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Nofrita
Departement of Biology, Faculty mathematic and natural sciences, Andalas University, Padang, West Sumatra, Indonesia

Dahelmi
Departement of Biology, Faculty mathematic and natural sciences, Andalas University, Padang, West Sumatra, Indonesia

Hafrijal Syandri
Faculty of fisheries and oseanografi, Bung Hatta University, Padang, West Sumatra, Indonesia.

Djong Hon Tjong
Departement of Biology, Faculty mathematic and natural sciences, Andalas University, Padang, West Sumatra, Indonesia

Correspondence
Nofrita
Departement of Biology, Faculty mathematic and natural sciences, Andalas University, Padang, West Sumatra, Indonesia

Morphological differentiation between Bilih Fish (Cyprinidae: *Mystacoleucus padangensis*, Blekeer) in Singkarak Lake and Anai River, West Sumatra, Indonesia

Nofrita, Dahelmi, Hafrijal Syandri, Djong Hon Tjong

Abstract
Mystacoleucus padangensis or bilih fish is an endemic species of Singkarak Lake. It has accidentally introduced to Anai River through water canal from Singkarak's hydroelectric system. Changes in habitat type from lentic to lotic have been suppossed to force this species to make morphological adaptation. This study aimed to compare morphological variation of bilih fish living at the two habitat types. We measured 29 morphological characters of 400 individuals from each habitat. We also measured 19 environmental parameters. To clarify differentiation between the two population and environmental parameters we used mann-whitney U- test. The results showed differentiation between 13 characters of Anai bilih fish, i.e. preorbital distance, eye diameter, postorbital distance, head length, prepelvic distance, predorsal distance, head depth, body depth, caudal fork length, caudal peduncle length (ventral), anal fin base length, pelvic and pectoral fin length. The differences between some environmental parameters could take responsible to the differentiation of bilih. This study supports that adaptation to the water velocity has caused anterior differences between the two populations.

Keywords: *Mystacoleucus padangensis*, Singkarak Lake, Anai River, morphology, differentiation

1. Introduction
Mystacoleucus padangensis is an endemic species of Singkarak lake, named by local people as bilih fish. In 1998, it was accidentally introduced to Anai River through water canal from Singkarak's hydroelectric system during early preparation. Since then, bilih population kept growing along Anai River. Population density of bilih fish in Anai was 4.606 ind/m, where Anai population was bigger than Singkarak [1].
After fourteen years Anai and Singkarak populations have been isolated to each other. Anai populations has been forced to adapt with water velocity. It is assumed that physical appearance of the fish has changed as a result of adaptation to the new environmental condition from lentic to lotic. Thus, the different environmental condition results morphological and genetic variations [2-4]. Further studies suggested that water velocity, physical and chemical parameters significant influenced fish morphology [5, 6]. More studies supported that morphological characters of fish shown their preference for a lentic or lotic habitat [7-12]. The different between environmental conditions in Anai River and Singkarak Lake may predict a significant morphological variation. As a lotic water, Anai River will form a specific pattern in morphology of bilih fish. This study aimed to compare morphological variation of bilih fish living in the two habitat types.

2. Materials and Methods
We collected 400 fish samples in January, May, July and November 2012 from Singkarak Lake (100 ° 31'20.1 "E and 00 ° 38'25.2" S), and 400 from Anai River (100 ° 20'20.4" E and 00 ° 38'10.4" S) (Fig. 1). We measured 29 morphological characters using digital calipers to an accuracy of 0.01 mm following Zahorska [13], modified from Strauss and Bookstein [14] (Fig. 2). We also measured 19 environmental parameters including air and water temperatures, water velocity, total suspended solid, total disolved solid, turbidity, conductivity, pH, biological oxygen demand, disolved oxygen, carbon dioxide free, nitrite, nitrate, ammonia, phosphate, sulfate, alkalinity, hardness, and altitude.

All morphological characters were standardized using standard length. Thus, all morphological and environmental parameters were compared between populations using Mann Whitney U-test ($p \leq 0.05$). Statistical analyses were done using SPSS vers. 16.

