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Original article (Orijinal araştırma)

The nematode assemblages of a lake ecosystem (Lake Korugöl Natural Park, Düzce, West Black Sea Cost of Türkiye): ecology and biodiversity patterns with first reports of 10 genera to the Türkiye nematofauna

Bir göl ekosisteminin nematod toplulukları (Korugöl Gölü Tabiat Parkı, Düzce, Türkiye): Türkiye nematofaunası için 10 cinsin ilk raporları ile ekoloji ve biyoçeşitlilik modelleri

Taylan ÇAKMAK[1*]

Abstract

This research was conducted to reveal the soil nematode fauna of Korugöl, Düzce and to contribute to the nematode diversity of the Western Black Sea Region of Türkiye. Field studies within the scope of the study were implemented in 2021. As a result of the study, 29 families, 45 genera and 46 nematode taxa were identified. 10 nematode taxon, namely Aporcelinus, Baladorylaimus, Dorylaimoides, Euteratocephalus, Labronemella, Laimydorus, Lindseyus, Metateratocephalus, Paractinolaimus and Tripylella are the first report for Türkiye's nematofauna. Classification of nematodes according to their feeding types were: 27.27% bacterivorous nematodes, 2.10% fungivoresnematodes, 1.51% herbivorous nematodes, 16.35% predator nematodes and 52.77% omnivorous nematodes.

Keywords: Biodiversity, coastal ecosystems, nematofauna, soil nematodes, Türkiye

Öz

Bu araştırma, Düzce Korugöl toprak nematod faunasını ortaya çıkarmak ve Türkiye'nin Batı Karadeniz Bölgesi nematod çeşitliliğine katkıda bulunmak amacıyla yapılmıştır. Çalışma kapsamında arazi çalışmaları 2021 yılında yapılmıştır. Çalışma sonucunda 29 familya ve 45 cinse ait 46 nematod taksonu tespit edilmiştir. Aporcelinus, Baladorylaimus, Dorylaimoides, Euteratocephalus, Labronemella, Laimydorus, Lindseyus, Metateratocephalus, Paractinolaimus ve Tripylella olmak üzere 10 nematod taksonu, Türkiye nematod faunası için ilk rapordur. Nematodların beslenme şekillerine göre sınıflandırılması: %27,27 bakteriovor, %2,10 fungivor, %1,51 herbivor, %16,35 predatör ve %52,77 omnivor nematodlar olarak tespit edilmiştir.

Anahtar sözcükler: Biyoçeşitlilik, kıyı ekosistemleri, nematofauna, toprak nematodları, Türkiye

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Introduction

Nematodes are animals with a wide variety of life strategies and feeding habits which comprise an important part of ecdysozoan. These varied life strategies of terrestrial nematodes have a critical impact on the food webs of the soil. To date, there are currently 25,000 to 30,000 identified species of nematodes, being the most diverse group with 1,000,000 estimated species number (Hugot et al., 2001). Free-living nematodes are the most abundant group of terrestrial habitats, which can be found in soils and freshwater sediments (Yeates et al., 1993). Parasitic species which are obligate to plants and animals (even man) cause worldwide damage and diseases (Lee, 2002). Their tremendous diversity, great abundance and survival ability give scientists a great chance to assess soil health via bio-indicator activity (Wilson & Kakouli-Duarte, 2009). Several biodiversity indices (Bongers, 1990; Bongers et al., 1997; Ferris & Bongers, 2009) have been used to monitor natural or human-impacted areas in terms of soil health (Bongers & Ferris, 1999). Korugöl is a mesotrophic lake, located in the Western Black Sea region of Anatolia within the borders of Düzce Province Merkez District and Kaynaşlı District, Türkiye, covering an area of 4.87 hectares at the altitude 480 m above sea level. It is first time that nematodes are being discovered from the zone with this contribution. This study was designed to characterize the soil nematode fauna and to monitor the dispersal of nematode groups that naturally occur in a lake ecosystem.

Materials and Methods

Sampling

A sampling survey was organized at Korugöl Natural Park, Düzce, Türkiye in September 2021. The sampling was done regarding to surrounding area of the lake including forestall and coastal soil habitats. A total of five different eco-habitats, namely marshland, meadow, *Quercus petraea* L., riverbed and *Fagus orientalis* L. trees (Figure 1, Table 1) were chosen as sampling sites.

