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Effect of Water Temperature on Population Ecology of Caryophyllid Cestodes *Lytocestus haryanii* (Babita *et al.*, 2022) in Fish *Clarias batrachus* (Linnaeus, 1758) of River Yamuna, Yamuna Nagar (Haryana), India

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Abstract: Helminthes parasites are reported from all habitat and group of organisms. The food, feeding habit and behavior of niche utilization favors the fish as most suitable group of hosts for parasitic helminthes. The consumption of fish and raw or uncooked product of fish infected by helminthes may lead to the transmission of infection and invasion of parasites in the top consumers of food chain of an ecosystem including human beings. The limnological attributes and physico-chemical factors of water body can determine the parasitic fauna of the same water body and also affect popolation ecology including prevalence, intensity and geographical distribution of endoparasitic helminthes. The water temperature noticed as the principal attribute which strongly not only affect immunology and physiology of fish but also affect the developmental stages, population dynamics and bio-ecology of all the classes of helminthes parasites. The present study was carried out to analyze the effect of water temperature (°C) on population ecology of caryophyllid cestodes *Lytocestus haryanii* (Babita *et al.*, 2022) in the catfish *Clarias batrachus* (Linnaeus, 1758) of river Yamuna, Yamuna Nagar (Haryana), India. During the present investigation, the average infection prevalence and worm burden was observed comparatively higher in the female fish hosts than the male hosts. Dual peak of infection prevalence was well marked and the augmented water temperature offered negative influence on the cestodes infection prevalence (IP%). On contrary the selected single hydrological attribute corroborated a positive association to mean worm burden of cestodes during study. Therefore, we recommend the awareness about parasitic helminthes among societies based on aquaculture for health, economy and sustainable management of fish culture.

Keywords: *Lytocestus haryanii*, *Clarias batrachus*, Population ecology, River Yamuna, Infection prevalence, Mean worm burden

