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Short communication

Heat waves in Kerala: Impacts on clownfish reproduction in captivity

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The clown fishes are valuable and popular marine ornamental fish, but scientific reports on their egg filial cannibalistic behaviour are scarce. The present study examines the impact of temperature and dissolved oxygen associated with clownfish breeding, particularly during temperature fluctuations in summer. Though increased spawning frequencies were observed with rising temperature, a notable surge in filial cannibalism was also documented when the temperature reached 31 °C. This coincided with a significant decline in dissolved oxygen levels to 3.43 mg/L, suggesting a potential link between temperature stress and reproductive anomalies in clownfish under captive conditions.

[**Keywords**: Clownfish, Filial cannibalism, Hatching rate, Heatwave]

Introduction

Clownfish, with their vibrant colours and intriguing behaviours, have long captivated marine enthusiasts and scientists. Known for their symbiotic relationship with sea anemones, clown fish seek shelter and protection within these host organisms. Their reproductive habits are equally fascinating. Clownfish are protandrous hermaphrodites, initially maturing as males and capable of changing their sex to female when the breeding hierarchy is disrupted. They exhibit distinctive reproductive behaviour by laying eggs on planar substrates close to their host sea anemones. After oviposition, male and female clownfish engage in parental care, protecting and maintaining the eggs' health until the larvae emerge. This collaborative parental investment and proximity to anemones enhance offspring survival, highlighting the ecological significance of their symbiotic relationship.

Given the high demand for clownfish in the aquarium trade and the need to reduce fishing pressure on wild populations, the Centre for Marine Living Resources and Ecology (CMLRE) has established an experimental hatchery at its Kochi campus to standardise mass production technology for clownfish. Fifteen pairs of wild-caught clownfish, *Amphiprion clarkii*, were sourced from the Gulf of Mannar and Lakshadweep on August 15, 2023. Though the fifteen pairs eventually became brooders, two became continuous spawners. However, during March – May 2024, filial cannibalism was observed in the brooders. This study aims to understand the reason behind the decreased egg hatching rates.

Materials and Methods

The fish were quarantined for ten days and introduced into the Recirculatory Aquaculture System (RAS) with synthetic seawater. Each RAS unit was equipped with nine 120 L glass tanks connected to a sump with biological filtration. Water parameters, including pH, salinity, temperature, and dissolved oxygen, were monitored daily (Table S1). Salinity was measured using a refractometer (Cole-Parmer SN14985), while the other parameters were assessed using a multiparameter testing kit (Oakton). Each tank was provided with a halved clay pot, and the fish were fed thrice a day with frozen artemia, prawn meat, and commercial pellets. The fecundity and egg hatching rate of each brooder were noted. Simultaneously, photographs of the initial clutch and the eaten clutch were taken. Statistical analysis of correlation and regression was performed using Microsoft Excel (ver. MS Office 2007) to evaluate the relationship between temperature and hatching rate. Statistical significance was determined at the $P \leq 0.05$ level.

Results

The spawning frequency of the pairs was relatively similar: each pair generally spawned every 10 – 12 days. The number of spawn events per month ranged from one to four and was generally between three and four times.

Information on 26 breeding events was gathered for both the continuous spawners. Full clutch cannibalism was observed in 9 out of the 26 breeding events, and 5 cases of partial filial hatching were also recorded. It was also noted that there was no variation in the spawning cycles. The pH and salinity of the

RAS were maintained at 8.1 – 8.3 and 30 ppt, respectively. The average number of eggs in an egg clutch was calculated to be 475±15 (Fig. 1c). However, during March, April, and May, the temperature rose to 31.8 °C in the RAS (Fig. 2), which significantly reduced the dissolved oxygen level to 3.43 mg/L (Fig. 3). Elevated water temperatures appeared to induce stress-related responses, leading to increased rates of egg consumption by adult clownfish and a decrease in hatching rate (Fig. 1b, d).

Table 1 — Month-wise mean data of water parameters and hatching rate

Month	Water temperature (^{0}C)	Dissolved oxygen (mg/L)	Fecundity (in nos.)	Hatching rate (%)
December	28.24	5.4	350	60
January	28.3	5.2	350	60
February	29.3	4.6	405	60
March	30	4.2	417	10.1
April	31.6	3.9	450	1.6
May	30.1	4	500	10
June	28.3	4.5	680	26.5

The month-wise hatching rate, fecundity, temperature, and dissolved oxygen levels are provided in Table 1, Figure 4. The temperature and hatching rate showed a significant positive correlation ($r^2 = 0.6$, $P < 0.05$).

