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Diversity, Abundance, and Distribution of Soil Nematode Communities in Wheat Agroecosystems

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Abstract

Soil nematodes are a part of soil food webs and are sensitive indicators of soil ecological conditions. In this study, the diversity, abundance, trophic structure and temporal distribution of soil nematode communities in a wheat (Triticum aestivum L.) agroecosystem were evaluated over a period of one year. We collected soil samples on 8 occasions from June 2008 to April 2009, with cover ranging from different crop growth stages, including fallow periods, in a conventionally cultivated wheat field, Aligarh district, India. Nematodes were obtained by modified Cobb's sieving and decantation followed by Baermann funnel technique and identified to the generic level. A total of 50 nematode genera with 10 orders and 30 families were identified. Number of genera per sample varied from 13 to 23, with total nematode abundance being between 105 to 1178 individuals. The most abundant order was Rhabditida, and Dorylaimida had the highest level of generic diversity. Within trophic groups, bacteriovores were the most common organisms (58%) and were followed by fungivores (21%), herbivores (13%), omnivores (5%), and predators (3%). The most common genus throughout the course of the study was Acrobeloides. The measured trophic diversity index was from 1.03 to 1.25, suggesting moderate trophic complexity. Seasonal dynamics were well recorded with high levels of bacteriovorous nematodes in post-harvest periods, probably as a consequence of the higher organic matter content generated due to crop residues. The evidence indicates that soil nematode community structure is highly determined by crop phenology, organic amendments and the season. Soil nematode faunal analysis was used in this study and is effective for assessing soil health and ecosystem functioning in wheat-based agroecosystems.

Keywords

Soil nematodes; Wheat agroecosystem; Trophic structure; Biodiversity; Bioindicators; Soil health

1. Introduction

Soil hosts diverse vertebrate and invertebrate organisms, invertebrates outnumbering vertebrates in population and diversity. Soil properties have a strong influence on the functional attributes of soil invertebrates, so changes in soil conditions largely shape their population dynamics and are reflected in quantitative data. The nematode community consists of plant-parasitic and free-living soil nematode species from natural or managed ecosystems. As noted by Yeates (1987) and according to Bongers et al., nematode communities are critical to decomposition processes and nutrient cycling (Anderson et al., 1983; Ingham et al., 1985) and are central in the soil food web. Considering their abundance and ubiquity within ecosystems, nematodes are regarded as reliable indicators of environmental disturbance (Bongers, 1990; Ferris et al., 2001; Yeates, 2003; Höss et al., 2004; Schratzberger et al., 2006). They have essential characteristics of effective bioindicators (Cairns et al., 1993) such as high population densities in different habitats, a wide range of feeding strategies and extensive life histories (Freckman, 1988; Yeates et al., 1993), short life cycles, and well-established sampling and identification approaches. Therefore, extensive research has been conducted to correlate nematode community structure with ecosystem succession and environmental disturbance (Ettema & Bongers, 1993; Freckman & Ettema, 1993; Wasilewska, 1994; Yeates & Bird, 1994). Primarily based on feeding biology, terrestrial nematodes are ecologically classified. Despite eight proposed trophic groups, the basic five most common feeding groups are plant feeders (herbivores), hyphal feeders (fungivores), bacterial feeders (bacteriovores), predators, and omnivores.

Nematode faunal analysis has become a novel alternative for soil condition determination and for assessing the structural and functional characteristics of the soil food web (Bongers & Ferris, 1999). Recent developments in this area have been the development of enrichment and structure trajectories. These structure trajectories are able to convey more broadly a complex trophic interaction and regulatory potential of the food web to regulate food web structure, and the enrichment trajectories are indicative of food resources and the responses of primary consumers to organic matter inputs (Ferris et al.). The current study investigated nematode communities, as well as their temporal distribution in a crop field during a period of one year. More specifically, population dynamics, composition of individuals, and faunal analysis of soil nematodes was investigated to assess the extent to which these could be useful signifiers of soil condition.

