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Population structure and some biological parameters of *Daphnia similis*, an important fish food organism

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Abstract
Population structure of *Daphnia similis* was analysed in a local perennial pond at Kot-Bhalwal, Jammu for a period of one year (January –December, 2013). Throughout the experimental period, density of *D. similis* remained quite high (12-15 ind/ml) with a maxima recorded to be 30 ind/ml during March (temperature 21 °C) and minima recorded during August (5 ind/ml) and September (2 ind/ml). Physico-chemical parameters during the entire study were recorded to be well within the tolerable range of the species. Field observations, as authenticated by laboratory studies reveal the mean length (1.66 mm), mean brood size (19.1mm) to be maximum during spring as compared to extreme summers (June onwards) and winter (January) when the mean length, mean brood size and incubation period was recorded to be minimum.

Keywords: *Daphnia similis*, population structure, brood size, incubation period.

1. Introduction
Daphnia belongs to sub-phylum Crustacea and order Cladocera. *Daphnia* range from 0.2mm-3mm in length and are commonly called as water fleas because of their saltatory swimming style. *Daphnia* constitutes an important link in the food chain as they make their energy available to higher tropic levels by serving as essential dietary component of many invertebrate as well as the preferred food of fish fries [1, 2, 3]. They also play an important role as biosensors of environmental degradation and find a use in the pollution monitoring as bio-indicator species.
Reproduction in *Daphnia* occurs via both asexual and sexual modes. During favourable environmental conditions, *Daphnia* reproduces parthenogenetically and the young ones are nurtured inside the brood pouch of the females. Parthenogenetic males are produced through sexual reproduction during harsh environmental conditions. The size of males is smaller than females and they have a specialized abdominal appendage with the help of which female's carapace is opened and spermatheca is inserted to fertilize the eggs. Such fertilized eggs are called winter eggs and they consist of an extra shell layer called ephippium.
Present contribution deals with the population structure and some biological parameters of *D.similis* in a local perennial pond in relation to different ecological conditions prevailing in the water body vs. laboratory conditions.

2. Materials and method
The samples were collected by filtering 20 litres of pond water through a silk (crave) cloth conical net with a vial attached at its cone in which zooplankton become concentrated. The zooplankton components thus collected were fixed by drop wise addition of formalin till its concentration reached to 5% in which they were preserved.

2.1 Identification
Preserved samples from the field were brought to laboratory and for the purpose of estimation of their population structure, they were studied under microscope. The species was identified [4, 5, 6]. The density was calculated using the formula.

$$\text{No. of organisms/litre} = \frac{\text{Total no.of organisms/drop} \times \text{volume of conc.solution (ml)}}{\text{Volume of sample (l)} \times \text{volume of one drop}}$$

3. Results and Discussions

The biological parameters of *D. similis* and its density calculations calculated from pond 1 during January, 2013 to December, 2013 are presented in tabular form (tables 1, 2, 3).

A look at table 1 indicates significant variations in various biological parameters. The overall scenario that emerges is that *D. similis* finds intermediate temperature range (20-25 °C) to be the most favourable at which time mean brood size (19.1), mean length (1.66mm) as well as density (30 ind/ml) were recorded to be the maximum. Density remained quite high during the months January-June, 2013 (12 ind/ml and above), the minima being evident in the month of August and September (5ind/ml and 2 ind/ml respectively). *Daphnia* were reported to be absent in the months of October and November. Exceptionally high density of *D.similis* was recorded during the month of March (30 ind/ml). Otherwise also, this particular water body supported a remarkable population of *D.similis*, not found anywhere, despite rigorous netting operations were conducted at a number of water bodies existing in the similar topographical regime.

Table 1: Morphometric measurements of *D.similis* in relation to temperature and density

Months	Density/ml	Temperature(°C)	Mean length of ind.(mm)	Mean brood size	Mean width of carapace(mm)	Mean eye diameter (mm)	Mean length of carapace spine(mm)
JAN	15	14.5	0.94±0.51	8.1±1.15	0.42±0.11	0.11±0.008	0.36±0.22
FEB	12	19	1.05±0.40	10±1.35	0.42±0.07	0.13±0.007	0.47±0.28
MAR	30	21	1.66±0.57	19.2±1.31	0.63±0.03	0.12±0.010	0.54±0.18
APR	15	28	0.96±0.36	16.5±1.31	0.44±0.10	0.14±0.009	0.48±0.23
MAY	12	33	0.94±0.40	12.5±1.08	0.44±0.10	0.12±0.012	0.52±0.22
JUNE	13	32	0.87±0.22	11±1.05	0.43±0.09	0.13±0.01	0.40±0.27
JULY	10	28	0.77±0.18	9.8±1.25	0.46±0.10	0.12±0.012	0.32±0.17
AUG	5	26	0.83±0.22	8.8±0.91	0.47±0.09	0.12±0.008	0.38±0.21
SEP	2	27	0.75±0.19	6.9±0.73	0.41±0.09	0.12±0.01	0.4±0.24
OCT	-	21	-	-	-	-	-
NOV	-	17	-	-	-	-	-
DEC	12	12	0.92±0.43	13.9±0.92	0.42±0.07	0.12±0.02	0.39±0.21

Table 2: Showing mean length, mean brood size and incubation time under laboratory conditions at different temperature regimes: a(10-12 °**C**); b(20-22 °C); c(25-27 °C); d(30-32 °C).

