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RELATIONSHIP BETWEEN NEMATODE SPECIES AND THE PHYSICO-CHEMICAL CHARACTERISTICS OF SPRING WATERS. II. TEMPERATURE

by
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Summary. In the province of Granada (Spain), 22 of the 38 springs sampled for a nematological study were defined as thermal, i.e., temperatures greater than 19°C. The present study considers the influence of temperature on nematode populations and the specific composition of nematode communities. Temperatures greater than 25°C were found to negatively affect the number of individuals more than the number of species found in the sampled sites. In studying specific nematode configuration, although none of the species could be considered thermophilic, species were found that showed a preference for hot-water habitats, i.e. greater than 25°C. Species measuring about 1 mm in length were found to proliferate in hot-water springs, and a significant number of male individuals were found in spring waters at 20-25°C.

In a nematological study of 38 mineral springs located in the province of Granada (Spain), the relationships between specific physico- chemical water characteristics and the nematode fauna were studied. Conductivity is discussed in Ocaña, 1991 as one of the parameters affecting nematode communities in springs.

Apart from specific ion concentrations, temperature is one of the most frequently measured and studied parameters in nematological studies on springs. Studies on this topic date back several years; e.g., De Coninck (1935), studied the hot geysers at Mont Banze in Central Africa; Hoeppli (1926), studied nematodes in the thermal waters of Yellowstone National Park (USA); Hoeppli and Chu (1932), free-living nematodes in hot-water springs in China and Formosa; Meyl (1953a, 1953b and 1954), nematodes of geysers and volcanic waters on the Island of Ischia, Italy; Pax and Soós (1943), nematodes in several sulphated and thermal springs in Germany; and Schneider (1937), studied nematodes in springs, many of wich were thermal, during an expedition to Sumatra, Java and Bali.

The present study analyzes the occurrence of species from the orders *Monhysterida*, *Araeolaimida*, *Chromadorida* and *Enoplida* in thermal springs with a range of temperatures.

Area of study and methodology

The location of the springs studied is referred to in Ocaña *et al.*, 1990. Temperature was measured using mercury thermometers on each sampling occasion. Nematodes were extracted using a modified Baermann's method (Hooper, 1986) and mounted in anhydrous glycerine by Seinhorst's (1962) modified method.

Results and discussion

On the basis of a study analyzing the thermal springs in the province of Granada (Cruz Sanjulian *et al.*, 1972) those springs showing temperatures greater than 19°C were classified as thermal. In applying this criterion to the 38 springs studied, 22 of them were classified as thermal. Of these, 16 were classified as moderately cold, 14 lukewarm, 4 as moderately warm, 3 as hot and 1 as very hot, according to Bogomolov's (1966) classification.

Temperatures above 25°C generally coincided with a substantial decrease in the numbers of individuals per species, with two exception (Fig. 1). Spring LJ2 showed a proliferation of individuals from *Heterocephalobus* sp. and *Neotylenchidae* 1st sp. represented 67% of the total nematode fauna reported for this spring. In spring ALH2, *Rhabdolaimus terrestris* comprimed 96% of the total nematode fauna.

In springs with water temperature between 10°C (lowest temp. reported) and 25°C, the mean number of individuals was found to augment with an increase in temperature, whereas in springs with temperatures greater than 25°C the mean number of individuals decreased. Temperatures greater than 25°C, however, did not always result

