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Nematode community structure and trophic group composition of fresh water nematodes from Sindh, Pakistan

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Abstract

Present study provides the information and estimation on fresh water nematode community structure from various water sources (river, lakes, canals, ponds, reservoirs and irrigation sources: tube well and tanks) and evaluation of feeding categories at eight collecting sites of Sindh. After analysis it was found that different parameters of community structure of fresh water nematodes varied considerably at different surveyed sites. Nematode community analysis revealed that frequency (absolute frequency, relative frequency), density (relative density) and prominence value were variable for nematode population within localities. Relative density of fresh water nematode species of studied sites ranged between 0.7-10.4 % while absolute frequency and relative frequency ranged between 15-98% and 0.86-8.8%, respectively. Analysis of overall occurrence percentage of feeding groups revealed that predators dominated the entire nematode community (35%) followed by bacterivores (32.5%), herbivores (20%), algal feeders and fungivores shared the same occurrence percentage (5%) while the least occurrence percentage was of omnivores (2.5%). These studies add to the knowledge of diversity of fresh water nematodes and evidence on their categorization of the basis of feeding habits and the community structure.

Keywords: Fresh water nematodes, Community structure, feeding groups, Sindh, Pakistan

Fresh water nematodes impact their environment in several important ways. The most important role of certain nematodes in fresh water is the ingestion of bacteria by many genera of freshwater bacteriophagous nematodes (Esser & Buckingham, 1987). The nematode abundance and its community structure were both reliable bioindicators for monitoring long-term river pollution in both qualitative and quantitative aspects. Nematodes community structure in river is related to the contamination sources and pollution level (Wu *et al*., 2010). Due to their unique characterstics *viz*., abundance, species richness, ecology, functional morphology (with regard to feeding type) and short life cycles they respond quickly to environmental changes and are the ideal organisms for ecological studies (Hakenkamp *et al*., 2002; Giere, 1993; Platt & Warwick, 1980).

Internationally, less attention has been endured on nematodes by scientists, although they belong to the dominant meio-benthic community in fresh water ecosystem, because of their diverse nature and difficulties with generalization about their belong (Strayer, 1985; Anderson, 1992; Eyualem-Abebe *et al*., 2008). Globally ecological studies of fresh water nematodes have been made from time to time which indicates that nematodes play an important role in nutrient cycling and biological indicators for health of fresh water.

In Pakistan, systematic surveys on fresh water and marine nematodes were carried out and revealed presence of 136 nematode species (Shahina *et al*., 2013; Shamim *et al*., 2014; Nasira *et al*., 2016).

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Literature search shows that globally studies have been carried out on nematodes of fresh water lakes and their role in ecosystem function, their community development *viz*., Polish lakes (Prejs, 1977 a, b); American lakes (Fisher, 1968; Strayer, 1985); African lakes (Jacobs, 1984; Tudorancea & Zullini, 1989; Eyualem-Abebe & Coomans, 1995; Tsalolikhin, 1996); Chinese lakes (Wu & Liang, 1999); Croatian lakes (Vidakovic & Bogut, 2004); European lakes (Peters *et al*., 2005; Witthoft-Muhlmann *et al*., 2007) and Swedish lakes (Peters & Traunspurger, 2005). These studies show that nematodes play an important role in nutrient cycling and biological indicators for health of fresh water. Distribution patterns (seasonal and spatial) of nematodes are well depicting for several lakes (Bretschko, 1984, Prejs & Prejs, 1992; Traunspurger, 1996 a, b; Wu *et al*., 2004; Michiels & Traunspurger, 2004). However, research studies about nematode communities at river mouth areas are rare (Nalepa & Quigley, 1983).

In river monitoring studies the nematode community structure was found as a reliable bioindicator of pollution as it is correlated to the pollution intensity and its source (Wu *et al*., 2010). Nematode community of rivers has been studied in different parts of the world by many researchers (Barbuto & Zullini, 2005; George *et al*., 2010; Wu *et al*., 2010; Majdi *et al*., 2011; Shabdin & Kasim, 2013). Nematodes from fresh water pool were reported by Coomans *et al*., (1985), fauna of springs by Ocana (1993) and Zullini *et al*., (2011) and nematode communities of farmland ponds were explored by Bert *et al*., (2007). The analysis of nematode feeding types in the samples showed variations. Among the six feeding types, the predators were most dominant group, followed by bacterivores, herbivorous, algal feeder, fungivorous and omnivorous, respectively. The presence of submerged vegetation is a good source of food supply for diverse trophic groups of nematodes (Wu & Liang, 1999). Their analysis for trophic group abundance helped to determine nematode food web. The free-living soil nematodes were mostly available due to the mixing of soil present near the banks of water sources. Plant parasitic nematodes occasionally found their way into the rivers due to water coming from irrigation canals and mixing with the main river water. The presence of algal feeders seems to depend on the substrate type. Stony bottom and aquatic vegetation are favourable for algal attachment. Bacterial feeder nematodes were found in polluted site as well (Zullini, 1976).

Characterization of trophic groups

Forty nematode species encountered were identified and characterized into six different trophic or feeding groups which are briefly characterized below:

Herbivores (Plant feeders): These are the plant parasites obtaining their nourishment directly from plants. This group includes many members of the order Tylenchida, as well as a few genera in the orders Aphelenchida and Dorylaimida. The mouth part is a needle like stylet/odontostyle which is used to puncture cell during feeding.

In terms of habitat these nematodes are either ectoparasites i.e., species that do not normally enter root tissue but feed only from the outside on the cells near the root surfaces, or endoparasites i.e., species that enter the host and feed within the roots. Both of these can be either migratory i.e., they live freely in the soil and feed on plants without becoming attached or move around inside the plant, or sedentary i.e., species that once within a root do not move about.

Bacterivores (Bacterial feeders): Many kinds of free-living nematodes feed only on bacteria, which are always extremely abundant in soil. In these nematodes, the mouth or stoma, is a hollow tube for ingestion of bacteria. This group includes many members of the order Rhabditida as well as several other orders which are encountered less often. These nematodes are beneficial in the decomposition of organic matter.

Fungivores (Fungal feeders): This group of nematodes feeds on fungi and uses a stylet to puncture fungal hyphae. Many members of the order Aphelenchida are in this group. Like the bacterivores, fungivores are very important in decomposition.

Algal feeders: These nematodes feed on diatoms or other algae. These feeding types include ingestion of fungal spores and whole yeast cells.

Carnivores (Predators/Flesh eaters): These nematodes feed on other soil nematodes and on other animals of comparable size. They feed indiscriminately on both plant parasitic and free-living nematodes.

One order of nematodes, the Mononchida, is exclusively predacious, although a few predators are also found in the Dorylaimida and some other orders. Compared to the other groups of nematodes, predators are not common, but some of them can be found in moist soils.

Omnivores: The food habits of most nematodes in soil are relatively specific. For example, bacterivores feed only on bacteria and never on plant roots and the opposite is true for plant parasites. A few kinds of nematodes may feed on more than one type of food material and therefore are considered omnivores.

For example, some nematodes may ingest fungal spores as well as bacteria. Some members of the order Dorylaimida may feed on fungi, algae and other animals, subsisting on all types of food, especially feeding on both animal and vegetable material.

The present study is based on fresh water sources of lower plains of Sindh which covers the main river, lakes, streams, ponds, irrigation canals, channels and estuary, around Karachi, Thatta, Karachi Canal and Al-Manzar at River Indus, Jamshoro, Hyderabad, Tandojam, Jamesabad and Mirpurkhas.

Materials and Methods

Community analysis: Nematode community analysis for each nematode species of fresh water nematodes encountered from eight sites of Sindh was conducted. The fresh water nematode community structure was characterized by using different parameters *viz*., absolute frequency and relative frequency of occurrence (AF % and RF %), relative density and prominence value (RD% and PV) according to the techniques given by Norton (1978).

Trophic group composition: The nematodes encountered during the present study were classified according to their feeding habits given by Yeates *et al*., (1993). Nematodes exhibit a great diversity in their food sources which is fundamental to trophic interaction and provides the basis of the essential feeding types (Yeates *et al*., 1993). Based on their diet the nematodes have been divided into following six different categories or feeding/trophic groups:

- Herbivores (plant feeders)
- Fungivores (hyphal/fungal feeders)
- Bacterivores (bacterial feeders)
- Algal feeders (unicellular eukaryote feeders)
- Carnivores (predators/flesh eaters)
- Omnivores (feed on multiple sources)

Results and Discussion

Nematode community structure

The community analysis of the samples showed high variability in fresh water nematode population density and occurrence at different surveyed sites. These nematode species were found with varied population density, relative density, absolute frequency of occurrence and relative frequency of occurrence. However, some nematode species were more frequently encountered in surveyed sites during the studies. Relative density of fresh water nematode species of studied sites ranged between 0.7-10.4% while absolute frequency and relative frequency ranged between 15-98% and 0.86-8.8%, respectively.

The overall mean frequency % of fresh water nematodes was highest at Malir, Karachi (32.04%) followed by Karachi Canal, Jamshoro (16.23%). The overall mean frequency of fresh water nematode at other sites was found in descending orders as follows: 13.95% at Al-Manzar, Jamshoro, 13.32% at Detha, Hyderabad, 12.88% at Mirpurkhas, 4.63% at Jamesabad, 4.56% at Kalri Lake, Thatta while the least overall mean frequency of fresh water nematode 2.37% was found from Khesana Mori, Tandojam (Fig.1).

The present study revealed that the most dominant genus among the other nematode genera was *Cephalobus nanus* with highest frequency and density (AF= 98%; RF= 8.11%; RD= 9.6) recorded from Detha, Hyderabad. Whereas, the lowest occurring genus in the nematode community was *Belbolla longispiculata* having minimum absolute and relative frequency (15% and 0.86%) from Detha, Hyderabad and Malir, Karachi, respectively; while relative density (RD) was also found minimum (0.77%) of *Belbolla* from Detha, Hyderabad.

The absolute and relative frequencies of occurrence of *C. nanus* at other sites were relatively high as compared to other nematodes. Its frequency (AF% and RF%) at different sites in descending orders is as follows: 97.8% and 5.98%, respectively from Karachi Canal, Jamshoro; 97.1% and 8.09%, respectively from Jamesabad; 96% and 5.79%, respectively from Kalri Lake, Thatta; 93.8% and 5.93%, respectively from Al-Manzar, Jamshoro; 92.8% and 5.57%, respectively from Mirpurkhas and 60% and 4.1%, respectively from Malir, Karachi.

The frequency of occurrence (AF% and RF%) of other nematodes varied in different surveyed sites. Same trend was noticed in the relative frequency, relative density and prominence value at all sites as shown in Fig. 2-9.

