



Critical thermal limit and behavior of the Barramundi (*Lates calcarifer* Bloch, 1790) fingerling exposure with different temperature

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ABSTRACT

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Barramundi (*Lates calcarifer*) is one of the commercial fish in Indonesia. The phenomenon of climate change due to global warming has affected the life of aquatic biota, including fish. The objectives of the present study were to determine a critical thermal maximum (CTMax) and the behavior of Barramundi (*L. calcarifer*) due to the increase in water temperature. The research was conducted at the Fishing Technology Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala in February 2021. The experiment was conducted in 10 aquariums equipped with heaters. The initial temperature of the treatment was 28°C and increased gradually every one minute by 0.2°C. The results showed that the abnormal behavior of Barramundi fingerling was started to appear at 37°C where the fish began to swim fast, then swim sideways at 38°C-39°C, hit the container wall at 39°C-40°C, jumped and weakened then dead at 40°C and 41°C. The average critical temperature of Barramundi fingerling was recorded at a temperature of 41°C within 65 minutes. Therefore, it is concluded that the Barramundi (*L. calcarifer*) display an abnormal behavior above the temperature of 35°C, however, they can survive up to 42°C exposure for 70 minutes.

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Introduction

Since 1900 the earth's surface temperature has increased by 0.8°C-1.0°C and it has increased to 1.1°C-1.3°C since 1950 (IPCC, 2007). The increase in the earth's surface temperature was also followed by an increase in sea surface temperature around the world, including Indonesia. This affects the distribution, migration disorientation, growth disturbances, and physiological stress in fish (Roessig *et al.*, 2004; Irianto, 2005; Islam *et al.*, 2019; Nur *et al.*, 2020); for instance, the exposure to temperatures exceeding 20°C will cause *Salvelinus confluentus* fish deaths (Selong *et al.*, 2001), an increase in temperature causes changes in the histological function of *Sparus aurata* and changes in blood physiology in *Oreochromis niloticus* (Trot *et al.*, 2004; Lubis *et al.*, 2016). Furthermore, climate change also resulted in a decrease in the production of anchovies (*Stolephorus* spp.) off the coast of Peru and Mackerel fisheries

(*Trachurus trachurus*) in Western Europe (Stenseth *et al.*, 2002; Reid *et al.*, 2001).

Barramundi (*Lates calcarifer*) is an economically important fish in Indonesia. This fish is distributed widely in Southeast Asia, including in Indonesian waters (Genisa, 1999). Good adaptability to changes in salinity makes these fish able to live in brackish, sea to freshwaters (Fishfact, 2011; Mulyono, 2011). Several studies related to the bioecology of Barramundi show that this fish is catadromous, they grow in fresh or brackish waters and migrate to the deep sea to spawn (Tarwiyah, 2001), at the age of 2-3 years, these fish live in freshwater, then migrate to marine waters after 3 years of age (FAO, 2006; Crook *et al.*, 2016), the fish reached 200 cm maximum (Mayunar and Slamet, 2000), and they inhabit the coastal waters with a depth of 10-40 m, and water temperature range of 28°C-33°C (Mahardika *et al.*, 2020). However, in general, the survival rate of larvae in the wild is low (Cotton *et al.*, 2003).

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Temperature plays an important role in fish metabolic processes, including reproduction and growth (Muchlisin, 2019). An increase in temperature to a certain level will increase the growth rate of fish, but if the temperature continues to increase, the growth rate will decrease, inducing stress and death (Wenberg and Smale, 2011; Rivaldy et al., 2017). The tolerance limit of temperature is species depending, for instance, *Plectrogyphidodon lacrymatus* fish can survive up to 37.4°C (Lha et al., 2017), *Amblygyphidodon curacao* has a critical thermal limit of 39.4°C (Deniro et al., 2017), *Barbodes binotatus* and *Rasbora caudimaculata* can survive up to 38.6°C and 37.3°C (Tongnunui and Beamish, 2017). However, the critical thermal limit of Barramundi was not examined yet, and how their behavior responds to the temperature changes was also not reported. Therefore, the objectives of the present study were to determine the critical thermal limit (CTMax), size (length and weight), and behavior of Barramundi fingerling to temperature increase.

