International
Journal of Science and Technology

ISSN 1905-7873
Available online at www.mijst.mju.ac.th

Full Paper

Application of fish-based index of biotic integrity to assessment of aquatic resource of Mae Ngad Somboonchon Reservoir, Thailand

Thapanee Pholdee*, Bunyat Montien-art, Jongkon Promya and Apinun Suvarnaraksha

Faculty of Fisheries Technology and Aquatic Resources, Maejo University, Chiang Mai, Thailand

* Corresponding author, e-mail: pondeeloei@gmail.com

Received: 10 November 2020 / Accepted: 16 November 2021 / Published: 30 November 2021

Abstract: A fish-based index of biotic integrity was applied to the assessment of aquatic resource of Mae Ngad Reservoir, Chiang Mai, Thailand. Surveys of the fish assemblage were conducted in 2002, 2004 and 2019. Eighteen metrics were designed and applied, viz. species richness, diversity index, dominant index, hybrid species, native species, alien species, omnivores, insectivores, carnivores, pelagic species, water-column species, bottom species, rocky-and-stone species, sandy-and-gravel species, silty-to-muddy species, intolerant species, tolerant species and anomalies. Scores for each of the 18 metrics were summarised to provide an index value for each fish community sample, which can be used to determine the relative health of the site. In 2019 it was found that the fish data consisted of 10 families and 20 species. The overall fish-based index for Mae Ngad Somboonchon Reservoir in 2019 was 38, indicating fair biotic integrity.

Keywords: ecological indicators, fish-based index of biotic integrity, species richness indicator, habitat quality, Mae Ngad Somboonchon Reservoir, Thailand

---

INTRODUCTION

Anthropogenic disturbances of watersheds, streams and lakes, such as urbanisation and agriculture, have altered water bodies not only in Thailand but also worldwide [1]. Historically, water quality has been primarily determined from measurements of chemical and physical characteristics [2], but such assessments may not adequately reflect the impact of human disturbance on the biotic integrity of a system [2, 3]. The monitoring of biological communities is mainly encouraged because it has been accepted that biological communities respond to long-term environmental conditions and reflect accurately the ‘health’ of the ecosystem, resonating the impact of the synergy of many pressures [4].

The index of biotic integrity (IBI) has been developed as an effective tool for monitoring the health of an aquatic ecosystem. The IBI describes associations between human influences and biological attributes [5] and is useful for estimating the aquatic ecosystem health, as the structures of fish communities principally reflect abiotic conditions [6]. The IBI has been developed as an effective indicator for monitoring aquatic ecosystem integrity. Although its origin was as a tool for biological monitoring of running waters, more recently the IBI has been modified and adapted for use as an assessment tool for reservoir monitoring. The IBI was first constructed using fish-based indices to numerically assess the health of aquatic ecosystems because fish are particularly advantageous as biological indicators. Fish communities are a reflection of the cumulative effects of natural and human-caused influences on rivers and other water resources. The communities are composed of a wide array of trophic guilds and enable the identification of watershed impairments of aquatic food webs [2], predictably responding to changes in many abiotic factors including organic enrichment, habitat transition, chemical toxicity, and transformed landscape structure [3, 7].

The IBI is created based on the expected fish communities under relatively undisturbed conditions [2]. Initially, it was applied to assess the biotic integrity of surface water in Midwestern streams and rivers [3]. It includes metrics on the number, composition, tolerance and health of the species assessed [8]. In early studies it was modified for regional usage; recently, it has been considered an acceptable tool for the evaluation of ecosystem health and also has been widely modified in world-wide usage [9]. Most fish-based indices are derived from the original IBI and are popular in the US [2, 6, 10] Canada [11], New Zealand [12], Africa [13], Brazil [14] and Europe [4, 10, 15]. In Asia the fish based index is available only from Pakistan [16], Japan [5], China [17-19], Taiwan [20] and Thailand [21, 22]. Most adaptations are according to the suggestions of Karr [3] and Karr et al. [7], where alterations in the composition of fish assemblage are used to assess the effects of anthropogenic perturbations.

Mae Ngad Somboonchon Reservoir is a small artificial reservoir in Mae Taeng district, Chiang Mai (Thailand), which is classified as an earth-fill type structure. It was constructed between 1977 -1984 on Mae Ngad River. The development of a lentic fish-based IBI is timely in the reservoir since recent changes in land use may influence the water quality of the reservoir. Continued watershed degradation is influenced by urban and agricultural activities and tourism, all increasing the consumption of water resources as well as the degradation of natural processes. The reservoir has great economic and biological values; an investigation of fish assemblage in the reservoir was conducted in 2004 [23], the study focussing on the diversity of fish. There has been no published study related to the evaluation of ecosystem health based on fish assemblage. Therefore, the aims of the present study are to develop and apply the fish IBI to assess the ecological health quality of a stagnant water ecosystem in this reservoir and to provide a baseline for future water quality assessment.