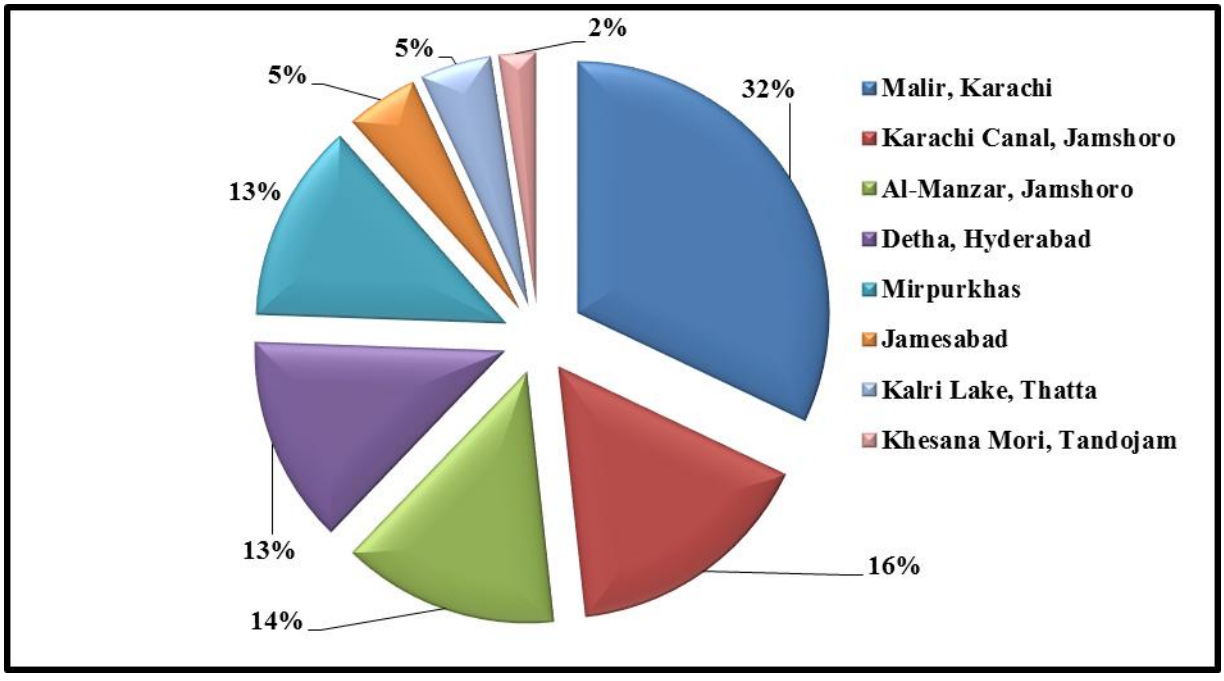

Fig. 1. Overall mean frequency % of nematodes at surveyed sites of Sindh.

Community structure of nematodes at surveyed sites

Locality wise different parameters of community structure of fresh water nematodes varied considerably at different surveyed sites. At Malir Karachi, regarding their occurrence, distribution and prominence value *Helicotylenchus dihystera* was the most frequently encountered species with highest values of all studied parameters (AF= 75%; RF= 5.16%; RD= 5.81% and PV= 519.61) followed by *Rhabditis producta* with AF= 65%; RF= 4.47% and RD= 5.32%; PV= 407.89 was of *H. falcatus*. *Belbolla longispiculata* was the least frequently encountered species with least values of parameters (AF= 12.5%; RF= 0.86%; RD= 0.77% and PV= 27.71), (Fig. 2).

From Kalri Lake, Thatta the highest frequency among fresh water nematodes was of *Cephalobus nanus* (AF= 96%; RF= 5.79%) while *Mylonchulus minor* has the highest value of density and prominence value (RD= 6.97%; PV= 110.30). The studied parameters *viz*., AF; RF, RD and PV of other nematode species in descending orders were of *Haliplectus dorsalis* (92%; 5.56%, 5.70% and 90.16, respectively, Fig. 3).

Cephalobus nanus had the highest frequency among fresh water nematodes from Karachi Canal, Jamshoro (AF= 97.8%; RF= 5.98%); whereas, the highest RD and prominence value was of *Dorylaimoides parateres* (RD= 6.39%; PV= 286. 18). *Pareurystomina vaughtae* was the least frequently encountered species with least values (AF= 31.1%; RF= 1.9%; RD= 1.70% and PV= 44.54), (Fig. 4).

At Al-Manzar, Jamshoro *Cephalobus nanus* was the most frequently encountered species with highest values of all parameters (AF= 93.8%; RF= 5.93%; RD= 6.63% and PV= 289.30) followed by *Rhabditis producta* with second highest values (AF= 87.5%; RF= 5.53%; RD= 6.19% and PV= 261.16). *Belbolla longispiculata* and *Pareurystomina vaughtae* were the least frequently encountered species sharing the least values (AF= 25%; RF= 1.58%; RD= 1.33% and PV= 30.0), (Fig. 5).

Analysis of community structure revealed that *Cephalobus nanus* has the highest frequency, density and prominence value among fresh water nematodes from Detha, Hyderabad (AF= 98%; RF= 8.11%; RD=9.6% and PV= 386.08) followed by *Acrobeles geraerti* with second highest values (AF= 90%; RF= 7.45%; RD= 8.26% and PV= 332.03). *Belbolla longispiculata* was the least frequently encountered species with least values (AF= 15%; RF= 1.24%; RD= 1.23% and PV= 19.36), (Fig. 6).

Data obtained from Khesana Mori, Tandojam shows that *Mylonchulus minor* has the highest frequency, density and prominence value than other nematodes (AF= 95%; RF= 8.84%; RD=10.42% and PV= 87.72) whereas *Psilenchulus hilarulus* had the least values (AF= 25%; RF= 2.33%; RD=3.01% and PV= 13.0), (Fig. 7).

From Mirpukhas *Cephalobus nanus* was found with highest values of all studied parameters of community structure (AF= 92%; RF= 5.5%; RD=6.69% and PV= 287.74) followed by *Rhabditis producta* having second highest values (AF= 88.6%; RF= 5.31%; RD= 5.56% and PV= 232.64). *Metoncholaimus siddiqii* n.sp., was the least frequently encountered species with least values (AF= 28.6%; RF= 1.71%; RD= 1.76% and PV= 41.27), (Fig. 8).

Cephalobus nanus and *Rhabditis producta* have the common highest values regarding their frequency, density and prominence value recorded from Jamesabad (AF= 97.14%; RF= 8.09%; RD= 8.76% and PV= 135.91) whereas *Halalaimus gidanensis* had the least values of all parameters (AF= 28.6%; RF= 2.38%; RD= 1.97% and PV= 16.40), (Fig. 9).

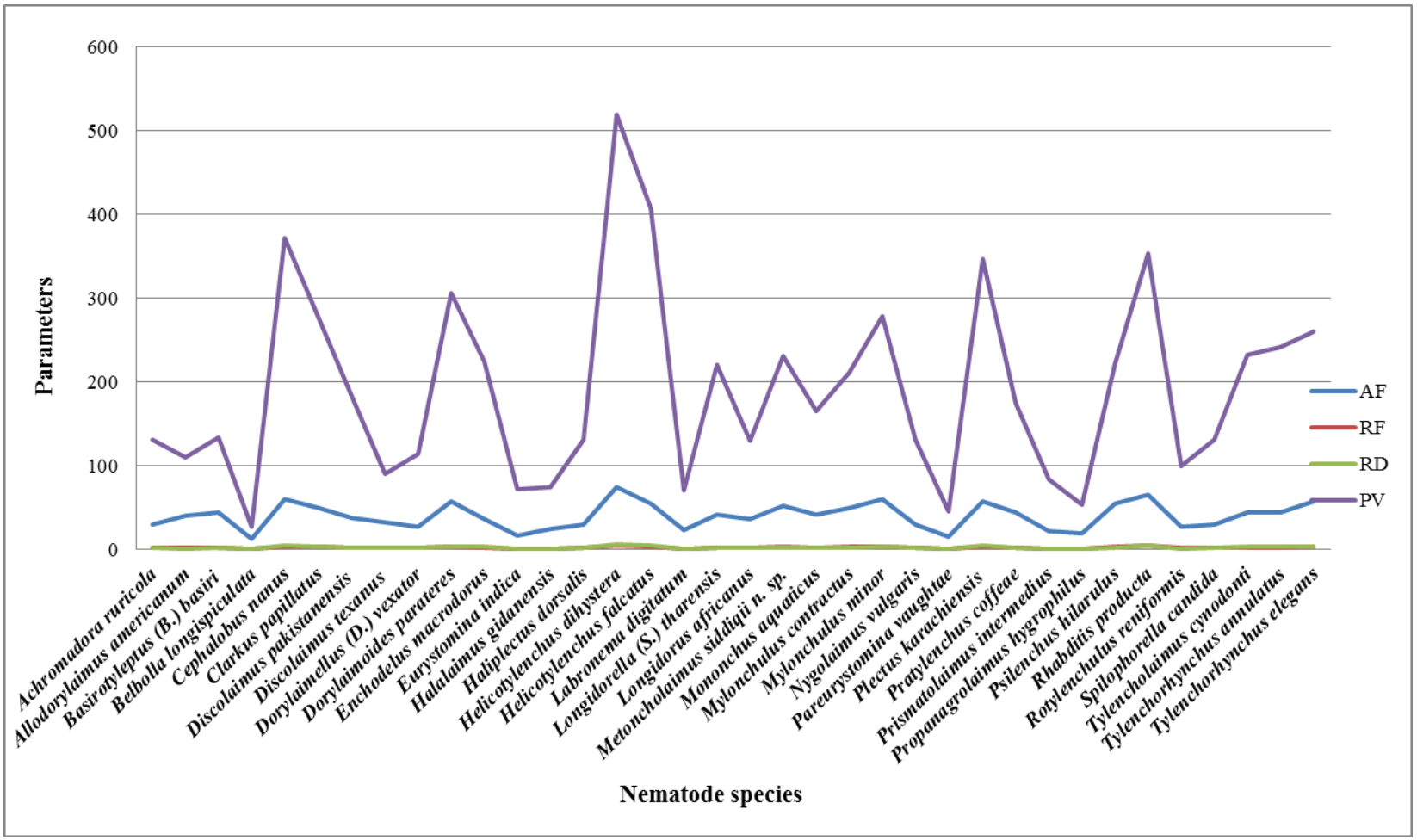

Fig. 2. Community structure of fresh water nematode species at Malir, Karachi.

