PATTERNS OF RELATIONSHIPS BETWEEN NEMATODE COMMUNITIES AND VEGETATION FROM SOME SALT-AFFECTED AREAS IN TRANSYLVANIA (ROMANIA)

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Summary. Plant and nematode communities from two inland salt-affected habitats located in the Transylvania province (Romania) were analyzed by detrended correspondence analysis (DCA). Vegetation samples were clearly separated into three clusters, each cluster including one distinct plant association, while nematode communities were less distinctly separated into groups. Differences in halotolerance were noted for both plant and nematode species. Extreme salt-affected habitats characterized by obligate halophilic phytocoenoses were dominated by opportunistic nematodes and were differentiated from other habitats by the lowest MI values. The most halotolerant species, *Laimydorus parabastiani,* could be used as key bioindicator for salt-affected areas. A characterization of plant and nematode communities is provided.

Soil nematodes possess several attributes that make them useful ecological indicators (Freckman, 1988). These organisms are represented at most trophic levels of the soil food web and they are thought to be intimately connected to, and may reflect, fundamental ecological processes, such as decomposition, mineralization and nutrient cycling in soils (De Goede and Bongers, 1994). Nematode community structure, specific distribution and activity are affected by plant species composition, soil physical and chemical characteristics and climate (Freckman, 1982).

The analysis of nematode community structure is frequently used as a tool in the ecological evaluation of soils, and in terrestrial habitat classification, and it is also applied to monitor effects of environmental changes. In some countries such as the Netherlands and the U.S.A. soil assessment, protection and monitoring systems became national priorities (Bongers, 1990; Neher *et al.*, 1995). Several studies have shown that for a series of terrestrial habitats nematode communities could be defined and related to specific soil characteristics and plant associations (De Goede, 1993; De Goede and Bongers, 1994; Popovici and Ciobanu, 2000).

Inland salt-affected areas represent particular types of habitats with a limited distribution in Transylvania. They are related to the presence of salt deposits close to the surface, dating from the Tertiary Period (Miocene Epoch) (Mészáros, 1997). The salt-affected areas are characterized by specific soils (halomorphic soils) with a high content of soluble salts, and by plants able to withstand the osmotic stress (halophilic plants). The most frequent soluble salts found are sodium, magnesium and calcium sulphates and chlorides, and sometimes sodium and potassium (bi)carbonates (Florea *et al.*, 1968). Physical and chemical soil properties act directly on the vegetation and soil fauna, being a strong selection factor in such areas. As a consequence, the organisms react by developing different degrees of halotolerance.

Preliminary ecological data on the nematode fauna from three salt-affected areas located in Transylvania (Cojocna, Turda and Ocna Sibiului) were given by Ciobanu and Popovici (1998) and seven species of Dorylaimoidea (one of them new for science) were described and illustrated by Ciobanu *et al.* (2004).

So far, there are no studies on the relationships between nematode species and the composition of plant communities from salt-affected areas in Romania.

In this paper we hypothesized that: a) both plant and nematode communities could be grouped into clusters, according to the salt tolerance gradient; and b) some halophilic nematode species could be used as bioindicators for salt-affected areas.

MATERIALS AND METHODS

Six sites from two inland salt-affected areas located in the Transylvania province, were investigated (Table I). Nematode specimens were collected by the first author between 1996 and 2000. Nematodes were extracted using the centrifugation method of De Grisse (1969), killed and preserved in a 4% formaldehyde solution heated at 65 °C, and mounted in anhydrous glycerin (Seinhorst, 1959). Nematode identification was carried out by using the following main papers: Andrássy (1984, 1986, 1988, 1990, 1991), Bongers (1988), Brzeski (1991), Fortuner *et al.* (1987), Goodey (1963), Goseco *et al.* (1975), Loof (1969, 1996), Loof and De Grisse (1989), Peña-Santiago and Coomans (1996), Peña-Santi-

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ago and Peralta (1999), Raski and Geraert (1986), Sher (1965), Siddiqi (1964, 1969, 1986), Siddiqi and Khan (1964), Thorne (1939), Thorne and Malek (1968).

Fifteen vegetation relevees (five for each of the three types of halophilic phytocoenoses) were carried out in late summer 2000 for the salt-affected area located at Cojocna, at the same locations where soil samples had been taken. Six vegetation relevees (two for each of the three types of halophilic phytocoenoses) were compiled from Todor (1948), who carried out the observations at Băile Turda salt-affected area, situated in the vicinity of the site sampled for nematodes. The grouping of the halophilic phytocoenoses in types and their syntaxonomic classification are according to Borhidi (1996), Coldea (2000), Mucina (1993) and Soó (1980).

RESULTS

Data analysis. Both vegetation and nematode data were analyzed by detrended correspondence analysis (DCA) using the computer package CANOCO 4 (Ter Braak and Smilauer, 1998). DCA was used because the gradient length for the vegetation data set was > 3 S.D., indicating unimodal and not linear response (Ter Braak and Smilauer, 1998). The two analyses were carried out separately and were compared in a qualitative way since vegetation and nematodes were not sampled exactly in the same site in the salt-affected area located near Turda.

A biplot of the vegetation data is given in Fig. 1 (A, B), while a biplot of the nematode data is shown in Fig. 2 (A, B).