METHODOLOGY

Study Area

Mae Ngad Somboonchon Reservoir is located in Mae Taeng district, Chiang Mai province in northern Thailand. It was constructed for hydroelectric power and irrigation by damming a first-order stream, the Mae Ngad. Its elevation ranges from 412 to 425 m a.s.l. with a catchment area of

1309 km^2. The dam wall is 59 m high and 1,950 m long, and the reservoir has a surface area of 16 km^2. The mean water depth of the reservoir is 30 m overlaying a mixture of clay and silt [23].

Fish Data

The databases of Maejo Aquatic Resources Natural Museum at Maejo university, Chiangmai, Thailand, which include fish community data of the Mae Ngad Reservoir, were used for selecting metrics, estimating reference values, and setting scoring criteria for deviation from reference conditions. Fish data were collected from 11 different sites in the reservoir (Figure 1 and Table 1) based on surveys undertaken between October 2002 to September 2003 (development data) [23] and in 2019 (independent validation data).

The fish assemblage data were obtained using electrofishing equipment (Honda EM 650, American Honda Motor Co., USA) in 100-m^2 area per sampling site and by fishers using gillnets of 6- , 15- and 30-cm mesh sizes. Each fish in each catch was identified on site, measured for total length (mm), counted and released back. Unidentified species from the survey were preserved in 10% formalin for 1 month and transferred to serially diluted ethanol (30% and 50%) and finally preserved in 70% ethanol [24]. Specimens were deposited at the Maejo Aquatic Resources Natural Museum for re-checking before being taxonomically identified to the species level following Nelson [25], So [26], Suvarnaraksha et al. [27] and Suvarnaruksha [23, 24, 28, 29].

Development and Application of Fish Index

The fish were attributed to the guild level based on literature review [2, 21, 23] and were categorised according to their origin, trophic composition, habitat composition, and tolerance to environmental degradation. The classification of a species as 'native' and 'exotic or local alien' was based on historical and archaeological records according to Suvarnaraksha [23] and Vithayanon [30]. Species were categorised according to their tolerance to oxygen deficiency and habitat structure degradation such as shoreline bank modifications [31].

The trophic composition was divided into three groups: (1) omnivore, with a diet of usually more than 25% plant material and more than 25% animal material [3, 7, 10, 32]; (2) insectivore, with a diet of nymphs, insects or small organisms on the surface layer of the substratum and associated organic matter [33]; and (3) carnivore, with a diet of usually more than 75% animal material [10, 32]. Habitat composition included pelagic species, water-column species, bottom species, and rocky-and-stone, sandy-and-gravel and silty-to-muddy species based on direct observation related to the literature [10, 21, 24, 28]. Tolerance and intolerance were based on information from the literature [21, 24, 28, 34].

Scoring Rubric

Metrics were scored as 5, 4, 3, 2 or 1. The scores were compared based on percentiles obtained in 2004 between the reference sampling site group [23] and the test sampling site group (fish data collected in 2004) in each season (rain, winter and summer). Values of evaluation results were determined for the 75^{th} percentile (for a metric where a high value indicated high quality) or the 25^{th} percentile (for a metric where a low value indicated high quality). Values less than the 25^{th} percentile were scored as 1 to represent 'very poor'; values over the 25^{th} percentile but less than the mean were scored as 2 to represent 'poor'; values between the 25^{th} and 75^{th} percentiles were scored as 3 to represent 'fair'; values over the mean but less than the 75^{th} percentile were scored as 4 to

