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Adaptation of Koi Carp *(Cyprinus carpio)* Exposed to Different Temperature Variants

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Abstract:- The present study elucidates thermal limits of a commercially important ornamental fish Koi carp (*Cyprinus carpio*), in a domesticated subsystem. The study aimed to understand the sub-lethal temperatures which Koi carp can tolerate. The lower (CT_{MIN}) and upper (CT_{MAX}) critical thermal limit was recorded at 15°C and 35°C respectively. Qualitative assessments majorly revealed aberrant swimming patterns at the higher slab. Contrarily, lower thermal slab was marked by laziness and mucous secretion. Thermal stress affects almost all biological indices and therefore, fish must be maintained in an appropriate temperature. The importance of the present study becomes even more relevant in the context of domestic conditions since the fish is largely used for ornamental purposes.

Keywords:- *Celsius, Koi Carp, Ornamental fish, Stress, Temperature, Thermal.*

I. INTRODUCTION

Shelford's law of tolerance [1] suggests that anything outside the norm will affect well-being of the organism. Two ends of such a norm with reference to temperature, the upper and lower, are collectively called thermal limits [2]. Thermal limits mark the scale of extremes and provide a range of values to the point of mortality. Temperature affects every organism and fish are no exemption to it. Temperature outside the ambient range causes disruption to almost all biological activities and therefore, any metabolic process is governed by thermal slab. Therefore, it is of paramount importance to establish the limits of temperature for any organism.

Critical limit (CT) is defined as the temperature at which locomotory activity of the organism is disturbed eventually resulting in mortality [3]. CT is specific to species and serves as a platform for elaborating investigations of thermal stress [4]. CT defines sub-lethal points for evaluating the organ and tissue specific responses to temperature stress. The lower and upper points are termed as CT_{MIN} and CT_{MAX} respectively [3,4]. The limits are dynamically evaluated in contrast to static method of Upper Incipient Lethal Temperature (UILT) [5].

Koi carps occupy a global commercial preference and widely traded for aesthetic purposes. The fish is generally spotted in lakes and ponds for beautification purposes but also domesticated in household conditions [6]. Presence of distinct barbels is an identifying feature of this species. It is biologically robust and very peaceful towards other occupants, which makes it maintainable in an aquarium system [7,6].

Whether global or regional, thermal stress is a concern in multitude contexts. Critical limit is considered as the first reliable step to understand the warnings of climate. It becomes even more relevant in the contexts of global warming. Therefore, the present study was designed to evaluate the upper and lower values of the critical thermal limit in Koi carps. Qualitative assessments at relevant temperatures are expected to explain implications of heat and cold stress. The study results are expected to facilitate the designing of thermal stress experiments.

II. MATERIALS AND METHODS

A. Fish Acclimation

Koi carp were collected from Ornamental Fish Research Centre, Bengaluru, Karnataka. During the two-week acclimation period, juveniles (5.00 ± 0.34g) were maintained under natural daylight conditions (≈ 12 L:12D) in 50L glass tanks installed with aerator and thermostat. Commercial fish feed (Taiyo, India) was provided twice a day (10:00 and 17:00 hours). The water parameters were checked for oxygen (6.8 mL/L) and pH (6.99 ± 0.1; Systronics digital pH meter) [8]. A holding temperature of 25 ± 1°C was maintained throughout the acclimation period. The tanks were covered with mosquito nets and cleaned on alternate days to prevent fecal toxicity.

B. Experimental Setup

The experimental setup of this exploratory study was maintained in duplicate (2 tanks × 10 fish = 20 fish) for both lower (CT_{MIN}) and upper (CT_{MAX}) limits. The test tanks were installed with aerator (Venus Aqua Aerator AP-608A, China) and thermostat (RS008A, China). The acclimation temperature (25 ± 1)°C was used as the starting point for the increase and decrease. The parameters of water maintained were similar to the acclimation period. The rate of change of temperature was by magnitude of 1°C/hour. A discrepancy

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of 0 ± 1°C was taken into consideration for all the temperatures during the experiment. Exposure time was recorded with a digital stopwatch and digital thermometer were used to check the temperatures.

C. Behavioral Checkpoint

The fish were characteristically observed at the onset of every one hour. Behavioral and health indicators were qualitatively assessed with the change of every 1°C [4]. Qualitative checkpoints, (1) abrupt swimming (2) mucous discharge (3) shedding of scale (4) repeated movements and (5) loss of vigor were correlated with the particular temperatures.

III. STATISTICAL ANALYSIS

Behavioral indicators were observed to establish the sub-lethal checkpoints. Paired t-test was computed to test the significant differences between the upper and lower temperatures. Behavior was correlated against temperatures of exposure for both the limits (Figure 1 & 2). The statistical tests were computed in GraphPad Prism (Version 5).

IV. RESULTS

The CT_{MIN} was recorded at 15°C and the CT_{MAX} value was record at 35°C. Aberrations in behavior were observed at temperatures nearing extremes for both upper and lower limits (Figure 1 & 2). Aberrations were majorly noted between 15°C to 21°C and, 29°C to 35°C. Mucous discharge was not observed at any of the temperatures nearing lower limits.