2. Materials and Methods

2.1 Site description: - The regional climate shows a distinct west–east gradient, with the western blocks being comparatively drier than those in the eastern parts. Summer temperatures rise to a maximum of about 44.6 °C, while winter temperatures may fall to as low as 4.8 °C. The mean maximum and mean minimum temperatures of Aligarh district are 26.7 °C and 15.5 °C, respectively. The monsoon season extends from July to September, whereas the winter months receive only scanty rainfall. The district records a mean annual rainfall of approximately 434 mm, mean relative humidity 65%. The crop field situated about 14 Kms from Aligarh city, on Aligarh – Moradabad highway (27° 57′ N, 78° 10′ E) was selected. The field was cultivated under annual conventional cropping system whereby wheat was the only crop sown during the sampling time with fallow periods in between. During sampling crop was at different stages of

development. Organic amendments were added to the crop field in form of manures during September-October. Chemical fertilizer mainly NPK were added to field during December-January

2.2 Sampling

Soil samples from crop field were collected following the growth pattern of the crop, In Aligarh district monsoon starts in July and runs to September. Wheat was sown during the month of October/November and harvested during February/March. Sampling was undertaken on eight occasions from June 2008 to April 2009 at different stages of development of wheat crop including the fallow periods before and after the cropping period. Each soil sample consists of five cores (1 cm^2 cross sectional area) from a depth of 0-10 cm. All the samples were collected windward in N-W direction. Samples were tagged, stored in sealed plastic bags and brought to laboratory for further processing. For sampling from both the areas a diagonal transect was selected and samples were collected from the same.

2.3 Processing of soil samples

Soil samples were processed using the modified Cobb's (1918) sieving and decantation method, followed by the modified Baermann funnel technique. Approximately 100 cc of each soil sample was thoroughly mixed with water to disintegrate soil clods and remove debris. The suspension was allowed to stand for 30 seconds to permit the settling of heavier particles, after which it was passed through a 2 mm sieve to eliminate coarse materials. The filtrate was then stirred, allowed to settle again for 30 seconds, and subsequently passed through a 300-mesh sieve (53 μm). Nematodes retained on the sieve were collected, and the procedure was repeated two to three times to ensure maximum recovery. The collected residue was transferred onto a tissue-lined coarse sieve and placed on a Baermann funnel containing water just sufficient to contact the underside of the sieve, ensuring the absence of air bubbles. Active nematodes migrated into the water and accumulated at the base of the funnel. After 24 hours, the nematode suspension was drawn off through the tubing and fixed using hot FA fixative.

2.4 Counting of Nematodes

Nematode populations were calculated by using a Syracuse counting dish. Before enumerating, the suspension was completely homogenized by method of repeated pipetting to give uniform distribution of nematodes. After that, a 2 ml volume of the suspension was pipetted into the counting dish to count. Each sample was counted three times, and the average value was calculated. The nematode population was calculated by directly multiplying the mean count with the final volume (50 ml) of nematode suspension and dividing by the volume used for counting (2 ml).

2.5 Identification

Approximately 200 nematodes per sample were used to prepare mass slides for taxonomic identification. Identification up to the generic level was mainly performed using standard keys and descriptions in the works of Goodey (1963), Jairajpuri and Khan (1982), Andrássy (1984, 2005), Siddiqi (1986), Jairajpuri and Ahmad (1992), and Ahmad (1996). Trophic groups were assigned in accordance with Yeates et al. (1993), while colonizer–persister (cp) groups were designated according to Bongers (1990).

2.6 Data Analysis

Nematode diversity was assessed using univariate measures, including the Shannon diversity index (H′) calculated at the genus level. Multivariate statistical analysis was conducted using analysis of variance (ANOVA) with the SPSS statistical software. Shannon's diversity index (H′) was computed using the SPECDIVE program. Nematodes were classified into five principal trophic groups—bacteriovores, fungivores, herbivores, omnivores, and predators—following Yeates et al. (1993). Trophic diversity was evaluated using the trophic diversity index (TDI) as proposed by Heip et al. (1988).

Formula used for **Shannon's diversity (H′)** = $-\Sigma$ (*pi* ln *pi*) and **Trophic Diversity index (TDI)** = $1/\sum pi^2$, where pi^2 is the proportional contribution of i_{th} trophic group.