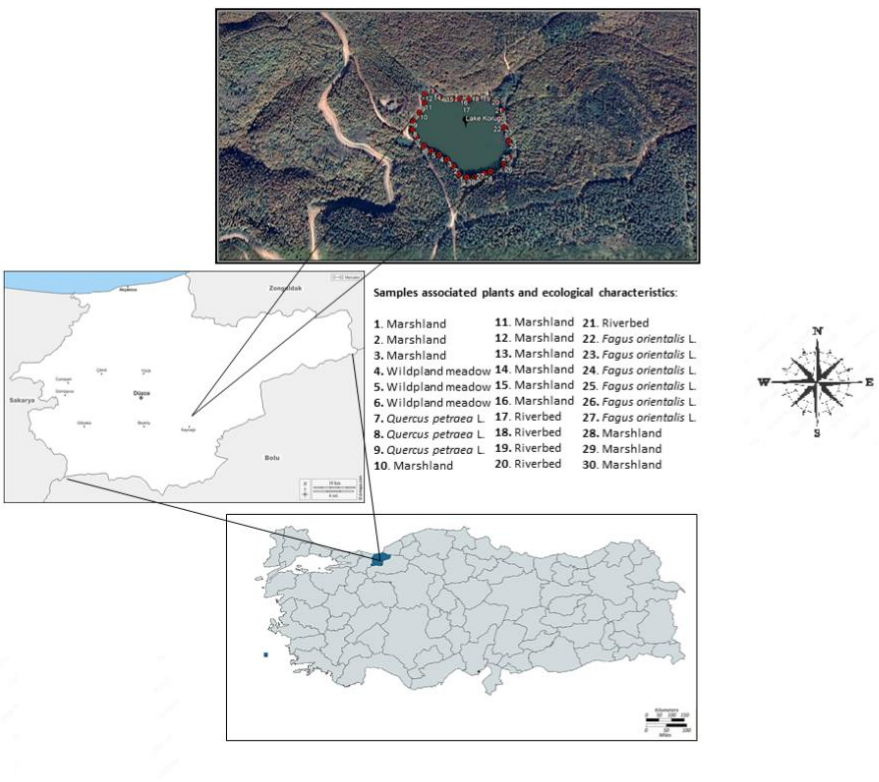

Figure 1. Location of Korugöl and sampling sites.

A total number of 30 samples were collected. Soil samples were collected from an area of 15 x 15 cm soil covering plots and digged up to 30 cm soil depth from each plot. Soil samples were stored into plastic bags, protected during the transport to the nematology laboratory with a thermo cooling bag and stored at +4°C. Then, the samples were prepared for the extraction of nematodes.

Table 1. The list of sampling sites studied in Korugöl Lake, Düzce, Türkiye

Sample Number	Habitat	UtmX	UtmY
1	Marshland	40°48'26.05"N	31°17'36.49"E
2	Marshland	40°48'26.74"N	31°17'35.94"E
3	Marshland	40°48'27.33"N	31°17'35.30"E
4	Wildpland meadow	40°48'27.75"N	31°17'34.50"E
5	Wildpland meadow	40°48'28.08"N	31°17'33.67"E
6	Wildpland meadow	40°48'28.53"N	31°17'32.91"E
7	*Quercus petraea* L.	40°48'29.35"N	31°17'32.04"E
8	*Quercus petraea* L.	40°48'30.04"N	31°17'31.61"E
9	*Quercus petraea* L.	40°48'30.91"N	31°17'31.56"E
10	Marshland	40°48'31.70"N	31°17'32.18"E
11	Marshland	40°48'32.70"N	31°17'32.63"E
12	Marshland	40°48'33.61"N	31°17'32.60"E
13	Marshland	40°48'33.98"N	31°17'33.49"E
14	Marshland	40°48'33.29"N	31°17'34.26"E
15	Marshland	40°48'33.10"N	31°17'35.65"E
16	Marshland	40°48'33.17"N	31°17'36.46"E
17	Riverbed	40°48'33.02"N	31°17'37.45"E
18	Riverbed	40°48'33.15"N	31°17'38.43"E
19	Riverbed	40°48'33.15"N	31°17'39.63"E
20	Riverbed	40°48'32.79"N	31°17'40.62"E
21	Riverbed	40°48'31.95"N	31°17'40.95"E
22	*Fagus orientalis* L.	40°48'31.15"N	31°17'40.75"E
23	*Fagus orientalis* L.	40°48'30.23"N	31°17'41.16"E
24	*Fagus orientalis* L.	40°48'28.93"N	31°17'41.58"E
25	*Fagus orientalis* L.	40°48'27.49"N	31°17'41.48"E
26	*Fagus orientalis* L.	40°48'26.87"N	31°17'40.98"E
27	*Fagus orientalis* L.	40°48'26.29"N	31°17'39.62"E
28	Marshland	40°48'26.09"N	31°17'38.95"E
29	Marshland	40°48'25.82"N	31°17'38.04"E
30	Marshland	40°48'25.78"N	31°17'37.27"E

Coastal ecosystems of Lake Korugöl

The studied area was a lake ecosystem. Vegetation varies widely from annuals to perennials around the lake. The flora around the lake consists of forest trees such as European black pine (*Pinus nigra* J.F. Arnold), beech (*F. orientalis*), oak (*Quercus robur* Asso) and hornbeam (*Carpinus betulus* L.) as the dominant tree species of Düzce province forests. Some of the forests around the lake are afforestation areas and coniferous trees have been planted. The terrestrial fauna around the lake is diverse in terms of forest structure. As it is known to be essential for soil biodiversity which depends on soil profile type, the soil type around the Korugöl lake has Class I alluvial soil. Alluvial soils are flat, nearly flat inclined, (A) C profile, azonal soils located at the bottoms of surface waters or on young sediments deposited by rivers (Keleş, 2006).

Nematode Extraction

Modified Baermann's (1917) funnel technique using petri dishes (12 cm ∅) was used during the extraction of nematodes. After separating rocks, a 100 g of fresh soil from each sampling site was evaluated. Plastic trays lined with paper towels were used for extraction of nematodes and were placed in the nematology laboratory for 48 hours. Extracted vermiform terrestrial nematodes were collected after 48 hours. Nematode suspensions were heated up to 60°C for killing before fixation. Formalin solution of 4% was used for fixation and preservation of nematodes until preparing permanent glass slides. Extractions were labeled with the relevant sample number, transferred to plastic tubes, and stored at Düzce University Nematology Laboratory. The rest of the soil samples were also stored in the soil laboratory for having a backup requirement in case of future studies. The nematodes were identified immediately. The preparation of nematodes for permanent mounts were processed. Total of 855 nematodes were mounted. Collected nematode samples are stored in Düzce University Faculty of Agriculture Agricultural Biotechnology Nematode Collection.