Maejo Int. J. Sci. Technol. **2021**, *15*(03), 261-272

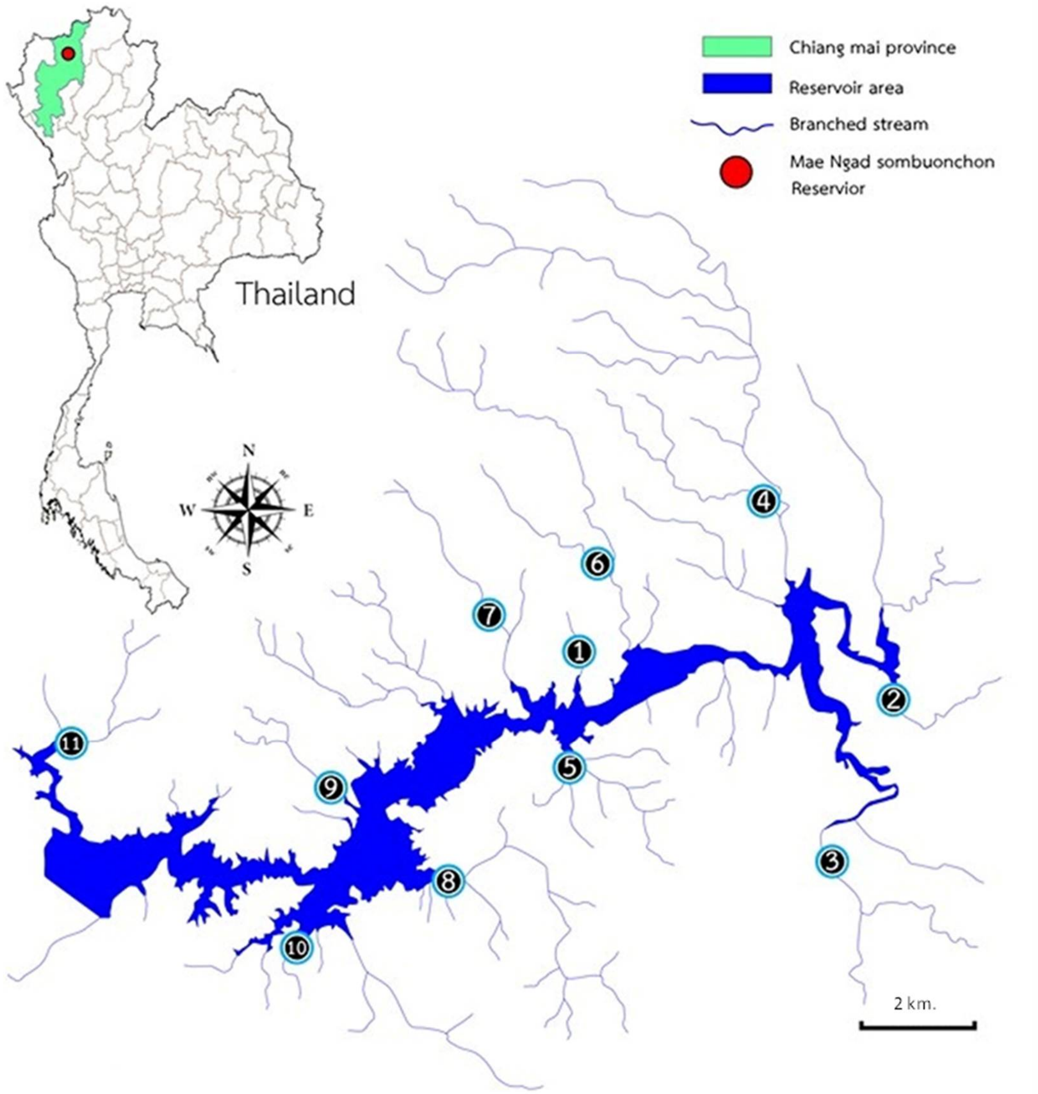

Figure 1. Sampling sites (1-11) in Mae Ngad Somboonchon Reservoir (Chiang Mai, Thailand)

Table 1. Description of sampling sites [23]

No.	Site name	Coordinate	Description of bottom type	Elevation (m a.s.l.)
1.	Paeplatip	19° 11' 55.7"N 99° 07' 07.6"E	M, S	417
2.	Huay Maesoon	19° 14' 46.8"N 99° 10' 15.5"E	S, G	425
3.	Huay Maecord	19° 09' 54.7"N 99° 04' 54.1"E	S, G	415
4.	Huay Maepaeng	19° 14' 33.9"N 99° 08' 58.8"E	M	416
5.	Huay Mae-gwua	19° 11' 12.7"N 99° 07' 03.6"E	M	423
6.	Huay Ton-Tong	19° 12' 46.6"N 99° 07' 28.6"E	S	418
7.	Huay Tonyang	19° 12' 01.3"N 99° 06' 23.7"E	R	421
8.	Huay Maejok	19° 10' 04.9"N 99° 05' 45.5"E	M, S	420
9.	Huay Pha-Gup	19° 10' 52.1"N 99° 04' 47.8"E	R, G, S	419
10.	Huay Punwa	19° 09' 25.6"N 99° 04' 22.3"E	M, S	415
11.	Huay Chomphu	19° 11' 16.9"N 99° 02' 05.7"E	S,G	415

Note: Nos. indicate locations shown in Figure 1; R=Rocky, G=Gravel, S =Sand, M=Muddy represent 'good'; and values greater than or equal to the 75th percentile were scored as 5 to represent 'excellent'.

The fish IBI metric for the reservoir was an adaptation of Karr's original IBI [3] and required deletion or inclusion adjustments of new metrics for subtropical conditions. However, the IBI conceptual model was suited to such modifications [3, 21, 32, 35].

Fish IBI Categories and Metrics

According to the studies of Karr [3], Karr et al. [7], Liu [18] and Shi [19], the scores were classified into 6 grades indicating 'excellent' to 'no fish', and from a high score to low score whose values ranged from 0 to 60. In this experiment the underlying concepts of the hypothetical reference score method [8, 17, 18, 36, 37] were adopted. The metrics were designed from the characterisation of the 67 fish species [23]; separate assemblage metrics and two categories were used based on biological parameters and environmental parameters.

The biological parameters comprised diversity parameters (species richness, diversity index and dominant index), fish status (hybrid species, native species and alien species), and trophic composition (per cent of omnivores, insectivores and carnivores). Environmental parameters consisted of habitat composition (pelagic species, water-column species, bottom species, rocky-and -stone species, sandy-and-gravel species, and silty-to-muddy species) and fish health (intolerant species, tolerant species and anomalies). In total, 18 metrics were used in this study.