Materials and Methods

Time, site and experimental fish

The experiment was conducted in the Laboratory of Fishing Technology, Faculty of Marine and Fisheries, Banda Aceh, Indonesia from 6-8 February 2021. A total of 10 fish samples were used in this experiment, the fish was purchased from a local fish farmer in Lhokseumawe City, Indonesia. The average fish sample was 6.66 ± 0.3 cm total length and 4.03 ± 0.74 g body weight. The fish was acclimatized in the fiber tank contained with sea waters (22 ppt) for 7 days before use for the experiment. The fish was fed on a commercial diet three times a day (9 AM, 12 AM and 5 PM) at satiation.

Experimental container preparation

A total of 10 plastic containers (Vol. 25L) were used as an experimental medium. The container was filled with 15L seawater (22 ppt) and equipped with a heater (Intra 220v-50 HZ) and aerator (Amara - BS-410). Every container was stocked with one fish. The initial water temperature was 28°C. The temperature was measured using a digital thermometer (Mester - IR01C).

CTMax test

The temperature increase was carried out gradually for 0.2°C min⁻¹, this procedure refers to Huntsman and Sparks (1924) that modified for this study. Fish behavior was observed every minute and recorded with the following categories: (a) Normal, when the fish still showed the same behavior as the beginning of the experiment), and (b) Abnormal, when the fish started to swim fast, swam sideways,

hit the container, jumped, weakened and dead (Muhammad, 2017). The critical point (CTMax) is when the fish no longer able to tolerate exposure temperature, so they lose balance, cannot swim straight, swim sideways, move irregularly and weaken and dead (Mora and Ospina, 2014). The survivor fish was measured for the body weight (g) and total length (cm).

Data analysis

The data of fish behavior was analyzed descriptively, while the data of CTMax, body weight, and total length were analyzed for correlation to examine the correlations between fish size with the CTMax using SPSS ver.19.0 (IBM22).

Results

The results showed that the Barramundi fingerling was still in a normal condition shortly after being put into the test container and until the temperature rose to 36°C. Abnormal behavior began to occur at 37°C exposure where the fish began to swim faster. At the temperature of 38-39°C, the fish showed symptoms of losing balance and swimming sideways, at higher temperatures (40-41°C) fish was jumped to try to get out of the water, and the longer the exposure at this temperature the movement weakened, died (Table 1).

The results also showed that the lowest CTMax of Barramundi fingerling was at 40°C while the highest CTMax was at 42°C, which means that the fish began to experience death at 40°C and some fish could still survive but then dead at 42°C. At a temperature of 40°C the fish died at 60-63 minutes. At 41°C the fish died at 66 minutes and the longest at 68 minutes, while at 42°C the fish died after 70 minutes of exposure (Table 1).

The total length of the experimental fish ranged from 6.3-6.9 cm, while the body weight ranged from 3.32-4.77 g (Table 2). Based on the correlation test, the correlation coefficient (r) between the total length of the fish and the CTMax value was 0.80, while the correlation coefficient value between fish body weight and CTMax value was 0.73. Indicates the r values tend to one, it means that there is a positive and strong correlation between fish length and body weight with the CTMax, where the bigger fish is stronger to exposure temperatures heat (Figure 1).

Discussion

The study showed that the behavior of Barramundi was normal at exposure temperature of 28°C-36°C, the abnormal behavior was detected begun at 37°C and above. That result indicate that Barramundi can survive at a temperature of 36°C. In general, presently, the sea temperature of Indonesia

waters ranged 27°C-32°C (Rivaldy et al., 2017). Fish is a poikilothermic animal that had the ability to adjust its body temperature to the temperature of the water (Maisano et al., 2016; Giannetto et al., 2014). However, the changes in temperature of more than 2°C cause fish stress (Nur et al., 2020), and death when exposed too long at these extreme temperatures (Ashaf-Ud-Doulah et al., 2019). According to Mahardika (2020), the Barramundi lives in waters with a temperature ranged of 28°C-33°C, but based on this study showed that these fish are