3. Result and Discussion

3.1 Nematode Diversity

During the present study, a total of 50 nematode genera belonging to 10 orders and 30 families were recorded. The number of genera per sample ranged from 13 to 23, while abundance varied from 105 to 1178 individuals. *Acrobeloides* was the most abundant genus. Based on the number of genera (Fig. 1A), the order Dorylaimida was most frequent (30%), comprising 15 genera under 8 families, followed by Rhabditida (22%; 11 genera, 4 families) and Tylenchida (20%; 10 genera, 6 families). Other orders included Araeolaimida (8%; 4 genera, 3 families), Aphelenchida (6%; 3 genera, 3 families), Enoplida (4%; 2 genera, 2 families) and Monhysterida (4%; 2 genera, 1 family). Alaimida, Diptherophorida and Chromadorida were each represented by a single genus (2% each). In terms of abundance (Fig. 1B), Rhabditida dominated (44%), followed by Tylenchida (19%), Dorylaimida (12%), Aphelenchida (11%) and Araeolaimida (8%). Enoplida contributed 2%, while Alaimida, Chromadorida, Monhysterida and Diptherophorida each accounted for 1%.

3.2 Trophic diversity

The present study showed that, bacteriovores constituted the most dominant group in terms of number of genera (Fig. 1 C) and were represented by 20 genera. This was followed by herbivores, fungivores, omnivores and predators, which were represented by 9, 8, 7 & 6 genera respectively. In terms of number of individuals (Fig. 1 C) bacteriovores (58%) was the most abundant group, followed by fungivores (21%), herbivores (13%), omnivores (5%) and predators (3%). The trophic diversity index (TDI) of the area ranged from 1.03-1.25 (1.1±0.07). Among bacteriovores the genus *Acrobeloides* was most dominant while the genera *Hoplolaimus*, *Aphelenchus*, *Moshajia* and *Discolaimus* were most dominant among herbivores, fungivores, omnivores and predators respectively. Least dominant genera among bacteriovores, herbivores, omnivores, fungivores and predators were *Drilocephalobus*, *Hemicriconemoides*, *Thornenema*, *Leptonchus* and *Tripyla* respectively (Table 1). Bacteriovores, fungivores and herbivores were present in all samples while omnivores and predators were absent from two samples each. All nematode population remained relatively low from June to December. Thereafter the bacteriovores increased in numbers with a peak population in March followed by a sharp decline. The fungivores followed a somewhat similar pattern but the population remained comparatively low. All other groups showed peak population in January but their number was very low.

Table 2: Population structure of soil inhabiting nematodes of crop field

Genera	N*	AF%	MD	RD%
Bacteriovores				
Acrobeles	27	88.89	7.95	3.60
Acrobeloides	40	133.33	35.45	16.05
Alaimus	8	27.78	1.48	0.67
Cephalobus	37	122.22	23.55	10.66
Cervidellus	5	16.67	0.63	0.28
Chiloplacus	40	133.33	21.53	9.75
Chromadora	8	27.78	2.03	0.92
Chronogaster	12	38.89	3.05	1.38
Drilocephalobus	2	5.56	0.15	0.07
Eucephalobus	15	50.00	2.83	1.28
Mesorhabditis	25	83.33	5.25	2.38
Monhystera	7	22.22	2.83	1.28
Monhystrella	3	11.11	0.13	0.06
Panagrolaimus	8	27.78	0.50	0.23
Plectus	27	88.89	3.25	1.47
Prismatolaimus	20	66.67	5.53	2.50
Rhabdolaimus	20	66.67	10.33	4.67
Stegellata	7	22.22	1.15	0.52
Wilsonema	3	11.11	0.25	0.11
Zeldia	15	50.00	1.10	0.50
Fungivores				
Aphelenchoides	30	100.00	10.58	4.79
Aphelenchus	33	111.11	11.63	5.26
Basirotyleptus	18	61.11	8.18	3.70
Dorylaimellus	20	66.67	6.20	2.81
Filenchus	3	11.11	0.20	0.09
Leptonchus	3	11.11	0.13	0.06
Tylencholaimus	12	38.89	0.93	0.42
Tylenchus	28	94.44	7.63	3.45
Herbivores				
Boleodorus	5	16.67	0.65	0.29
Ditylenchus	25	83.33	8.95	4.05
Helicotylenchus	12	38.89	0.88	0.40
Hemicriconemoides	2	5.56	0.05	0.02
Hoplolaimus	28	94.44	8.75	3.96
Merlinius	5	16.67	0.43	0.19
Pratylenchus	5	16.67	0.40	0.18
Trichodorus	5	16.67	1.03	0.46
Tylenchorhynchus	27	88.89	8.80	3.98
Omnivores				
Epidorylaimus	3	11.11	0.08	0.03
Eudorylaimus	8	27.78	1.10	0.50
Latocephalus	3	11.11	0.05	0.02
Moshajia	32	105.56	8.30	3.76

