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Impact of Temperature and *Notonecta* predation on Cyclomorphosis in *Daphniapulex*: A Field Study in Subtropical environment, Jammu, India

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Abstract

The present study was carried out to find the impact of temperature and predation on cyclomorphosis in Daphnia pulex in a shallow pond with subtropical climatic conditions. Average values for carapace length and tail spine length were recorded to be 1.28 mm ± 0.143 and 0.529 mm ± 0.073 respectively during whole period of study. The length of carapace and tail spine were distributed over a very wide range of values during period of low temperature (10-24ºC) as compared to the high temperature period (25-30ºC). The results indicated that though D. pulex didn't exhibit the characteristic cyclomorphic traits like crest enlargement but body allometry showed certain variations among two different seasons with temperature difference of 22ºC which has suggested producing cyclomorphic/phenotypic alterations. Regression analysis revealed that temperature exerted a highly significantly impact on carapace length in D. pulex. However, predation of Notonecta sp. on the D. pulex was not observed to show any direct phenotypic implications on the individuals.

Keywords: Cyclomorphosis, *D. pulex*, temperature, Notonectids.

Introduction

Cyclomorphosis is a temporal (seasonal or occasional), cyclic or induced morphological changes that occur in the planktonic population primarily as an outcome of abiotic or biotic cues in the environment. Though this concept began with mere appreciation of variations in freshwater plankton but later on various workers generate a lot of new and valuable findings on the causes and biological significance of this phenomenon[1]. Among several assumptions that are put forth to explain its ecological significance, most important ones suggested that cyclomorphosis probably act as an adaptive strategy against potential predators (both vertebrates and invertebrates) and/or as a phenomenon involved in maintaining and stabilizing buoyancy of organismsin the water column[2-8]. Furthermore, some workers emphasized the importance of abiotic factors like temperature, turbulence and light for morphological variability among plankton[9-13].

Among various Cladoceran taxa, cyclomorphosis is thoroughly investigated in several species of genus *Daphnia* (*D. retrocurva, D. lumholtzi, D. carinata, D. galeata, D. cucullata, D. pulex* etc.).*Daphnia* are most common pond cladocerans[14]. These small crustaceans exhibit an array of morphological changes in their overall body shape and size and also develop exuberant structures like helmets, crests, horns, neck teeth etc[5]. Such variations can be either cyclic (when induced by environmental variables) or polymorphic (in response to predator).

Though this phenomenon was generally believed to be absent in tropical and subtropical fresh waters because of limited temperature fluctuations as compared to temperate regions but since the seasonal temperature difference for the study area was about 22ºC which may be sufficient toproduce certain cyclomorphic variations in plankton[16]. In addition to this, the study pond was also observed to be infested by notonectid predators particularly during the period of low temperature which was also taken into account. Thus, these two factors prompted us to investigate the process of induction of cyclomorphosis in *Daphnia pulex* and to find whether temperature and /or predator in natural sub-tropical environment have any impact on the phenotype of *D. pulex*.

Material and Methods

Study area: The study pond was a small rural pond located near Shivalik ranges of Himalaya (74°19' E to 75° 20'E longitude and 32°27' N to 33°50'N latitude) in India. Itis a small shallow pond with an area of 300 m^2 and depth ranging from 2.5-5 ft suitable for the pond dwelling daphnid, *D. pulex*. It is rich in organic matter and nutrients as well as support fairly high population of *D. pulex* for most part of the year. Moreover, during the colder periods *Notonecta* sp. was also recorded from the pond as indicated from previous surveys.

Sampling and Allometric measurements of *D.pulex*: Zooplankton samples were collected (every week) using plankton net having a mesh size of 95 µm and were preserved in 4% formaldehyde. The zooplankton were identified to the species level using a dissecting microscope (10X) and compound microscope (40X). Though the distribution of *D. pulex* was discontinuous throughout the study period (absent in monsoon season) but the population is continuous in both the high and low temperature periods to make the necessary

allometric measurements and comparisons. Since *D. pulex* population consist of different age-size classes so, only mature adult organisms (berried individuals) were selected for measurements. For each zooplankton sample, approximately 50% of adult *Daphnia pulex* were measured with an uncertainty of 10 µm. Morphological measurements were carried out using a microscope with an ocular micrometer. The cyclomorphic parameters measured were carapace length and tail spine length. Carapace length was measured as the distance between the posterior boundaries of the insertion point of the second antennae to the posterior margin of the carapace while tail spine length was measured from the posterior margin of the carapace to the apex of the caudal spine. Carapace length and tail spine length were measured at 40X magnification[17-19].