RESULTS AND DISCUSSION

Fish Assemblage

The characteristics of fish assemblage consisting of 14,505 individual fish samples belonging to 22 families and 67 species collected from 11 sampling sites in Mae Ngad Reservoir were described in 2004 based on fish status, habitat and trophic guild [23].The survey identified species under the following categories: tolerant (23), intolerant (44), omnivore (16), insectivore (35), carnivore (16), pelagic (8), water-column (26), bottom (10), rocky-and-stone (4), sandy-and-gravel (7), silty-to-muddy (12), hybrid (2), native (56) and alien (8). From that time until 2019, the Mae Ngad Reservoir fish diversity decreased to 20 species (*Barilius koratensis, Danio albolineatus, Rasbora paviana, Ceratocarra cambodgiensis, Hampala macrolepidota, Labeo chrysophekadion, Mystacoleucus obtusirostris, Neolissochilus stracheyi, Puntioplites proctozysron, Puntius brevis, Systomus rubripinnis, Syncrossus beauforti, Schistura sexcauda, Pangasianodon hypophthalmus, Hemibagrus spilopterus, Amblyceps foratum, Clarias* (hybrid), *Oreochromis niloticus, Parambassis siamensis* and *Channa micropeltes*) in 10 families.

Scoring of Mae Ngad Reservoir

In this study we used a 1, 2, 3, 4 and 5 scaling system. For these metrics, a frequency distribution of value was generated. Finally, scored metrics were summed and then scaled as necessary to produce an index with scores ranging from 18 (worst) to 90 (best). For interpreting the final scores, the scoring classes for environmental quality were: 18 (very poor condition), 19–36 (poor condition), 37–54 (fair condition), 55–72 (good condition) and 73–90 (very good condition). The classification of biological integrity and the associated attributes corresponding to the IBI scores based on the sum ratings are shown in Table 2.

Maejo Int. J. Sci. Technol. **2021**, *15*(03), 261-272

Table 2. Detailed attributes of biological integrity associated with each IBI category

Category	IBI score	Attribute
Excellent	73-90	Similar to unimpacted sites in the region with minimal or no human activity in the reservoir
Good	55-72	Species richness somewhat below expectation, loss of most intolerant forms
Fair	37-54	Signs of additional deterioration including fewer intolerant forms
Poor	19-36	Dominated by omnivores, alien species and pollution-tolerant and habitat generalists; few top carnivores; growth rate and condition factors commonly depressed; hybrids often present
Very poor	18	Few fish, mostly alien species or very tolerant forms

Fish IBI Evaluation

The fish IBI index systems were established for Mae Ngad Reservoir based on the data given in 2004 [23] using the scoring method described above. The results are presented in Table 3. The percentiles of data in 2004 were used for assessment of data of the present study. The data are summarised in Table 4 and the evaluation results are summarised in Table 5. The present study provides a good perspective of the community structure of fish and fish assemblage, which can act as an indicator of anthropogenic stress and its impact on the reservoir.

Metrics 1-3 (species diversity) have a diversity score of 1, which is lower than in 2004, indicating low species richness and a lack of variability in food supplies, while a low diversity index also reflects environmental degradation through natural or human activity [27]. These metrics have been used in several studies of lakes such as Shihoudian Lake in China [19].

Metric 4 (native species) has a score of 2, which is lower than in 2004, as was reported also by Rayan and Ngamsnae [21] who examined fish IBI values in Nong Han Wetland where the score for native species was 3. Native species decrease with increasing environmental degradation and non-native species represent biological degradation. They feed and reproduce in a benthic habitat with stone, rocks and gravel and surrounded by large rocks [27]. This metric was used in several investigation including the biotic indicators for the Great Lakes coastal wetlands [6] and those by Araujo [38], Raburu and Masese [32], and Pinto and Araújo [39].

Metrics 5-6 (alien species and hybrid species) provide estimates of the increase in environmental degradation [24], specifically the preying on eggs and juveniles of native fish species, which can have a major impact on native fish assemblage [10]. In this study we separate alien species and hybrid species into two metrics instead of using Karr's [3] percentage of hybrid individuals. Alien species such as the *Clarias* hybrid (*C. macrocephalus* x *C. gariepinus*) are generally accidentally released from fish farms [38], while *Channa micropeltes*, which has not been reported in the reservoir, is used as a sport fish. This metric is scored as 2 in the present study. The increase in the number of alien species is in accordance with the findings of Wolter [40], suggesting that such changes result from prolonged anthropogenic effects on the fish community structure [10].

Metrics 7-9 (trophic composition) are an important category in assessing biotic integrity using the feeding habitat [38, 39]. In this study we select 3 metrics (omnivore, insectivore and carnivore) following Karr [7]. The current scores are 4 for both the percentages of omnivore species and insectivore species and 2 for carnivore species. The omnivore species are in high abundance at polluted sites since these fish species comsume a wide range of food, both plants and animals, and

Table 3. Classification of fish assemblage in terms of origin, trophic group, tolerance, habitat and status according to International Union for Conservation of Nature (IUCN)