Oriverutus	2	5.56	0.08	0.03
Thonus	8	27.78	0.63	0.28
Thornenema	2	5.56	0.05	0.02
Predators				
Aporcelaimellus	10	33.33	0.93	0.42
Aquatides	5	16.67	0.70	0.32
Discolaimus	20	66.67	2.00	0.91
Discolaimoides	8	27.78	0.93	0.42
Seinura	10	33.33	1.73	0.78
Tripyla	2	5.56	0.03	0.01

*Mean of five replicates

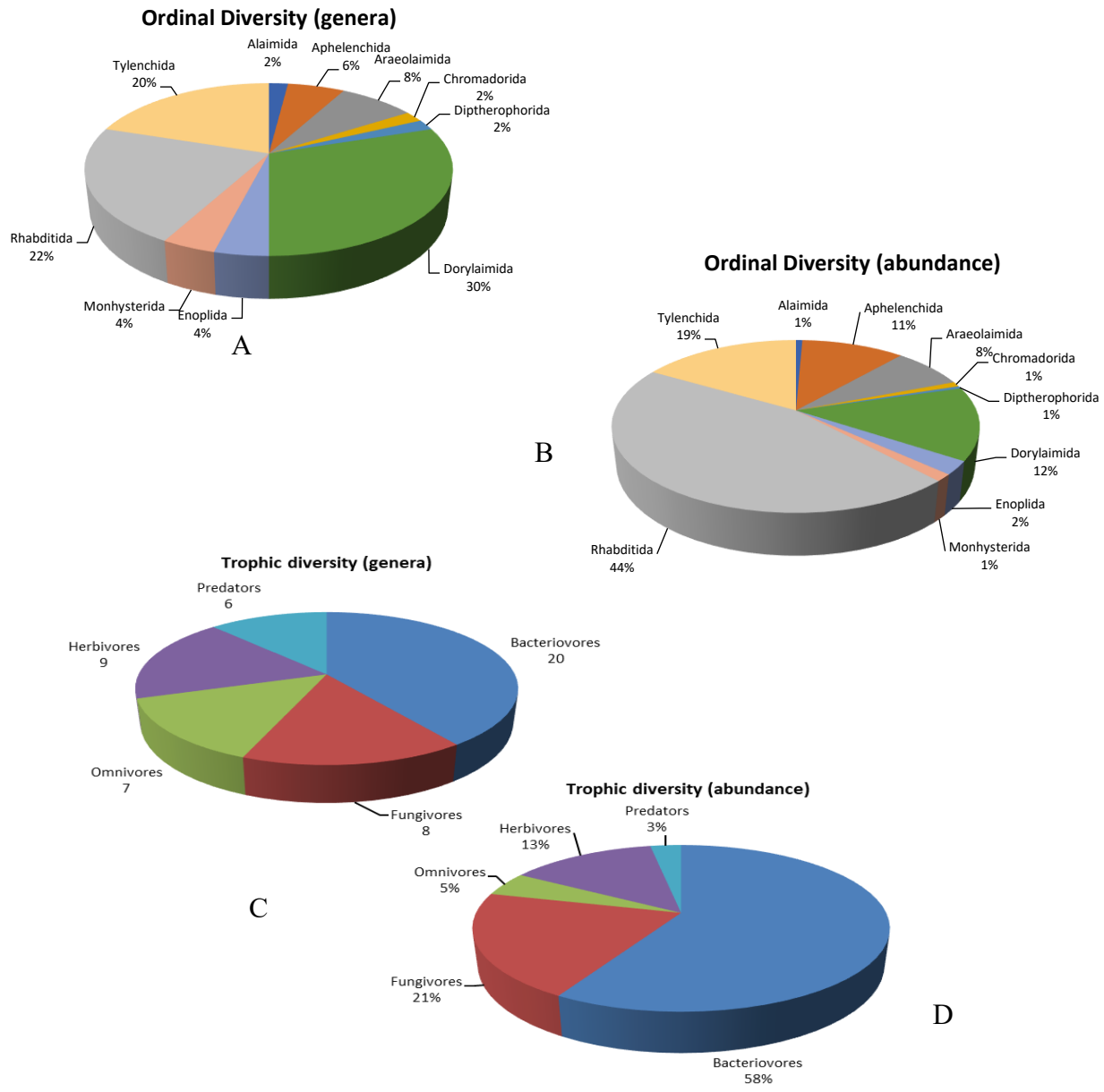

Fig. 1: Ordinal Diversity and Trophic Diversity of nematodes in terms of Genera and Abundance

4. Conclusion

Soil fauna are closely linked to essential ecosystem processes such as decomposition, nutrient cycling, interactions with microbial communities, plant growth, and pedogenesis, and therefore serve as valuable indicators of ecosystem condition (Parmelee, 1994; Auerswald et al., 1996). The diversity of nematodes in agro-ecosystems provides considerable potential for their use as biological indicators of agricultural management practices, soil properties, and the level of soil conservation. In many instances, the overall structure of nematode functional groups represents a more reliable indicator of soil condition than information derived from individual species alone (Yeates & Bongers, 1999). Soil nematodes play a regulatory role in bacterial and fungal populations and are thus closely involved in the cycling of major soil nutrients (Ingham et al., 1985). Consequently, a more positive perspective on the ecological significance of nematodes in soil processes has emerged (Yeates, 1987). These attributes highlight the strong potential of nematode populations and their diversity as indicators of overall soil health. In the present study, *Acrobeloides* was the most abundant genus in the crop field, corroborating earlier findings by Yeates and Bird (1994) and Gomes et al. (2003), who reported cephalobids as the dominant bacterial feeders in cultivated systems.

Bacteriovores in the crop fields showed two phases of population increase (Fig. 2). A small increase during December-January and a big increase during February-March. One factor that may be responsible for the increase in the population of these nematodes in the early part is farmyard manure that was added to the fields before sowing. However the greater increase in the later (post-harvest) part of the study may also be due to organic matter. This becomes available because of decaying roots and rotting stubble after