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Introduction

Parasites in fish are natural, ubiquitous, rich and common in occurrence (Madhavi and Lakshmi, 2012; Upadhyay, 2012; Wali *et al.*, 2016; Frantz *et al*., 2018; Upadhyay and Babita, 2022; Upadhyay *et al*., 2023a, b). Parasites community of fishes give vital information about the ecosystem as these have good close communication with aqautic environment and host fish (Chai *et al.*, 2005; Mas-Coma *et al.*, 2008; Kumar *et al*., 2011; Upadhyay *et al*., 2024). Parasites species richness and their relative abundance in a host population or community depends on factors such as extrinsic factors, environment, host and vector availability, intrinsic factor of hosts or vectors, etc. (Morand *et al.*, 2000; Macpherson, 2005; Malhotra *et al.*, 2009; Jaiswal *et al.*, 2013; Nanware *et al.*, 2019; Upadhyay, 2023a). In the aquatic hosts, hydro-biological attributes played important role in the invasion, occuurence, flourishment, population biology and ecology, infracommunity dynamics, parasites transmission and host-parasite relation-ships (Morand and Hervey, 2000; Reed *et al*., 2012; Jaiswal *et al.*, 2014; Fartade and Chati, 2016; Turner *et al.*, 2021; Panwar and Upadhyay, 2022; Benedek *et al.*, 2024). The parasitic helminthes can also be used as bioindicator for biotic and abiotic attributes of the environment which may be helpful to correlate varieties of specialized traits, life-history and planning strategies for aquaculture management (Iwanowicz, 2011; Upadhyay *et al*., 2023a, 2024). Small number of cestodes often occur in healthy fish, but high numbers cause illness or even death that may hamper overall productive capacity and economic status of aquaculture systems (Upadhyay *et al*., 2015, 2019a; Babita *et al*., 2019; Upadhyay, 2020a; Paliwal *et al.*, 2023). There exists many reports showing greater host sociality or gregariousness corroborated to the higher parasite prevalence and diversity and transmission among host species in the same habitat and different trophic level of variable ecosystem (Jaiswal *et al.*, 2014; Upadhyay and Singh, 2018; Upadhyay *et al*., 2019b; Briard and Ezenwa, 2021; Deere *et al*., 2021; Schmid-Hempel, 2021; Upadhyay, 2023b; Ezenwa, 2024). Increased prevalence and intensity of parasites may also offer information to hosts of a larger habitat which further analogous to island biogeography (Morand, 2000; Altizer *et al.*, 2003; Britton *et al.*, 2011; Upadhyay *et al*., 2013, 2020; Upadhyay, 2017). The characteristic changes in the aquatic reservoirs (lotic and lentic) such as fluctuations in physico-chemical conditions, buffering capacity, temporal and special attributes along other biotic interactions may have the profound potential to reflect out in life and maturity cycle, population ecology, community dynamics and transmission behavior of the parasitic helminthes (Puniyabati *et al.*, 2010; Turner *et al.*, 2012; Jones, 2013; Mutphy *et al.*, 2013; Cable *et al*., 2017, 2020; Kołodziej-Sobocińska, 2019; Upadhyay and Nanware, 2020; Upadhyay, 2020b; Hernandez-Caballero *et al.,* 2022; Esposito *et al.,* 2023). The effect of temperature dependent host–parasite rejection response was established in earlier literature and showed variability in response of life cycle stages to sudden changes in ambient temperature (Macnab and Barber, 2012; Paul *et al.*, 2012; Cornet *et al.*, 2014; Barber *et al.*, 2016; Byers, 2020; Selbach *et al.*, 2020; Kirk *et al*., 2022; Suh *et al*., 2024; Vanalli *et al*., 2024). Therefore, the present study was planned to assess the effect of single hydrological attribute (water temperature, °C) on population ecology of caryophyllid cestodes *Lytocestus haryanii* (Babita *et al*., 2022) in the catfish *Clarias batrachus* (Linnaeus, 1758) of river Yamuna in the region Yamuna Nagar (Haryana), India.