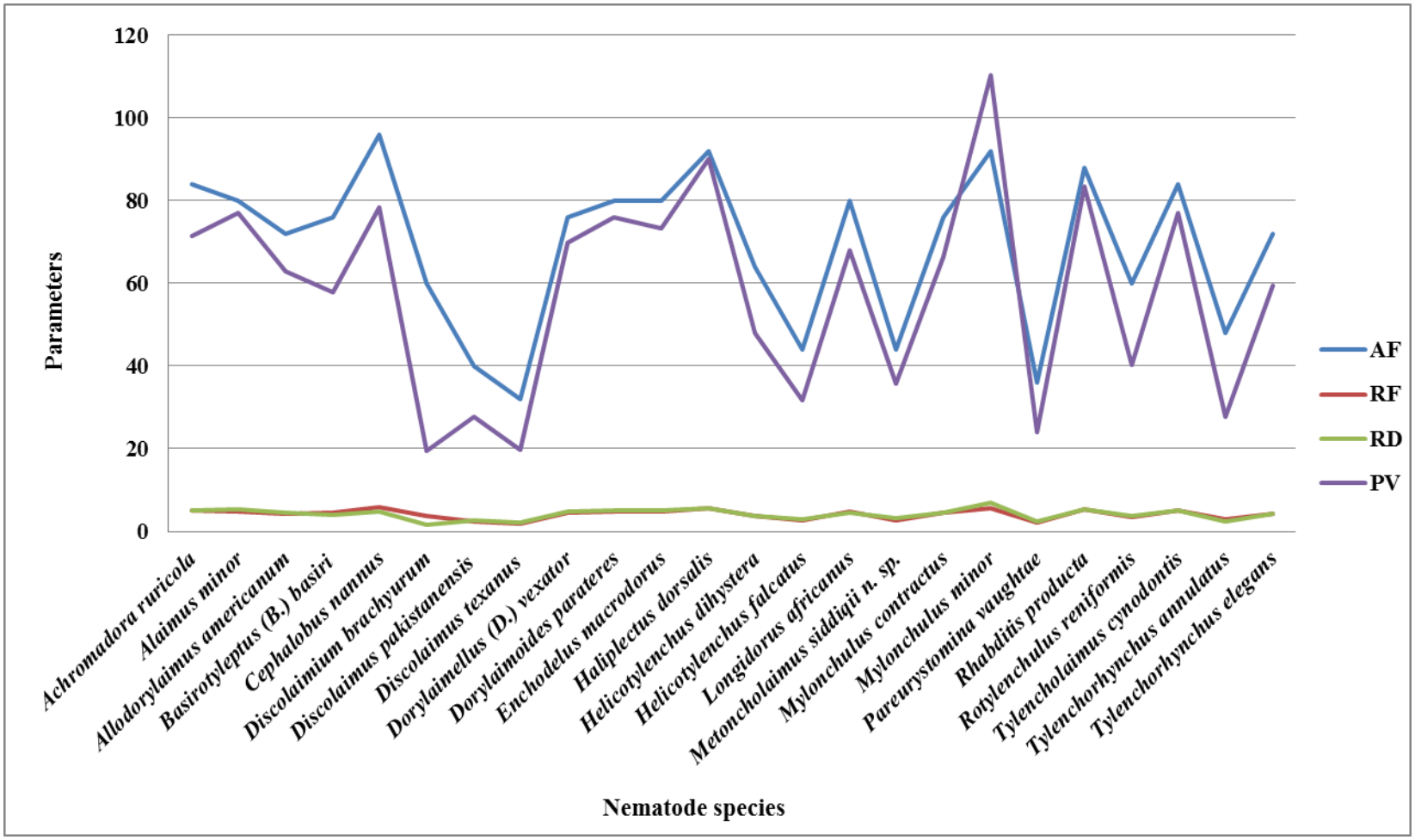

Fig. 3. Community structure of fresh water nematode species at Kalri Lake, Thatta.

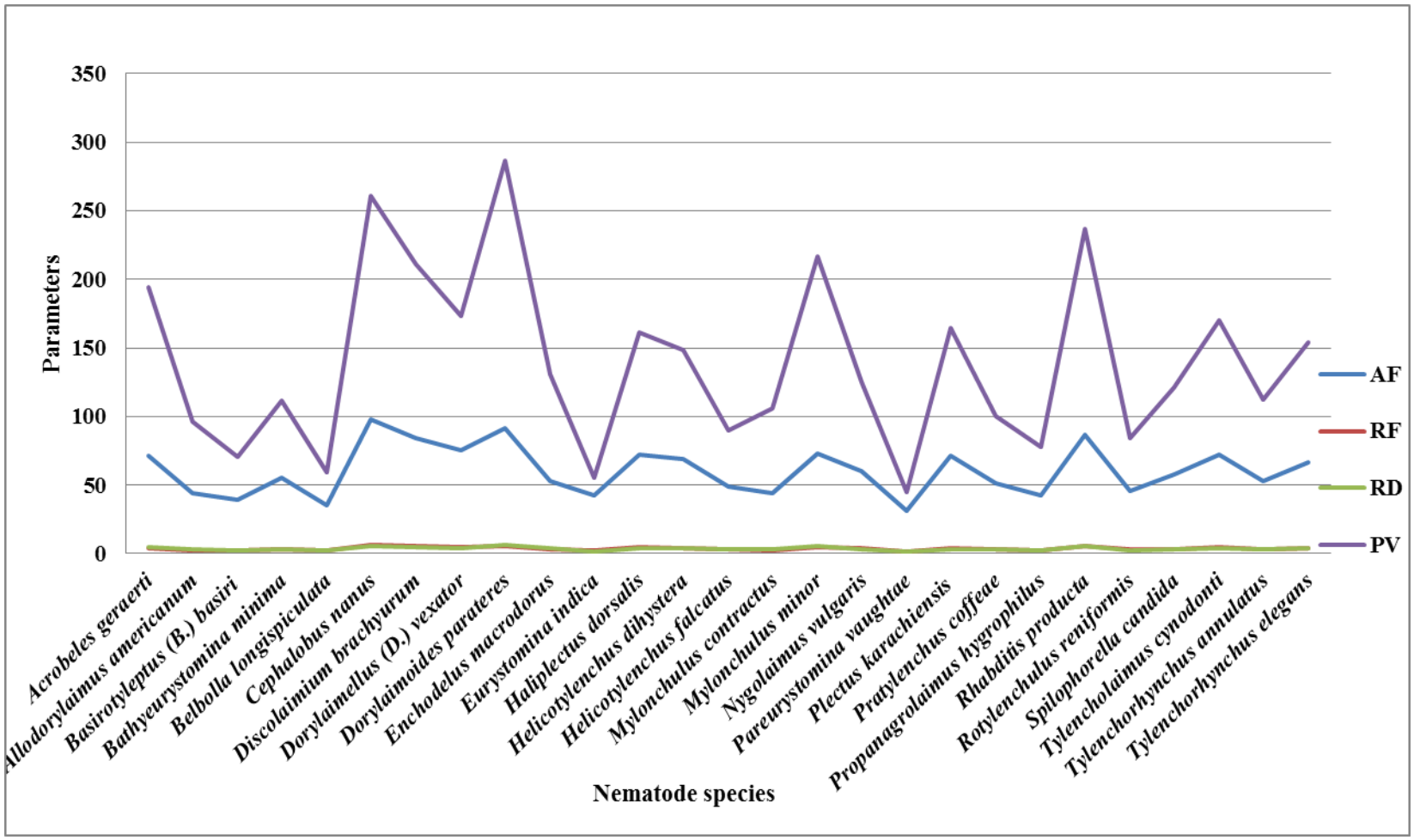

Fig. 4. Community structure of fresh water nematode species at Karachi Canal, Jamshoro.

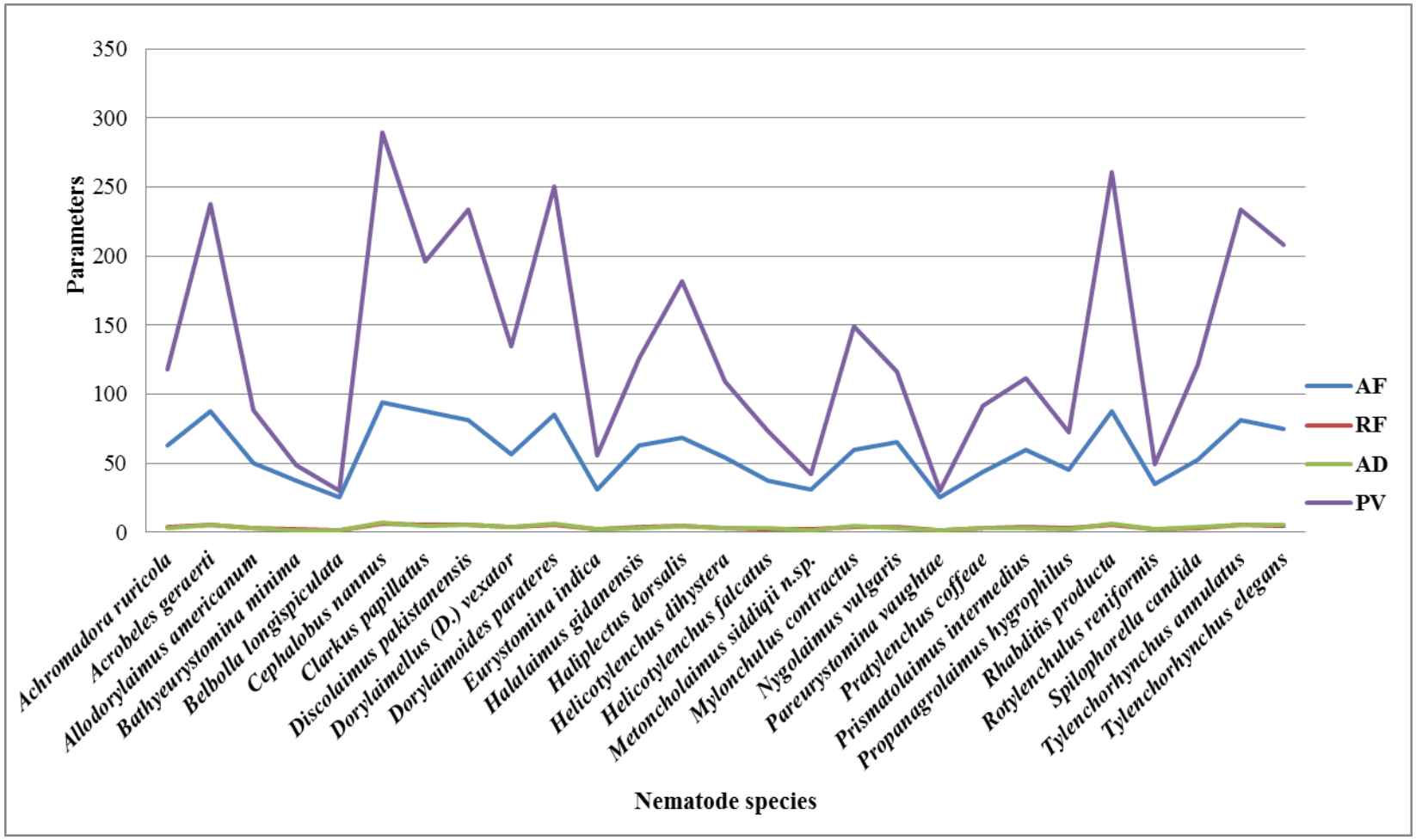

Fig. 5. Community structure of fresh water nematode species at Al-Manzar, Jamshoro.