able to tolerate the temperature up to 36°C, or approximately 4°C above its ambient temperature. In comparison, Brown-marbled grouper (*Epinephelus fuscoguttatus*) could only survive temperatures of 38.3°C (Cheng et al., 2012), Spotted rose snapper (*Lutjanus guttatus*) at 37.5°C (Ospina and Mora, 2004), and Nile tilapia (*Oreochromis niloticus*) at a temperature of 41.25°C (Islam et al., 2020). Therefore, this study showed that the Barramundi has a good ability to adapt to changes in water temperature compared to other fish that have been previously reported.

Table 1. Behavior of Barramundi in each temperature rise.

Fish No.	Temperature (°C)								Time of exposure (Minutes)
	35	36	37	38	39	40	41	42	
I	Normal	Normal	Fast swam	losing balance and swimming sideways	Jumped and weak	Dead	-	-	60
II	Normal	Fast swam	Fast swam	losing balance and swimming sideways	Jumped and weak	Dead	-	-	60
III	Normal	Normal	Fast swam	Swimming sideways, lose balance	Jumped	Weak and dead	-	-	62
IV	Fast swam	Swimming sideways	Fast swan	Lose balance	Jumped	Weak and dead	-	-	63
V	Normal	Normal	Fast swam	Lose balance	Jumped	Weak and dead	-	-	63
VI	Normal	Normal	Normal	Fast swam	Swimming sideways	Lose balance	Weak and dead	-	66
VII	Normal	Normal	Fast swam	Swimming sideways	Lose balance	Jumped and weak	Mati	-	67
VIII	Normal	Normal	Fast swam	Swimming sideways	Lose balance	Jumped	Weak and dead	-	68
IX	Normal	Normal	Normal	Fast swam	Fast swam	Lose balance	Weak	Dead	70
X	Normal	Normal	Normal	Fast swam	Fast swam	Lose balance	Jumped and weak	Dead	70

Table 2. Body weight and total length of Barramundi (*Lates calcarifer*).

No.	Fish No.	Total length (cm)	Body weight (g)	CTMax
1	I	6.3	3.43	40.0°C
2	II	6.4	3.89	40.3°C
3	III	6.5	3.75	40.0°C
4	IV	6.5	3.94	40.6°C
5	V	6.6	3.32	40.6°C
6	VI	6.6	4.18	42.0 °C
7	VII	6.7	4.46	41.6°C
8	VIII	6.8	4.09	41.4°C
9	IX	6.8	4.77	41.2°C
10	X	6.9	4.51	42.0°C
Average		6.6	4.03	41.0°C