Materials and Methods

The study was conducted for the two years (July

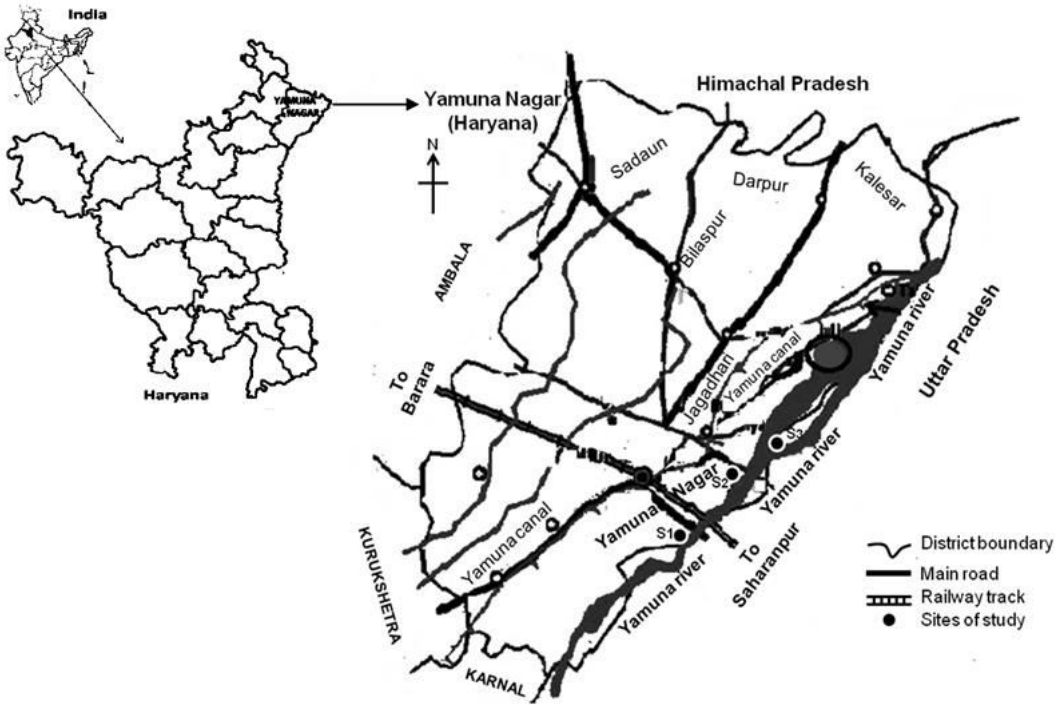

Fig. 1: The district map of Yamuna Nagar showing sampling sites (S_1, Near Yamuna bridge; S_2, Dadwa-Fatehpur; S_3, Dadupur) of river Yamuna (Map not to scale bar).

2018 to June 2020) to analyze the effect of water temperature (°C) on the population ecology, infectivity patterns of caryophyllid cestodes *L. haryanii* (Babita *et al.,* 2022) in the catfish *C. batrachus* (Linnaeus, 1758) from three sampling sites (Fig. 1) of river Yamuna in a stretch of 5 km up-stream and down-stream from the central point [Site-1 (S_1), Near Yamuna Bridge; Site-2 (S_2), Dadwa-Fatehpur; Site-3 (S_3), Dadupur] at Yamuna Nagar (Haryana), India. The fish hosts were brought to Zoology Laboratory, Department of Bio-Sciences and Technology, MMEC, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala (HR), India for further parasitological study including taxonomic identification (Upadhyay, 2012). The infection prevalence per cent (IP%) and mean worm burden (MWB) of parasitic helminthes in hosts was calculated (Malhotra and Nanda, 1989; Malhotra and Chauhan, 1981; Malhotra, 1982). The fortnightly oscillations in the riverine water were recorded onsite using digital thermometer throughout the period of investigation. There were various modern numerical tools (time series curves, regression analysis, one-way ANOVA, f-test, etc.) applied for substantiation and validation of water temperature (°C) effect on the population ecology and infectivity patterns of caryophyllid cestodes *L. haryanii* (Babita *et al.,* 2022) in the selected hosts (*C. batrachus*) through software SYSTAT11.

Results

The worms isolated from the intestine of *C. batrachus* (Linnaeus, 1758) were characterized and identified as caryophyllid cestodes *Lytocestus* Cohn, 1908 (Yamaguti, 1934, 1959) species *L. haryanii* (Babita *et al.,* 2022). The samples showed monthly fluctuations in water temperature (°C) throughout investigation and ranged between 11.9-29.6 °C during 2018-2019 (Table 1) and 11.6-30.2 °C during 2019-2020 (Table 2). The month wise pattern of variation in the water temperature (°C) was assessed through the time series curve during both the year of study (Fig. 2). The mean peak water temperature 29.6±4.8 °C; however, the lowest water temperature 11.9±2.5 °C was recorded during July 2018 and January 2019, respectively (Fig. 3). The next year of study (2019-2020) corroborated the same pattern

Table 1: Monthly variation of water temperature (°C; Mean±SD) and *Lytocestus haryanii* (Babita *et al.,* 2022) in *Clarias batrachus* of river Yamuna, Yamuna Nagar (HR), India during 2018-2019