Permanent glass slide preparation

Double distilled water was used to rinse nematodes and avoid soil debris after picking up nematodes from all samples. Each sample were put into staining blocks with 1.25 cm depth containing 96% ethanol with the extracted nematodes and placed in an incubator at 40°C. A few drops of glycerol: formalin (4%) (1:99) were added into staining block. A few drops of a solution of glycerol: ethanol (five parts glycerol and 95 parts of 96% ethanol) were added in the next morning, two-thirds of staining block's cavity was covered with a glass square. On day 2, a few drops of glycerol: ethanol (5:95) solution were added every two hours so that glycerol can transudate gradually for covering nematodes. The staining of nematodes process was continued by adding glycerol of two drops: ethanol (50:50) into the staining block at the end of the second day. One day later, all nematodes were found to be covered by glycerol (100%) before proceeding to make permanent glass slides preparation (Yoder et al., 2006).

Nematode Identification and analysis of ecological parameters

Nematodes were identified manually by using an Olympus CH microscope (Olympus Optical, Tokyo, Japan). Classification of nematodes were determined by the taxonomical key that was provided by De Ley & Blaxter (2005). Additional taxonomical data was included from Hodda et al. (2006) and Andrássy (2002, 2005, 2009). Nematodes were identified mostly down to genus level. Coloniser-persister classification of nematode life cycle properties (1-5) were obtained from Bongers (1990, 1999). Nematode feeding types classification was established according to Yeates et al. (1993). Structure index and Enrichment index were calculated according to Ferris et al. (2001) and Ferris & Bongers (2009) in order to obtain the maturity degree of nematode community composition in the ecosystem. Nematode Indicator Joint Analysis calculation system (Sieriebriennikov et al., 2014) was used to analyze food web structure, feeding type diagnostics and MI family indices. Shannon -Wiener index (Shannon & Weaver, 1949) was used for diversity index.

Results

The total number of identified nematodes have reached up to 855 individuals (number of females: 455; male: 83 and juvenile: 317). They belong to 46 species, 45 genera, 29 families, and 8 orders (Table 2).

Table 2. Nematode taxa collected in this study from Korugöl Lake, Düzce, Türkiye

Class	Order/Suborder	Number of Families	Number of Genera	Number of Specimen
Enoplea	Enoplida	2	3	52
	Mononchida	2	4	55
	Dorylaimida	11	16	293
	Triplonchida	2	2	119
Chromadorea	Monhysterida	1	2	43
	Plectida	5	6	197
	Rhabditina	2	2	15
Rhabditida	Tylenchina	4	10	81
Total	8	29	45	855

Nematodes were found at all sampling sites (480 m a.s.l. approx.). Besides, the total nematode abundance showed great variability among samples. The average number of nematodes per 100 gr of soil from the sampling sites were 10 to 56 individuals (Table 3).

Table 3. Abundance and occurrence rates of nematode genera at Korugöl Lake, Düzce, Türkiye

Genus Name	Family Name	Total Abundance	Relative Abundance (%)	Occurrence (%)	C-P Class	P-P Class	Feeding Type
Aporcelaimellus Heyns, 1965	Aporcelaimidae	135	15.79	86.67	5	0	Predators
Prismatolaimus Micoletzky, 1922	Prismatolaimidae	114	13.33	73.33	3	0	Bacterivores
Plectus Bastian, 1865	Plectidae	103	12.05	86.67	2	0	Bacterivores
Anaplectus Coninck & Schuurmans Stekhoven, 1933	Plectidae	87	10.18	86.67	2	0	Bacterivores
Tripylella Brzeski & Winiszewska-Slipinska, 1993	Tripylidae	51	5.96	36.67	3	0	Predators
Eudorylaimus Andrássy, 1959	Dorylaimidae	46	5.38	63.33	4	0	Predators
Tylencholaimus De Man, 1876	Tylencholaimidae	45	5.26	60.00	4	0	Fungivores
Geomonhystera Andrássy, 1981	Monhysteridae	39	4.56	53.33	2	0	Bacterivores
Clarkus Jairajpuri, 1970	Mononchidae	31	3.63	46.67	4	0	Predators
Coslenchus Siddiqi, 1978	Tylenchidae	29	3.39	33.33	0	2	Herbivores - epidermal/root hair feeders
Malenchus Andrassy, 1968	Tylenchidae	19	2.22	40.00	0	2	Herbivores - epidermal/root hair feeders
Mononchus Bastian, 1865	Mononchidae	18	2.11	33.33	4	0	Predators
Pungentus Thorne & Swanger, 1936	Nordiidae	17	1.99	36.67	4	0	Omnivores
Panagrolaimus Fuchs, 1930	Panagrolaimidae	13	1.52	26.67	1	0	Bacterivores
Nygolaimus Cobb, 1913	Nygolaimidae	12	1.40	16.67	5	0	Predators
Belondira Thorne, 1939	Belondiridae	9	1.05	23.33	0	5	Herbivores - ectoparasites
Filenchus Andrassy, 1954	Tylenchidae	9	1.05	16.67	2	0	Fungivores
Eucephalobus Steiner, 1936	Cephalobidae	8	0.94	23.33	2	0	Bacterivores
Tylencholaimellus Cobb, 1915	Tylencholaimellidae	8	0.94	10.00	4	0	Fungivores
Labronemella Andrássy, 1985	Qudsianematidae	6	0.70	3.33	4	0	Omnivores
Tobrilus De Man, 1879		5	0.58	16.67	3	0	Predators
Cephalobus Bastian, 1865	Cephalobidae	4	0.47	10.00	2	0	Bacterivores
Criconema Hofmanner & Menzel, 1914	Criconematidae	4	0.47	10.00	0	3	Herbivores - ectoparasites
Eumonhystera Andrássy, 1981	Monhysteridae	4	0.47	10.00	2	0	Bacterivores
Laimidorus Siddiqi, 1969	Dorylaimidae	4	0.47	13.33	4	0	Omnivores
Baladorylaimus Andrassy, 2001	Dorylaimidae	3	0.35	3.33	4	0	Predators
Hoplolaimus von Daday, 1905	Hoplolaimidae	3	0.35	6.67	0	3	Herbivores - semi-endoparasites
Metateratocephalus Eroshenko, 1973	Metateratocephalidae	3	0.35	6.67	3	0	Bacterivores
Mylonchulus Cobb, 1916	Mylonchulidae	3	0.35	6.67	4	0	Predators
Prionchulus (Cobb, 1916) Wu & Hoeppli, 1929	Mononchidae	3	0.35	10.00	4	0	Predators