Collection of Insect predator (*Notonecta* sp.): *Notonecta* sp. was present only during winters. Aquatic insects were collected by kick sampling with a D-frame pond net and preserved in the field in 80% ethanol[20-21]. Then, the number per tow was calculated by dividing the total number of insects collected with the number of sampling effort (not less than 3).

Statistical analysis: From the field data,descriptive statistics and regression relationships were deduced using SPSS 4.0 statistical software and the level of significance was taken at P ≤0.01.

Results and Discussion

The temperature of water varied from as low as 10ºC (January) to as high as 32ºC (June), giving a large seasonal difference of 22ºC.For whole investigative period, average values for carapace length and tail spine length were recorded to be 1.28 mm ± 0.143 and 0.529 mm ± 0.073 respectively.

The values of carapace length and tail spine length was distributed over a very wide range during period of low temperature (10-24ºC) as compared to the high temperature period (25-30ºC) (figure 1).

During summer, the individuals of *D.pulex* were recorded with an average value of 1.18mm ± 0.02 and 0.532mm ± 0.03 for carapace length and tail spine length respectively. However, in the period of low temperature carapace increased in length with a higher average value of 1.36mm ± 0.15 while tail spine length (0.526mm ± 0.09) was observed to decrease by a small fraction. When *Notonecta* population appeared and became abundant, the carapace length of *D. pulex* recorded with sharp decline which then followed by a rise again (figure 2). Figure 3 revealed regression results for observed allometry of *D. pulex*i.e. carapace length and tail spine length corresponding to temperature. Apparently, only carapace length was significantly related to temperature (r^2 = 0.72, P ≤0.01).Also, Figure 4 suggested that population of *D. pulex* was observed to rise at much faster pace in presence of *Notonecta* sp. in the pond.

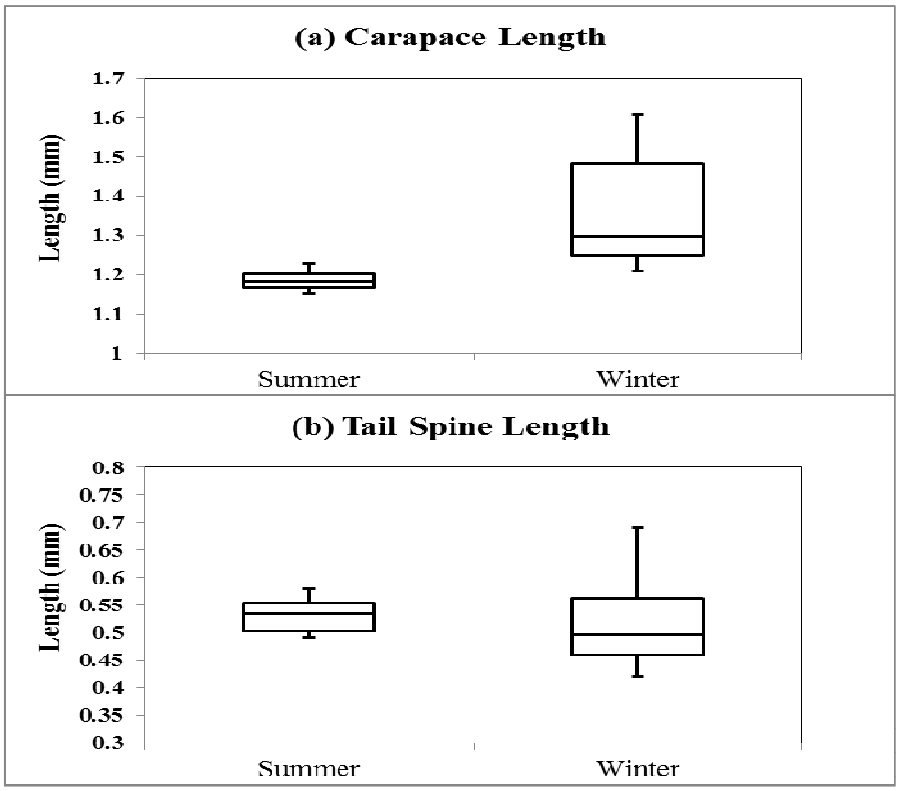

Figure-1

Box plots for (a) Carapace Length and (b) Tail Spine Length values for *D. pulex* during the summer and winter period of study