Months	Wat. Temp. (°C)	Infection Prevalence (IP %)			Mean Worm Burden (MWB)		
		Male	Female	Total	Male	Female	Total
2018							
July	29.6±4.8	20.00	30.00	25.00	5.50	5.67	5.60
August	27.3±4.7	22.22	18.18	20.05	4.50	5.50	5.00
September	25.7±4.5	25.00	37.50	31.50	2.66	4.50	3.50
October	25.6±2.7	83.30	14.29	48.80	1.20	2.50	2.06
November	22.7± 4.0	23.08	42.86	33.00	1.66	2.00	1.83
December	17.3±3.7	35.00	45.00	40.00	5.75	6.25	6.00
2019							
January	11.9±2.5	55.55	45.45	50.00	4.60	4.20	4.50
February	16.5±1.9	28.57	83.83	55.92	2.50	3.40	3.00
March	17.4±1.4	25.00	50.00	37.50	2.00	2.50	2.25
April	23.2±2.7	30.00	40.00	35.00	4.00	5.33	4.53
May	22.1±1.7	50.00	33.33	40.50	5.33	6.25	5.75
June	23.8±1.8	27.27	22.22	24.75	5.66	6.00	5.80

SD, Standard Deviation; Wat. Temp., Water Temperature.

Table 2: Monthly variation of water temperature (°C; Mean±SD) and *Lytocestus haryanii* (Babita *et al.,* 2022) in *Clarias batrachus* of river Yamuna, Yamuna Nagar (HR), India during 2019-2020

Months	Wat. Temp. (°C)	Infection Prevalence (IP %)			Mean Worm Burden (MWB)		
		Male	Female	Total	Male	Female	Total
2019							
July	30.2±4.1	22.25	27.27	24.50	2.00	4.50	3.25
August	26.9±3.8	16.67	14.29	15.50	4.50	3.55	4.00
September	25.8±4.2	18.33	25.00	21.60	3.50	5.00	4.33
October	26.3±2.5	30.00	20.00	25.00	2.33	2.82	2.50
November	22.4±3.5	33.33	37.50	35.50	2.00	3.33	2.65
December	17.8±3.8	45.45	64.44	55.00	3.90	4.75	4.18
2020							
January	11.6±2.9	50.00	60.00	55.50	5.20	5.60	5.40
February	15.1±2.9	61.40	30.77	46.00	1.33	2.25	1.80
March	17.2±2.4	48.00	42.85	45.50	2.33	3.00	2.70
April	23.7±2.4	40.00	50.00	45.00	5.60	4.60	5.10
May	22.1±1.8	44.44	54.55	49.50	4.50	5.25	4.88
June	23.1±2.7	50.00	70.00	60.00	5.33	5.75	5.57

SD, Standard Deviation; Wat. Temp., Water Temperature.

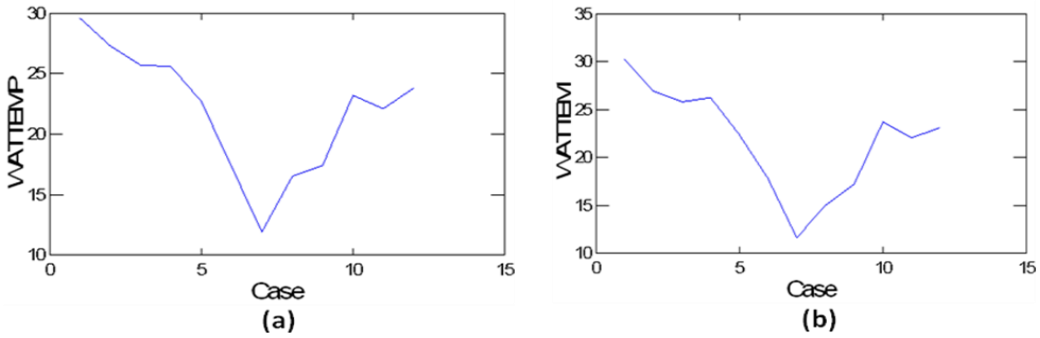

Fig. 2: Time series curves illustrating pattern of fluctuation in water temperature (WATTEMP, °C) of river Yamuna during 20018-2019 (a) and 2019-2020 (b). *Where:* Case, Months.