Table 3. Continued

Genus Name	Family Name	Total Abundance	Relative Abundance (%)	Occurrence (%)	C-P Class	P-P Class	Feeding Type
Tylenchus Bastian, 1865	Tylenchidae	3	0.35	6.67	0	2	Herbivores - epidermal/root hair feeders
Anonchus Cobb, 1913	Aphanolaimidae	2	0.23	3.33	3	0	Bacterivores
Aporcelinus (Cobb, 1893) Andrassy, 2009	Aporcelaimidae	2	0.23	6.67	5	0	Omnivores
Dorylaimoides Thorne & Swanger, 1936	Mydonomidae	2	0.23	3.33	4	0	Omnivores
Rhabditis Dujardin, 1845	Rhabditidae	2	0.23	3.33	1	0	Bacterivores
Acrobeles von Linstow, 1877	Cephalobidae	1	0.12	3.33	2	0	Bacterivores
Alaimus de Man, 1880	Alaimidae	1	0.12	3.33	4	0	Bacterivores
Cervidellus Thorne, 1937	Cephalobidae	1	0.12	3.33	2	0	Bacterivores
Chronogaster Cobb, 1913	Chronogastridae	1	0.12	3.33	3	0	Bacterivores
Dorylaimellus Cobb, 1913	Belondiridae	1	0.12	3.33	0	5	Herbivores - ectoparasites
Euteratocephalus Andrassy, 1968	Metateratocephalidae	1	0.12	3.33	3	0	Bacterivores
Lindseyus Ferris & Ferris, 1973	Belondiridae	1	0.12	3.33	5	0	Predators
Mesodorylaimus Andrássy, 1959	Dorylaimidae	1	0.12	3.33	4	0	Omnivores
Paractinolaimus Meyl, 1957	Actinolaimidae	1	0.12	3.33	5	0	Predators
TOTAL		855					

Diversity and community analysis

Shannon-Wiener index was calculated for the30 sampling sites. The average value was 1.95±0.27. Obtained results from Shannon-Wiener index showed higher diversity between ecological characteristics of the sampling sites. The highest biodiversity was found at the five sampling points where a riverbed ecosystem is meeting the lake (2.09±0.35). After that, six samples associated with *F. orientalis* trees were found (2.02±0.30) to be the second most diverse nematode assemblages around the lake. Marshland related samples (13 samples) were found the third most diverse by the mean of Shannon-Wiener index (1.95±0.25). Three samples associated to meadow plants were found to be the fourth most diverse which was (1.94±0.38) followed by the three *Q. petraea*-associated samples (1.87±0.22) as it is the least value according to the terms of Shannon-Wiener index.

The average value of Maturity Index calculation for each sampling sites was 3.25±0.49. Nematode maturity indices (Maturity 2-5 & Sigma Maturity) were classified and found to have high values and showed variability at average of sampling plots (Average value of Sigma MI: 3.20±0.50; Maturity 2-5: 3.30±0.47). The average Enrichment Index value was 16.36±16,36. Overall, evaluated by means of ecological indices and soil maturity, soil characteristics were found at the highest value where habitat was occupied by *F. orientalis* and marshland plants (Table 4).

By the terms of plant parasitic nematodes, there were fifteen soil samples (Sample 2, 4, 6, 7, 8, 12, 17, 18, 19, 21, 22, 26, 28, 29, 30), associated with Marshland, Wildpland meadow, *Quercus petraea* L. trees, Riverbed and *Fagus orientalis* L. trees, dominated by Epidermal/root hair feeders such as Coslenchus, Malenchus and Tylenchus. Three samples (5, 9 and 11), associated with Wildpland meadow, *Quercus petraea* L and Marshland were dominated by ectoparasitic nematodes (Belondira, Criconema and Dorylaimellus). Samples 13 and 14, associated with Marshland, were dominated by semi endoparasitic nematodes (Hoplolaimus) (Figure 4).