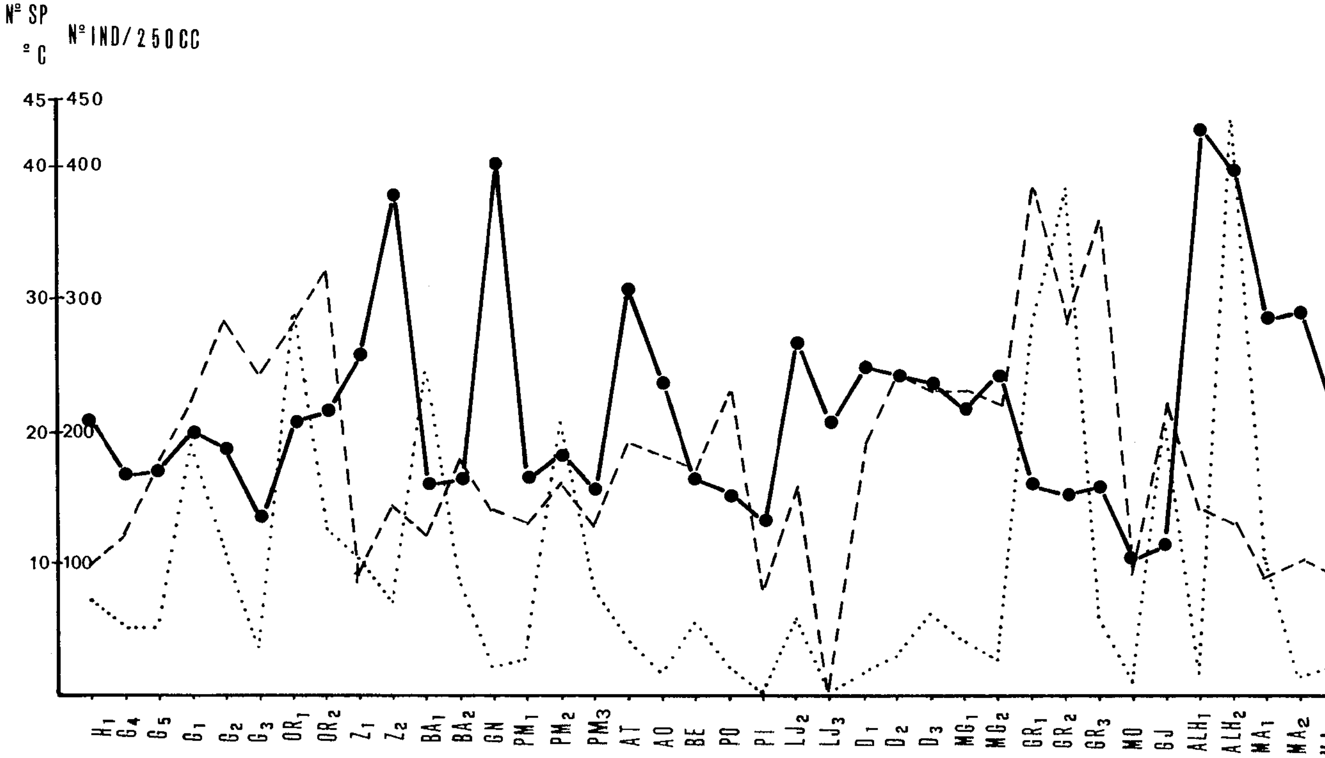

Fig. 1 - Temperature for each spring (—•—); Mean nematode numbers per 250 cc sample (- - -); number of species (. . .) for each spring.