Family/Species	Origin	Trophic group	Tolerance	Habitat	IUCN status
Cypriniformes					
Cyprininae					
Barilius koratensis (Smith, 1931)	Na[7]	IN[1, 2, 3]	IT[7]	PG[3]	LC
Danio albolineatus (Blyth, 1860)	Na[7]	IN[1, 2, 3]	TO[7]	PG[3]	LC
Rasbora paviana Tirant, 1885	Na[7]	IN[1,2, 3]	IT[7]	PG[3]	LC
Ceratogarra cambodgiensis (Tirant 1884)	Na[7]	ON[1, 2, 3]	IT[6]	RS[7]	LC
Hampala macrolepidota Kuhl & van Hasselt 1823	Na[7]	CA[1, 2, 3, 5]	IT[7]	WC[3]	LC
Labeo chrysophekadion (Bleeker, 1849)	Na[7]	ON[1, 2]	IT[7]	BT[3]	LC
Mystacoleucus obtusirostris (Valenciennes, 1842)	Na[7]	IN[2, 3]	TO[3, 6]	WC[3]	LC
Neolissochilus stracheyi (Day, 1871)	Na[7]	ON[1, 2]	IT[6]	WC[3]	LC
Puntioplites proctozysron (Bleeker, 1865)	Na[7]	ON[1,2,5]	IT[7]	WC[3, 5]	-
Puntius brevis (Bleeker, 1849)	Na[7]	IN[1,2,5]	IT[7]	WC[3, 5]	LC
Systomus rubripinnis (Valenciennes, 1842)	Na[7]	IN[1, 2, 5]	IT[5]	WC[3, 5]	-
Botiidae					
Syncrossus beauforti (Smith, 1931)	Na[7]	IN[1, 2, 3]	IT[7]	SM[7]	NT
Nemacheilidae					
Schistura sexcauda (Fowler, 1937)	Na[7]	IN[1, 2,3]	IT[6]	SM[7]	LC
Pangasiidae					
Pangasianodon hypophthalmus (Sauvage, 1878)	Al[1]	ON[1]	IT[7]	BT[3]	EN
Bagridae					
Hemibagrus spilopterus Ng & Rainboth, 1999	Na[7]	CA[3]	IT[7]	BT[3]	LC
Amblycipitidae					
Amblyceps foratum Ng & Kttlelet, 2000	Na[7]	CA[3, 3]	IT[7]	SG[3]	LC
Clariidae					
Clarias hybrid	Hy[1], Al[2,5]	CA[1, 2]	TO[7]	SG[7]	-
Cichliformes					
Cichlidae					
Oreochromis niloticus (Linnaeus, 1758)	Al[1,2,3,5]	ON[1, 2]	TO[5]	WC[5]	LC
Anabantiformes					
Channidae					
Channa micropeltes (Cuvier, 1831)	Al[2,3]	CA[2, 3]	TO[2]	WC[3]	LC
Perciformes					
Ambassidae					
Parambassis siamensis (Fowler, 1937)	Na[7]	IN[1, 2, 5]	TO[5]	WC[3]	LC

Note: Na=Native, Al=Alien, Hy=Hybrid; Trophic group: ON=omnivore, IN=insectivore, CA=carnivore; Tolerance: IT=intolerant, TO=tolerant.; Habitat: PG=pelagic, WC=water-column, BT=bottom, RS=rocky-and-stone, SG=sandy-and- gravel, SM=silty-to-muddy.; IUCN Red List status: DD=data deficient, LC=least concern, NT=near threatened, NE=not evaluated, EN=endangered
Superscript numbers correspond to the following references: 1. Suvarnaraksha [23], 2. Suvarnaraksha [24], 3. Suvarnaraksha [28], 4. Vithayanon [30], 5. Rayan and Ngamsnae [21], 6. IUCN Red List [34], and 7. Information from expert.

Maejo Int. J. Sci. Technol. **2021**, *15*(03), 261-272

Table 4. Metric scores for Mae Ngad Reservoir

Metric	Scoring				
	5	**4**	**3**	**2**	**1**
No. of species (richness)	>47.00	37–47	27–36	22–26	<22
Diversity index	>2.93	2.65–2.93	2.57–2.64	2.30–2.56	<2.29
Dominant index	>0.33	0.29–0.33	0.27–0.28	0.25–0.26	<0.24
% Native sp.	>99.67	98.22–99.67	95.63–98.21	65.99–95.62	<65.98
% Alien sp.	<1.79	1.80–4.49	4.50–4.52	4.53–17.01	>17.01
% Hybrid sp.	<1.33	1.33–2.65	2.66–3.90	3.91–5.71	>5.71
% Omnivore	<0.85	0.85–3.71	3.72–5.36	5.37–112.5	>12.5
% Insectivore	>95.89	87.98–95.89	75.15–87.97	63.65–75.14	<63.64
% Carnivore	>86.67	27.24–86.67	18.14–27.23	4.23–18.13	<4.22
% Pelagic sp.	>65.50	27.52–65.50	16.07–27.51	5.67–16.07	<5.66
% Water-column sp.	<34.49	34.48–55.31	55.32–77.57	77.58–98.63	>98.63
% Bottom sp.	>19.64	2.99–19.64	2.84–2.99	0.78–2.83	<0.77
% Rocky-and-stone sp.	>35.44	17.83–35.44	10.04–17.82	1.97–10.03	<1.96
% Sandy-and-gravel sp.	>77.93	40.42–77.93	25.03–40.41	6.91–25.02	<6.90
% Silty-to-muddy sp.	>13.33	4.45–13.33	3.05–4.44	0.84–3.04	<0.83
% Intolerant sp.	>88.94	52.52–88.93	37.51–52.51	22.26–37.50	<22.25
% Tolerant sp.	<47.59	47.60–63.51	63.52–78.15	78.16–97.26	>97.26
No. of anomalies	<1	1–2	3	4	>4

Note: Results data are calculated using the metric score for Mae Ngad Reservoir in 2004 [23].