The vegetation samples shown in Fig. 1A are clearly grouped into three clusters, each cluster including a distinct plant association, as follows: ass. Salicornietum prostratae (indicated in the plot as SalCoj 1-5 and SalTur 6,7) is obligate halophilic; ass. Puccinelietum peisonis (indicated in the plot as PucCoj 1-5 and PucTur 6,7) is preferant halophilic; and ass. Artemisio-Festucetum pseudovinae (indicated in the plot as ArtCoj 1-5 and ArtTur 6,7) is halotolerant (Soó, 1980; Mucina, 1993; Borhidi, 1996; Coldea, 2000). The horizontal axis in Fig. 1A therefore represents a gradient, from extreme (high) salt influence (at the left side of the figure) to low influence (at the right side). The vertical axis distinctly separates two clusters of the same halotolerant plant association (Artemisio-Festucetum pseudovinae) according to the geographical location of the sites: the two relevees from Turda plotted at the top (indicated as ArtTur 6,7), and the five relevees from Cojocna (indicated as ArtCoj 1-5) at the bottom. This separation is less distinct (but still present) for the preferant halophilic plant association Puccinelietum peisonis, and absent for the obligate halophilic plant association Salicornietum prostratae.

The differences in salt tolerance can also be seen from the species plot (Fig.1B), where the extreme halophilic species appear at the left side (e.g. *Salicornia europaea* ssp. *prostata, Suaeda maritima* ssp. *pannonica, Spergularia marginata*) while most of the species at the right side are species of alkaline soils that are salt-tolerant (e.g. *Gypsophila muralis, Aster linosyris*, etc.).

The nematode communities are less distinctly separated into groups, but the salt tolerance gradient is still clearly present (Fig. 2A). Nematode communities collected from soils where plant association Artemisio-Festucetum pseudovinae was present (indicated as ArtCoj and ArtTur) are at the extreme right of the figure. However, nematode communities collected from the soils covered by plants belonging to ass. Salicornietum prostratae and ass. Puccinelietum peisonis (SalTur, PucTur, SalCoj and PucCoj) are not separated. Instead, the nematode communities collected from soils covered by obligate and preferant halophilic plant species are grouped together according to the two locations, Cojocna and Turda, respectively. Therefore, the first (horizontal) axis represents both differences in salt tolerance and in location. The second (vertical) axis mainly separated the sample ArtCoj from all other samples.

The gradient in salt influence represented by the first axis is also seen in the species plots (Fig. 2B). The most salt-tolerant nematode species *Laimydorus parabastiani* appears at the extreme left side in the figure and can be considered a good indicator for the halomorphic soils (and implicitly for the salt-affected habitats), while species at the right are mostly ubiquitous ones. *Achromadora ruricola, Geomonhystera villosa, Eumonhystera vulgaris* which are grouped at the extreme left side in the figure 2B, are cosmopolitan species that have a high grade of ecological tolerance and can hence be found in any kind of environment.

The species at the upper right in Figure 2B were more or less restricted to the somewhat unique sample ArtCoj.

Characterisation of plant communities. The plant association Salicornietum prostratae Soó (1947) 1964 (Table II) includes obligate halophilic phytocoenoses built up by *Salicornia europaea* ssp. *prostrata*, which occurs in small patches in the lower parts of depressions. Soil is heavily salt-affected; NaCl soil content increases with depth from 2.1-2.3% at 0.5 cm to 12.1% at 50 cm. Soil humidity is high from spring to early summer (26-42.4%), but towards the end of summer it decreases below 20% and soil will be covered by a heavily cracked salt-rich crust. *Suaeda maritima* ssp. *pannonica, Atriplex hastata, Spergularia marina, Aster tripolium, Puccinellia peisonis* are other halophilic species that occur in this association, but all have low coverages, below 5%, as compared to *Salicornia europaea* ssp. *prostrata*, which has an average coverage of about 50-60% (Todor, 1948; Coldea, 2000; Pop., 2002).

The plant association Puccinellietum peisonis Franz *et al.* 1937 (Table II) includes preferant halophilic phytocoenoses built up by *Puccinellia peisonis* (Syn. *Puccinellia intermedia* Schur.), which inhabits the areas in which seasonal fluctuations of soil humidity occur. The