Table 4. Values of Maturity, Maturity 2-5, Shannon Wiener, Sigma Maturity, Enrichment and Structure Indices values of all sampling sites in this study

Sample N° / Index name	Maturity	Maturity 2-5	Sigma Maturity	Shannon-Wiener	Enrichment	Structure
1	2.60	2.60	2.60	1.37	0.00	77.14
2	3.54	3.67	3.37	2.17	61.54	96.45
3	3.36	3.36	3.36	1.84	7.69	86.59
4	2.60	3.00	2.19	1.56	66.67	80.95
5	2.98	2.98	3.00	1.95	0.00	79.46
6	3.13	3.13	3.06	2.32	0.00	86.67
7	3.00	3.00	2.87	2.12	0.00	81.68
8	4.13	4.13	4.06	1.70	0.00	97.80
9	2.81	2.81	2.97	1.80	0.00	80.88
10	3.16	3.16	3.16	1.72	0.00	88.30
11	3.18	3.18	3.23	1.90	6.25	81.98
12	3.34	3.34	3.31	2.11	0.00	89.69
13	3.60	3.60	3.56	1.92	0.00	98.00
14	3.57	3.77	3.50	2.14	66.67	95.90
15	3.38	3.42	3.38	1.93	44.44	97.06
16	2.71	2.71	2.71	1.56	8.70	66.40
17	2.94	3.14	2.88	2.53	51.72	82.39
18	3.06	3.06	3.06	2.11	0.00	82.91
19	2.76	2.95	2.64	2.29	58.82	84.44
20	4.00	4.00	3.95	1.62	0.00	94.89
21	2.30	2.40	2.37	1.89	32.00	55.84
22	2.54	2.67	2.59	2.14	36.36	70.83
23	3.79	3.79	3.79	1.87	0.00	94.52
24	4.00	4.00	4.00	1.97	0.00	96.63
25	3.80	3.80	3.80	1.61	0.00	97.42
26	3.33	3.50	3.21	2.51	50.00	91.53
27	3.60	3.60	3.60	2.03	0.00	94.34
28	2.77	2.77	2.68	1.93	0.00	79.28
29	3.55	3.55	3.41	1.84	0.00	95.64
30	4.00	4.00	3.89	1.92	0.00	97.40
Average ± SD	3.25±0.49	3.30±0.47	3.20±0.50	1.95±0.27	16.36±16.36	86.76±10.40

Nematode composition by feeding types

Abundance of nematodes according to their feeding types is showed in Figures 2 & 3 for each soil sample. It is figured out that omnivore nematodes are dominating the community (52.77%) at all sampling sites. They are followed by bacterivorous nematodes (27.27%), predator nematodes (16.35%), fungivores nematodes (2.1%), and plant parasitic nematodes (herbivores) (1.51%). The high number of omnivore and predator nematodes occurrence was unusual compared to similar ecological characteristics. Plant parasitic nematodes were less abundantly present at all sampling zones. The relationship of density of nematodes is strongly related to the body size of nematodes. Omnivorous nematodes are known to be large in body size. The abundance of omnivorous nematodes might be explained as a result of less disturbance and balanced ecosystem around the Korugöl Lake (Traunspurger et al., 2006).

Within the plant-parasitic-nematodes, root hair feeders were found to be the most abundant group by 69.94% (Coslenchus, Malenchus and Tylenchus) followed by ectoparasitic nematodes (22.91%) (Belondira, Criconema and Dorylaimellus). Semi-endoparasitic plant-parasitic nematodes are the third common group with 7.14% (Hoplolaimus). Sedentary and Migratory endoparasites were not found at any sampling sites (Figure 3).

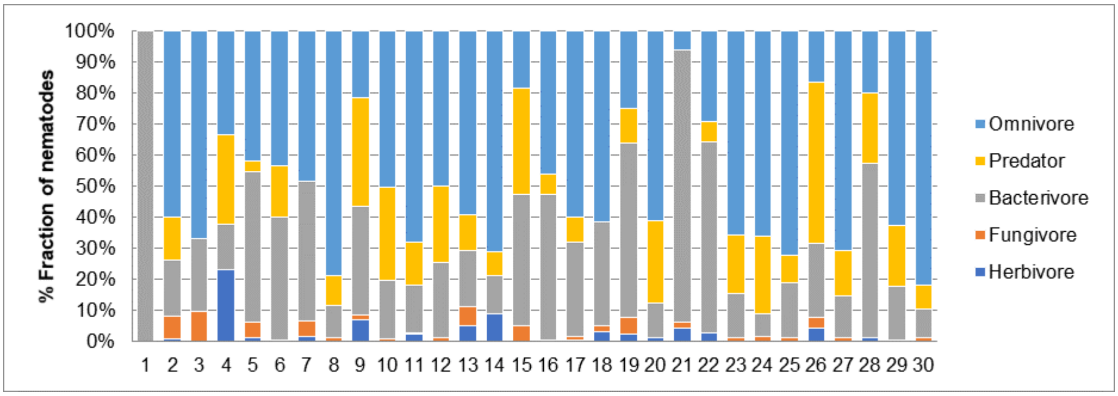

Figure 2. Feeding types and their abundance at the sampling sites.