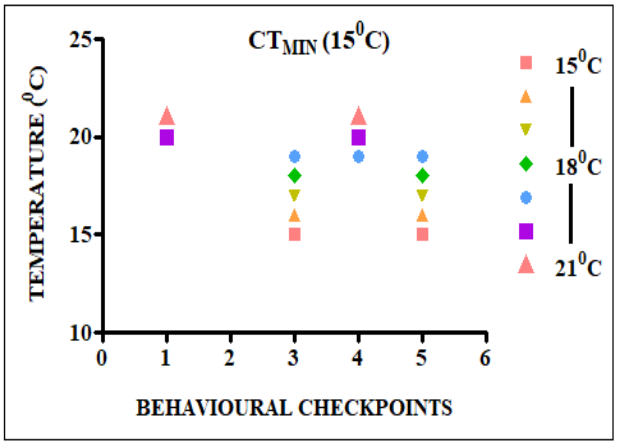

Fig 1 – Correlation of behavior with temperature exposures approaching lower critical limit **(CT_{MIN} - 15°C)** from 15°C to 21°C. Behavioral checkpoints are marked as **(1)** Abrupt swimming **(2)** Mucous discharge **(3)** Shedding of scale **(4)** Repeated movement **(5)** Loss of vigor

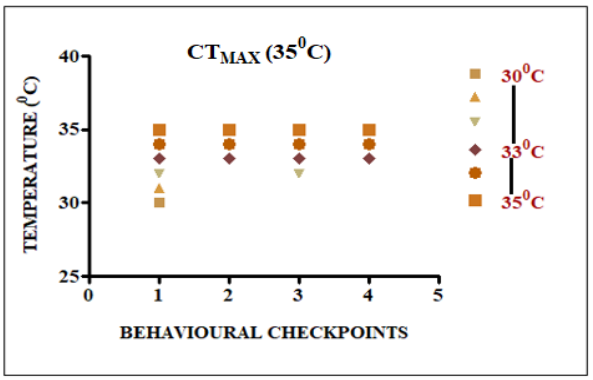

Fig 2 – Correlation of behavior with temperature exposures approaching upper critical limit **(CT_{MAX} - 35°C)** from 30°C to 35°C. Behavioral checkpoints are marked as **(1)** Abrupt swimming **(2)** Mucous discharge **(3)** Shedding of scale **(4)** Repeated movement **(5)** Loss of vigor.

V. DISCUSSION

Temperature is a prerequisite for the right metabolic balance in all organisms. Therefore, evaluation of critical thermal limits (CT) can elucidate the temperatures that are metabolically beneficial. In the course of exposed temperatures graduating to extremes, the exclusivity of CT is that it details the dynamic adaptations associated with the relevant temperatures. Therefore, a correlation of the metabolism and temperature can be spooled out through CT_{MAX} and CT_{MIN}. The information also sheds light on ecological preference of all the organisms.

This study involved an ornamental fish that is popularly reared across the globe for aesthetic values [9]. The preliminary results evaluated in this study suggest the ideal temperatures that Koi can tolerate and creates a platform for investigations about ecological adaptations [10]. A wide range of exposed temperatures in this study gives an elaborate idea of hourly adaptations. This would be important for stakeholders and aquarists rearing this species. Aquaculture is known to generate employment opportunities and the species dealt here is important enough from commercial aspect.

Behavioral indicators evaluated here allocate a qualitative description of the species to the relevant temperatures. Altogether, aberrations were majorly observed between 15°C to 21°C and, 30°C to 35°C. Abrupt swimming patterns were greater at upper thermal range, especially between 30°C to 35°C. Even mucous discharge was exclusively observed at the upper limits (between 30°C to 35°C). Contrarily, shedding of scale was more at the lower (15°C to 19°C) than the corresponding upper range. Repeated movement was common observation for both the range exposures. Most movements observed with the increase of temperature, were tracked to be at diagonal end of tanks, which also indicated avoidance behavior to higher temperatures [11].

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This was prevalent in case of upper temperature ranges, especially between 33 to 35°C. Loss of vigor was noted for temperatures nearing the lower limits. Symptoms were distinctly visible by 19°C and dominant at CT_{MIN}. At CT_{MIN} the fish showed sedentary behavior, negligible movement and seemed severely depressed. This characteristic was exclusive to lower limits and not observable for any of the upper thermal exposures.

VI. CONCLUSION

The study suggests that the optimum temperature of Koi carp under general holding conditions can be 23°C to 28°C. Outside this range, anything would not lead to mortality up till 15°C and 35°C but can have implications on the metabolism thereby stressing the fish.

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➢ *Authorship Statement*

The experimental design of the present study and guidance was given by **Dr. Usha Anandhi D**. Experimentation, data analysis and writing was done by **Proteek Dasgupta**.

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