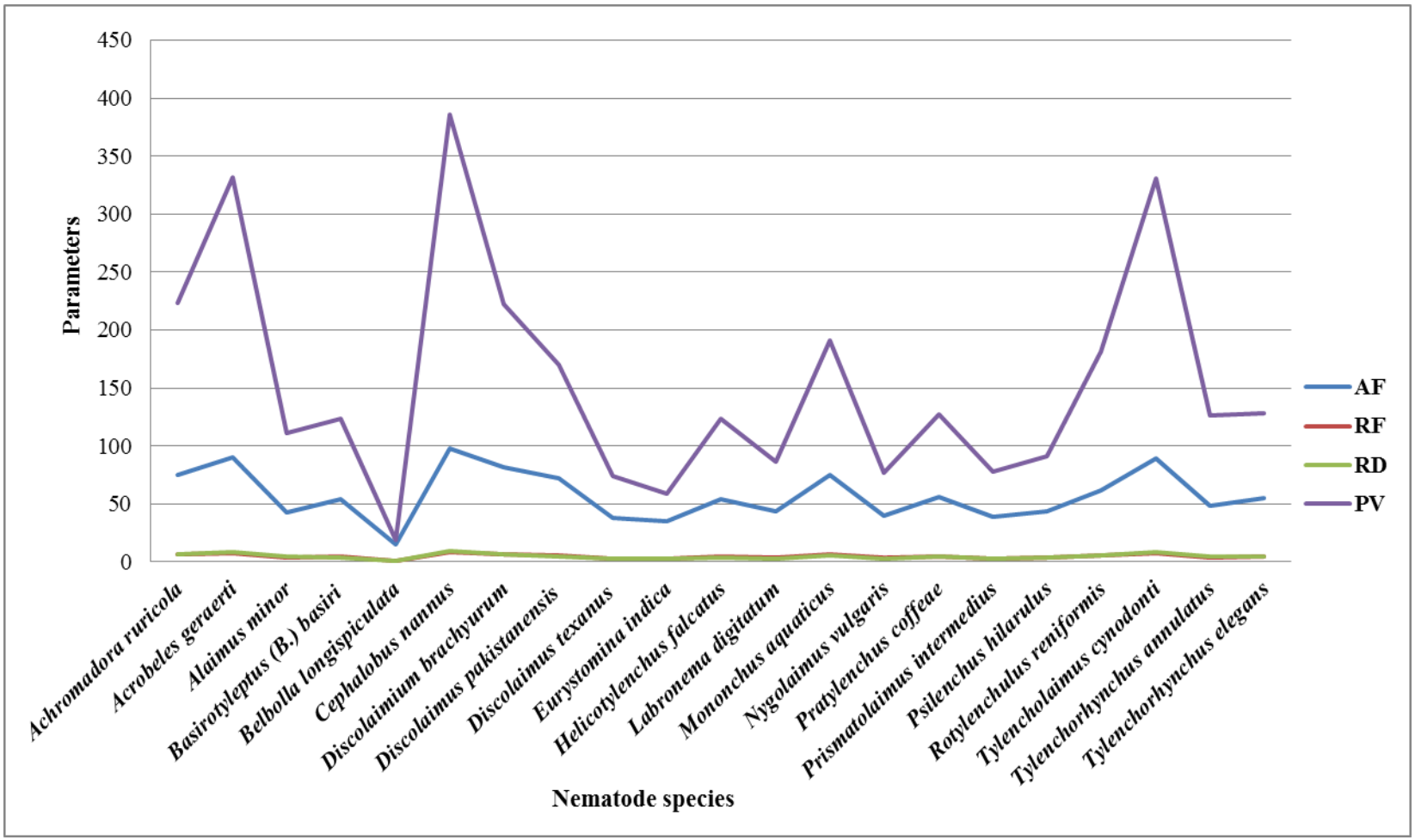

Fig. 6. Community structure of fresh water nematode species at Detha, Hyderabad.

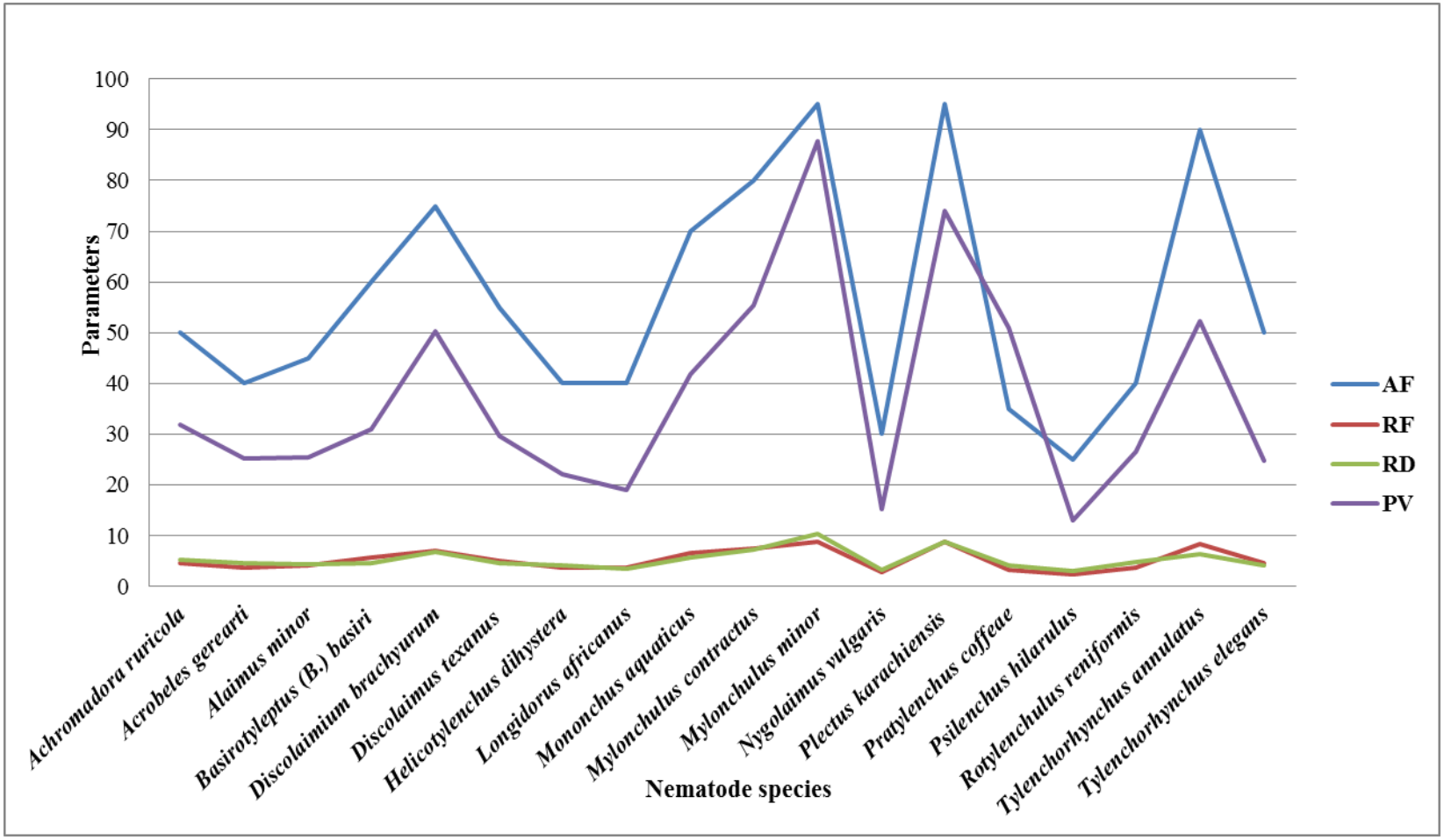

Fig. 7. Community structure of fresh water nematode species at Khesana Mori, Tandojam.

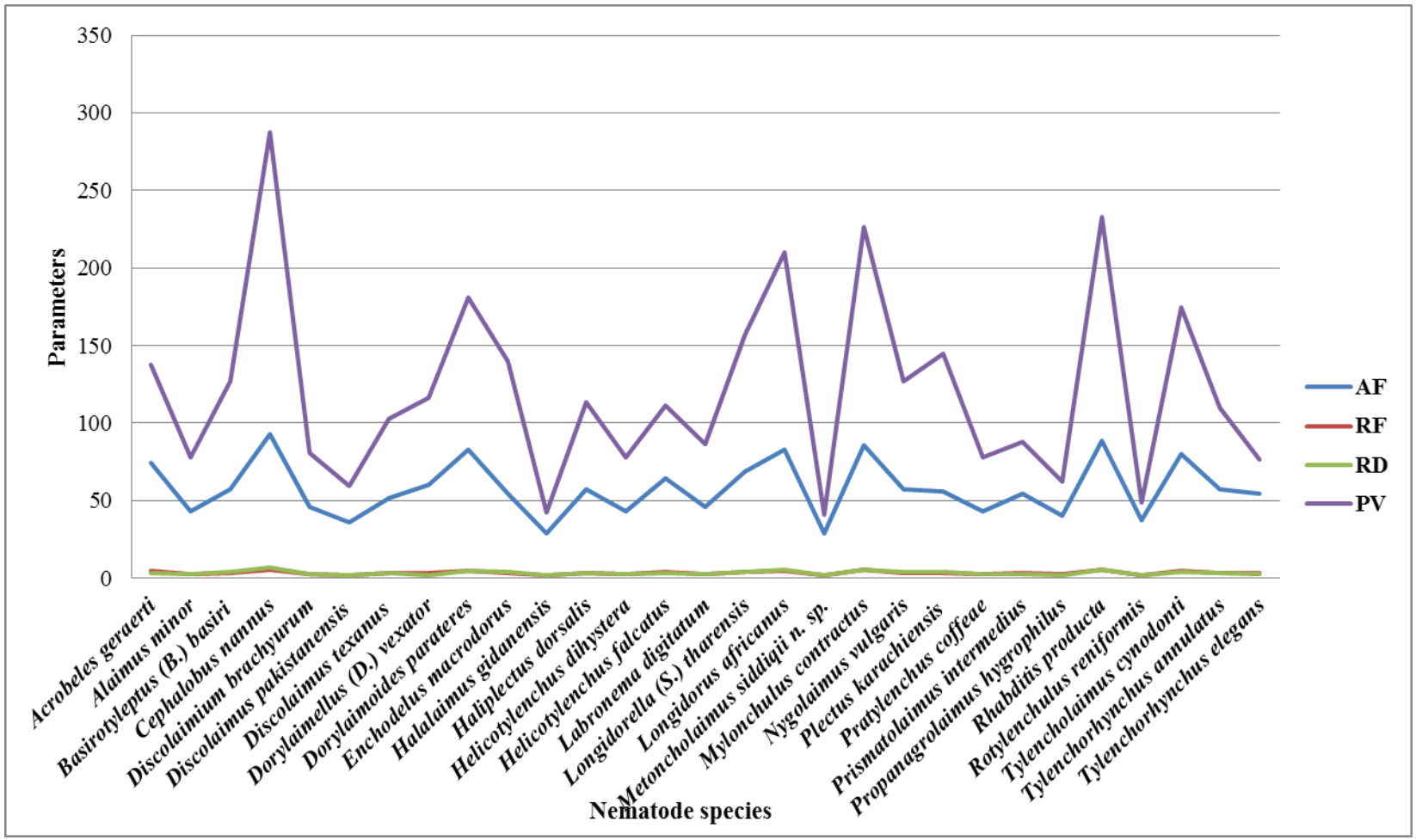

Fig. 8. Community structure of fresh water nematode species at Mirpurkhas.