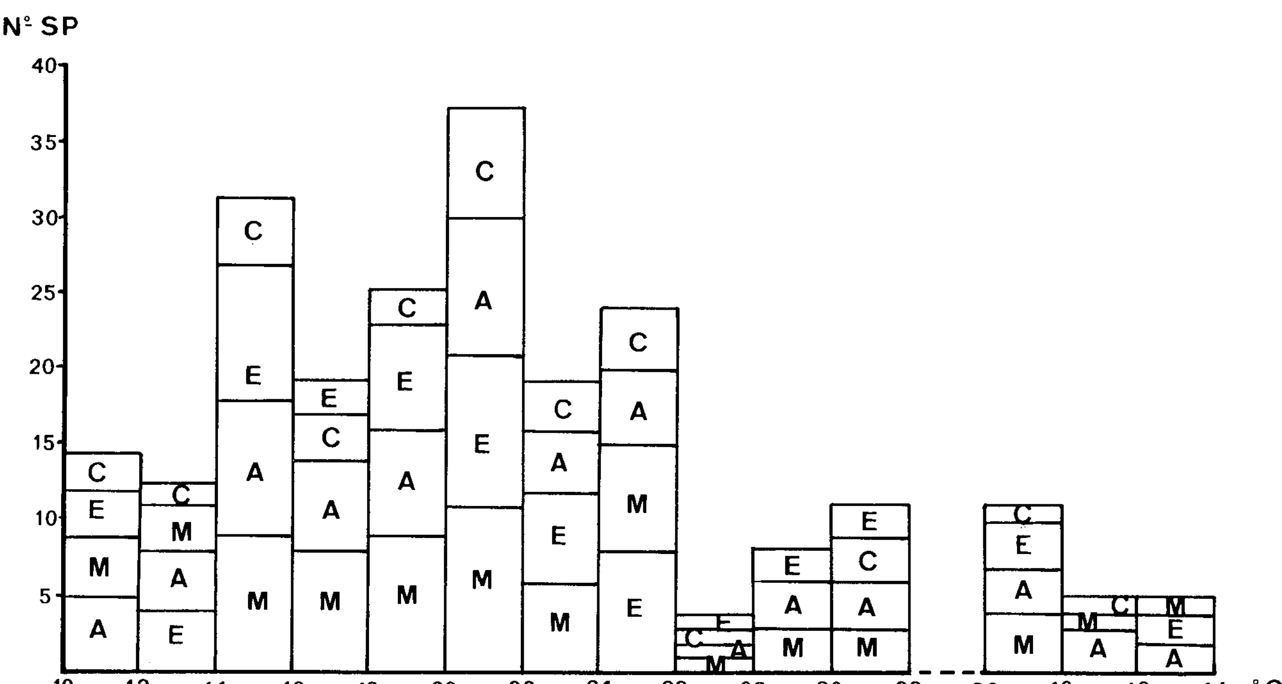

Fig. 2 - *Monhysterida (M), Araeolaimida (A), Chromadorida (C)* and *Enoplida (E)* in relation to water temperature. No springs were represend for temperatures 32- 38°C.

in a decrease in number of species (Fig. 1), where 9 to 19 species were found in springs with temperatures greater than 25°C. The largest number of species in the orders *Monysterida*, *Araeolaimida*, *Chromadorida* and *Enoplida* occurred in springs with temperatures between 14-26°C (Fig. 2). Above and below this temperature range the total number of species was fewer. Some species showed an affinity for moderately warm to very hot (greater than 25°C) temperatures (Table I).

TABLE I - *Species in the orders* Monhysterida, Araeolaimida, Chromadorida *and* Enoplida *living in springs with high temperatures.*

Temp. (°C)	Species
43-42	*Monhystrella hastata* Andrássy, 1968; *Plectus parvus* Bastian, 1865; *Udonchus tenuicaudatus* Cobb, 1913; *Tobrilus granatensis* Ocaña *et* Zullini, 1987; *Rhabdolaimus terrestris* De Man, 1880
42-40	*Plectus aquatilis* Andrássy, 1985; *Chronogaster cameroonensis* Heyns *et* Coomans, 1983; *Achromadora micoletzkyi* (Stefanski, 1915) Van der Linde, 1938
40-38	*Monhystera paludicola* De Man, 1881; *Eumonhystera pseudobulbosa* (Daday, 1896) Andrássy 1981; *Monhystrella lepidura* (Andrássy, 1963) Andrassy, 1968; *Chronogaster typica* (De Man, 1921) de Conick, 1935; *Paracyatholaimus intermedius* (De Man, 1880) Filipjev, 1930; *Prismatolaimus intermedius* (Bütschli, 1873) De Man, 1880; *Plectus geophilis* De Man, 1880; *Odontholaimus chlorurus* De Man, 1880
32-30	*Eumonhystera barbata* Andrássy, 1981; *Eumonhystera andrassyi* (Biró, 1969) Andrássy, 1981; - *Trischistoma monohystera* De Man, 1880
28-30	*Monhystera stagnalis* Bastian, 1865; *Tobrilus pellucidus* Bastian, 1885; *Plectus palustris* De Man, 1880
28-26	*Monhystera stagnalis, Plectus parvus, Prismatolaimus intermedius* (species found in higher water temperatures)

Some species were found over a wide temperature range and may be considered to be cosmopolitan species. Examples are *Plectus parvus* Bastian, 1865 which was found in springs with temperatures between 10-12°C and 42-43°C; *Monhystrella hastata* Andrássy, 1968 and *Odontolaimus chlorurus* De Man, 1880, 10-12°C and 38-40°C; *Eumonhystera pseudobulbosa* (Daday, 1896) Andrássy, 1981 at 10-12°C and 38-40°C; *Plectus aquatilis* Andrássy, 1895 at 10-12°C and 40-42°C; *Eumonhystera barbata* Andrássy, 1981 at 10-12°C and 30-32°C; and *Chronogaster typica* (De Man, 1921) De Coninck at 1935, 10-12°C and 38-40°C.

Those species found in non-thermal springs were also consistently found in springs waters with temperatures greater than 25°C, e.g. *Monhystera stagnalis* Bastian, 1865, in springs at 14-16°C and 26-30°C. *Plectus geophilus* De Man, 1880, at 28-30°C and 38-40°C; *Achromadora micoletzkyi* (Stefanski, 1915) Van der Linde, 1938 and *Chronogaster cameroonensis* Heyns *et* Coomans, 1983 at 30-32°C and 40-42°C; *Rhabdolaimus terrestris* De Man, 1880 at 30-32°C and 38-43°C; and *Udonchus tenuicaudatus* Cobb, 1913 at 28-32°C, 38-40°C, and 42-43°C. *Paracyatholaimus intermedius* (De Man, 1880) Filipjev, 1930 was found in springs at 16-18°C, and also frequently in springs at 30-32°C and 38-40°C. Although these species cannot be defined as thermophilic, they are better adapted to living in hot-water environments (i.e. »25°C) than other species that only sporadically inhabit environments at similar temperatures.