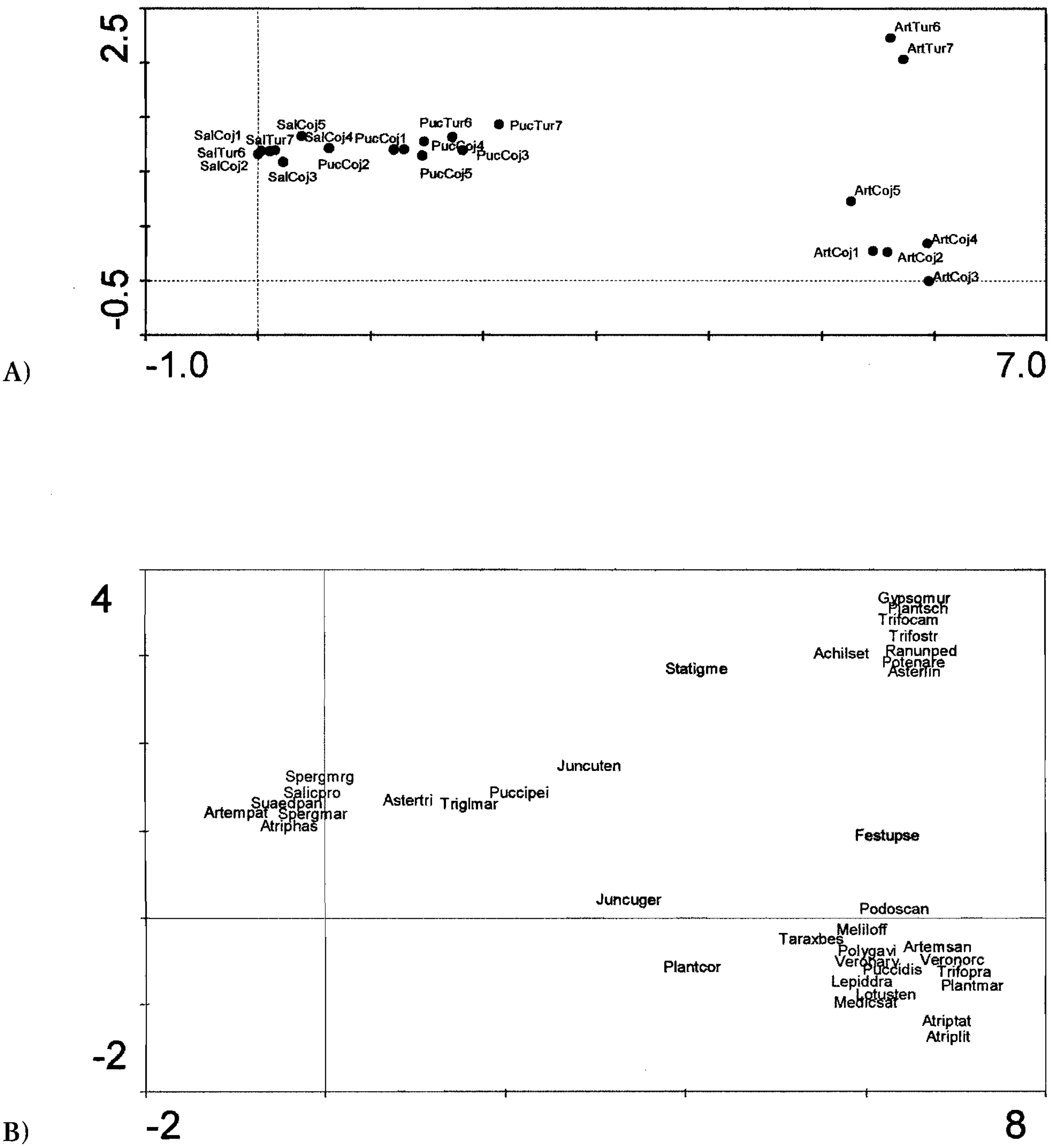

Fig. 1. Biplot (A: samples, B: species) of vegetation data using DCA (detrending by segments). Eigenvalues: 0.928 and 0.419 for the first (horizontal) and second (vertical) axis, sum of all eigenvalues: 3.157, i.e. the axes explain 29% and 13%, respectively, of the total variance in the species data. Number of species: 37, number of samples: 21. Species abundances were ln(X+1) transformed. Explanation of sample codes in Table I (numbers indicate vegetation relevees at the same site). Explanation of species codes: Achilset = *Achillea setacea*; Artempat = *Artemisia santonicum* ssp. *patens*; Artemsan = *Artemisia santonicum* ssp. *santonicum*; Asterlin = *Aster linosyris*; Astertri = *Aster tripolium*; Atriphas = *Atriplex hastata*; Atriplit = *Atriplex littoralis*; Atriptat = *Atriplex tatarica*; Carexdis = *Carex distans*; Festupse = *Festuca pseudovina*; Gypsomur = *Gypsophila muralis*; Juncuger = *Juncus gerardi*; Juncuten = *Juncus tennes*; Lepiddra = *Lepidium draba*; Lotusten = *Lotus tenuis*; Medicsat = *Medicago sativa*; Meliloff = *Melilotus officinalis*; Plantcor = *Plantago cornuti*; Plantmar = *Plantago maritima*; Plantsch = *Plantago schwarzenbergiana*; Podoscan = *Podospermum canum*; Polygavi = *Polygonum aviculare*; Potenare = *Potentilla arenaria*; Puccidis = *Puccinellia distans*; Puccipei = *Puccinellia peisonis*; Ranunped = *Ranunculus pedatus*; Salicpro = *Salicornia europaea ssp. prostrata*; Spergmrg = *Spergularia marginata*; Spergmar = *Spergularia marina*; Statigme = *Statice gmelini*; Suaedpan = *Suaeda maritima* ssp. *pannonica*; Taraxbes = *Taraxacum bessarabicum*; Trifocam = *Trifolium campestre*; Trifopra = *Trifolium pratense*; Trifostr = *Trifolium striatum*; Triglmar = *Triglochin maritima*; Veronarv = *Veronica arvensis*; Veronorc = *Veronica orchidea*.