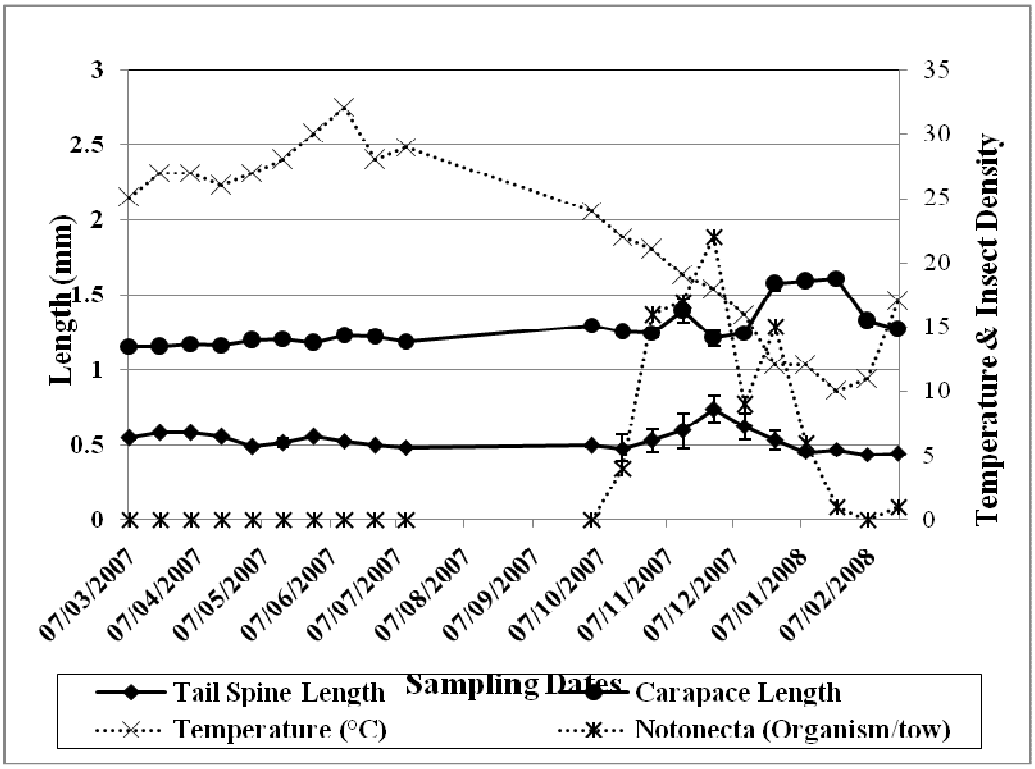

Figure-2
Seasonal variations in temperature (ºC), *Notonecta* sp. (Organisms/tow) and observed allometry for Carapace & Tail spine for *D. pulex*, throughout the period of investigation

