Oxygen consumption of barred loach *Nemacheilus fasciatus* (Valenciennes, 1846) on different temperatures

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**Abstract.** This study aims to investigate the effects of temperature regimes on oxygen consumption of barred loach *Nemacheilus fasciatus*. Three experimental groups were set to measure oxygen consumption (OC) of the rearing fish (Length: 6.14 ± 0.4 cm; Weight: 1.46 ± 0.05 g) on different temperatures (21.5, 26.5, and 31.5°C) with six replicates. Fish were adapted in an aquarium before stocked and observed in a closed respirometer system (Stocking density: 10 fish/L; Respirometer volume: 1.4 L). Barred loach consumed 365.9, 320.9, and 298.4 mg O₂/kg/h at 21.5, 26.5, and 31.5°C indicating that the OC decreased gradually with increasing water temperature. However, oxygen consumption of barred loach did not change significantly within the temperature range from 21.5 to 31.5°C. The ventilation rate of barred loach increased from 115.0 ± 8.9 to 265.2 ± 42.5 times/min between 21.5 and 31.5°C. Oxygen consumption per breath of barred loach was higher at a lower temperature (3.18 ± 0.63, 2.11 ± 1.22, and 1.13 ± 0.57 mg O₂/kg/breath at 21.5, 26.5, and 31.5°C) (P<0.05). In terms of Q₁₀, the lowest value was found between 26.5 – 31.5°C with a value of 1.16. The thermal range was a comfort zone for barred loach to maintain their metabolic efficiency.

**Keywords:** Barred loach, *Nemacheilus fasciatus*, temperature, oxygen consumption

1. **Introduction**

Barred loach *Nemacheilus fasciatus* is an endemic Indonesian freshwater fish that inhabits rivers in Sumatera and Java Island [1]. This species has a high economic value that traditionally the principal market for the fish has been as crunchy fish and ornamental fish commodity [2, 3]. The exploitation of the fish without concern on its sustainability in the natural water environment is considered as the main factor of overfishing in many fishing grounds [4]. Therefore, domestication needs to be developed to improve sustainable production.

In terms of supporting domestication program, many studies on barred loach were conducted to identify biology reproduction [4-6], feeding habits [7], growth performance [2], and genetic performance [8]. However, the study of effect water temperatures related to oxygen consumption (OC) to investigate the metabolic performance of the Barred loach has not been done yet. The OC is an essential physiological factor influenced by changing water quality parameters, such as temperature, pH, salinity, DO, and CO₂, and fish performance [9]. Water temperature is one of the most essential critical factors in the metabolic activities of fish that are related to oxygen consumption [10].
change in temperature normally affects the oxygen consumption of the fish and it also varies among species [11, 12]. Dalvi et al. [13] reported that the OC of the catfish *Horabagrus brachysoma* increased significantly with increasing acclimation temperature between 15 to 31 °C and 33 to 36 °C, while Das et al. [14] stated that OC of the commercially important freshwater mahseer *Tor tambroides* evaluated under five temperatures (22, 24, 26, 28, and 30°C) was significantly high at 30°C but low at 22°C. Different results of oxygen consumption evaluated in many species indicate that investigation of the effects temperature regimes on oxygen consumption of barred loach needs to be carried out to understand the proper water temperature supporting optimum metabolic activities of the fish. This study was conducted to test the basic null hypothesis that oxygen consumption of barred loach did not change significantly within the temperature range from 21.5 to 31.5°C.

This research also investigated the effect of different temperatures on the stress level of the barred loach. Ventilation rate (VR) was used as an indicator of fish physiological responses to stress levels [15] and it can be linked to metabolic rates [16]. VR normally increases in response to stress caused by temperature and dissolved oxygen [17, 18], chemical [19], confinement [20], and predator [21, 22]. The stress level of fish threatened by different temperatures using VR value was observed in two species gobies [17] and Spangled perch *Leiopotherapon unicolor* [18].

### 2. Materials and methods

This research was conducted at the Research Institute for Freshwater Aquaculture and Fisheries Extension (RIFAFE), Bogor in August 2018. Fish (Length: 6.14 ± 0.4 cm; Weight: 1.46 ± 0.05 g) maintained in the indoor recirculation system before the experiment. During maintenance, fish were fed with commercial feed (protein 39-41% and 5% fat) as much as 2% per day from the fish biomass. Feed was given in the morning and evening. The day before the experiment, fish were starved for 24 hours to avoid the feed influence on metabolism.