Temperature	Mean length (mm)	Standard deviation(±)	Mean brood size	Standard deviation(±)	Incubation time
a	1.9	0.25	15.7	1.76	105 hours
b	2.2	0.19	16.4	1.57	78 hours
c	1.68	0.21	17.8	1.22	49 hours
d	1.53	0.24	12.7	1.56	32 hours

The population structure in the field could be authenticated by laboratory observations where the mean number of eggs per female was found to be 15.7 at 10-12 °C; 16.4 at 20-22 °C; 17.8 at 25-27 °C and 12.7 at 30-32 °C (table 2). The development time from eggs to adult based on laboratory observations was 105 hours at 10-12 °C, 78 hours at 20-22 °C, 49 hours at 25-27 °C and 32 hours at 30-32 °C. Present observations are also in conformation to those made by Langer (1991) wherein they have also recorded a similar trend of increase in mean length and brood size up to the temperatures 20-27 °C after which the population structure as well as other parameters (mean length, mean brood size) recorded a decline.

A point worth mentioning here is that the population decline recorded in the month of April and onwards (up to September) may be attributed to a) rise in temperature b) overcrowding c) acidic pH. As already mentioned, temperature plays an important role in determining the population structure of a species due to its complex relationship with various biological parameters like growth and egg production. A rise in temperature, therefore, favoured the increased growth and production of offspring (up to optimum range i.e., 20-25 °C) (table 1 and 3) beyond which a further rise in temperature lead to reduced growth and reproduction, though the mean density in field conditions never reached below 12ind/ml.

In the month of March, population density was maximum (30ind/ml), therefore the space available to the organisms also becomes a limiting factor as it results in intraspecific competitions and therefore, leading to increased mortality. That the population growth is a function of available space has already been documented by various workers [7] who have reported the lower limits of space for *Diaphanosoma* to be $6cm^3$ ind^{-1} ($30cm^3$/5ind) and $12cm^3$ ind^{-1} ($60cm^3$/5ind), since *Diaphanosoma* failed to survive and generate off-springs at this particular space volume. Their studies (1983) also revealed that mean length of *M. micrura* is adversely affected by population density. Population density also exerts an impact on egg production.

Available space is thus one of the most critical factors for the survival of animals. Dense aggregations of populations are, therefore, likely to cause mortality at higher inoculations. While working on the effect of harvesting on the population structure various workers [8] have recommended a space requirement of $13.88cm^3$/ind for *M. micrura* and *S.vetulus*, $41.6cm^3$/ind for *D. similis* and $4.62cm^3$ for *C. cornuta*. The same principle seems to hold true in the present study i.e., when all the ecological conditions of the aquatic ecosystem are favourable, rather the most suitable to hold a particular community, population explosion of that species take place which ultimately reaches its peak (30ind/ml in present study). Every ecosystem, however, has got a carrying capacity beyond which it cannot sustain the biota; the decline in population has to follow due to increased intraspecific as well as interspecific competitions between the individuals.

Table 3: Monthly variations in the physico-chemical parameters of water body

Parameters	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Air Temp	17	22	26.5	31	39	34	31	30	28	25	20	15
Water Temp	14.5	19	21	28	33	32	28	26	27	21	17	12
Transparency	46	45	44	49	48	48	45	45	44	44	46	48
pH	6.3	837	8.9	8.2	8.0	6.7	7.8	7.2	6.1	5.3	7.8	7.9
Do	4.0	5.6	4.4	4.2	4.0	4.8	4.0	4.1	6.4	5.1	6.3	7.0
FCO_2	8.5	4.0	5.0	3.8	2.8	7.6	4.0	4.3	4.6	4.0	4.2	4.1
Carbonates Mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Bicarbonates Mg/L	304.00	208.8	265.96	280.96	320.1	507.5	638.1	768.9	779.1	644.9	400.2	396.4
Nitrates Mg/L	0.572158	0.572196	0.57250	0.57250	0.572147	0.572136	0.572260	0.5722530	0.572244	0.57219	0.572177	0.572169
Phosphates Mg/L	0.047	0.069	0.085	0.086	0.090	0.094	1.03	0.96	0.93	0.153	0.077	0.083

The decline and complete absence of *daphnids* from the pond during the months of October and November respectively might be due to acidic pH conditions prevailing in the pond as all other physico-chemical conditions seem to be within the permissible limits. Although there has been no single comprehensive study on the effects of pH on all cladoceran species, the evidence provided by available studies suggest that, approximately two-thirds of cladocerans flourish in alkaline waters (or are broadly tolerant to a range of conditions) while just over one-third prefer acidic waters. Population of *D.longispina* was reported to decline in acidified lakes but when the water was limed an increase in their numbers was restored [9]. Table 4 summarises the available data on pH references of various cladoceran species from the literature [10].