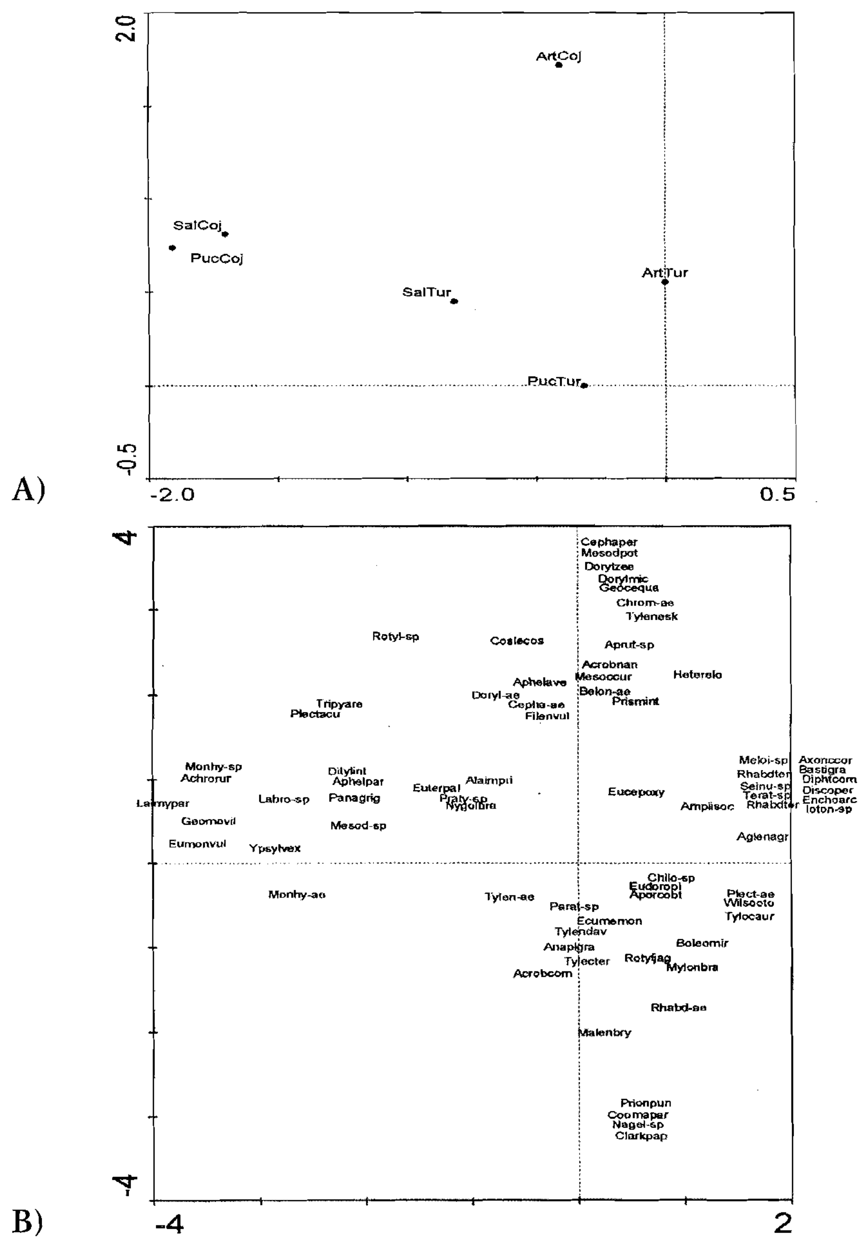

Fig. 2. Biplot (A: samples, B: species) of nematode data using DCA (detrending by segments). Eigenvalues: 0.359 and 0.155 for the first (horizontal) and second (vertical) axis, sum of all eigenvalues: 0.986, i.e. the axes explain 36% and 16%, respectively, of the total variance in the species data. Number of species: 73, number of samples: 6. Species abundances were ln(X+1) transformed. Explanation of species codes: Achrorur = *Achromadora ruricola*; Acrobcom = *Acrobeles complexus*; Acrobnan = *Acrobeloides nanus*; Aglenagr = *Aglenchus agricola*; Alaimpri = *Alaimus primitivus*; Amplisoc = *Amplimerlinius socialis*; Anaplgra = *Anaplectus granulosus*; Aphelpar = *Aphelenchoides parietinus*; Aphelave = *Aphelenchus avenae*; Aporcobt = *Aporcelaimellus obtusicaudatus*; Aprut-sp = *Aprutides* sp.; Axonccor = *Axonchium coronatum*; Bastigra = *Bastiania gracilis*; Belon-ae = Belonolaimidae; Boleomir = *Boleodorus mirus*; Cepha-ae = Cephalobidae; Cephaper = *Cephalobus persegnis*; Chilo-sp = *Chiloplacus* sp.; Chrom-ae = Chromadoridae; Clarkpap = *Clarkus papillatus*; Coomapar = *Coomansus parvus*; Coslecos = *Coslenchus costatus*; Diphtcom = *Diphtherophora communis*; Discoper = *Discolaimus perplexans*; Ditylint = *Ditylenchus intermedius*; Doryl-ae = Dorylaimidae; Dorylmic = *Dorylaimoides micoletzkyi*; Dorylzee = *Doryllium zeelandicum*; Ecumemon = *Ecumenicus monohystera*; Enchoarc = *Enchodelus arcuatus*; Eucepoxy = *Eucephalobus oxyuroides*; Eudoropi = *Eudorylaimus opistohystera*; Eumonvul = *Eumonhystera vulgaris*; Euterpal = *Euteratocephalus palustris*; Filenvul = *Filenchus vulgaris*; Geocequa = *Geocenamus quadrifer*; Geomovil = *Geomonhystera villosa*; Heterelo = *Heterocephalobus elongatus*; Ioton-sp = *Iotonchus* sp.; Labro-sp = *Labronema* sp.; Laimypar = *Laimydorus parabastiani*; Malenbry = *Malenchus bryophilus*; Meloi-sp = *Meloidogyne* sp.; Mesoccur = *Mesocriconema curvatum*; Mesodpot = *Mesodorylaimus potus*; Mesod-sp = *Mesodorylaimus* sp.; Monhy-sp = *Monhystera* sp.; Monhy-ae = Monhysteridae; Mylonbra = *Mylonchulus brachyuris*; Nagel-sp = *Nagelus* sp.; Nygolbra = *Nygolaimus brachyuris*; Panagrig = *Panagrolaimus