Table 5. Evaluation results of Mae Ngad Reservoir

No.	Metric	Result	Score
1	No. of species (richness)	20	1
2	Diversity index	0.67	1
3	Dominant species index	0.78	5
4	% Native sp.	90.38	2
5	% Alien sp.	5.56	2
6	% Hybrid sp.	4.06	2
7	% Omnivore	2.94	4
8	% Insectivore	84.14	4
9	% Carnivores	12.92	2
10	% Pelagic sp.	2.98	1
11	% Water-column sp.	90.06	2
12	% Bottom sp.	0.98	2
13	% Rocky-and-stone sp.	3.37	2
14	% Sandy-and-gravel sp.	1.94	1
15	% Silty-to-muddy sp.	0.68	1
16	% Intolerant sp.	23.11	2
17	% Tolerant sp.	76.89	3
18	No. of anomalies	6	1
			IBI score = 38

detritus or organic matter [39]. The disruption to the food base caused by environmental degradation has been found to lead to a higher percentage of omnivores and a decrease in the proportions of insectivores and carnivores [20, 21, 32]. This group of metrics was frequently used in the literature [10, 20, 32, 33, 39].

Metrics 10-15 (habitat composition) are based on the percentages of pelagic species that are active swimmers living on the surface and feeding on surface insects. The water-column species explain some species decrease with increasing degradation such as family Centrarchidae in Illinois; they are particularly sensitive to the degradation of pool habitat [7]. The percentages of bottom species, rocky-and-stone species, sandy-and-gravel species and silty-to-muddy species show that some species are sensitive to siltation and benthic oxygen depletion because they feed and reproduce in benthic habitat [22]. The use of benthic species in the development of lake indices is less common [15]. However, benthic species are sensitive to poor water quality, low oxygen concentration, and toxic substances deposited in the sediment since they use this habitat to feed and spawn, and margin erosion also impairs benthic species through substrate homonisation [39]. Many smaller species live among rocks and feed on algae, insects or invertebrates that grow on the rocks or pebbles, for example *Ceratogarra cambodgiensis* and *Schistura sexcauda.*

Metric 16 (intolerant species) has a proposed score of 2, which is lower than the past record. This indicates that the intolerant species decrease when the quality of water in the reservoir becomes poorer. This metric does not show a relationship with pressure from the environment and humans. The catchability of many intolerant species is relatively low, especially benthic species, because of the relatively low mobility of many intolerant species [15]. We use this metric for the first time to evaluate the health of the reservoir because the base data collected in 2004 [23] showed many intolerant species.

Metric 17 (tolerant species) has a score of 3 (Nong Han Wetland had the score of 1 for tolerant species [21]), which indicates that the tolerant species increase when the reservoir water is poor in quality due to degradation of habitat for insects or invertebrates that provide a food source for other species. For example, the tolerant Black Margin Spiny Barb (*Mystacoleucus obtusirostris*) can increase in relative abundance in degraded streams and might change from an incidental to a dominant species [28, 34]. It is therefore an appropriate species for this metric which evaluates the degree to which typically tolerant species dominate the community. Also, *Oreochromis niloticus* is generally considered to be tolerant to physico-chemical changes while *Clarias* spp. are known to be tolerant to pollution [32]. In another study *Lepidocephalichthys hasselti* increased upstream, indicating the poor quality of the river studied due to degradation of the substrate that provided habitat for insects or invertebrates that acted as a food supply for other species [24]. In the current study tolerant species are widely distributed from the upper to the lower reaches of the reservoir, making them useful indicators of poor water and environmental quality [32].

Metric 18 (the number of anomalies) is used to depict the health and condition of individual fish. This occurs infrequently or is absent from minimally impacted reference sites but does occur frequently downstream of contaminated point sources and in areas where toxic chemicals are concentrated. This is an excellent measure of the sub-acute effects of chemical pollution and the aesthetic value of game and non-game fish [21]. The current study produces a proposed score of 2, which differs from Nong Han Wetland where the score was 5 [21].

CONCLUSIONS

Compared with 67 fish species found in 2004, the present study found 20 fish species in the reservoir. The species richness, diversity index, dominant species index, native species, intolerant species, bottom species, rocky-and-stone species, sandy-and-gravel species and silty-to-muddy species have all decreased. However, alien species, hybrid species, omnivores, insectivores and carnivores have increased. Species richness decline reflects degradation due to natural events, human activity and low variability of food supplies. Low diversity index also reflects degradation from human activity.

The mean IBI value for Mae Ngad Reservoir is 38, which implies that it is dominated by omnivores, alien species, pollution-tolerant species and habitat generalists with few top carnivores. The growth rates are commonly depressed and hybrids are often present. Overall, these conditions result in a fair score for biotic integrity.