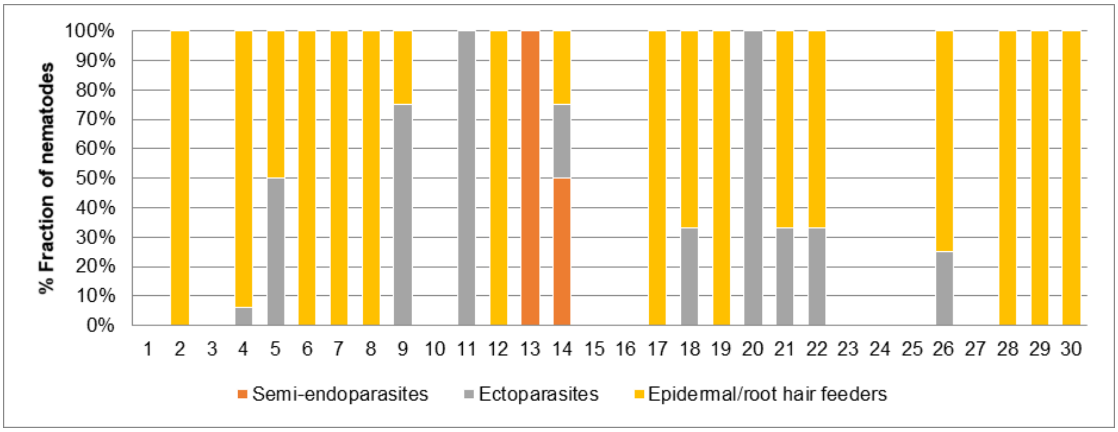

Figure 3. Distribution (%) of feeding types within the plant-parasitic nematodes from Korugöl Lake, Düzce, Türkiye.

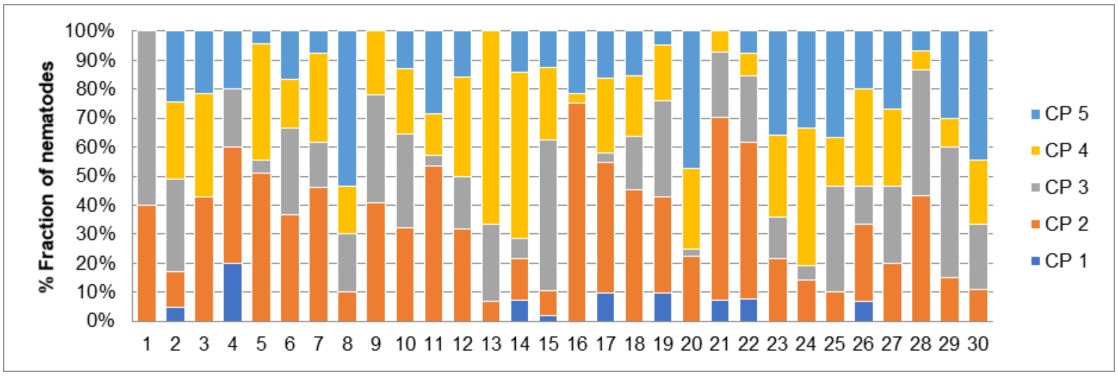

Figure 4. Free-living nematode c-p classification from Korugöl Lake, Düzce, Türkiye.

Community structure of free-living nematode assemblages

A classification within Free-living nematodes were provided from c-p 1 (colonizers, enrichment opportunists) to c-p 5 (persisters with long life cycle) based on their life cycles. The free-living nematode community at Lake Korugöl, did not show recognizable patterns but high average values of c-p classification. Colonizer nematodes with short life cycle (c-p 2 value) were found to be dominating the nematode assemblages by consisting of 32.23% of the sampling sites. On the other hand, enrichment opportunist nematodes with c-p value 4 were the second by 23.75% domination. 22.26% of the free living nematodes were appeared to be c-p 3 class, 19.26% of the community is at c-p 5 and the lowest group was detected 2.49% within c-p 1 nematodes (Figure 4).

Discussion

Faunistic

The rising interest of learning about nematode community behavior in soil food web allows us to monitor their role in the ecosystem. In Türkiye, the discovery of soil nematodes and especially diversity of free-living nematodes are still receiving very little interest from scientific community. The aim of this study is to determine soil nematode fauna in the West Blacksea region, Düzce Province with a holistic approach and to identify vermiform terrestrial nematodes up to genus level. As mentioned, (see results), ten taxa, namely, Aporcelinus ((Cobb) Andrassy), Baladorylaimus (Andrassy), Dorylaimoides (Thorne & Swanger), Euteratocephalus (Andrassy), Labronemella (Andrássy), Laimydorus (Siddiqi), Lindseyus (Ferris & Ferris), Metateratocephalus (Eroshenko), Paractinolaimus (Meyl) and Tripylella (Brzeski & Winiszewska-Slipinska) genera are first reports to the Türkiye nematofauna. Our contribution therefore not only significantly expand on what is known about nematode species in Türkiye, but also highlightsthe available knowledge regarding the geographic records in the West Black Sea Region of Türkiye.

Nematodes are biological indicators, and provide valuable information about soil health. The study is conducted in a natural park habitat where mostly rare animals and endemic plants are living. Therefore, it can be counted as a fragile ecosystem that any chemical contamination or disruption in soil will affect biodiversity drastically. On the other hand, lake ecosystems are rarely discovered in terms of terrestrial nematofauna in Türkiye. Unfortunately, there is no study to our knowledge, related to free-living nematode biodiversity in the West Black Sea region. The studies so far have investigated mostly the soil nematode communities from agricultural lands but not from natural habitats (Yildiz et al., 2021; Imren, 2015). These taxa are worldwide distributed; however, it is clear that most of the free-living nematode species are rarely known in Türkiye. Regarding the total diversity, this study makes a valuable contribution to faunistic studies of terrestrial nematode species.