rigidus*; Parat-sp = *Paratylenchus* sp.; Plect-ae = Plectidae; Plectacu = *Plectus acuminatus*; Praty-sp = *Pratylenchus* sp.; Prionpun = *Prionchulus punctatus*; Prismint = *Prismatolaimus intermedius*; Rhabd-ae = Rhabditidae; Rhabdter = *Rhabditis terricola*; Rhabdter = *Rhabdolaimus terrestris*; Rotyljag = *Rotylenchus jagatpurensis*; Rotyl-sp = *Rotylenchus* sp.; Seinu-sp = *Seinura* sp.; Terat-sp = *Teratocephalus* sp.; Tripyare = *Tripylina arenicola*; Tylecter = *Tylencholaimus teres*; Tylen-ae = Tylenchidae; Tylenesk = *Tylencholaimellus eskei*; Tylendav = *Tylenchus davainei*; Tylocaur = *Tylocephalus auriculatus*; Wilsooto = *Wilsonema otophorum*; Ypsylvex = *Ypsylonellus vexilliger*.

presence of the species *Aster tripolium* and *Triglochin maritima* is indicative of this fluctuation of soil humidity-salinity.

The plant association Artemisio-Festucetum pseudovinae Soó (1933) 1945 (Table II) includes tolerant halophilic phytocoenoses built up by *Artemisia santonicum* ssp. *santonicum* and *Festuca pseudovina*, which populate higher areas with lower soil salt content and humidity. The association includes halotolerant species, some of which, such as *Trifolium pratense, T. repens, Melilotus officinalis* and *Plantago media*, are even indifferent to salinity. These grasslands have an economic value because of their specific composition and are sometimes used for grazing (Todor, 1948; Coldea, 2000; Popovici, 2002).

Table I. Site locations, vegetation and soil types of the nematological survey in Romania.

Site no.	Site code	Locality	Altitude (m)	Geographical position	Plant association	Soil type
1	SalTur	Turda	350	46°34'N-23°48'E	Salicornietum prostratae	Halomorphic soil
2	PucTur	Turda	350	46°34'N-23°48'E	Puccinellietum peisonis	Halomorphic soil
3	ArtTur	Turda	350	46°34'N-23°48'E	Artemisio-Festucetum pseudovinae	Halomorphic soil
4	SalCoj	Cojocna	335	46°45'N-23°50'E	Salicornietum prostratae	Halomorphic soil
5	PucCoj	Cojocna	335	46°45'N-23°50'E	Puccinellietum peisonis	Halomorphic soil
6	ArtCoj	Cojocna	335	46°45'N-23°50'E	Artemisio-Festucetum pseudovinae	Halomorphic soil

Table II. Structure[1] of halophilic plant association from some salt-affected areas located in Transylvania.