the harvest and could be the likely cause of this second peak. Organic amendments are known to increase the population of the Ba1 group of nematodes and maintain them till the material is exhausted (Bongers & Ferris, 1999; Porazinska *et al*., 1999). Manuring is also known to bring about a sudden increase in the population of bacterial feeders (Dmowska & Kozlowska, 1988). The sharp decline of bacteriovorous nematodes during March-April may also be due the organic matter; although this time acting perhaps differently. Depleted organic matter, of the decaying roots and stubble, could result in depleted bacterial populations and hence a reduced food source for the bacteriovores resulting in their decline. Bulluck *et al*., (2002) have shown that when food supply is exhausted bacteriovores populations also decline. Although temperature records were not maintained, there is a relatively big increase in maximum temperatures from February to April, and it may not be improper to speculate that this could lead to drying of the top soil and also a decline in nematode populations.

The herbivore population of the crop field varied little during the period of study except for a small peak in January. This coincides with the maturing of the crops and as such represents a period of an abundant food source brought about by the proliferated root system and seems to be the most likely cause of the peak. Increase nutrient availability is known to increase herbivore populations through an enhanced food resource (Pattison *et al*., 2004). Fertilizer application after sowing in October did not seem to affect nematodes as all trophic group populations remained relatively unchanged till December. Furthermore, peak abundance of herbivorous nematodes coincided with peak or increasing populations of other trophic groups. This observation contrasts

with earlier reports by Yeates (1982), Sohlenius and Boström (1986), and Edwards (1989), who documented increases in plant-parasitic and bacterivorous nematodes following fertilizer application in cultivated soils, along with a decline in fungal feeders and omnivores (Sohlenius & Boström, 1986; Sohlenius, 1990). These findings suggest that nematode faunal analysis is a valuable diagnostic tool for evaluating the complexity and functional status of soil food webs (Ritz & Trudgill, 1999).