Experiments for measuring oxygen consumption were carried out in a closed respirometer (volume: 1.4 L). Dissolved oxygen meter (Trans Instrument HD3030, Singapore) was connected to a respirometer for measuring dissolved oxygen concentration. The experiment was conducted on three different water temperature treatments with six replications. In this experiment, the temperatures used were representing low (21.5°C), medium (26.5°C), and high (31.5°C) temperature. The stocking density on each experiment was 14 fish inside a 1.4 L closed respirometer or equal as 10 fish/L (table 1). Measurement of dissolved oxygen concentration was carried out every five minutes during observation. In addition to the level of oxygen consumption, measurements of ventilation rates were carried out using the method of Wares and Igram [23]. Oxygen consumption is calculated by following Kawamoto [24].

\[
OC = (DO_0 - DO_t) \times \frac{V}{t \times W}
\]

Descriptions:
- **OC** = oxygen consumption expressed on milligram oxygen per hour per kilogram of fish (mg O\(_2\)/kg/h)
- **DO\(_0\)** = initial dissolved oxygen concentration (mg O\(_2\)/L)
- **DO\(_t\)** = dissolved oxygen concentration after t hour (mg O\(_2\)/L)
- **t** = time elapsed for fish consuming oxygen (h)
- **V** = water volume on respirometer (L)
- **W** = total weight of fish (kg)

Oxygen consumption data based on different temperatures were analyzed by one-way ANOVA with a 5% confidence level (\(p<0.05\)). The test was carried out using PASW Statistics 18 statistical software.

### 3. Results

Oxygen consumption (OC) in *Nemacheilus fasciatus* at three different temperatures is shown in table 2. Barred loach consumed 365.9, 320.9, and 298.4 mg O\(_2\)/kg/h at 21.5, 26.5, and 31.5°C, respectively.
The lowest OC was observed at 31.5 °C (298.4 ± 152.3), whereas the highest OC was performed at 30°C (365.9 ± 72.5). The result shows that the OC likely decreased gradually with increasing water temperature. However, oxygen consumption of barred loach did not change significantly within the temperature range from 21.5 to 31.5°C (p>0.05).

Table 1. Experimental conditions during observation of oxygen consumption of barred loach *Nemacheilus fasciatus*.

| Treatment | Water temperature (°C) | Fish stocking density (fish/L) | Replication |
|-----------|------------------------|-------------------------------|-------------|
| 1         | 21.5                   | 10                            | 6           |
| 2         | 26.5                   | 10                            | 6           |
| 3         | 31.5                   | 10                            | 6           |

Table 2. The average value of oxygen consumption on barred loach *Nemacheilus fasciatus* at three different temperatures.

| Temperature (°C) | Oxygen consumption (mg O₂/kg/h) |
|------------------|---------------------------------|
| 21.5             | 365.9 ± 72.5ₐ                   |
| 26.5             | 320.9 ± 185.6ₐ                  |
| 31.5             | 298.4 ± 152.3ₐ                  |
| b                 | -33.75                          |
| a                 | 395.87                          |
| r²                | 0.964                           |

Description: Each value represent means ± SD (n=6). Different superscript letters in the same column indicate significant differences (p<0.05).

The ventilation rate of opercular movements per fish per minute was counted within the control aquarium. Ventilation rates raised at higher temperatures about 115.0 ± 8.9, 152.4 ± 11.7, and 265.2 ± 42.5 times/min at 21.5, 26.5, and 31.5°C, respectively (figure 1). The ventilation rates increased significantly with increasing temperature.

Oxygen consumption per breath of barred loach also decreased gradually with increasing water temperatures (figure 2). The highest OC per breath of barred loach is about 3.18 ± 0.63 mg/kg/breath occurred at a lower temperature (21.5 °C), while the lowest OC is 1.13 ± 0.57 mg O₂/kg/breath at 31.5°C. The OC per breath of barred loach increased significantly with decreasing temperatures.

The temperature quotient (Q₁₀) values estimated from the oxygen consumption rates decreased with increasing acclimation temperature (table 3). The highest and lowest Q₁₀ values of 1.30 and 1.16 were observed between 21.5 – 26.5°C and 26.5 – 31.5°C °C temperatures regimes, respectively. The lowest Q₁₀ value (1.30) is normally used to predict the preferred temperature for optimal fish growth.

4. Discussion
The barred loach performs specific behavior in response to different temperatures. This species did not show a significant change in oxygen consumption as temperatures increased. The range temperature from 21.5 to 31.5 °C was likely within acceptable limits for this fish suggesting that an increase of the temperatures did not affect significantly to increasing metabolism activities. The wide temperature limit related to certain behaviors to establish an adaptation of the species to meet the demands of diurnal behavioral routines [16]. During the day the fish inhabits at the bottom of the water, primarily
to hide among the rocky areas of the rivers [4], but at night they likely seek towards warmer shallow waters for feeding.