Type of phytocoenoses:	Obligate halophilic								Preferant halophilic								Tolerant halophilic						
Plant association:	Salicornietum prostratae								Puccinellietum peisonis								Artemisio-Festucetum pseudovinae						
Nr. of relevee[2]:	1	2	3	4	5	6	7		1	2	3	4	5	6	7		1	2	3	4	5	6	7
Salicornia e. prostrata	4	3	3	4	3	4	2	*Puccinellia peisonis*	4	3	5	4	4	5	4	*Artemisia s. santonicum*	2	3	4	3	.	1	+
Suaeda m. pannonica	1	1	+	.	+	+	+	*Juncus tennes*	.	.	.	.	.	.	+	*Achillea setacea*	.	.	.	.	+	2	.
Puccinellia peisonis	1	+	+	1	+	+	+	*J. gerardi*	.	.	.	.	+	.	+	*Festuca pseudovina*	4	3	3	2	4	4	4
Juncus gerardi	.	.	+	+	.	.	.	*Triglochin maritima*	1	1	+	1	+	.	.	*Juncus gerardi*	+	.	.	.	+	.	.
Atriplex hastata	.	+	+	.	.	.	.	*Salicornia e. prostrata*	.	+	.	.	.	.	.	*Puccinellia peisonis*	.	.	.	.	+		
Spergularia marginata	+	.	.	.	+	.	.	*Spergularia marina*	+	.	.	.	.	.	.	*Plantago cornuti*	+	+	.	.	.	.	.
Spergularia marina	+	+	+	+	.	.	.	*Plantago cornuti*	.	.	+	.	.	.	.	*Statice gmelini*	1	1	+	+	+	2	1
Statice gmelini	.	.	.	+	+	.	.	*Statice gmelini*	.	.	+	+	.	+	1	*Aster linosyris*	.	.	.	1	.	4	4
Artemisia s. patens	+	+	.	.	.	.	.	*Aster tripolium*	3	3	+	2	2	+	.	*Podospermum canum*	1	+	.	+	+	.	+
Aster tripolium	+	+	.	.	+	.	.									*Taraxacum bessarabicum*	+	+	.	.	+	.	.
																Plantago maritima	.	.	.	+	.	.	.
																Veronica orchidea	.	.	.	+	.	.	.
																Lotus tenuis	+	+	.	+	.	.	.
																Atriplex tatarica	.	.	+	.	.	.	.
																Puccinellia distans	+	+	+	+	+	.	.
																Medicago sativa	+	+	.	.	.	.	.
																Melilotus officinalis	.	.	.	+	+	.	.
																Trifolium pratense	.	.	.	+	.	.	.
																Atriplex littoralis	.	.	1	.	.	.	.
																Polygonum aviculare	.	.	+	.	+	.	.
																Lepidium draba	+	.	.	.	.	.	.
																Veronica arvensis	1	+	.	.	.	.	.
																Ranunculus pedatus	.	.	.	.	.	+	.
																Trifolium striatum	.	.	.	.	.	+	+
																Potentilla arenaria	.	.	.	.	.	+	+
																Trifolium campestre	.	.	.	.	.	+	+
																Plantago schwarzenbergiana	.	.	.	.	.	+	
																Gypsophila muralis	.	.	.	.	.	+	+
																Podospermum canum	.	.	.	.	.		+

[1] Braun-Blanquet (1932) scale for cover percentages: + = <1%; 1 = 1-5%; 2 = 5-25%; 3 = 25-50%; 4 = 50-75%; 5 = 75-100% = absent (but not excluded)

[2] Relevees 1-5 from Cojocna salt-affected area; relevees 6-7 from salt-affected area at Băile Turda (Todor, 1948)

Table III. Structure of nematode communities (% relative abundance) from some salt-affected areas from Transylvania.

Cp value[1]	Feeding type[2]	Taxon	Site					
			SalTur	PucTur	ArtTur	SalCoj	PucCoj	ArtCoj
3	AF	*Achromadora ruricola*				0.26	0.09	
2	B	*Acrobeles complexus*	0.10	0.32	0.20		0.09	
2	B	*Acrobeloides nanus*	0.10	0.06	0.10			0.27
2	PF	*Aglenchus agricola*		0.13	2.86			
4	B	*Alaimus primitivus*			0.20	0.13		
2	PF	*Amplimerlinius socialis*	0.31	0.63	3.73			0.53
2	B	*Anaplectus granulosus*		1.96	2.66		0.70	
2	HF	*Aphelenchoides parietinus*	1.55	2.33	2.93	5.53	10.54	2.66
2	HF	*Aphelenchus avenae*	0.31	0.32	1.17	0.13	0.18	1.33
5	O	*Aporcelaimellus obtusicaudatus*	0.10	1.32	5.26	0.39	0.09	0.27
2	HF	*Aprutides* sp.		0.19	0.10			0.80
5	O	*Axonchium coronatum*			0.13			
3	B	*Bastiania gracilis*			0.03			
3	PF	Belonolaimidae	0.31	0.57	4.53	0.26	0.18	3.19
2	PF	*Boleodorus mirus*	0.21	0.76	1.23			
2	B	Cephalobidae	0.41	1.14	2.10	0.39	0.53	2.66
2	B	*Cephalobus persegnis*						0.27
2	B	*Chiloplacus* sp.	0.10	0.06	0.20			
3	AF	Chromadoridae			0.10			0.27
4	P	*Clarkus papillatus*		0.06				
4	P	*Coomansus parvus*		0.06				
2	PF	*Coslenchus costatus*			0.13	0.13		0.27
3	HF	*Diphtherophora communis*			0.03			
5	O	*Discolaimus perplexans*			0.03			
2	HF	*Ditylenchus intermedius*	0.10		0.27	0.66		
4	O	Dorylaimidae	0.31	0.50	2.10	0.53	0.88	2.39
4	O	*Dorylaimoides micoletzkyi*			0.03			0.27
4	HF	*Doryllium zeelandicum*						2.56
4	O	*Ecumenicus monohystera*		0.19	0.43		0.09	
4	O	*Enchodelus arcuatus*			0.23			
2	B	*Eucephalobus oxyuroides*	0.62	2.15	4.76	0.13		2.13
4	O	*Eudorylaimus opistohystera*		1.07	2.60	0.39		0.27
2	B	*Eumonhystera vulgaris*		0.19		0.66	4.92	
3	B	*Euteratocephalus palustris*	0.10					
2	PF	*Filenchus vulgaris*	2.38	10.22	8.89	1.58	1.05	38.07
3	PF	*Geocenamus quadrifer*			0.37			4.26
2	B	*Geomonhystera villosa*		0.06	0.10	0.26	2.19	
2	B	*Heterocephalobus elongatus*			0.70			0.27
4	P	*Iotonchus* sp.			0.03			
4	P	*Labronema* sp.			0.10		0.26	
4	O	*Laimydorus parabastiani*					12.20	
2	PF	*Malenchus bryophilus*	0.62	7.44	0.50	0.13		
3	PF	*Meloidogyne* sp.			0.03			
3	PF	*Mesocriconema curvatum*	0.41		0.40			0.27
4	O	*Mesodorylaimus potus*						5.06
4	O	*Mesodorylaimus* sp.	7.04	9.84	2.06	14.47	18.27	4.25
2	B	*Monhystera* sp.			0.03	3.16	0.26	
2	B	Monhysteridae	0.21	0.13			0.44	
4	P	*Mylonchulus brachyuris*		0.44	0.57			
3	PF	*Nagelus* sp.		0.57				
4	P	*Nygolaimus brachyuris*	1.14	5.68	0.93		2.19	5.05
1	B	*Panagrolaimus rigidus*	76.33	6.81	2.63	60.02	24.73	5.32
2	PF	*Paratylenchus* sp.	0.93	1.26	0.87		0.18	0.27
2	B	Plectidae		0.25	1.63			
2	B	*Plectus acuminatus*	0.10	0.38	1.86	3.29	15.98	2.13
3	PF	*Pratylenchus* sp.	0.31	4.48	3.03	0.79	2.46	4.52
4	P	*Prionchulus punctatus*		0.44	0.03			
3	B	*Prismatolaimus intermedius*	0.21		1.46		0.09	0.27