Discussion

This research indicates that the rise in temperature altered the dissolved oxygen level in the tanks, which significantly altered clownfish behaviour, particularly their reproductive processes. Under normal conditions, cannibalism of the egg mass is rare and typically associated with the removal of infertile or damaged eggs from the egg clutch to prevent pathogen attack on viable eggs. Previous studies suggest that filial cannibalism in fish is a stress-induced response to harsh environmental conditions, disrupting their usual behaviour and physiology[1]. When egg survival and hatching success are compromised, fish may resort to egg consumption as an adaptive strategy. According to the Oxygen-and Capacity-Limited Thermal Tolerance (OCLTT) concept[2], animal performance declines progressively

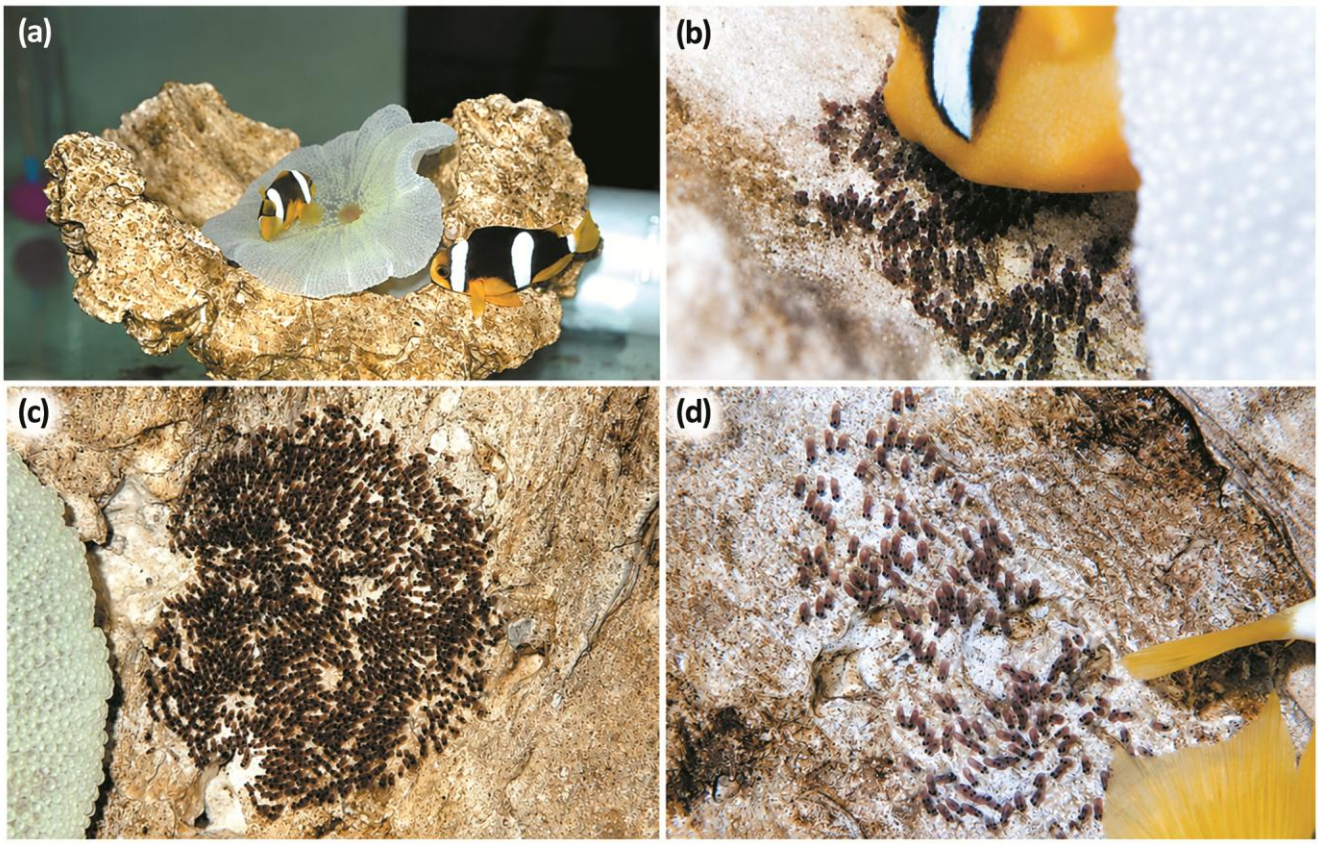

Fig. 1 — a) A pair of *A. clarkii*; b) Clownfish under stress eating the egg clutch; c) Complete egg clutch of *A. clarkii*; and d) Partially eaten egg clutch