Table 4: Preferences of cladocerans for acidic or alkaline water bodies. (Derived from Duigan and Kovach, 1991).

Species favouring acidic water bodies	Species favouring alkaline water bodies
Alona rustica	*Alona affinis*
Alona guttata	*Alona costata*
Alonella excisa	*Alona rectangulara*
Alonella nana	*Daphnia longispina*
Alonopsis elongata	*Anchistropus emarginatus*
Chydorus sphaericus	*Eurycercus lamellatus*
Chydorus piger	*Leydigia leydigi*
Daphnia obtusa	*Pleuroxus aduncus*
Graptoleberis testudinaria	*Pleuroxus laevis*
	Pleuroxus uncinatus
	Pseudochydorus globosus
	Rhynchotalona falcata

As during a large fraction of experimental duration (January-June, 2013), the density of the organisms remained quite high (12 ind/ml and above), it could be attributed to a number of parameters, a few most relevant being: a) favourable pH b) high nutrient status of water body c) absence of predators. pH in the water body was mostly found to be alkaline and is a favourable factor for the growth and sustenance of zooplankton communities (table 3). The higher values of pH during study period may be attributed to a number of factors like higher levels of bicarbonates and wind action which share a direct relationship with pH. In this regard Cattle washing could also be one of the causes for alkaline pH as the pond is located in the residential area of the village Kot-Bhalwal and cattle washing are a common activity that is frequently witnessed there.

High nutrient status of the water body seems to be the most contributing factor as indicated by high nitrates and phosphate level (table 3). Nitrates and phosphates are considered as major macronutrients that result in biological productivity and eutrophication of the water body. Various contributing factors known to operate and account for increased levels of nitrates and phosphates in a water body are: (a) increased rate of decomposition of organic matter (b) discharge of sewage into the water body [11] (c) increased concentration of excreta of aquatic and terrestrial organisms [12,13] (d) surface run-off [14] (e) decaying macrophytes [12]. All these factors operate quite actively in this water body and therefore, can be held responsible for observed higher values of nitrates and phosphates.

Increased concentration of phosphates beyond 0.2mg/l increases the growth of phytoplanktons [15]. Increased concentration of nitrates beyond 0.15mg/l is an indicative of eutrophication [16]. In the present studies, nitrates ranged from 0.572136 to 0.57250 mg/l and phosphates from 0.047 to 1.03 mg/l (table 3). It can, therefore, be safely concluded that the water body was nutrient rich supporting an enormous production of algae and other phytoplanktons due to which there was an ample availability of food for the survival and maintenance of a large population of *D.similis.*

Besides these factors, one of the most significant factors accounting for high density of *D.similis* during March and otherwise is undoubtedly the absence of predators, because throughout the period, not a single fish could be collected from the water body. As group cladocera constitute one of the choicest food for fish particularly early larval stages, their abundance to such a large number is probably indicative of the fact that the water body is free of predatory fishes. Predatory communities for cladocera, however, are not only restricted to fishes but also includes other organisms which are bigger in size than cladocerans and are at higher tropic level in the food chain like aquatic insects and their larvae, e.g., *Lecotrophes* species, *Renanthera* species, *Chironomous* larvae, Dragon flies and Damsel flies, *Anisops sardea* etc., that could be seen in good numbers in the water body. The density of daphnids remained significantly higher during the study period, therefore indicating their resistant behaviour towards various predatory groups. In this regard, large size of the species itself (1mm and above) may be one of the primary factor that that makes it less prone to aquatic insects. Besides having a large size and reproduction potential (table 1), daphnids possessed certain other features which made it difficult for insects to predate upon this particular community.

Other possible reasons for the absence of *Daphnia similis* during the months of October and November may be due to the presence and flourishing of many other invertebrate predator species which remained less active or dormant during rest part of the year. Otherwise also mean brood size starts declining during the months of August-September.

Another important aspect that needs to be mentioned here is the presence of cyclomorphic forms that are induced in response to physico-chemical or biological cues. A good number of cyclomorphic forms have been observed that may have appeared in response to high density (because at all the temperature regimes, density was quite high) or chemicals released by predators like aquatic insects as has been reported by various workers [17].

4. Conclusion

Present observations seem to be quite significant in the sense that they present a very different picture of a water body, where the density of *D. similis* remained very high despite a wide range of temperature variations (14.5-33 °C). This water body characterised by favourable conditions also provide some important information on cyclomorphosis which is otherwise believed to be induced during harsh environmental conditions.

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