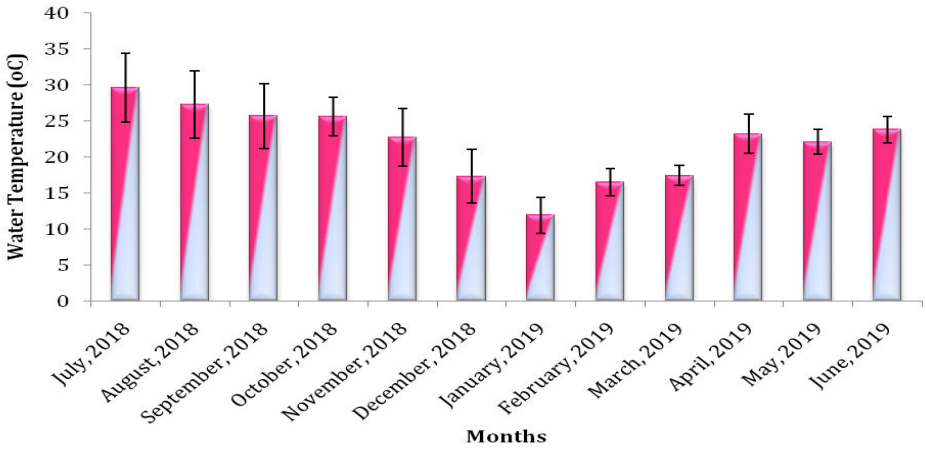

Fig. 3: Monthly variation (Mean±SD) in water temperature (°C) of river Yamuna, Yamuna Nagar (HR) during 2018-2019.

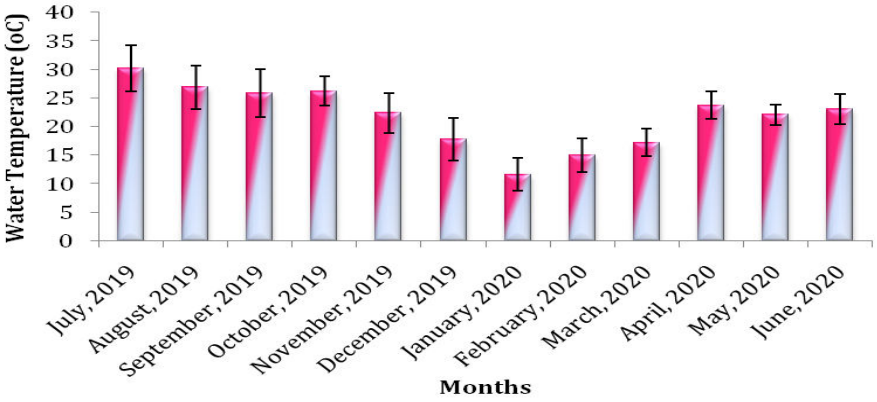

Fig. 4: Monthly variation (Mean±SD) in water temperature (°C) of river Yamuna, Yamuna Nagar (HR) during 2019-2020.

with highest water temperature 30.2±4.1 °C and the lowest water temperature 11.6±2.9 °C in the month of July 2019 and January 2020, respectively (Fig. 4).

The observations of monthly parasitic prevalence and intensity corroborated to the month wise variations in the hydrobiological attributes of the habitat utilized by the hosts. The cestodes infection prevalence in the total host fish ranged between 20.05-55.92 % (IP in male fish, 20.00-83.30 %; IP in female fish, 14.29-83.83 %) with abrupt decline in the month of July 2018 and October 2018 in male and female fish, respectively (Table 1). The infection recorded to be random throughout investigation but the mean worm burden in total host fish was ranged between 1.83-6.00 (MWB in male fish, 1.20-5.75; MWB in female fish, 2.00-6.25) during 2018-2019 (Table 1). The highest mean intensity was documented in the month of December, 2018 and June, 2019 corroborated to the maximum oscillation in the hydrological attributes.