Table III. Continuation.

Cp value[1]	Feeding type[2]	Taxon	Site					
			SalTur	PucTur	ArtTur	SalCoj	PucCoj	ArtCoj
1	B	Rhabditidae		0.19	0.13			
1	B	*Rhabditis terricola*			0.10			
3	B	*Rhabdolaimus terrestris*			0.17			
3	PF	*Rotylenchus jagatpurensis*	3.62	33.64	30.96			
3	PF	*Rotylenchus* sp.				1.45	0.18	2.13
2	P	*Seinura* sp.			0.03			
3	B	*Teratocephalus* sp.			0.10			
3	P	*Tripylina arenicola*	0.21	0.06	0.10	0.13	0.53	0.27
4	HF	*Tylencholaimus teres*	0.31	1.83	0.23	0.13		0.27
2	PF	Tylenchidae	1.35	0.57	1.10		0.26	
4	HF	*Tylencholaimellus eskei*			1.56			7.18
2	PF	*Tylenchus davainei*	0.10	1.26	0.50	0.26		0.27
2	B	*Tylocephalus auriculatus*		0.06	0.23			
2	B	*Wilsonema otophorum*		0.06	0.23			
2	B	*Ypsylonellus vexilliger*	0.10	0.32	0.20	4.74	0.44	

[1] According to Bongers (1990) and Bongers *et al.* (1995)
[2] According to Yeates *et al.* (1993); PF-plant feeding; B-bacterial feeding; HF-hyphal feeding; O-omnivorous; P-predator; AF-algal feeding

Characterisation of nematode communities

Structure of nematode communities. The nematode fauna of the studied areas includes 73 taxa (53 species, 12 taxa identified to the genus level and 8 taxa identified only to higher rank because of insufficient material) (Table III). A relatively low diversity characterizes salt-affected habitats. The number of taxa in each habitat was different: SalTur (31), PucTur (43), ArtTur (61), SalCoj (26), PucCoj (28) and ArtCoj (33). The highest number of taxa was found in the soil collected from the salt-affected area located near Turda (ArtTur), which was covered by a continuous layer of plants belonging to tolerant halophilic phytocoenoses (ass. Artemisio-Festucetum pseudovinae). The nematode communities from two sites at Cojocna (SalCoj and PucCoj) had the lowest diversity, and were characterized by obligate and preferant halophilic phytocoenoses.

Dominant taxa differ according to habitat: a single eudominant taxon (D%>10.1) was present in ArtTur (*Rotylenchus jagatpurensis*, 30.96%), in ArtCoj (*Filenchus vulgaris,* 38.07%) and in SalTur (*Panagrolaimus rigidus*, 76.33%). More than one eudominant species were found in the rest of the habitats, namely: *Rotylenchus jagatpurensis* (33.64%) and *Filenchus vulgaris* (10.22%) in PucTur, *Panagrolaimus rigidus* (60.02%) and *Mesodorylaimus* sp. (14.47%) in SalCoj, *Panagrolaimus rigidus* (24.73%), *Mesodorylaimus* sp. (18.27%), *Plectus acuminatus* (15.98%), *Laimydorus parabastiani* (12.2%) and *Aphelenchoides parietinus* (10.54%) in PucCoj. Both salt-affected areas (Cojocna and Turda) have in common only two eudominant taxa, namely *Filenchus vulgaris* (in PucTur and ArtCoj) and *Panagrolaimus rigidus* (in SalTur, SalCoj and PucCoj).