Species distribution and nematode abundance

The distribution of species around a lake ecosystem was investigated with an integrative approach to the species relative abundance and occurrence patterns. This approach allowed us to detect species from a widespread group of nematodes that are occurring within the very abundant or abundant and very frequently or frequently around Lake Korugöl. These nematodes are listed as follows: *Aporcelaimellus* (Heyns), *Prismatolaimus* (Micoletzky), *Plectus* (Bastian), *Anaplectus* (Coninck & Schuurmans Stekhoven), *Tripylella* (Brzeski & Winiszewska-Slipinska). On the other hand, 19 genera are occurring scarce or very scarce and less constant or very less constant such as *Baladorylaimus* (Andrassy), *Hoplolaimus* (von Daday), *Metateratocephalus* (Eroshenko), *Mylonchulus* (Cobb), *Prionchulus* ((Cobb) Wu & Hoeppli), *Tylenchus* (Bastian), *Anonchus* (Cobb), *Aporcelinus* ((Cobb) Andrassy), *Dorylaimoides* (Thorne & Swanger), *Rhabditis* (Dujardin), *Acrobeles* (von Linstow), *Alaimus* (de Man), *Cervidellus* (Thorne), *Chronogaster* (Cobb), *Dorylaimellus* (Cobb), *Euteratocephalus* (Andrassy), *Lindseyus* (Ferris & Ferris), *Mesodorylaimus* (Andrássy) and *Paractinolaimus* (Meyl). When we look at the genera profile of nematodes, we found mostly omnivorous nematodes which prefer relatively undisturbed areas such as Forest - Boreal forests, tundra graslands, subtropical/tropical high altitude grasslands and temperate grasslands.

According to Yeates & Bird, 1994; Stamou et al., 2005, it is suggested that a nematode survey during the late summer season is optimal for the environmental variables in terms of soil humidity, high metabolic activity and temperature of soil. In our survey, which agrees with this contribution, the total nematode abundance was found minimum 10 to maximum 56 individuals per 100 gr of soil.

The nematode community

In general, nematode trophic groups did not show a detectable pattern. Apparently, omnivorous nematodes were found the most common group at all samples. Mostly the diverse group in terms of species richness was within the order Dorylaimida. Predatory nematodes as the most persistent group, were found at all sampling sites. The persistency of this group stems from their biology which also refers to occurrence at mature and fertile soils and having a long-life cycle. The total percentage of omnivorous and predator nematodes has reached to 69% of all nematode taxa which shows clues of soil maturity and an undisturbed ecosystem in Lake Korugöl. On the other hand, the abundance of bacterivorous, fungivores and plant parasitic nematodes had a little variation between the sampling sites. This shows clues about how dynamic can be a lake ecosystem as it has a unique cycle within itself. Maturity indices had similar values at all sites and did not differ significantly between sites. According to Schnürer et al. (1986) and Yeates (2007), the most important factors affecting the nematode community are that the environmental effect of regional and seasonal changes such as soil organic matter, texture, structure, chemical differences, and moisture along with environmental disturbances caused by humans. Some studies that are conducted in lake ecosystems shows a tendency of several patterns in respect with the seasonal fluctuations in the population dynamics of nematodes which have a short life cycle. Some authors noted significant annual density fluctuations (Fisher, 1968; Tudorancea & Zullini, 1989), whereas others found no such distinct changes of nematode abundance (Strayer, 1985). Previously similar nematode abundance and occurrence patterns were detected in high altitude nematode faunal survey in Mount Ağrı according to Cakmak et al. (2019) and Zhang et al. (2012). Overall, the ecological indices and impact of environmental changes by terms of nematode community did not show any consistent pattern at the surrounding soils of Lake Korugöl. It is recommended to monitor regularly the nematode community and the soil properties for further explanation of this matter.

This statement definitely once again discloses the critical position of terrestrial nematodes in the soil food web. The range of high tolerance may occur at different climatic conditions such as highly polluted habitats to mature soils which create habitat for tolerant species and sensitive species. Nematodes have low mobility and rapid responses to disturbance and enrichment changes. Life-cycle properties of nematodes ranging from 6 days to over 2 years provides wide opportunities, perspectives and practical tools to scientists not only for understanding environmental changes but also conservation of soil biodiversity.

Finally, this contribution indicates a study of the fauna of terrestrial nematodes at Lake Korugöl might give beneficial information on conservation of terrestrial nematode fauna of Türkiye and show how nematodes can be useful for soil monitoring as a rarely known approach.

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References

Andrássy, I., 2002. "Free-Living Nematodes from The Fertő-Hanság National Park, Hungary, 21-97". In: The Fauna of the Fertő-Hanság National Park, Budapest, Hungary (Eds. S. Mahunka), Hungarian Natural History Museum and Systematic Zoology Research Group of the Hungarian Academy of Science Budapest, Hungary, 829 pp.

Andrássy, I., 2005. Free-Living Nematodes of Hungary, I (Nematoda Errantia). Hungarian Natural History Museum and Systematic Zoology Research Group of the Hungarian Academy of Science, Budapest, Hungary, 518 pp.

Andrássy, I., 2009. Free-Living Nematodes of Hungary (Nematoda Errantia), Vol. III. Hungary, Hungarian Natural History Museum, 608 pp.

Baermann, G., 1917. Eine einfache methode zur auffindung von Ancylostomum (Nematoden) larven in Erdproben. Geneeskd Tijdschr Ned Indie, 57: 131-137 (in German).

Bongers, T. & H. Ferris, 1999. Nematode community structure as a bioindicator in environmental monitoring. Trends in Ecology & Evolution, 14 (6): 224-228.

Bongers, T., 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. Oecologia, 83 (1):14-19.

Bongers, T., H. van der Meulen & G. Korthals, 1997. Inverse relationship between the nematode maturity index and plant parasite index under enriched nutrient conditions. Applied Soil Ecology, 6 (2): 195-199.