The average cestodes prevalence in total host fish ranged between 15.50-60.00 % (IP in male fish, 16.67-61.40 %; IP in female fish, 14.29-70.00 %) during 2019-2020 (Table 2). The monthly observation for parasitic infection showed that the female hosts were more prone to infection than the male hosts. Dual peak of infection prevalence was well marked and recorded in the month of December 2019 and June 2020. On contrary the abrupt decline in the cestodes prevalence was observed during August, 2019 in both sexes of hosts. On the other hand regarding the parasitic observations, the mean worm burden was enumerated between 1.80-5.57 with

Table 3: Linear regression trends and One way ANOVA depicting correlation and biostatistical significance of IP % and MWB of *L. haryanii* (Babita *et al.,* 2022) in *C. batrachus* with oscillations in water temperature (Wat Temp, °C) of river Yamuna at Yamuna Nagar during 2018-2020

Factors	Infection Prevalence (IP%) in Fish Host			Mean Worm Burden (MWB) in Fish Host		
	Male	Female	Total	Male	Female	Total
2018-2019						
Wat Temp (°C)	Y=25.208-0.752X r=-0.208 p≤0.518	Y=18.439-2.474X r=-0.690 p≤0.013	Y=16.198-0.868X r=-0.356 p≤0.256	Y=1.974+0.188X r=0.580 p≤0.048	Y=1.668+0.188X r=0.626 p≤0.029	Y=1.834+0.180X r=0.572 p≤0.052
	$F_{1/10}$=0.450 p≤0.518	$F_{1/10}$=9.092 p≤0.013	$F_{1/10}$=1.449 p≤0.256	$F_{1/10}$=5.060 p≤0.048	$F_{1/10}$=6.450 p≤0.029	$F_{1/10}$=4.863 p≤0.052
2019-2020						
Wat Temp (°C)	Y=16.413-2.603X r=-0.748 p≤0.005	Y=16.260-1.621X r=-0.578 p≤0.049	Y=11.365-2.503X r=-0.842 p≤0.001	Y=1.811+0.118X r=0.420 p≤0.174	Y=1.777+0.133X r=0.468 p≤0.125	Y=1.658+0.116X r=0.446 p≤0.146
	$F_{1/10}$=12.671 p≤0.005	$F_{1/10}$=5.009 p≤0.049	$F_{1/10}$=24.439 p≤0.001	$F_{1/10}$=2.145 p≤0.174	$F_{1/10}$=2.811 p≤0.125	$F_{1/10}$=2.484 p≤0.146

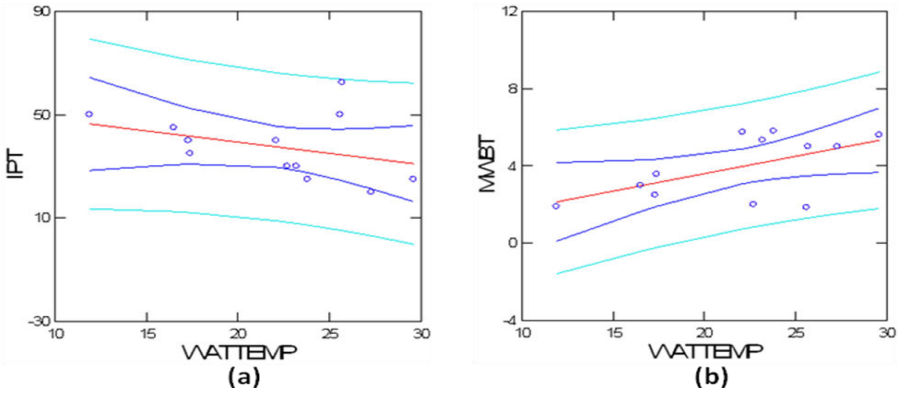

Fig. 5: Effect of water temperature (WATTEMP °C) on infection attributes of *L. haryanii* (Babita *et al.,* 2022) in *C. batrachus* during 2018-2019. *Where:* IPT, Infection Prevalence % in total fish; MWBT, and Mean Worm Burden total fish.