ACKNOWLEDGEMENTS

T. P. is grateful to Thailand Research Fund for supporting her Ph.D. study through the Royal Golden Jubilee Programme (Grant PHD/0132/2558). The Faculty of Fisheries Technology and Aquatic Resources (Maejo University) provided laboratory facilities.

REFERENCES

1. J. L. Nel, D. J. Roux, R. Abell, P. J. Ashton, R. M. Cowling, J. V. Higgins, M. Thieme and J. H. Viers, “Progress and challenges in freshwater conservation planning”, *Aquat. Conserv.*, **2009**, *19*, 474-485.
2. D. T. Nelson, “Development and application of a fish-based index of biotic integrity for lakes in eastern South Dakota”, *Master Thesis*, **2017**, South Dakota State University, USA.
3. J. R. Karr, “Assessment of biotic integrity using fish communities”, *Fisheries*, **1981**, *6*, 21-27.
4. O. Petriki, M. Lazaridou and D. C. Bobori, “A fish-based index for the assessment of the ecological quality of temperate lakes”, *Ecol. Indic.*, **2017**, *78*, 556-565.
5. R. Lopa, H. Hayashi, Y. Shimatani and J. Nakazima, “Applying a fish biological integrity index for restoration plan in small-sized river: Case study in the Kamisaigo River”, Proceedings of 6th International Conference on Sustainable Water Resources Management, **2011**, Riverside (CA), USA.
6. M. J. Cooper, G. A. Lamberti, A. H. Moerke, C. R. Ruetz, D. A. Wilcox, V. J. Brady, T. N. Brown, J. J. H. Ciborowski, J. P. Gathman, G. P. Grabas, L. B. Johnson and D. G. Uzarski, “An expanded fish-based index of biotic integrity for Great Lakes coastal wetlands”, *Environ. Monit. Assess.*, **2018**, *190*, Art. no.580.
7. J. R. Karr, K. D. Fausch, P. L. Angermeier, P. R. Yant and I. J. Schlosser, "Assessing Biological Integrity in Running Waters. A Method and Its Rationale”, Illinois Natural History Survey, Champaign, **1986**, p.28.
8. G. B. G. Souza and M. Vianna, “Fish-based indices for assessing ecological quality and biotic integrity in transitional waters: A systematic review”, *Ecol. Indic.*, **2020**, *109*, Art.no. 105665.
9. M. J. Lydy, A. J. Strong and T. P. Simon, “Development of an index of biotic integrity for the Little Arkansas River Basin, Kansas”, *Arch. Environ. Contam. Toxicol.*, **2000**, *39*, 523-

530.
10. M. Lenhardt, G. Markovic and Z. Gacic, "Decline in the index of biotic integrity of the fish assemblage as a response to reservoir aging", *Water Resour. Manag.*, **2009**, *23*, Art.no. 1713.
11. C. Stevens and T. Council, "A fish-based index of biological integrity for assessing river condition in central Alberta", *Technical Report*, **2008**, Alberta Conservation Association, Canada.
12. M. K. Joy and R. G. Death, "Application of the index of biotic integrity methodology to New Zealand freshwater fish communities", *Environ. Manage.*, **2004**, *34*, 415-428.
13. B. Hugueny, S. Camara, B. Samoura and M. Magassouba, "Applying an index of biotic integrity based on fish assemblages in a West African river", *Hydrobiologia*, **1996**, *331*, 71-78.
14. B. F. Terra and F. G. Araújo, "A preliminary fish assemblage index for a transitional river-reservoir system in southeastern Brazil", *Ecol. Indic.*, **2011**, *11*, 874-881.
15. C. Argillier, S. Caussé, M. Gevrey, S. Pédron, J. De Bortoli, S. Brucet, M. Emmrich, E. Jeppesen, T. Lauridsen, T. Mehner, M. Olin, M. Rask, P. Volta, I. J. Winfield, F. Kelly, T. Krause, A. Palm and K. Holmgren, "Development of a fish-based index to assess the eutrophication status of European lakes", *Hydrobiologia*, **2013**, *704*, 193-211.
16. A. Qadir and R. N. Malik, "Assessment of an index of biological integrity (IBI) to quantify the quality of two tributaries of river Chenab, Sialkot, Pakistan", *Hydrobiologia*, **2009**, *621*, 127-153.
17. K. Chen, Y. Jia, X. Xiong, H. Sun, R. Zhu and Y. Chen, "Integration of taxonomic distinctness indices into the assessment of headwater streams with a high altitude gradient and low species richness along the upper Han River, China", *Ecol. Indic.*, **2020**, *112*, Art.no. 106106.
18. T. Li, X. Huang, X. Jiang and X. Wang, "Assessment of ecosystem health of the Yellow River with fish index of biotic integrity", *Hydrobiologia*, **2018**, *814*, 31-43.
19. X. Wang, B. Zheng, L. Liu and L. Wang, "Development and evaluation of the lake multi-biotic integrity index for Dongting Lake, China", *J. Limnol.*, **2015**, *74*, 594-605.
20. T. J. Hu, H. W. Wang and H. Y. Lee, "Assessment of environmental conditions of Nan-Shih stream in Taiwan", *Ecol. Indic.*, **2007**, *7*, 430-441.
21. S. Rayan and P. Ngamsnae, "Application of Fish Index of Biotic Integrity (Fish-IBI) for Quality Evaluation of Nong Han Wetland", *Rajamangala Univ. Technol. Tawan-ok Res. J.*, **2020**, *13*, 59-70 (in Thai).
22. S. Phaewcham, S. Tongnunui, S. Mekprayoon, W. Pakdee, S. Kulkanya, and K. Lommetta, "Modified fishes based on index of biotic integrity (IBI) for a bioassessment model of water quality in eastern watersheds, Thailand", *Annual Report*, **2010**, Rambhai-Barni Rajabhat University, Chanthaburi, Thailand (in Thai).
23. A. Suvarnaraksha, "Fish diversity in Mae Ngad Somboonchon Dam, Maetang district, Chiangmai province", *Annual Report*, **2004**, Maejo University, Chiang Mai, Thailand (in Thai).
24. A. Suvarnaraksha, "Biology of two keystone fish species and fish assemblage patterns and modeling approaches in tropical river basin: Case study of Ping River Basin, Thailand", *PhD Thesis*, **2011**, Ubon Ratchathani University, Thailand.
25. J. S. Nelson, T. C. Grande and M. V. H. Wilson, "Fish of the World", 5th Edn., John Wiley and Sons, New Jersey, **2016**, p.707.