The presence and relative abundance of certain nematode taxa suggest the structural complexity of the soil food web. Taxonomic identification of closely related taxa that share similar morphological, anatomical, and physiological traits tends to be characteristically observed by comparable feeding behaviour and therefore relevant faunal analysis could be offered (Bongers & Ferris, 1999). In line with earlier studies, this study establishes that nematodes are robust indicators of soil condition. Anthropogenic disturbances, such as the loss of topsoil, can dramatically change the structure of the soil food web and this would reduce the system's ability to maintain efficient nutrient cycling, plant productivity, and other ecosystem functions. It must be noted that indices based on nematode faunal analysis refer primarily to the proportion of functional guilds and hence show the relative distribution of ecological functions instead of their absolute magnitude. The actual contribution of these functions depends on the biomass and abundance of organisms in each functional guild. Using biomass measurements would therefore give a more complete picture of resource availability and functional dynamics within the soil food web.

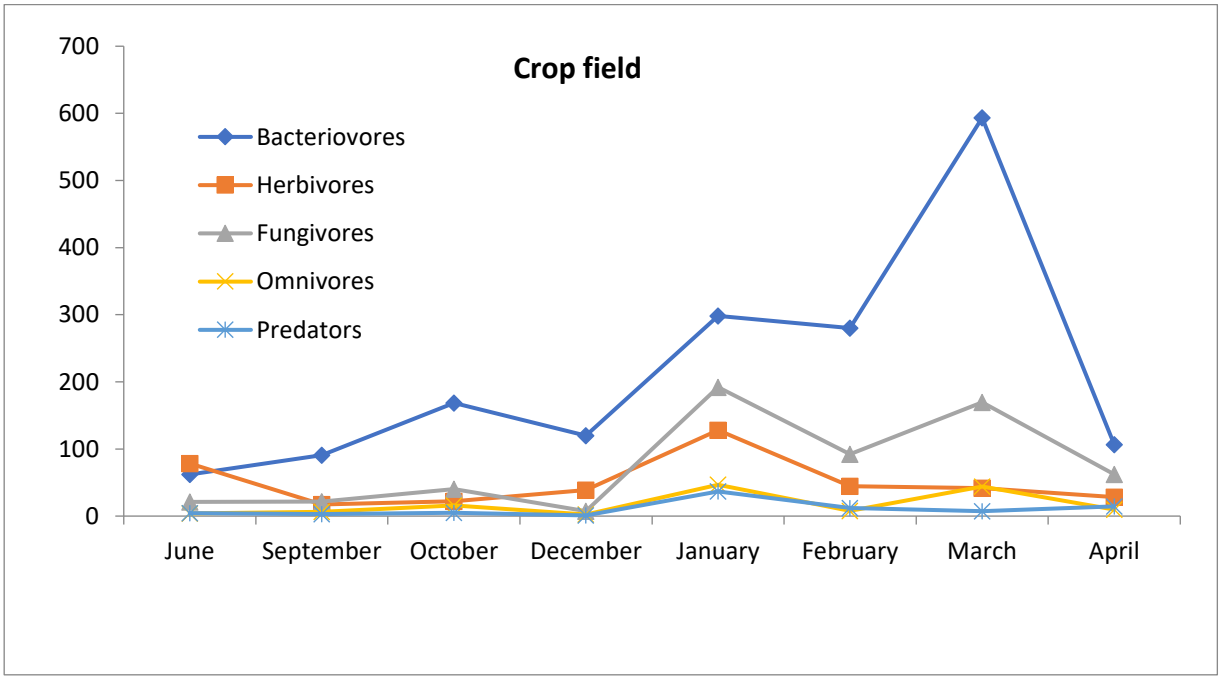

Fig. 2: Population structure of different trophic groups during variuos sampling times

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