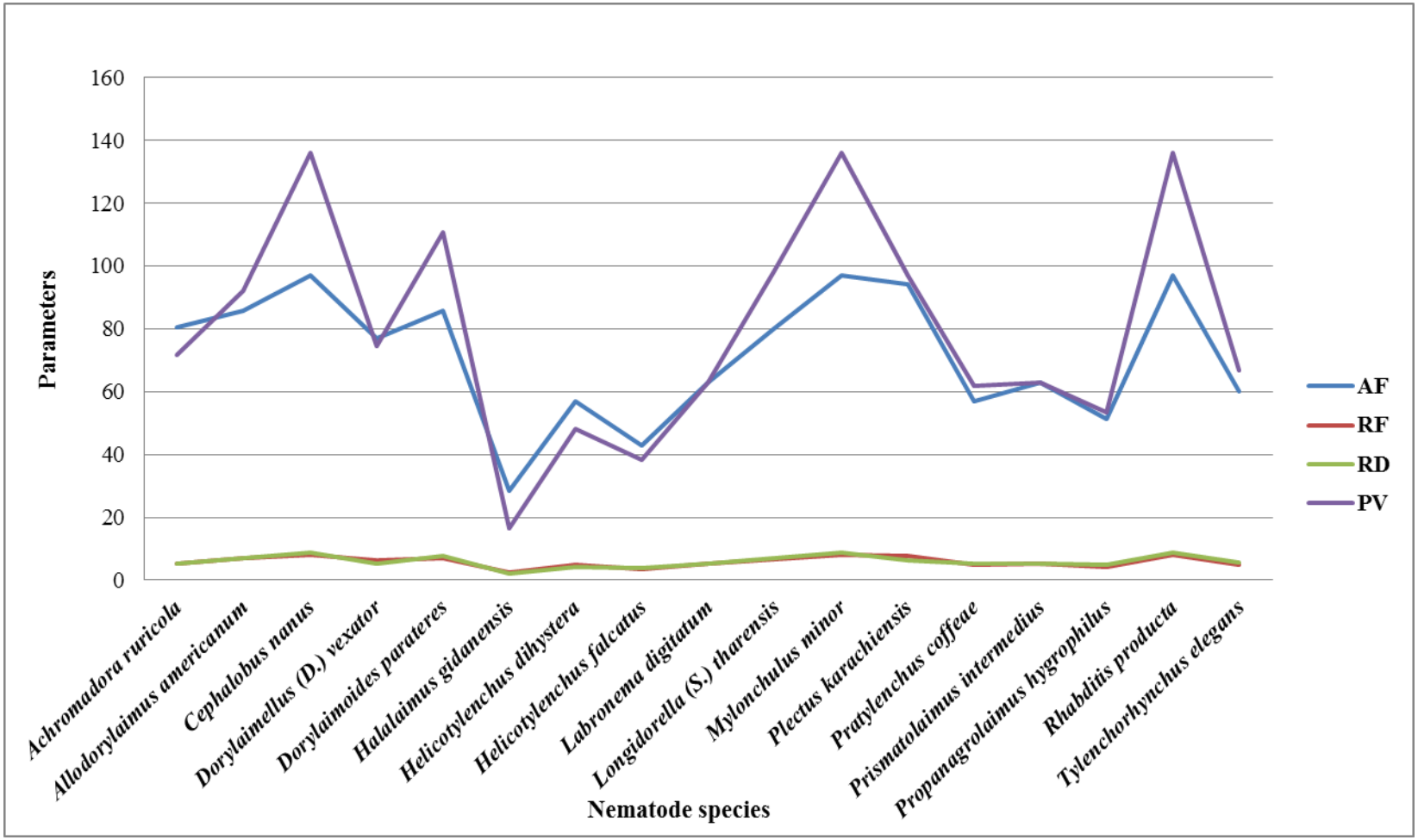

Fig. 9. Community structure of fresh water nematode species at Jamesabad.

The present research was focused on nematodes encountered from fresh water sources at different sites of Sindh. These include plant-parasitic nematodes, free-living soil nematodes and free-living marine nematodes; which were analyzed within the framework of their environment.

Little attention has been given to fresh water nematodes regarding their community structure in the environment. Literature search indicated that diminutive information has so far been available on the importance of these nematodes from our country. For community analysis nematodes were considered as the most significant group owing to their detailed taxonomic information as compared to others (Gupta & Yeates, 1997).

Diversity and prominence values in nematode community analysis helped in understanding the ecological situation. Nematode community analysis is an important technique and used along with other conventional methods for a better understanding of ecological study (Norton, 1978). During this research many nematodes were encountered from fresh water sources; however their abundance greatly differed between investigated sites of Sindh. It may be due to the differences in the physico-chemical environment and food resources (Higgins & Thiel, 1988; Beier & Traunspurger, 2003).

Trophic group composition

During surveys of fresh water sources like river, lake, canal, pond, stream, irrigation water, tube well, storage tank and other water sources, forty nematode species were recovered in samples at the surveyed sites of Sindh.

Trophic group composition of these nematode species was investigated during the study period at eight different fresh water sites of Sindh. All the nematode species were classified according to the substrate upon which they feed.

Occurrence percentage of different trophic groups of fresh water nematode species at surveyed sites of Sindh.

Analysis of fresh water showed that the samples contained nematode species of diverse trophic groups with a range of 2.5 to 35%. However, the composition of these trophic groups varied at different sites. Analysis of overall occurrence percentage of these groups revealed that predators dominated the entire nematode community (35%) followed by bacterivores (32.5%), herbivores (20%), algal feeders and fungivores shared the same occurrence percentage (5%) while the least occurrence percentage was of omnivores (2.5%) (Fig.10).

Composition of nematodes species of trophic groups

Results of the trophic group analysis show that the composition of nematode species of six different feeding/trophic groups varied at different sites.

Herbivores: Overall occurrence percentage of herbivores feeding group of fresh water at different sites was 20%. Out of 40 nematode species eight species belong to this group *viz*., *Helicotylenchus dihystera*, *H. falcatus*, *Longidorus elongatus*, *Pratylenchus coffeae*, *Psilenchus hilarulus*, *Rotylenchulus reniformis*, *Tylenchorhynchus annulatus* and *T. elegans*.

Bacterivores: Trophic group, bacterivores came next to predators regarding the occurrence percentage with 32.5%. Thirteen nematode species belong to bacterivores *viz*., *Acrobeles geraerti*, *Alaimus minor*, *Basirotyleptus* (*B.*) *basiri*, *Cephalobus nanus*, *Dorylaimoides parateres*, *Enchodelus macrodorus*, *Halalaimus gidanensis*, *Haliplectus dorsalis*, *Longidorella* (*S.*) *tharensis*, *Plectus karachiensis*, *Prismatolaimus intermedius*, *Propanagrolaimus hygrophilus* and *Rhabditis producta*.

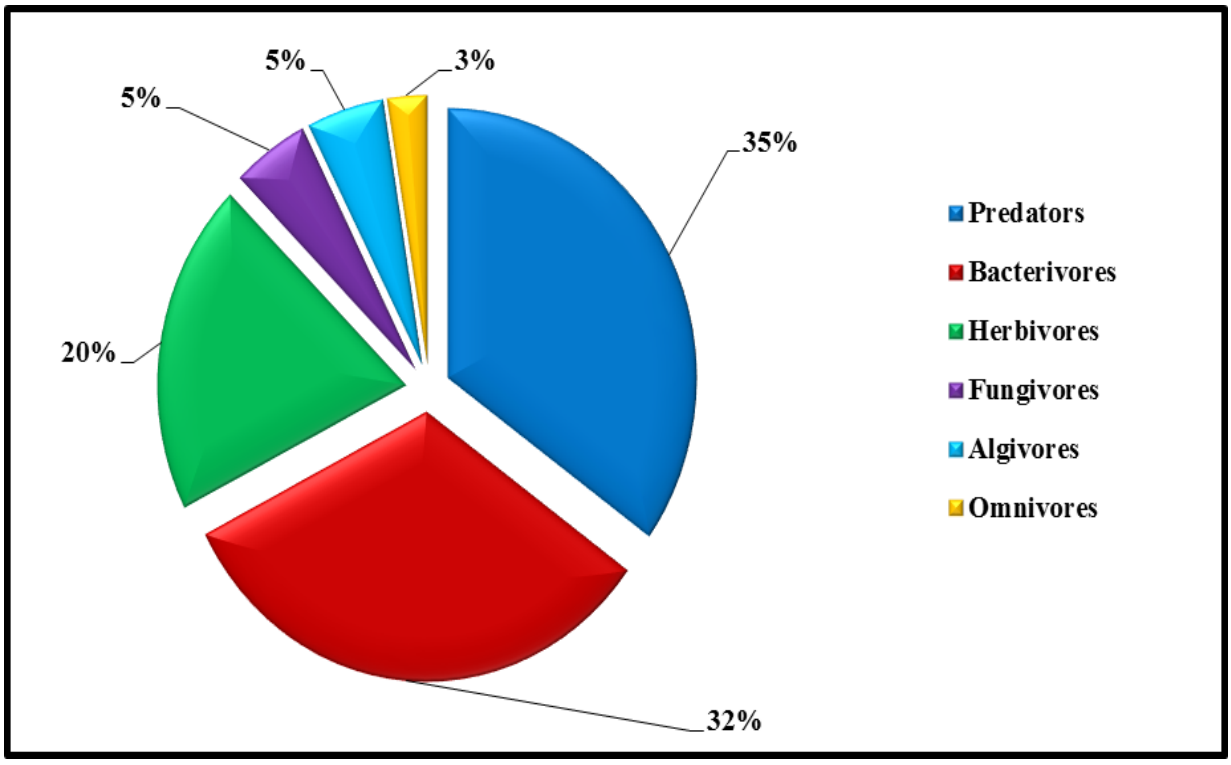

Fig. 10. Overall occurrence % of different trophic groups of fresh water nematode species in Sindh.