Maejo Int. J. Sci. Technol. **2021**, *15*(03), 261-272
26. N. So, K. Utsugi, K. Shibukawa, P. Thach, S. Chhuoy, S. Kim, D. Chin, P. Nen and P. Chheng, "Fishes of Cambodian Freshwater Bodies", Inland Fisheries Research and Development Institute of the Fisheries Administration, Phnom Penh, **2019**. p.197.
27. A. Suvarnaraksha, S. Lek, S. Lek-Ang and T. Jutagate, "Fish diversity and assemblage patterns along the longitudinal gradient of a tropical river in the Indo-Burma hotspot region (Ping-Wang River Basin, Thailand)", *Hydrobiologia*, **2012**, *694*, 153-169.
28. A. Suvarnaraksha, "Fish of the Ping Basin", 1st Edn., Maejo University Press, Chiangmai, **2017**, p.292 (in Thai).
29. A. Suvarnaraksha, "Ichtyology", 2nd Edn., Smart Coating and Service, Chiangmai, **2018**, pp.329-390 (in Thai).
30. C. Vidthayanon, "Checklist of Freshwater Fish in Thailand", Phaya Printing and Publishing, Bangkok, **2017**, pp.48-122 (in Thai).
31. J. Breine, G. Van Thuyne and L. de Bruyn, "Development of a fish-based index combining data from different types of fishing gear. A case study of reservoirs in Flanders (Belgium)", *Belg. J. Zool.*, **2015**, *145*, 17-39.
32. P. O. Raburu and F. O. Masese, "Development of a fish-based index of biotic integrity (FIBI) for monitoring riverine ecosystems in the Lake Victoria drainage Basin, Kenya", *River Res. Appl.*, **2012,** *28*, 23-38.
33 M. A. Khalaf and M. Kochzius, "Changes in trophic community structure of shore fishes at an industrial site in the Gulf of Aqaba, Red Sea", *Mar. Ecol. Prog. Ser.*, **2002**, *239*, 287-299.
34 IUCN, "Assessment approaches for estimating biological integrity using fish assemblages", **2020**, http://www.iucnredlist.org (Accessed: September 2019).
35 S. Rayan and P. Ngamsnae, "Fish-Based Index of Biological Integrity (IBI) for Freshwater Ecosystems", *Burapha Sci. J.*, **2018**, *23*, 928-943 (in Thai).
36 J. HaRa, M. Mamun and K. G. An, "Ecological river health assessments using chemical parameter model and the index of biological integrity model", *Water*, **2019**, *11*, Art.no.1729.
37. A. S. Sapounidis, E. T. Koutrakis and I. D. Leonardos, "Fish-based river integrity index: A first attempt in developing a water quality index for the assessment of the Greek rivers", *Ecohydrol. Hydrobiol.*, **2019**, *19*, 620-628.
38. F. G. Araujo, I. Fichberg, B. C. T. Pinto and M. G. Peixoto, "A preliminary index of biotic integrity for monitoring the condition of the Rio Paraíba do Sul, southeast Brazil", *Environ. Manage.*, **2003**. *32*, 516-526.
39. B. C. T. Pinto and F. G. Araújo, "Assessing of biotic integrity of the fish community in a heavily impacted segment of a tropical river in Brazil", *Braz. Arch. Biol. Technol.*, **2007**, *50*, 489-502.
40. C. Wolter, J. Minow, A. Vilcinskas and U. A. Grosch, "Long-term effects of human influence on fish community structure and fisheries in Berlin waters: An urban water system", *Fish. Manag. Ecol.*, **2000**, *7*, 97-104.

© 2021 by Maejo University, San Sai, Chiang Mai, 50290 Thailand. Reproduction is permitted for noncommercial purposes.