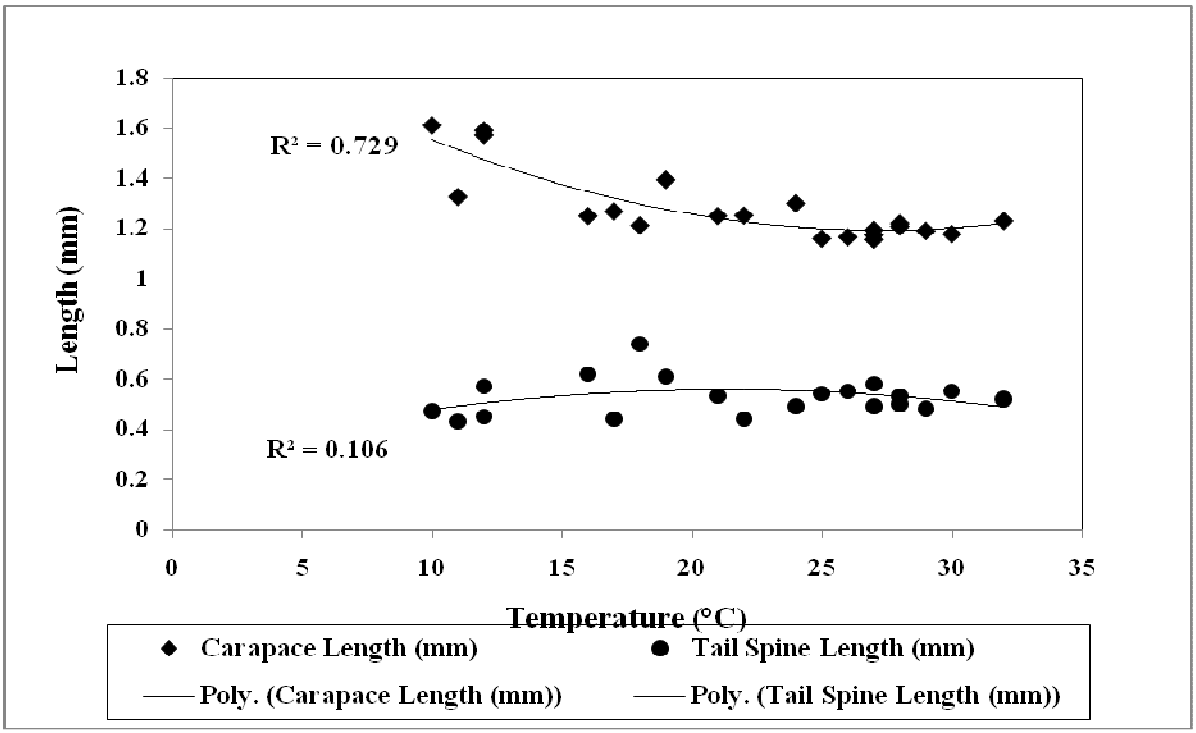

Figure-3
Relationship between temperature and the other cyclomorphic parameters of *D. pulex* collected from the pond, significant between temperature vs carapace length ($r^2 = 0.72$; $P \leq 0.01$)