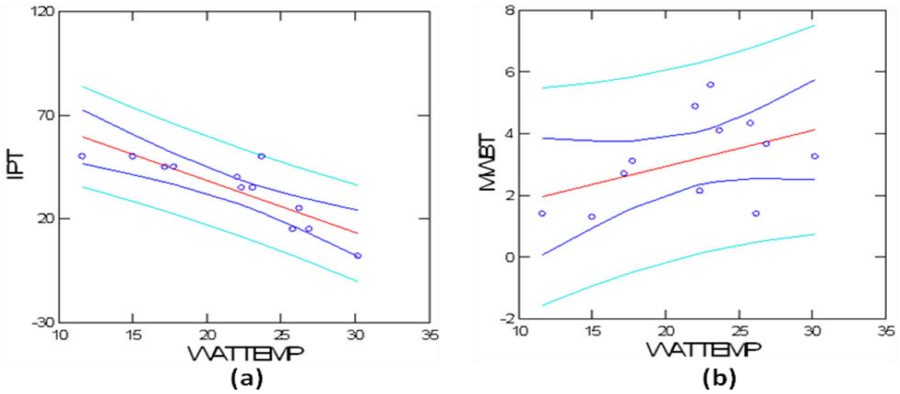

Fig. 6: Effect of water temperature (WATTEMP °C) on infection attributes of *L. haryanii* (Babita *et al.,* 2022) in *C. batrachus* during 2019-2020. *Where:* IPT and MWBT was IP % in total fish, and MWB total fish, respectively.

comparatively higher parasitic load in infected female hosts [MWB in infected female fish, 2.25-5.75(4.20±0.50)] than the infected male fish [MWB in infected male fish, 1.33-5.33 (3.50±0.38)] during 2019-2020 (Table 2). Similar to the trend of infection prevalence, dual peak of mean intensity was recorded in the month of January 2020 (MWB in male fish, 5.20; MWB in female fish, 5.60) and June 2020 (MWB in male fish, 5.33; MWB in female fish, 5.75) during current year of investigation (Table 2).

The correlation of parasitic prevalence and mean worm burden with water temperature (°C) of river Yamuna was analyzed through the linear regression equation (Table 3) and the significance of association enumerated through one way ANOVA/ f-test (Table 3) showed remarkable results in both the year of study 2018-2019 and 2019-2020.

The findings and biostatistical studies reflected that the augmented water temperature (°C) significantly affected the establishment, richness, distribution and transmission of cestodes in the host population as illustrated through the linear regression graphs (Fig. 5,6). The observations and biostatistical enumeration through linear regression graph to correlate the effect of hydrological attribute (single parameter) reflected that augmented water temperature (°C) offered negative influence on the cestodes infection prevalence (IP%) in the total host fish during 2018-2020 (Figs. 5a, 6a). On contrary the increased water temperature (°C) showed a positive association with the mean worm burden of cestodes in the host fish (Figs. 5b, 6b) during same year (2018-2020).

Discussion

In the present investigation the caryophyllid tapeworms of *L. haryanii* (Babita *et al.,* 2022) harbored the *C. batrachus* from river Yamuna. During the present investigation, the average infection prevalence in total fish hosts was observed as 36.90% that found to be comparatively higher in the female fish hosts than the male hosts. The mean worm burden (MWB) of present cestodes also showed the sex biased correlations with comparatively higher average MWB value (4.40) in female host fish than male hosts (MWB, 3.40). On contrary, Borde and Jawale (2012) documented comparatively lower overall infection prevalence of *Lytocestus* (Cohn, 1908) in *C. batrachus* that was 22.7 % with mean intensity 1.7 and dominance 80.8%. On the other hand Arora *et al.* (2010) also reported significantly lower overall prevalence of the *L. fossilisi* in *C. batrachus* that was 28.0%. According to Chandra *et al*. (1997) the overall prevalence and intensity of *L. indicus* in the catfish *C. batrachus* was 33.14% and 3.75, respectively. The occurrence of infection was host specific but the distribution and dynamics was regulated by physiological, ecological factors, diet and mode of feeding (Kennedy, 1976; Jadhav and Bhure, 2006; Upadhyay, 2020c; Upadhyay *et al.,* 2024).