Fungivores: During the analysis occurrence percentage of fungivore group was 5%; this feeding group contain two nematode species *viz*., *Dorylaimellus* (*D.*) *vexator* and *Tylencholaimus cynodonti.*

Algal feeders: Algal feeding group has the same occurrence percentage as of fungivores i.e., 5%. Two nematode species belong to this algal feeder group *viz*., *Achromadora ruricula* and *Spilophorella candida.*

Predators: During the present study, the overall highest occurrence percentage was of predators (35%). Fourteen nematode species belong to predators *viz*., *Bathyeurystomina minima*, *Belbolla longispiculata*, *Clarkus papillatus*, *Discolaimium brachyurum*, *Discolaimus pakistanensis*, *D. texanus*, *Eurystomina indica*, *Labronema digitatum*, *Metoncholaimus siddiqii*, *Mononchus aquaticus*, *Mylonchulus contractus*, *M. minor*, *Nygolaimus vulgaris* and *Pareurystomina vaughtae*.

Omnivores: Only a single nematode species belongs to omnivore feeding group *viz*., *Allodorylaimus americanum* with the least occurrence percentage (2.5%).

Occurrence percentage of trophic groups at each surveyed site

Over all occurrence percentage of different trophic groups of fresh water nematode species at each surveyed site varied considerably.

Karachi (Malir): At Malir, Karachi thirty six nematode species were recorded during the present study. Predators were the dominant feeding group. They comprised 33.3% of the total nematode fauna followed by bacterivores 30. 5%, herbivores 22.2%, fungivores and algal feeders had the same occurrence percentage 5.5% while omnivores represented by 2.7% only (Fig. 11).

Thatta (Kalri Lake): Twenty four nematode species were encountered from fresh water samples at Kalri Lake, Thatta. Composition of

feeding groups showed that predators and bacterial feeders are the dominant groups regarding the occurrence percentage, 29.1% followed by herbivores 25%, fungivores 8.3%. Omnivore and algal feeders have the least occurrence percentage 4.1% (Fig. 12).

Jamshoro (Karachi Canal): Twenty seven species were encountered at Karachi Canal, Jamshoro with bacterivores as a dominant feeding group with the highest percentage 33.3%. Predators came next to bacterivores with 29.6% followed by herbivores 22.2%, fungivores 7.4%. Least occurrence percentage 3.7% was shared by omnivores and algal feeders (Fig. 13).

Jamshoro (Al-Manzar): A total of twenty seven species were recorded at Al-Manzar, Jamshoro. Predators dominated than other feeding groups with the highest percentage 33.3% of the total nematode fauna followed by bacterivores 29.62%, herbivores 22.2%, algal feeders 7.4%, while fungivores and omnivores have similar occurrence with least percentage 3.7% (Fig. 14).

Hyderabad (Detha): At Detha, Hyderabad a total of twenty one species were identified. Regarding the feeding groups they were grouped into predators having the highest percentage 38%. Herbivores came next to it with 28.5% and bacterivores 23.8%. Fungivores and algal feeders shared the same occurrence percentage 4.7% while omnivores were not found at Detha, Hyderabad (Fig 15).

Tandojam (Khesana Mori): Eighteen nematode species were identified during analysis at Khesana Mori. Only four feeding groups were found. Herbivores dominated the other feeding groups with highest occurrence percentage 38.8% followed by predators 33.3%, bacterial feeders 22.2% while algal feeders were found with least occurrence percentage 5.5%. The two feeding groups *viz*., fungivores and omnivores were not encountered in fresh water samples at Khesana Mori, Tandojam (Fig. 16).

Mirpurkhas: Over all twenty nine species were identified at Mirpurkhas. These species were distributed into three groups based upon their feeding habits. Bacterivores dominated over the other two groups with the highest percentage 44.8% followed by predators and herbivores with same occurrence percentage 24.1%, fungivores with 6.8%. The two feeding groups *viz*., omnivores and algal feeders were not encountered at Mirpurkhas during the present study (Fig. 17).

Jamesabad: At Jamesabad the least number of nematode species (17) were recovered from fresh water samples. Analysis showed that bacterial feeders were the dominant feeding group. They comprise 47% of the total nematode fauna at Jamesabad followed by herbivores 23.5%, predators 11.7% while the three other feeding groups *viz*., fungivores, omnivores and algal feeders represented 5.8% only (Fig. 18). In terms of frequency percentage of occurrence of nematode species among six different trophic groups, the result shows that it varied among all species as well as in all groups (Table 1). Among herbivores the overall highest frequency % of occurrence was of *Tylenchorhynchus annulatus* (28.1%) at Khesana Mori, Tanjojam, followed by *Tylenchorhynchus elegans* (27.6%) at Jamesabad. *Psilenchus hilarulus* has the least % occurrence (7.8%) from Khesana Mori, Tanjojam. *Plectus karachiensis* of bacterivors has the overall highest % occurrence (39.5%) at Khesana Mori, Tandojam, followed by *Longidorella* (*S.*) *tharensis* (37.8%) at Jamesabad. The least % occurrence (3.3%) was of *Halalaimus gidanensis* from Mirpurkhas. In fungivore group two nematode species have overall 100% occurrence *viz*., *Dorylaimellus* (*D.*) *vexator* from two sites Al-Manzar, Jamshoro and Jamesabad and *Tylencholaimus cynodonti* from Detha, Hyderabad. In Algal feeder group also two nematode species have over all 100% occurrence *viz*., *Achromadora ruricola* from four sites; Kalri Lake, Thatta; Detha, Hyderabad; Khesana Mori, Tandojam and Jamesabad and *Spilophorella candida* from Karachi Canal, Jamshoro. Omnivore group is represented by a single nematode species *Allodorylaimus americanum* with overall 100% occurrence at five sites; Malir, Karachi; Kalri Lake Thatt; Karachi Canal, Jamshoro; Al

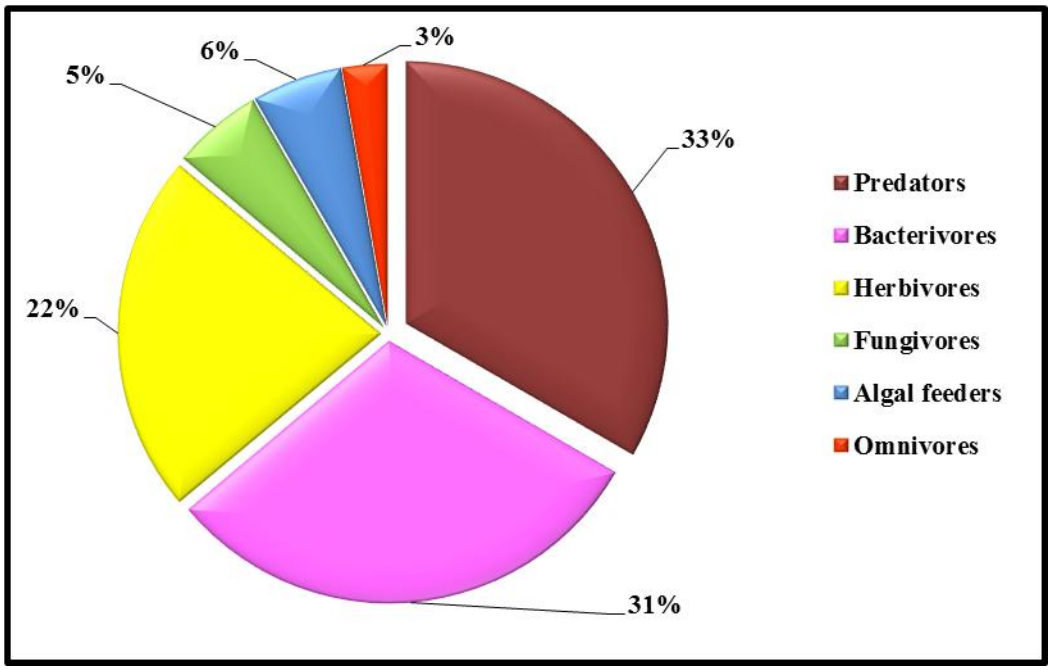

Fig. 11. Occurrence % of trophic groups of nematode species at Malir, Karachi.

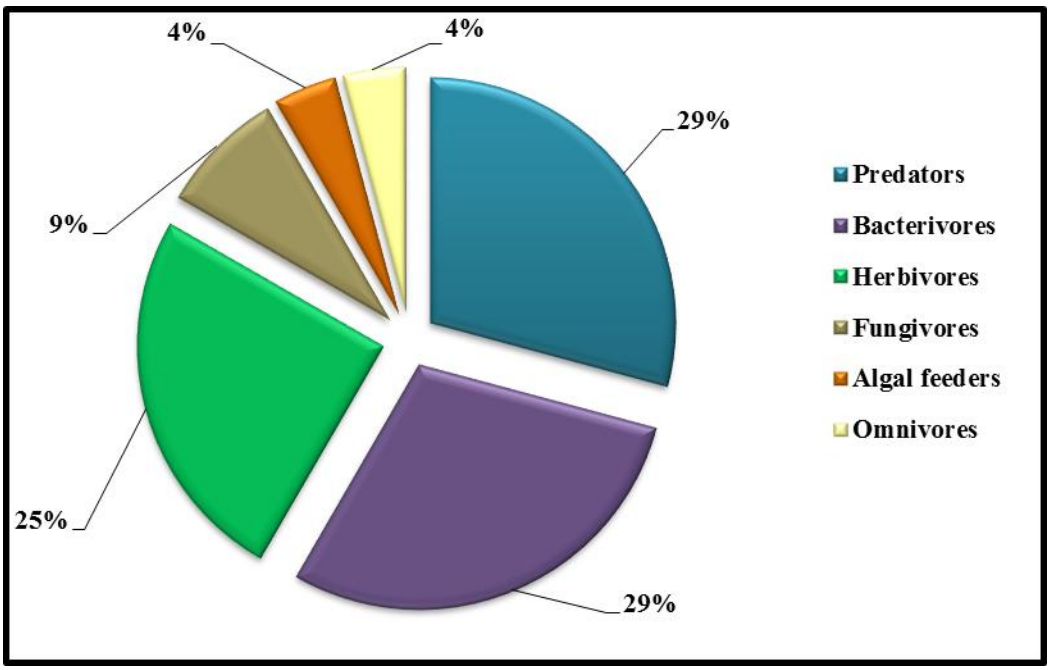

Fig. 12. Occurrence % of trophic groups of nematode species at Kalri Lake, Thatta.