Species reported elsewhere for environments with temperatures greater than 25°C and found in the springs in Granada are: *P. parvus* in Meyl, 1953a (40-90°C), Meyl, 1953b (27-30°C); Pax and Soós, 1943 (25.2-32.1°C); *R. terrestris* in De Coninck, 1935 (30-50°C); Meyl, 1953a (40-90°C); Meyl, 1953b (35-50°C); Meyl, 1954 (38°C); Schneider, 1937 (25.4-45°C), *Prismatolaimus intermedius* (Bütschli, 1873) De Man, 1880 in Meyl, 1953a (40-90°C); Meyl, 1953b (30-35°C); Schneider, 1937 (25-33°C); *Trischistoma monohystera* De Man, 1880 in Meyl, 1953b (27-30°C); and Pax and Soós, 1943 (33.5°C), *U. tenuicaudatus* in Schneider, 1937 (25-40°C). *R. terrestris* is defined as thermophilic in Meyl, 1953a.

De Coninck (1935) and Meyl, 1953b (in Nicholas, 1975) consider that high temperatures suppress males and reduce the size of individuals in thermal waters. The data from the present study do not support this view. In spring ALH2 (mean temp. 39.8°C) the population of *R. terrestris*, consisted of 3% males whereas males are rarely found with this species; *M. stagnalis* consisted of 40% males in G1 (mean temp. 19.9°C), 42-45% in MA3 (mean temp. 21.4°C) and 26% in MA1 (mean temp. 28.4°C); *Monhystera paludicola* De Man, 1881 was 25% males in H1 (mean temp. 20.5°C); *Eumonhystera andrassyi* (Biró, 1969) Andrássy, 1981, was 33% males in H1 (mean temp. 20.5°C); *Tobrilus granatensis* Ocaña *et* Zullini, 1987, was 29% males in OR1 (mean temp. 20.6°C) and 19% in OR2 (mean temp. 21.4°C); and *Dorylaimus stagnalis* Dujardin, 1845, was 17% males in OR2 (mean temp. 21.4°C). With the exception of ALH2, the remaining springs in the province of Granada had no males in both lukewarm and moderately warm environments, whereas De Coninck (1935) and Meyl (1953b) reported males in habitats with temperatures 30-50°C and 27-50°C, respectively.

These authors found that at high temperatures individuals were usually 0.5 mm for all species studied, and only a small percentage were greater than 1 mm in length. In Granada springs, *Monhystrella lepidura* (Andrássy, 1963) Andrássy, 1968 predominated in Z2, (48% of total nematode fauna) and individuals were 0.4-0.5 mm long and *R.*

terrestris (13%) with length 0.3-0.6 mm. *Aphelenchoides sacchari* Hooper, 1958, (37%) and *Panagrolaimus higrophilus* Bassen, 1940 (32%) were the predominant species in GN, and were 0.5-1 mm and 0.9-1.6 mm long, respectively. *M. hastata* (6%) 0.3-0.5 mm long and *R. terrestris* (4%) 0.3-0.6 mm long were also found for spring GN. In spring ALH1 the predominant species were *R. terrestris* (27%) and *Mesorhabditinae* 1st sp. (39%) with length 0.6-1.2 mm. *R. terrestris* (96%), size 0.3-0.6 mm, was found in spring ALH2.

Conclusions

The results indicate that at temperatures greater than 25°C fewer individuals were found in comparison to springs with temperatures between 10-25°C. However, in springs with temperatures greater than 25°C the number of species found ranged between 9 and 19 (average number of species per spring for all springs studied, 18 ± 8.2). In these springs individuals were usually smaller in size, measuring approximately 1 mm in length.

Species inhabiting thermal springs in the province of Granada (from orders *Monhysterida*, *Araeolaimida*, *Chromadorida* and *Enoplida*) cannot be described as exclusively inhabiting warm-water springs (i.e., thermophilic), but rather as species showing a preference for warm-water environments such as: *Monhystera stagnalis*, *Plectus geophilus*, *Achromadora micoletzkyi*, *Chronogaster cameroonensis*, *Rhabdolaimus terrestris*, *Udonchus tenuicaudatus* or *Paracyatholaimus intermedius*.

The absence of male individuals in thermal waters must be related to higher water temperatures, certainly greater than 40°C, as those springs with temperatures between 20-25°C did show a considerable percentage of male individuals present.

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