The different responses to the effect of thermal regimes on oxygen consumption were reported in many freshwater species. Sarma et al. [25] stated that OC of climbing perch Anabas testudineus increased significantly with increasing temperatures, but there was no significant change in the OC observed between 25 and 30°C. Similarly, the OC values of common carp Cyprinus carpio were not significantly changed between 25 and 30°C, but it was significant at 35°C [26]. The OC of silver catfish Pangasius pangasius increased significantly with increasing acclimation temperature from 30 to 34°C, but the change was not significant from 34 to 38°C [27]. Besides, Luo and Xie [28] reported that Southern catfish Silurus meridionalis did not perform any subsequent increase in the OC between 22.5 and 32.5°C, but the significant change occurred between 17.5 to 22.5°C. These reports indicate that each species has a range of preferred temperatures that generate a variation of oxygen consumption used for the metabolic processes [29, 30]. However, as unfavorable temperatures occurred in the water environment, fish species can develop their specific adaptive mechanism, both behavioral and physiological aspects to maintain their homeostasis process to deal with a critical temperature [31]. Thus, it is important to pay attention to the water temperature beyond normal conditions because it can lead to stress, disease outbreak, and mortality [27].

The ventilation rates of barred loach increased significantly with increasing temperature. This result is in line with VR investigated in Pikeperch Sander lucioperca that begins to increase depends

Table 3. Average Q₁₀ values of barred loach Nemacheilus fasciatus on three different temperatures measured at 21.5°C to 31.5°C

| Temperature range | Q₁₀ value |
|-------------------|-----------|
| 21.5 – 26.5°C     | 1.30      |
| 21.5 – 31.5°C     | 1.23      |
| 26.5 – 31.5°C     | 1.16      |
on the temperature [16]. The ventilation rate in Goby *Favonigobius exquisitus* increased fivefold acclimated in temperature regimes from 20 to 35°C, while *Pseudogobius* sp did not even double, indicating that *Pseudogobius* sp. is a better thermal regulator than the other one [17]. On the contrary, the oxygen consumption per breath of barred loach tends to decreased significantly with increasing temperature. Result from this study is different with the most of observation on oxygen consumption, such as in Black porgy *Acanthopagrus schlegeli* [32, 33], Grey mullet *Mugil cephalus* [34], and Rock bream *Oplegnathus fasciatus* [35]. However, the pattern of decreasing oxygen consumption per breath is similar to Starry flounder *Platichthys stellatus* which decreased with increasing temperature [36]. The VR of barred loach increased from 115.0 ± 8.9 to 265.2 ± 42.5 times/min at 21.5, and 31.5°C. Meanwhile, the oxygen consumption of barred loach decreased from 3.18 ± 0.63 to 1.13 ± 0.57 mg O₂/kg/breath at 21.5 to 31.5°C. Those results suggested that this fish likely also has an excellent thermal regulator as the temperatures were increased from their natural habitat. Based on the previous study, in the natural habitat, the barred loach was found in water temperatures ranged between 19 and 29°C during observation [4].

The optimal temperature for growth can be predicted based on the lowest Q₁₀ value. The lowest Q₁₀ represents that the fish has greater plasticity in the metabolic process indicating that they provide more energy potentially available for growth [37, 38]. The lowest Q₁₀ value is 1.16 observed between 26.5 and 31.5°C. Thus, it could be suggested that the optimum temperature of barred loach is in the range of 26.5 – 31.5°C. These temperatures are still in the range preferred temperature for many fish living in the tropical region. The previous studies based on Q₁₀ values reported that the preferred temperature for Mahseer *Tor tambroides* was between 28 and 30°C [14], Indian major carps including *Labeo rohita*, *Catla catla*, and *Cirrhinus mrigala* were from 31 to 33°C [30] and similarly, Q₁₀ for the catfish *Horabagrus brachysoma* between 31 and 33 °C [13]. As the optimal temperature range for the fish was found, it should be continued through further studies on growth rates and feed conversion efficiency to verify this finding for aquaculture practices [16].

### 5. Conclusion

The oxygen consumption of barred loach did not perform a significant change as temperature increased between 21.5 and 31.5°C. This range was likely within acceptable limits for this fish and it is supported by ventilation rate suggested that the fish has an excellent thermal regulator in this temperature range. Based on temperature quotient (Q₁₀), temperature between 26.5 and 31.5°C is the preferred temperature for the growth of this species. This Information likely can be used as basic information to determine the optimum condition for the growth of this species leading towards a domestication program.

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The oxygen consumption of barred loach did not perform a significant change as temperature increased between 21.5 and 31.5°C. This range was likely within acceptable limits for this fish and it is supported by ventilation rate suggested that the fish has an excellent thermal regulator in this temperature range. Based on temperature quotient (Q₁₀), temperature between 26.5 and 31.5°C is the preferred temperature for the growth of this species. This Information likely can be used as basic information to determine the optimum condition for the growth of this species leading towards a domestication program.

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