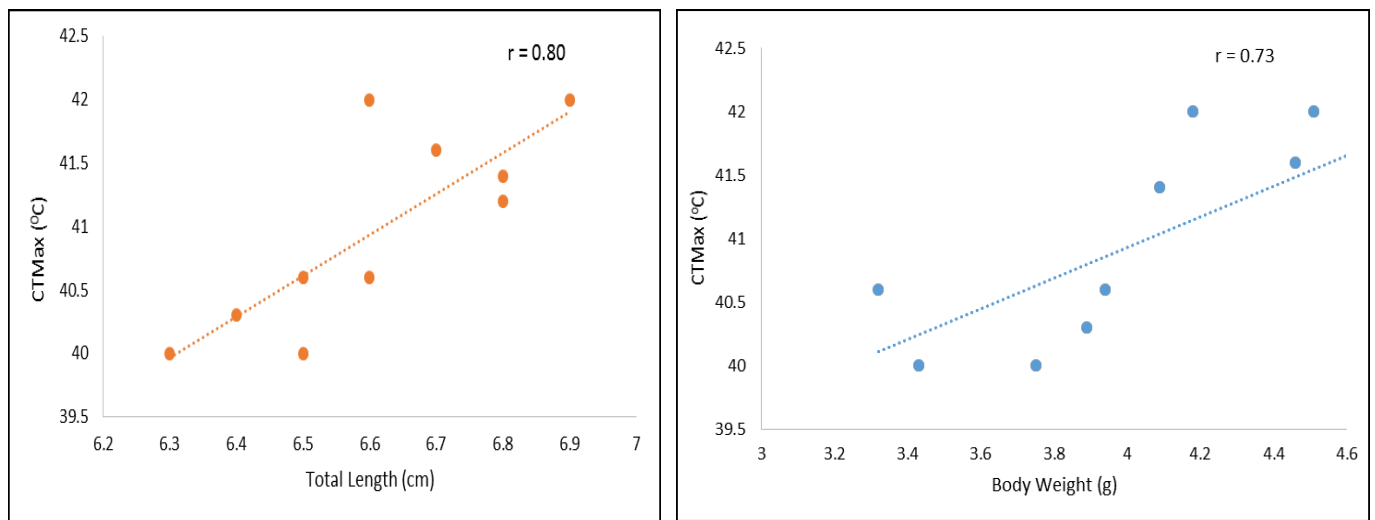


Figure 1. Body weight and total length of Barramundi (*Lates calcarifer*) after temperature exposure.

Similar findings have also been previously reported by Ktersky and Carter (2005) and Glen and Bermudes (2010) that Barramundi juvenile is able to tolerate temperatures of 25°C-36°C. However, an increase in temperature that exceeds the tolerance limit causes the fish to stress which is characterized by fish swimming abnormally, disrupting respiration, physiological function, increasing metabolism, and excretion (Bangsa et al., 2015). In general, aquatic biota including fish has the ability to adapt to temperature changes that occur gradually, but when the temperature increases suddenly and extremes it will have a negative impact on the physiological conditions of fish even death (Azwar et al., 2016).

The result showed that the average CTMax of Barramundi was 41°C with an average test duration of 65 minutes, which means that the Barramundi can only survive for 65 minutes at this temperature. In general, the temperature of sea waters in Indonesia ranges from 27°C-32°C (Rivaldy, 2017). It is still at the optimum limit for Barramundi. However, based on Hansen et al. (2010) that since the mid-19th century the earth's average temperature rise to 0.8°C and continued to increase 0.1°C every ten years. Moreover, Allen et al. (2018) and IPCC (2014) have estimated that if global warming continues to occur, by the end of the 21st century global temperature changes will increase by more than 1.5°C.

Besides affecting the distribution of fish, water temperature is also affected the productivity of the aquatic ecosystem, in this case, the presence and abundance of phytoplankton, then affecting fish migration (Aliza et al., 2013; Sumantri et al., 2017), which in turn will affect regional fishery production. Changes in temperature have also affected the maturity of fish gonads, for example in Yellowstripe scad (*Selaroides leptolepis*), this fish matured earlier or at a smaller size when the water temperature warmer

(Mustofa and Setyobudiandi, 2019). In addition, temperature increases have also affected the reproduction of fish, where at temperatures higher than the normal temperature, the fish will produce more male than female larvae (Luckenbach et al., 2003; Arfah et al., 2005; Azaza et al., 2008; Wang et al., 2014), causing the natural sex ratio of fish to be disturbed.

The correlation test showed that there is a positive and strong correlation between fish size and fish resistance, for example, fish with a length of 6.7 cm and a weight of 4.46 g can survive for 68 minutes at a temperature of 41.6°C, while the smaller fish with a length of 6.3 cm and a weight of 3.43 g can only last for 60 minutes at a temperature 40°C. Probably, this is related to gill function. Gills play a crucial role in the respiration process in fish. In warmer temperatures, the metabolic rate will increase and oxygen demand will also increase (Muchlisin, 2017). At larger (older) fish, the gills have well developed and function better than a small fish, and therefore they will have better adaptability (Mohammed, 2013). In addition, Nur et al. (2020) reported that gill abnormalities occurred in *Betta rubra* exposure with higher temperature.

Conclusion

It is concluded that the Barramundi (*L. calcarifer*) shows symptoms of abnormal behavior starting at 37°C exposure, but these fish are still able to survive up to a temperature of 41°C for 65 minutes. The CTMax is closely related to fish size, where larger fish can survive longer at the CTMax temperature.

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