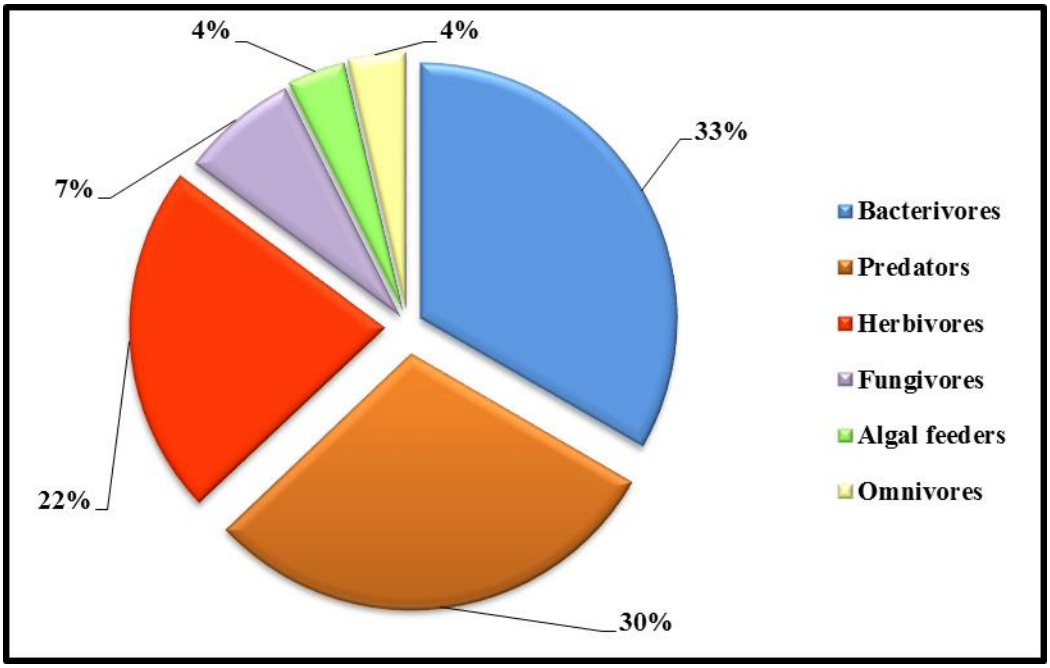

Fig. 13. Occurrence % of trophic groups of nematode species at Karachi Canal,Jamshoro.

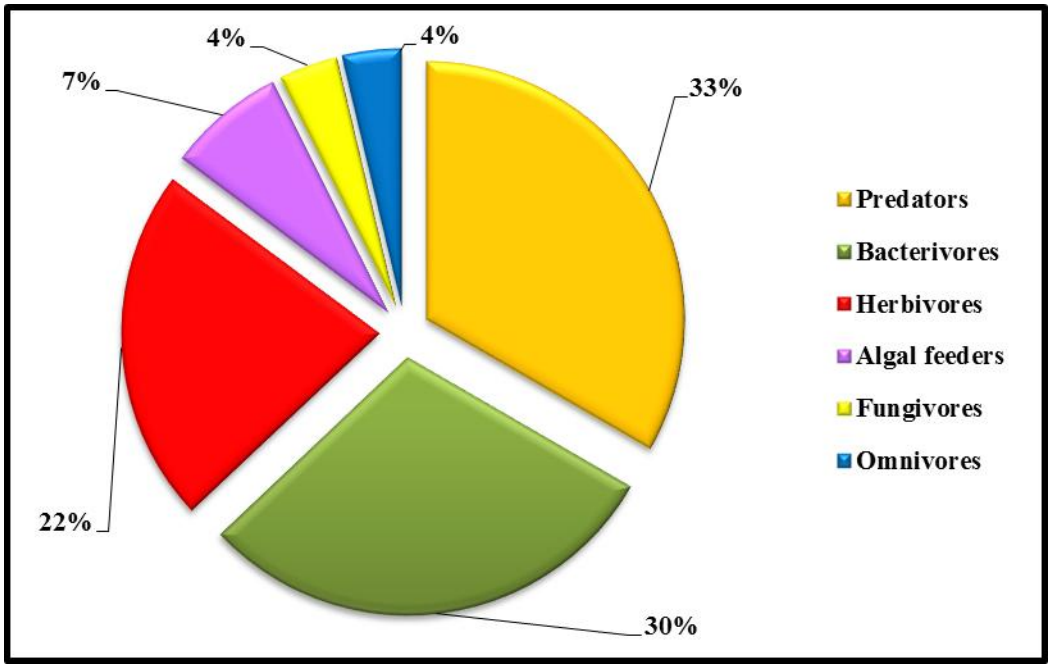

Fig. 14. Occurrence % of trophic groups of nematode species at Al-Manzar, Jamshoro.

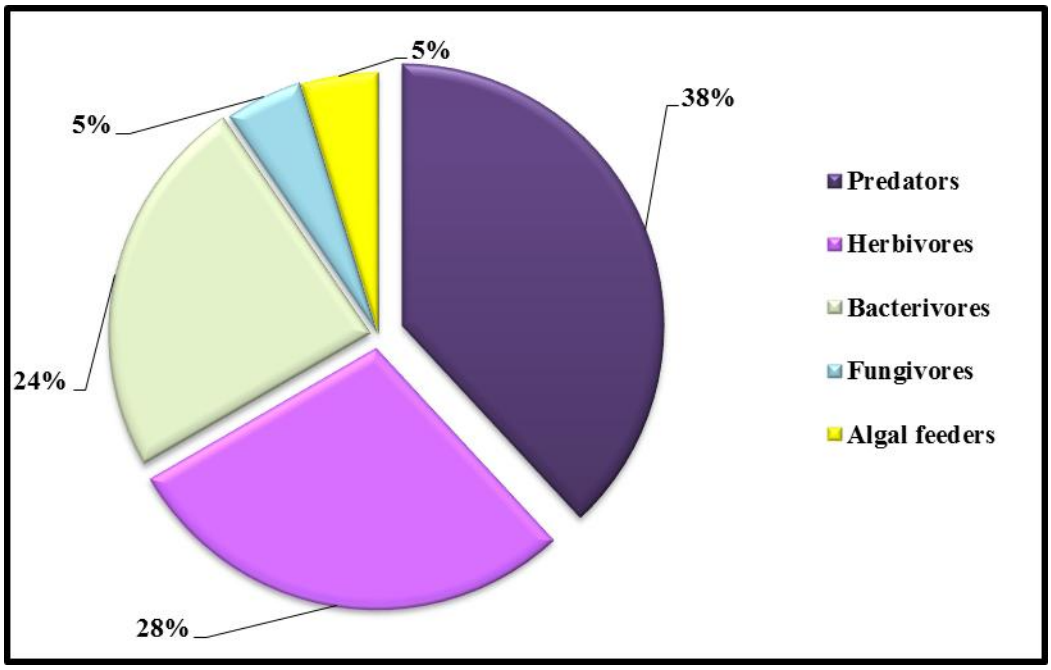

Fig. 15. Occurrence % of trophic groups of nematode species at Detha, Hyderabad.

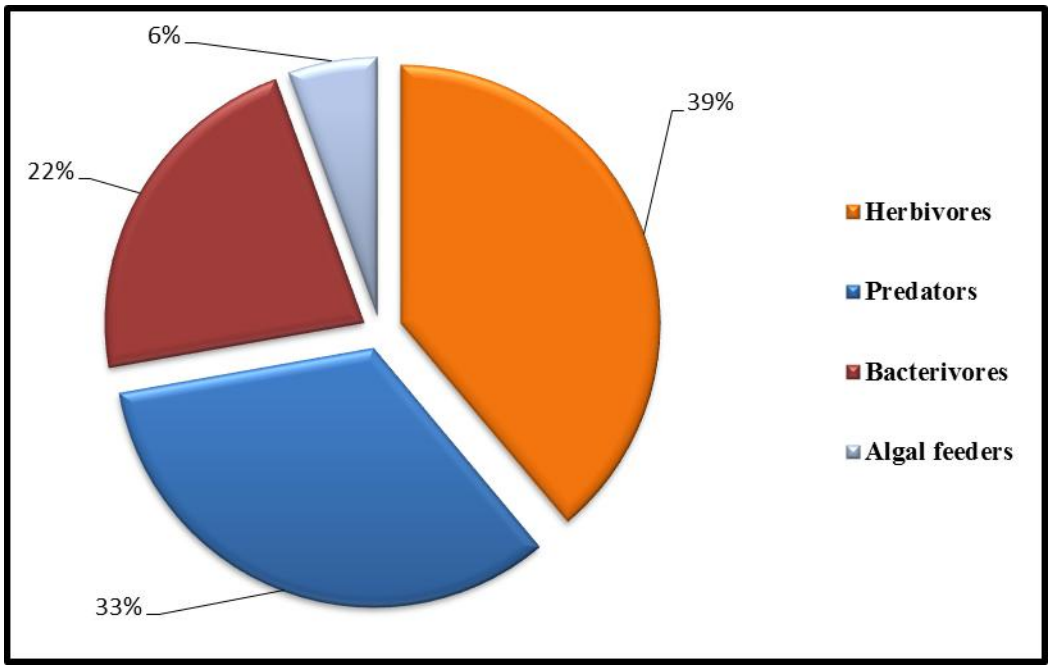

Fig. 16. Occurrence % of trophic groups of nematode species at Khesana Mori, Tandojam.

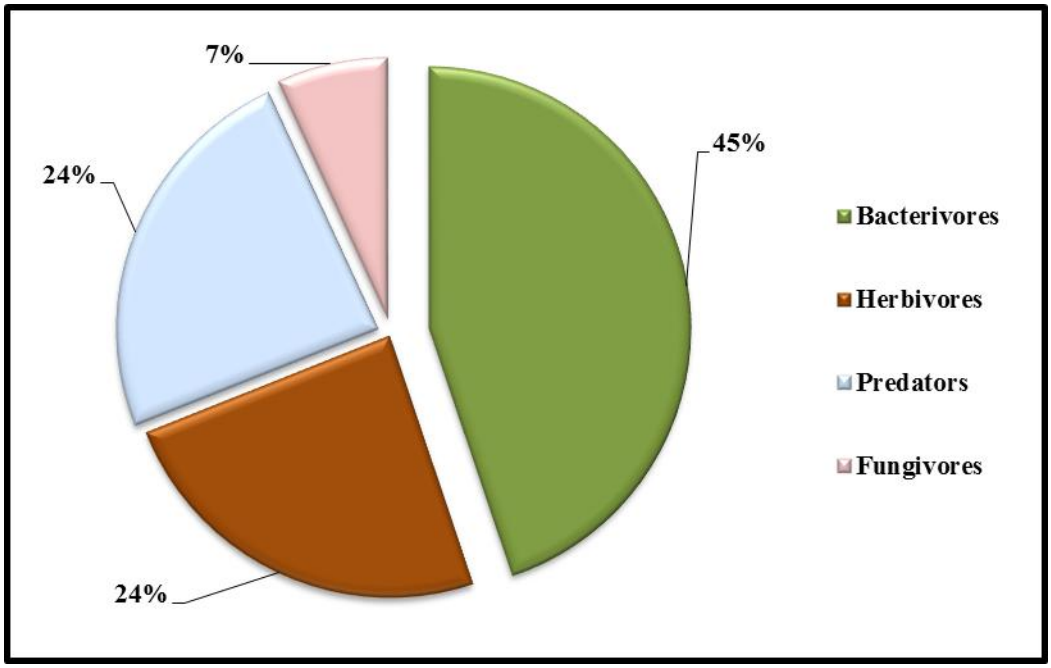

Fig. 17. Occurrence % of trophic groups of nematode species at Mirpurkhas.