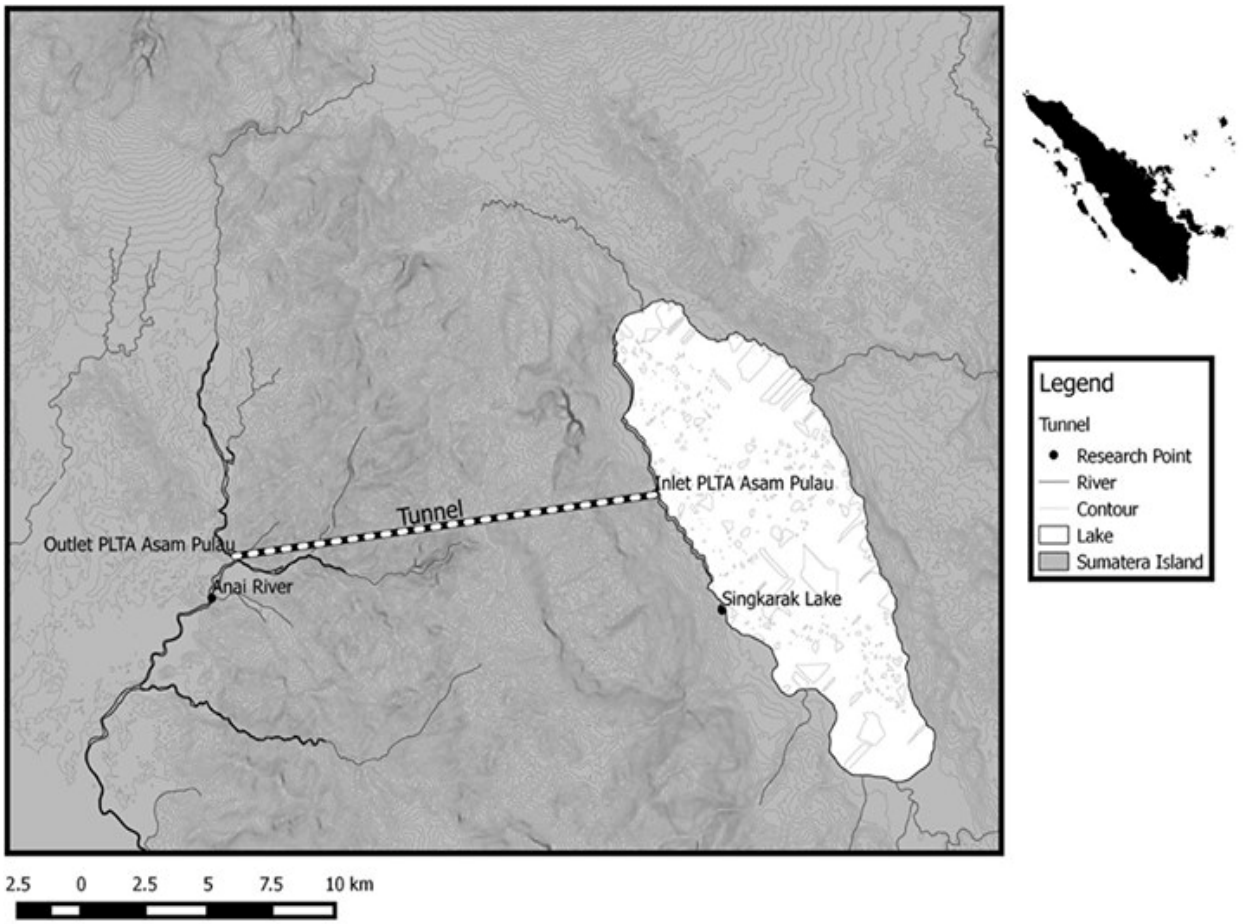

Fig 1: Location of study area in the Singkarak Lake (100 ° 31'20.1 "E and 00 ° 38'25.2" S) and Anai River (100 ° 20'20.4" E and 00 ° 38'10.4" S)