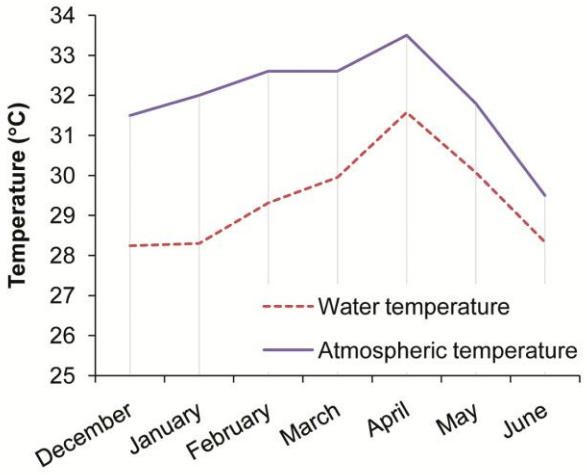

Fig. 2 — Temporal variation in temperature

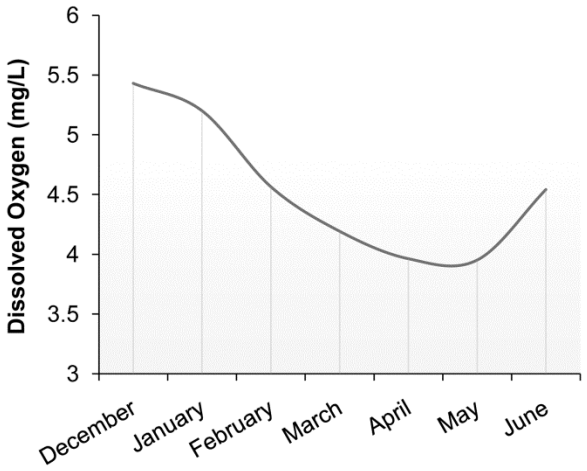

Fig. 3 — Temporal variation in dissolved oxygen

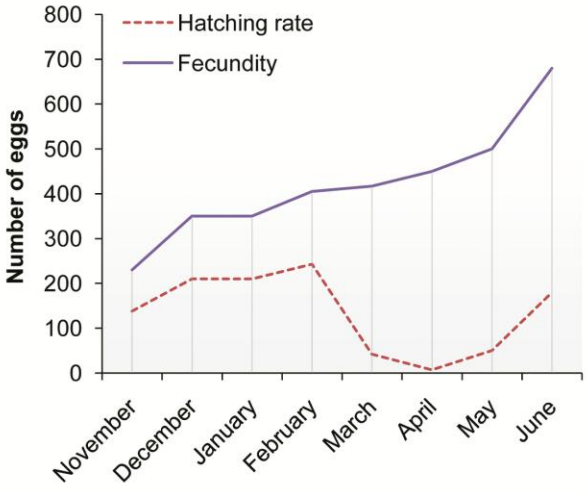

Fig. 4 — Comparison between the fecundity and the hatching rate of *A. clarkii* in captivity

as temperatures approach limiting thresholds due to constraints on oxygen supply to tissues[3,4]. Additionally, increased water temperatures reduce fish activity and lead to a cessation of continuous spawning behaviour in clownfish.

Observations of the present study suggest that an unusual rise in filial cannibalism can be due to the significant reduction in dissolved oxygen levels. One of the three models studied by Payne *et al*.[5] supports present study results, by analysing the relation of environmental conditions (oxygen) and clutch cannibalism. On the other hand, several studies report that males that were given plenty of food showed less filial cannibalism than the males that received little food[6]. Similarly, males that had eaten food items other than their own eggs also cannibalised less than the males without other food items in their stomachs[7]. However, Lissakar *et al*.[8] found no effect of low levels of dissolved oxygen on filial cannibalism, and the negative result can be explained by introducing a temperature and dissolved oxygen-controlled RAS system.

Filial cannibalism is quite common, and the reasons for it may vary. To date, relevant research data on filial cannibalism of *A. clarkii* remain scarce, even though this cannibalistic behaviour is considered an aquaculture bottleneck for *A. clarkii* as well as many other damsel species[9,10]. Given their relatively low fecundity compared to food fish, maintaining year-round productivity is crucial for clownfish sustainability. Furthermore, elevated temperature and reduced dissolved oxygen levels may lead to reduced growth rates, increased mortality, and disruptions in reproductive cycles, ultimately affecting their population dynamics.

Hence, it is crucial to integrate adaptive strategies in hatchery management, including enhanced temperature regulation, oxygenation, and selective breeding for the heavily priced ornamental fish species. Additionally, research should focus on understanding the broader ecological implications of climate change on clownfish aquaculture programs while safeguarding the economic stability of aquaculturists and contributing to the conservation of marine biodiversity in an increasingly unpredictable climate.

Supplementary Data

Supplementary data associated with this article is available in the electronic form at

https://nopr.niscpr.res.in/jinfo/ijms/IJMS_54(06)305-308_SupplData.pdf

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Conflict of Interest

The authors declare no competing or conflict of interest.

Ethical Statement

No separate ethical clearance was required, as specimens were not harmed in the study.

Author Contributions

SJ: Preparation and drafting of the manuscript; VP: Data compilation and editing of the manuscript; VMSN: Idea conceptualisation; CNS & PV: Data collection; and RSK: Overall guidance and final editing of the manuscript.

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