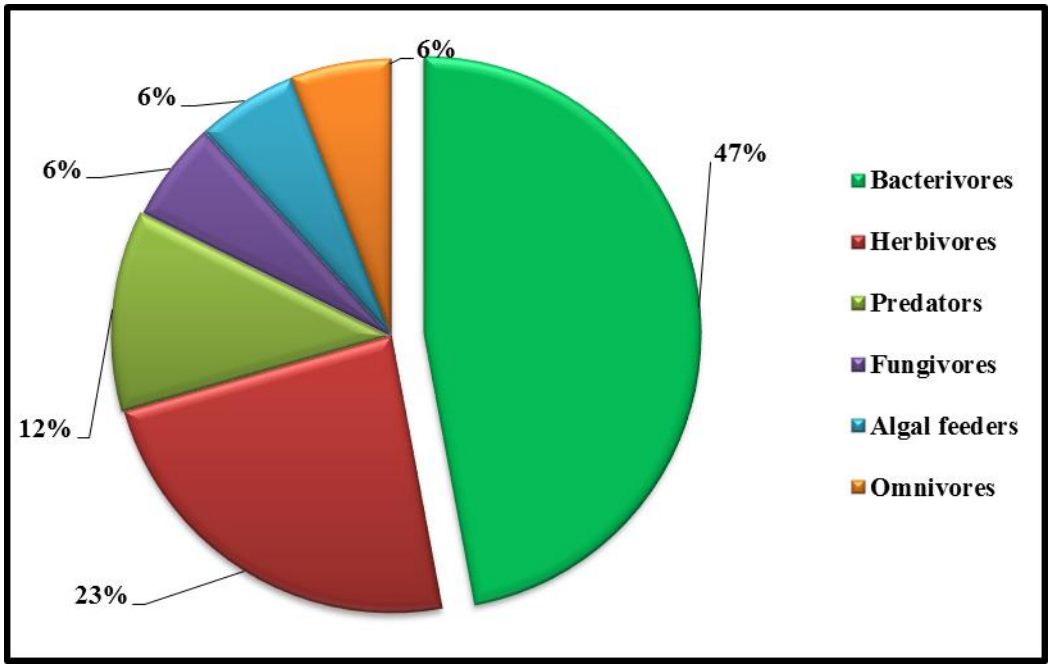

Fig. 18. Occurrence % of trophic groups of nematode species at Jamesabad.

Table 1. Frequency percentage (%) of nematode species trophic groups at eight fresh water sites of Sindh Province Pakistan.

Trophic groups of nematode	Surveyed sites*							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Herbivore nematodes								
Helicotylenchus dihystera	18.9	17.3	20.5	16.4	-	12.5	11.2	26.3
Helicotylenchus falcatus	13.9	11.9	14.6	11.4	16.9	-	16.8	19.7
Longidorus africanus	9.1	21.7	-	-	-	12.5	21.7	-
Pratylenchus coffeae	11.1	-	15.2	13.4	17.5	10.9	11.2	26.3
Psilenchus hilarulus	13.9	-	-	-	13.7	7.8	-	-
Rotylenchulus reniformis	6.9	16.3	13.6	10.7	19.4	12.5	9.7	-
Tylenchorhynchus annulatus	11.4	13.0	15.9	24.9	15.0	28.1	14.9	-
Tylenchorhynchus elegans	14.5	19.5	19.9	22.9	17.2	15.6	14.2	27.6
Bacteriovores								
Acrobeles geraerti	-	-	11.3	14.8	27.7	16.6	8.6	-
Alaimus minor	-	13.5	-	-	13.2	18.7	5.0	-
Basirotyleptus (*B.*) *basiri*	9.6	12.8	6.2	-	16.6	25.0	6.6	-
Cephalobus nanus	12.9	16.2	15.6	15.8	30.2	-	10.8	11.6
Dorylaimoides parateres	12.3	13.5	14.5	14.4	-	-	9.6	10.3
Enchodelus macrodorus	7.9	-	8.5	-	-	-	6.3	-
Halalaimus gidanensis	5.9	13.5	-	10.5	-	-	3.3	3.4
Haliplectus dorsalis	6.4	15.5	11.5	11.6	-	-	6.6	-
Longidorella (*S.*) *tharensis*	9.1	-	-	-	-	-	31.6	37.8
Plectus karachiensis	12.3	-	11.3	-	-	39.5	6.5	11.3
Prismatolaimus intermedius	4.8	-	-	10.1	12.0	-	6.3	7.5
Propanagrolaimus hygrophilus	4.3	-	6.7	7.6	-	-	4.6	6.1
Rhabditis producta	13.9	14.8	13.8	14.8	-	-	10.3	11.6
Fungivores								
Dorylaimellus (*D.*) *vexator*	38.1	47.5	51.1	100	-	-	42.8	100
Tylencholaimus cynodonti	61.8	52.5	48.8		100	-	57.1	-
Algal feeders								

Achromadora ruricola	50	100	-	54.3	100	100	-	100
Spilophorella candida	50	-	100	45.6	-	-	-	-
Omnivores								
Allodorylaimus americanum	100	100	100	100	-	-	-	100
Predators								
Bathyeurystomina minima	-	-	13.0	8.4	-	-	-	-
Belbolla longispiculata	2.9	-	8.3	5.6	3.7	-	-	-
Clarkus papillatus	11.7	-	-	19.7	-	-	-	-
Discolaimium brachyurum	-	15.7	19.7	-	20.4	18.5	13.0	-
Discolaimus pakistanensis	8.8	10.5	-	18.3	5.4	-	10.2	-
Discolaimus texanus	7.6	8.4	-	-	9.4	13.5	14.6	-
Eurystomina indica	4.1	-	9.8	7.0	8.7	-	-	-
Labronema digitatum	5.6	-	-	-	10.9	-	13.0	39.2
Metoncholaimus siddiqii	12.3	11.5	-	7.0	-	-	8.1	-
Mononchus aquaticus	10.0	-	-	-	18.7	17.2	-	-
Mylonchulus contractus	11.7	20.0	10.4	13.5	-	19.7	24.4	-
Mylonchulus minor	14.1	24.2	17.1	-	-	23.4	-	60.7
Nygolaimus vulgaris	7.0	-	14.0	14.6	9.9	7.4	16.3	-
Pareurystomina vaughtae	3.5	9.4	7.2	5.6	-	-	-	-

*1= Malir, Karachi; 2= Kalri Lake, Thatta; 3= Karachi Canal, Jamshoro; 4= Al-Manzar, Jamshoro; 5= Detha, Hyderabad; 6= Khesana Mori, Tandojam; 7= Mirpurkhas; 8= Jamesabad.

Manzar, Jamshoro and Jamesabad. Among carnivores (predators) group *Mylonchulus minor* has the overall highest occurrence % (60.7%) at Jamesabad followed by *Labronema digitatum* (39.2%) also from Jamesabad. *Belbolla longispiculata* has the least % occurrence (2.9%) from Malir, Karachi.

Distribution-wise, the nematode species *Tylenchorhynchus elegans* (herbivores) occurred in all eight surveyed sites. Whereas six nematode species; *Tylenchorhynchus annulatus*, two species of *Helicotylenchus viz*., *H. dihystera* and *H. falcatus*, *Pratylenchus coffeae* and *Rotylenchulus reniformis* (herbivores) and *Cephalobus nanus* (bacterivores) occurred in seven out of eight surveyed sites but they differ in their frequency percentage at all investigated sites (Table 1).

Nematodes are the most abundant group of meiofauna in the benthos of aquatic ecosystem (Traunspurger, 2002) and play an important role in the trophic food web (Vidakovic *et al*., 2001). According to Traunspurger (1996a, b) feeding categories of nematodes is useful for the interpretation of their ecological role in the meiobenthos.

Their frequency, density and diversity varied depending upon ecological and other edaphic factors (Khatoon *et al*., 2001).

On the basis of trophic composition nematodes encountered during the present research study were grouped into six categories: herbivores, bacterivores, fungivores, algal feeders, omnivores and carnivores (predators). Among the trophic groups predators represent the highest number of genera and also the highest abundance which is in accordance with the earlier finding of Eyualem-Abebe *et al*., (2008). However, the composition, abundance and distribution of nematode species of six different feeding/trophic groups greatly differed between investigated sites. This may be due to the differences in the physico-chemical environment and availability of food quantity (Bogut & Vidakovic, 2002; Wu *et al*., 2004) and the absence and presence of predators or grazers (Hillebrand *et al*., 2002; Schmid & Schmid-Araya, 2002; Beier *et al*., 2004).

Conclusions

Fresh water nematodes impact their environment in several important ways. The most important role of certain nematodes in fresh water is the ingestion of bacteria by many genera of freshwater bacteriophagous nematodes (Esser & Buckingham, 1987). Due to their unique characterstics *viz*., abundance, species richness, ecology, functional morphology (with regard to feeding type) and short life cycles they respond quickly to environmental changes and are the ideal organisms for ecological studies (Hakenkamp *et al*., 2002; Giere, 1993; Platt & Warwick, 1980). The nematode abundance and its community structure were both reliable bioindicators for monitoring long-term river pollution in both qualitative and quantitative aspects. Nematodes community structure in river is related to the contamination sources and pollution level (Wu *et al*., 2010). The present study is based on the community analysis and trophic groups of freshwater nematodes.

The study discloses the increase in number of nematodes at one or more locations, while a decrease in other locality, showing their tolerance to a certain pollutant which they resist surviving and thus imparting knowledge of being bioindicator to pollutants present in freshwater and its sediments. This proclaims the health and quality of water of different water sources like rivers, streams, irrigation canals, estuary and stagnant water in ponds.

Among the 40 nematodes species of 36 genera, belonging to 27 families in 7 orders, it was observed that the order Dorylaimida was the most dominant taxa (32.5%) which shows their survival and resistance at varying level of polluted water. The least tolerant to polluted water were the nematodes of the order Triplonchida (2.5%).

The analysis of nematode feeding types in the samples showed variations. Among the six feeding types, the predators were most dominant group, followed by bacterivores, herbivorous, algal feeder, fungivorous and omnivorous, respectively. The presence of submerged vegetation is a good source of food supply for diverse trophic groups of nematodes (Wu & Liang, 1999). Their analysis for trophic group abundance helped to determine nematode food web. The free-living soil nematodes were mostly available due to the mixing of soil present near the banks of water sources. Plant parasitic occasionally found their way into the rivers due to water coming from irrigation canals and mixing with the main river water. The presence of algal feeders seems to depend on the substrate type. Stony bottom and aquatic vegetation are favourable for algal attachment. Bacterial feeder nematodes were found in polluted site (Zullini, 1976).

Among the overall trophic groups the minimal percentage was obtained for omnivorous nematodes. These trophic groups have potential to provide insight condition of the food web at a particular collecting site and to understand their biology and role in an ecosystem. The present research, based on different freshwater environment (river, lakes, canals, ponds, reservoirs and irrigation sources: tube well and tanks) provides the basic information about the

nematode species composition, feeding types and community structure.

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