Trophic structure of nematode communities. The most abundant nematodes were bacterial feeders (26 taxa) followed by plant feeders (17), omnivores (11), predators (9), hyphal feeders (8) and algal feeders (2) (Table IV).

Bacterial feeding nematodes dominated the communities in SalTur, SalCoj (*Panagrolaimus rigidus*) and PucCoj (*Plectus acuminatus* and *Panagrolaimus rigidus*). These nematodes, known also as colonizers, are r-strategists and are characterized by short biological cycles, an ability to colonize new habitats quickly, high tolerance to disturbances, high numbers of small eggs, high fluctuations of density, and they generally inhabit ephemeral habitats (Bongers, 1990), explaining their high abundance in the salt-affected habitats.

A high abundance of omnivorous nematodes (*Mesodorylaimus* sp. 18.27%) in the nematode community from PucCoj was noted. Plant feeding nematodes dominated the communities from ArtTur (*Rotylenchus jagatpurensis* 30.96%), PucTur (*Rotylenchus jagatpurensis* 33.64% and *Filenchus vulgaris* 10.22%) and ArtCoj (*Filenchus vulgaris* 38.07%). These habitats were characterized by a denser plant cover.

A high abundance of bacterial feeding nematodes was generally observed in habitats characterized by obligate halophilic phytocoenoses, where soil was covered with a crust of salt. Furthermore, a low abundance of predator nematodes (very sensitive to disturbances) was noted in the extreme salt-affected habitats SalTur and SalCoj.

Cp scaling and Maturity Index. Cp scaling (colonizers-persisters), proposed by Bongers (1990), is based on the life strategy of nematodes (r-strategy *vs* K-strategy). Nematodes were classified in five groups, from cp value 1 to cp value 5; those with cp value 1 are r-selected or colonizers, with short generation times, large population fluctuations, and high fecundity. Nematodes with cp val-

Table IV. Main ecological parameters of the nematode communities from some salt-affected areas from Transylvania grouped according to the plant association.

Site	SalTur	PucTur	ArtTur	SalCoj	PucCoj	ArtCoj
Number of taxa /site	31	43	61	26	28	33
Maturity Index[1]	1.47	2.77	2.77	1.75	2.47	2.65
Cp scaling						
1	76.33	7.00	2.86	60.02	24.73	5.32
2	9.60	32.25	39.31	21.05	37.76	51.93
3-5	14.07	60.75	57.83	18.93	37.51	42.75
Plant feeding	10.55	61.53	59.13	4.60	4.31	53.78
Bacterial feeding	78.38	14.14	19.82	72.78	50.37	13.32
Hyphal feeding	2.27	4.67	6.29	6.45	10.72	14.80
Omnivorous	7.45	12.92	12.87	15.78	31.53	12.51
Predators	1.35	6.74	1.79	0.13	2.98	5.32
Algal feeding			0.10	0.26	0.09	0.27

[1] Including cp value 1 nematodes.

ue 5 are K-selected or persisters, produce few offspring, and generally appear later in succession (Bongers and Bongers, 1998; Bongers and Ferris, 1999). Low and high cp values correspond with taxa relatively tolerant and sensitive to ecological disturbance, respectively.

Over 80% of the nematode taxa collected from the extreme salt-affected habitats SalTur and SalCoj were opportunistic nematodes (enrichment opportunists with cp value 1 and general opportunists with cp value 2), but the major contribution to this percentage was by the enrichment opportunists (74.03-88.83%).

The highest contribution of the persisters (cp value 3-5) was noted for the communities from habitats with preferant and tolerant halophilic phytocoenoses (PucTur 60.75 %, ArtTur 57.83% and ArtCoj 42.75%).

The highest values of the Maturity Index (MI) were observed for the nematode communities from ArtTur, PucTur and ArtCoj (with tolerant and preferant halophilic phytocoenoses), where the highest percentage of persisters was noted.

The lowest values of MI (indicating a disturbed environment) were noted for the nematode communities from SalTur and SalCoj (with obligate halophilic phytocoenoses), where the highest percentage of opportunistic nematodes (with cp values 1 and 2) was observed.

DISCUSSION

These results show that, in the salt-affected areas studied, salt is the most important and restrictive environmental factor, which drastically reduced plant and nematode diversity. Most salt-affected sites have species-poor communities for both vegetation and nematodes, consisting of more or less specialized halotolerant species. The plant species of these communities are partly the same species that are found in coastal sites of Western Europe (Schaminée *et* al., 1998).

The nematode communities are less clearly separated into groups, but the most halotolerant species (*Laimydorus parabastiani*) could be used as a key bioindicator for salt-affected areas. *Laimydorus parabastiani* is one of the eudominant (12.20%) nematode species found in the sample collected from soil covered by the plant association Puccinellietum peisonis from Cojocna (PucCoj, Table III). Ciobanu *et al.* (2004) pointed out that, since this species is only known from a comparable type of habitat (a salt-affected area located in the central part of Germany (Paetzold, 1958), these data confirm its preference for halomorphic soils (stenohaline species).

Extreme salt-affected habitats characterized by obligate halophilic phytocoenoses were dominated by the opportunistic nematodes and were differentiated from the other habitats by the lowest MI values.

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