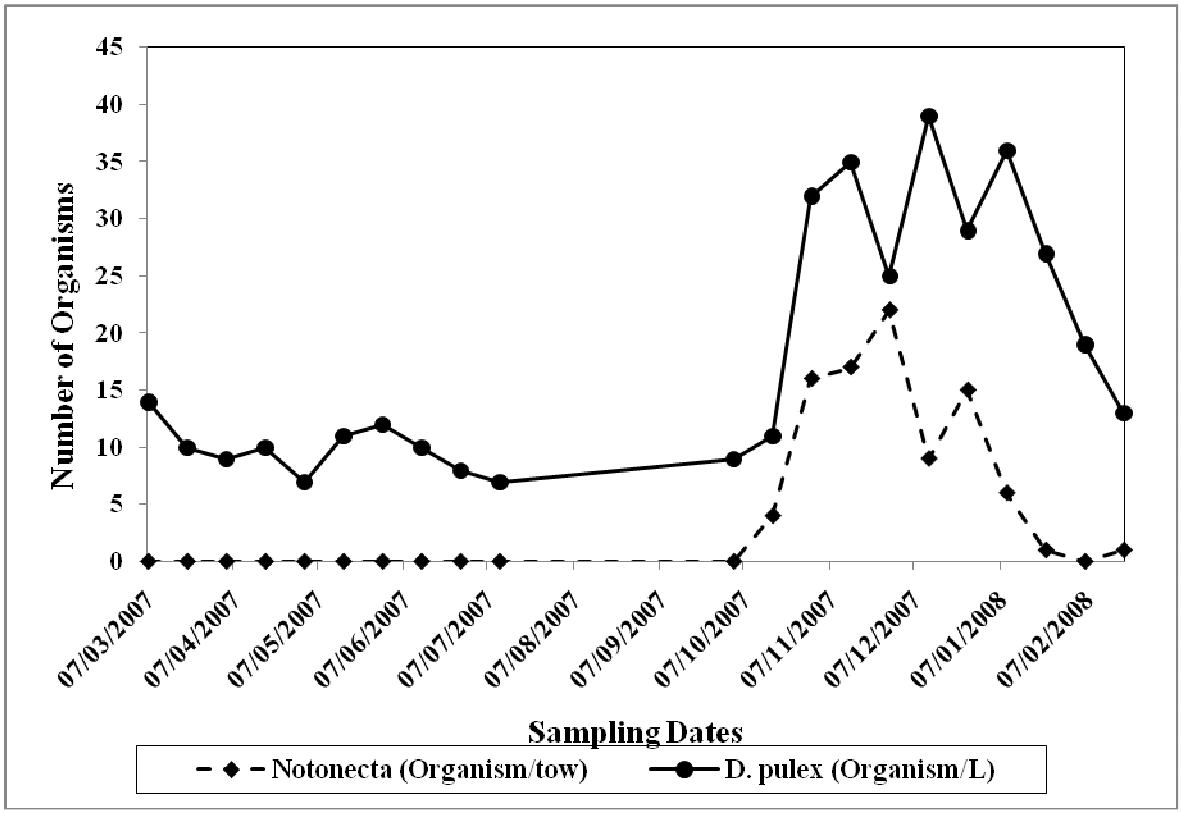

Figure-4
Seasonal variation in the population of *D. pulex* and *Notonecta* sp. throughout the period of investigation

The phenomenon of cyclomorphosis in *Daphnia* was known to be influenced by both temperature and invertebrate predators[6, 22-27]. Several workers are of the opinion that temperature was of little significance for the phenomenon of cyclomorphosis in zooplankton in tropical regions because seasonal temperature difference in such regions was not very large as for the temperate areas[16,28-29]. However, from current observations, *D.pulex* showed some morphometric alterations corresponding to the temperature variations in the subtropical pond.

The negative slope in figure 3 evidently indicated that temperature casted a negative effect on the carapace length of *D. pulex*. Thus, with lowering of temperature there was an increment in the carapace length. Angilletta et al. reported that a large number of ectotherms including copepods and cladocerans grow at slower rate and attain maturity at larger body size at low temperature[30]. Several workers like Atkinson, Van der Have and Jong and Panov and McQueen also reported that maximum adult size is inversely correlated to temperature[31-33]. In Australia, Mitchell also emphasized that when water temperature decreased, the adults of *D. carinata* showed an expansion of carapace which had gone larger than 2 mm[34]. Yurista also put on record that the body size differences in *D. lumholtzi* obtained from Fairfield Reservoir (1.8 mm) and Kentucky (1.2 mm) may be due to environmental temperature experienced by either clones[13]. Thus, the determination of body size (or carapace length in present study) by temperature could be of some physiological importance to organisms as also emphasized by Angilletta et al.[30]. The insignificant variability in mean tail spine length during the two seasons and significant variability within the winter period (figure 1) was perhaps related to occurrence of *Notonecta* sp. as predator.

When insect predation came into play during winter there is an unexpected fall and then again a rise in carapace length (figure 2) of *D.pulex*. This was probably because when *Notonecta* sp. appeared in the pond, it might prey upon the large bodied individuals from the wild population and smaller individuals escape its visual predation. This may have resulted in a population of *D. pulex* with small carapace length which was observed as a drop in the average carapace length during that period. Several workers emphasized that *Notonecta* sp. are common invertebrate predators of larger cladocerans like *D. pulex* and being a size selective predator could potentially alter the size frequency of adults in a Daphnid populations in ponds[25, 35-37].

During later winter with intensified notonectid predation, the size frequency of community again shifted to the larger bodied individuals (with large carapace) and there is also increase in population of *D. pulex*. This may suggest that the individuals of *D. pulex* instead of changing body size to foil predator, produce large number of individuals thereby increasing its population density. According to Black, *D. pulex* in response to *Notonecta*

predation showed increased reproductive output (clutch size); juveniles grow rapidly and attain a larger size at first reproduction[25].

Conclusion

Thus, from the present work we can suggest that organisms can producecyclomorphic variabilityvto some extent even in tropical and subtropical regions provided there issufficient temperature difference among the seasons.Variability in phenotype was observed in the body allometry (carapace length) of *D. pulex* and not in the form of crest enlargement or elongated tail spine which is otherwise common cyclomorphic feature in *D.pulex* inhabiting temperate waters. However, predation of *Notonecta*sp. on the *D.pulex* was not observed to show any direct phenotypic implications on the individuals but perhaps notonectid predation altered the size frequency of the *D. pulex* individuals in the population during initial period of predator occurrence.

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