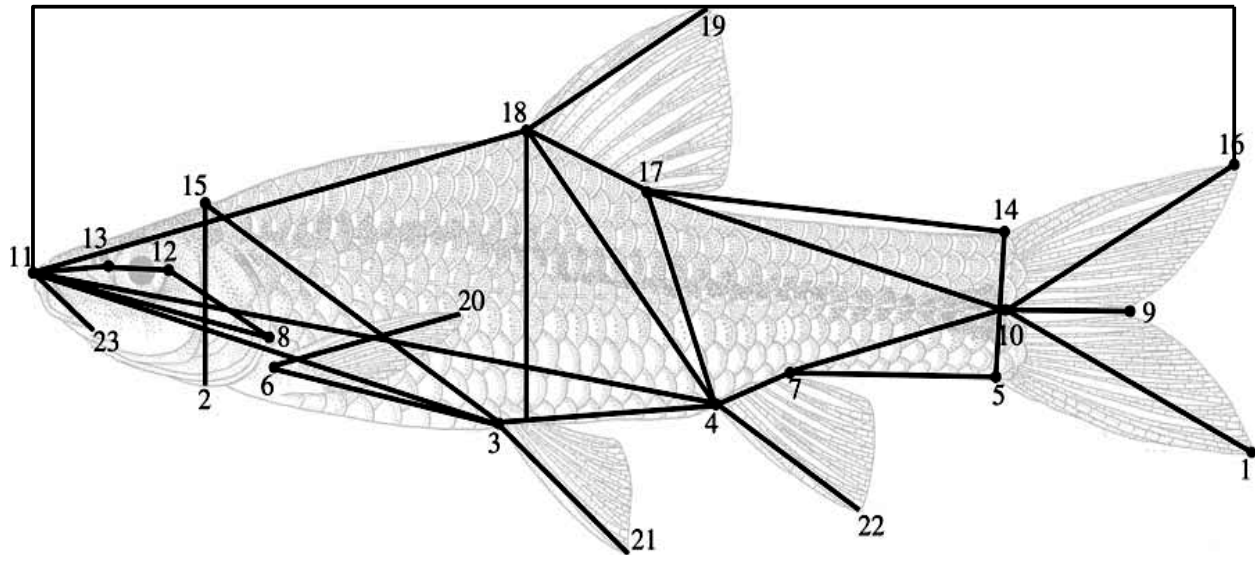

Fig 2: Scheme of of morphometric characters measurement: total length (TL) (11-16); head length (HL) (11-8); preorbital distance (PrOD) (11-13); eye diameter (ED) (13-12); postorbital distance (PoOD) (12-8); head depth (HD) (15-2); predorsal distance (PDD) (11-18); prepelvic distance (PPD) (11-3); preanal distance (PD) (11-4); pectoral fin-pelvic fin distance (PFPF) (6-3); pelvic fin-anal fin distance (PFAF) (3-4); body depth (BD) (18); dorsal fin (anterior end)-anal fin distance (DFAF) (18-4); dorsal fin (posterior end)-anal fin (DFPAF) (17-4); postdorsal distance (PoDD) (17-10); postanal distance (PAD) (7-10); caudal peduncle length (dorsal) (CPLD) (17-14); caudal peduncle length (ventral) (CPLV) (7-5); caudal peduncle depth (CPD) (14-5); dorsal fin base length (DFBL) (18-17); anal fin base length (AFBL) (4-7); pectoral fin length (PFL) (6-20); pelvic fin length (PL) (3-21); caudal upper lobe length (CULL) (10-16); caudal fork length (CFL) (10-9); caudal lower lobe length (CLLL) (10-1); dorsal fin length (DoFL) (18-19); anal fin length (AFL) (4-22); gape (G) (11-23) [13]

3. Results and Discussion

Singkarak's hydroelectric system has isolated two bilih populations of Anai River and Singkarak Lake for about 14 years. The result showed thirteen out of 29 morphological characters were significantly different between the two populations (Mann Whitney U-test. $p \leq 0.05$). (Table 1. Fig. 3). Anai population have bigger average size for all morphological characters than Singkarak population (Table 1). Fish population are very sensitive to environmental changes and quickly modify the morphological characters. The result of another study also found a clear relationship between shape and function in adaptation of Rainbow fish (*Melanotaenia* spp) living at river and lake habitats[2]. This study shown the differences of environmental parameters between Anai River and Singkarak Lake could take responsible to the differentiation of bilih fish.

Environmental parameters showed six significantly different parameters between river and lake habitat i.e: water temperature, water velocity, total suspended solid, total dissolved solution, conductivity and altitude (Mann Whitney U test, $p < 0.05$) (Table 2). As a lotic habitat type, Anai River has stronger water velocity factor than Singkarak Lake. These condition contribute to the occurrence of morphological changes found in Anai populations. Many authors have also reported that body, head and fins fish highly affected by water velocity[16,18]. Salmonids from stream environments typically have larger morphological characteristics than those from habitats with slower moving water [15-17].