The moderate water temperature, favored the zooplankton fauna, thereby it may corresponds to the richness of parasitic population in comparison to the period of higher temperature. The monthly changes in hydrological attributes of river water (e.g. temperature, pH, conductivity) affected occurrence of parasites in the aquatic hosts and played an important role in the establishment richness of infection of parasitic helminthes (Dogiel *et al*., 1970; Kisielwska, 1970; Chauhan and Malhotra, 1984; Rao and Rao, 1996; Gupta *et al*., 2013). Even the water temperature does not have a direct impact on parasitic infection, but it has key influence on the occurrence of infection in aquatic organisms, their developmental cycle and parasitization (Chubb, 1980, 1982; Jha *et al*., 1992; Upadhyay *et al*., 2023b). Joshi (1982) stated that lower environmental temperature might reduces feeding, breeding, respiration and all other physiological activities in fishes which resulted in induced metabolic demand of oxygen at low temperature. Thereby the higher temperature favored the augmentation of infection incidence, mean intensity, mean worm burden, and flourishment, while it leads to declined transmission, infection pattern and prevalence

(Kennedy, 1971). Dhar and Peerzada (1989), Dorucu (1999), Shomorendra *et al*. (2005), Jarkovsky *et al.* (2007) and Sinha and Sinha (2008) have reported that the factors including environmental temperature were responsible for population dynamics of parasitic helminthes and the distribution of parasitic infections. Experimental studies by Kennedy (1969) have shown that the cestode *Caryophyllaeus lattices* can establish in fish and survive for longer period at lower temperature and reported that the temperature was major controlling factors of tapeworms' infection. Similar results were published by the Raipalli and Raipalli (2021) and stated that the infection of caryophyllidean tapeworm *Lytocestus* sp. was comparatively higher during the period of lower temperature and vice versa in the period of high temperature. The findings may also correspond to the development of parasite which needs high temperature and sufficient moisture thereby the population fluctuations corroborated to the variations in water temperature (Borde and Jawale, 2012). Hence, higher worm burden substantiated in the month of higher water temperature which further validated by the linear regression graphs.

Conclusion

In the present investigation single water quality parameter (water temperature, ^{o}C) of the river Yamuna from three different sampling locations of Yamuna Nagar (Haryana) was assessed during 2018 to 2020 which revealed that there was month-biased oscillation with significant fluctuation to the desire prescribed limit. The findings of research investigation reflected that the tapeworms' prevalence was comparatively higher during 2019-2020 than the earlier year (2018-2019) investigation; however, the mean worm burden did not showed the significant variations. The trend of infection prevalence and intensity was found to be identical in the both the year of study. The findings reflected that during this period most of the male fish was carrying infection but harbor minimum number of parasites in comparison to female hosts. It means the intrinsic and extrinsic factors may not support the transmission dynamics and infectivity pattern of parasites; however, the load, richness and flourishment of the caryophyllid tapeworms corroborated to augmented single attribute (water temperature, ^{o}C) among the hosts were noticeable. Therefore, study of parasitic helminthes and their population dynamics can be used as the biological basis of method to regulate population and infra-communities of parasitic helminthes in aqua-culture. The authors wish to emphasize on the awareness of relationships between aquatic fauna *vs.* water quality and parasitic infra-community *vs.* human health and supposed to be an essential aspect to carry out customary monitoring and surveillance of such important aquatic ecosystems.

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