De Ley, P. & M. Blaxter, 2005. A new system for Nematoda: combining morphological characters with molecular trees, and translating clades into ranks and taxa. Nematology Monographs & Perspectives, 2 (1): 633-653.

Ferris, H. & T. Bongers, 2009. “Indices for Analysis of Nematode Assemblages, 124-145”. In: Nematodes as Environmental Bioindicators (Eds. M. Wilson & T. Kakouli-Duarte). CABI, Wallingford, USA, 352 pp.

Ferris, H., T. Bongers & R. G. de Goede, 2001. A framework for soil food web diagnostics: extension of the nematode faunal analysis concept. Applied Soil Ecology,18 (1): 13-29.

Fisher, K.D., 1968. Population patterns of nematodes in Lake Champlain. Nematologica 14 (1): 1-19.

Hodda, M., A. Ocana & W. Traunspurger, 2006. “Nematodes from Fresh Water Habitats, 179-211”. In: Freshwater Nematodes: Ecology and Taxonomy (Eds. E. Abebe, I. Andrássy & W. Traunspurger). CABI, Wallingford, USA, 752 pp.

Hugot, J. P., P. Baujard & S. Morand, 2001. Biodiversity in helminths and nematodes as a field of study: an overview. Nematology, 3 (3): 199-208.

Imren, M., Ş. Yıldız, E. Kasapoğlu, H. Toktay, H. Kütük & A. A. Dababat, 2015. “The Plant-Parasitic Nematodes Associated with Cereal Crops in Bolu, Turkey, 131-140”. Proceedings of the Nematodes of Small Grain Cereals: Current Status and Research, Fifth International Cereal Nematode Initiative Workshop (12-15 September 2015, Ankara, Turkey), (Eds. A. A. Dababat, H. Muminjanov & R. W. Smiley), Food and Agriculture Organization of United Nations, Ankara, Turkey, 384 pp.

Keleş, Z., 2006. Düzce İli Mikrobölgesel Zemin Parametrelerinin Haritalanması. Sakarya University (Unpublished) Doctoral Dissertation, Sakarya, Turkey, 87 pp (in Turkish with abstract in English).

Lee, D. L., 2002. The Biology of Nematodes. CRC Press, 338 pp.

Schnürer, J., M. Clarholm, S. Boström & T. Rosswall, 1986. Effects of moisture on soil microorganisms and nematodes: a field experiment. Microbial Ecology, 12 (2): 217-230.

Shannon, C. E. & W. Weaver, 1949. The mathematical theory of communication. University of Illinois Press, Urbana, 117 pp.

Sieriebriennikov, B., H. Ferris & R. G. M. de Goede, 2014. NINJA: An automated calculation system for nematode-based biological monitoring. European Journal of Soil Biology, 61 (1): 90-93.

Stamou, G. P., E. M. Papatheodorou, A. Hovardas & M. D. Argyropoulou, 2005. Some structural and functional characteristics of a soil nematode community from a Mediterranean grassland. Belgian Journal of Zoology, 135 (2): 253-259.

Strayer, D., 1985. The benthic micrometazoans of Mirror Lake, New Hampshire. Archiv für Hydrobiologie, 3 (Suppl. 72): 287-426.

Traunspurger, W. & Bergtold, M. 2006. “Patterns in the Size Structure of Freshwater Nematode Communities: The Cases of Lakes Königssee and Brunnsee, Germany, 132-143”. In: Freshwater Nematodes: Ecology and Taxonomy. Wallingford UK: CABI Publishing, 736 pp.

Tudorancea, C. & A. Zullini, 1989. Associations and distribution of benthic nematodes in the Ethiopian Rift Valley lakes. Hydrobiologia, 179 (1): 81-96.

Turkish Ministry of Culture and Tourism, 2021. Kurugöl tabiat parkı. (Web page: https://www.kulturportali.gov.tr/turkiye/duzce/TurizmAktiviteleri/kurugol) (Date accessed: 06.07.2023) (in Turkish).

Wilson, M. J. & T. Khakouli-Duarte, 2009. Nematodes as Environmental Indicators. CABI, USA, 326 pp.

Yeates, G. W. & A. F. Bird, 1994. Some observations on the influence of agricultural practices on the nematode faunae of some South Australian soils. Fundamental & Applied Nematology, 17 (2): 133-145.

Yeates, G. W., T. Bongers, R. G. M. De Goede, D. W. Freckman & S. S. Georgieva, 1993. Feeding habits in soil nematode families and genera-an outline for soil ecologists. Journal of Nematology, 25 (3): 315-331.

Yeates, G., 2007. Abundance, diversity, and resilience of nematode assemblages in forest soils. Canadian Journal of Forest Research, 37 (2): 216-225.

Yıldız, Ş., G. Emine, Ö. Göksel & M. İmren, 2021. Investigations on soil nematode diversity in three contrasting habitat types in Bolu, Turkey. Turkish Journal of Entomology, 45 (4): 451-461.

Yoder, M., I. T. De Ley, I. Wm King, M. Mundo-Ocampo, J. Mann, M. Blaxter, L. Poiras & P. De Ley, 2006. DESS: a versatile solution for preserving morphology and extractable DNA of nematodes. Nematology, 8 (3): 367-376.

Zhang, M., W. J. Liang & X. K. Zhang, 2012. Soil nematode abundance and diversity in different forest types at Changbai Mountain, China. Zoological Studies, 51 (5): 619-626.