Table 1: Mean value ± SD of the 29 morphology characters population Bilih Fish from Singkarak Lake and Anai River and Mann-Whitney U-Test (n = 800)

Characters	Singkarak Lake	Anai River	Mann Whitney U-Test
TL	82.57±8.76	85.57±13.88	0.355^{ns}
PrOD	4.40±0.53	4.72±0.84	0.000*
ED	4.87±0.50	5.18±0.75	0.000*
PoOD	6.86±0.74	7.42±1.18	0.000*
HL	15.48±1.43	16.47±2.32	0.000*
GA	4.10±0.54	4.24±0.78	0.589^{ns}
PPD	33.01±3.56	34.66±5.83	0.000*
PDD	31.65±3.39	33.25±5.45	0.000*
PAD	45.47±5.20	47.22±8.01	0.458^{ns}
HD	12.33±1.50	13.03±2.36	0.000*
BD	18.34±2.58	19.53±4.07	0.000*
DoFL	14.04±1.74	14.64±2.74	0.472^{ns}
DFBL	10.12±1.26	10.56±1.97	0.413^{ns}
DFAF	21.69±2.66	22.46±4.35	0.547^{ns}
DFPAF	14.32±1.86	14.98±3.16	0.097^{ns}
CPLD	21.06±2.66	21.68±3.76	0.184^{ns}
CPD	6.92±0.73	7.15±1.25	0.520^{ns}
CULL	20.71±2.30	21.49±3.86	0.292^{ns}
CLLL	20.71±2.30	21.49±3.86	0.292^{ns}
CFL	7.67±1.04	8.14±1.56	0.000*
CPLV	10.09±1.44	10.61±2.04	0.000*
AFBL	8.49±1.25	9.21±1.98	0.000*
AFL	9.10±1.25	9.59±1.91	0.142^{ns}
PFAF	13.76±2.05	14.24±2.92	0.353^{ns}
PL	10.43±1.32	11.56±1.97	0.000*
PFPF	17.89±2.27	18.59±3.69	0.985^{ns}
PFL	11.03±1.47	11.94±2.40	0.000*
PoDD	21.82±2.89	22.66±3.91	0.783^{ns}
PoAD	10.65±1.47	11.17±2.21	0.181^{ns}

TL (total vlength); (HL) head length; PrOD (preorbital distance); ED (eye diameter); PoOD (postorbital distance); HD (head depth); PDD (predorsal distance); PPD (prepelvic distance); PD (preanal distance); PFPF (pectoral fin-pelvic fin distance); PFAF (pelvic fin-anal fin distance); BD (body depth); DFAF (dorsal fin (anterior end)-anal fin distance); DFPAF (dorsal fin (posterior end)-anal fin); PoDD (postdorsal distance); PAD (postanal distance); CPLD (caudal peduncle length (dorsal)); CPLV (caudal peduncle length (ventral); CPD (caudal peduncle depth); DFBL (dorsal fin base length); AFBL (anal fin base length; PFL (pectoral fin length); PL (pelvic fin length); CULL (caudal upper lobe length); CFL (caudal fork length); CLLL (caudal lower lobe length); DoFL (dorsal fin length); AFL (anal fin length); G (gape). *: significant ($p \leq 0.05$); ns: non significant

Table 2: Mean value ± SD of environmental parameters in Singkarak Lake and Anai River

Parameters	Singkarak Lake	Anai River	Mann Whitney U-Test
Air temperature	24.750±0.50	26.000±1.15	0.096^{ns}
Water temperature	29.250±0.50	26.750±0.96	0.017*
Water velocity	0.000±0.00	82.738±22.13	0.014*
TSS	17.053±8.38	0.275±0.19	0.021*
TDS	96.175±2.26	74.825±10.76	0.021*
Turbidity	1.253±1.26	4.500±6.35	0.356^{ns}
DO	6.703±0.20	6.700±0.10	0.642^{ns}
BOD	1.413±2.02	0.758±1.11	0.144^{ns}
CO_2 free	0.375±0.39	0.648±0.70	0.663^{ns}
pH	7.388±0.29	7.175±0.22	0.378^{ns}
Conductivity	193.725±2.16	150.125±22.46	0.021*
Hardness	67.000±8.87	43.025±13.89	0.083^{ns}
Alkalinity	8.100±0.62	7.590±0.77	0.191^{ns}
Nitrite	0.004±0.00	0.012±0.01	0.139^{ns}
Nitrate	1.625±1.40	1.453±1.38	0.564^{ns}
Ammonia	0.230±0.33	0.750±0.85	0.375^{ns}
Phosphate	0.108±0.07	0.115±0.04	0.885^{ns}
Sulfate	11.515±1.62	12.728±2.42	0.564^{ns}
Altitude	362.000±0.00	54.000±0.00	0.019*

We found that differentiated morphological characters were mainly located in the body anterior including snout length, eye diameter, postorbital distance, head length, prepelvik distance, predorsal distance, head depth, body depth, and the pelvic and pectoral fin length (Table 1, Fig. 3). All those characters predicted an adaptive response to environmental factors, especially water velocity. We suggest effect of velocity in aquatic ecosystem between the lake and the river is a significant factor on fishes morphological divergences. Differentiation process on anterior parts of bilih fish could reduce the friction of the body while moving. In addition, the size of swimming morphologies also has undergone differentiation between Anai and Singkarak populations. Pelvic and pectoral fins were longer at Anai than Singkarak populations. The longer size of fins is one of the anterior functioned to facilitate movement at faster water velocity. The deeper bodies and slightly larger fins are typical for swimmers which could sustain swimming for long periods of time [19]. The Rainbow trout from stream populations had deeper caudal peduncle and longer fins than lake populations [3]. Many authors have also stated water velocity is one of the most important factor affecting on the body shape and fin of fish [16, 17, 20, 21]. While the three differentiated characters in the posterior (anal fin base length, caudal fork and ventral caudal peduncle) generally contribute to the efficiency of swimming [22].

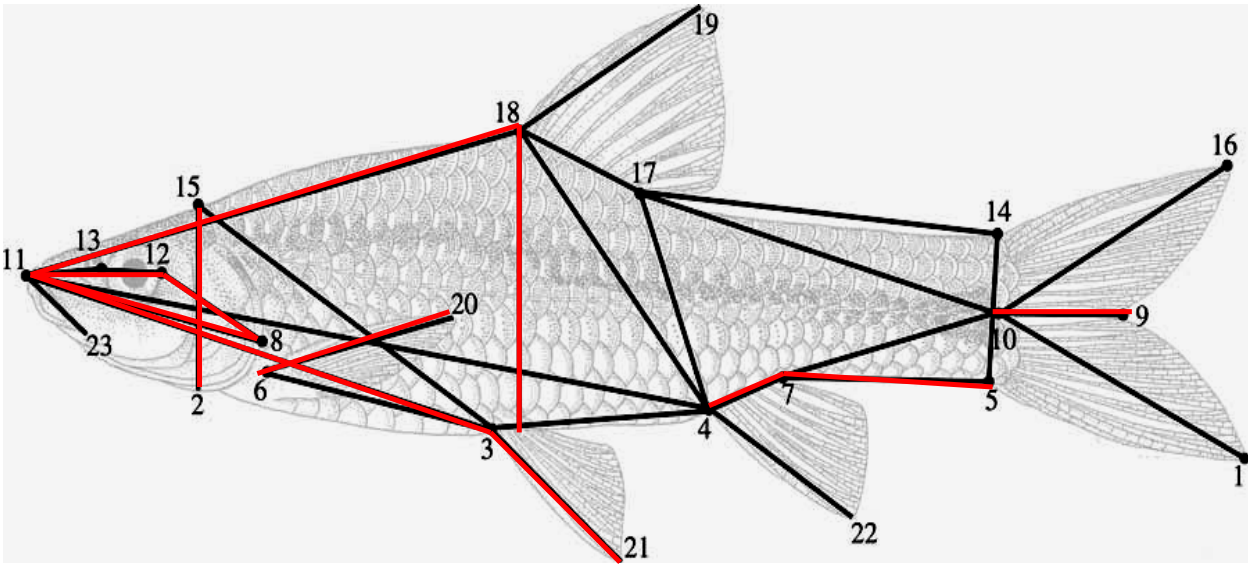

Fig 3: Morphology characters were diffrentiated of bilih fish from Anai population: head length (HL) (11-8); preorbital distance (PrOD) (11-13); eye diameter (ED) (13-12); postorbital distance (PoOD) (12-8); head depth (HD) (15-2); predorsal distance (PDD) (11-18); prepelvic distance (PPD) (11-3); body depth (BD) (18); caudal peduncle length (ventral) (CPLV) (7-5); anal fin base length (AFBL) (4-7); pectoral fin length (PFL) (6-20); pelvic fin length (PL) (3-21); caudal fork length (CFL) (10-9)

The result of previous studies found that fish of lake habitat was characterized by the dorsal and pelvic fins located more posteriorly, body and head flat, longer snout, eyes bigger and longer pectoral fins [2, 3]. However, the results of this study did not find differentiation those characters between river and lake populations. It may indicate that Anai populations showed morphological characteristics resemble to fish lake, although the position of the dorsal and pelvic fins are shifted toward the caudal (Table 1).

In conclusion, although the results of this study showed similarity of 16 morphological characters between Anai and Singkarak populations, but 13 characters have shown differentiation. We suggest that new population of Anai undergoes adaptation process to the environmental parameters, especially water velocity. Adaptation appearance of bilih fish at a Anai River may require a relatively long period, although we have now found differentiation after fourteen years isolation.

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