A contribution to the faunistics of aquatic and semiaquatic bugs (Heteroptera: Nepomorpha, Gerromorpha) in Portugal, with the review of biology of the Nearctic corixid *Trichocorixa verticalis* (Fieber, 1851)

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Abstract: Several small samples of aquatic and semiaquatic bugs (Heteroptera: Nepomorpha, Gerromorpha) collected mainly in southern Portugal in 2004 were examined. Altogether 20 species were identified, including two species of halobiont Corixidae – *Sigara stagnalis stagnalis* (Leach, 1817) and alien *Trichocorixa verticalis verticalis* (Fieber, 1851) – just recently discovered in Portugal. Distribution, ecology and the life cycle of *T. v. verticalis* are reviewed.
Key words: Corixidae, Naucoridae, Nepidae, Notonectidae, Pleidae, Gerridae, Hebridae, Mesoveliidae, alien species, Portugal

Introduction

Despite several contributions published in the last decades, the true bug fauna of Portugal is still insufficiently known. The aquatic and semiaquatic Heteroptera were listed in papers by de Seabra (1941), Serrao-Nogueira & Azevedo y Silva (1970), Nieser & Montes (1984), Baena & Vázquez (1986), and Aukema & Rieger (1995). Additional information, including exact records and descriptions of new species may be found in several papers, especially Baena (1996), Grosso-Silva (2005), Hebsgaard *et al*. (2004), Jansson (1981, 1986), Lindberg (1962), Nieser (1969a, 1969b, 1979, 1983), Nieser *et al*. (1994), Nieser & Millán (1989), Poisson (1957), Sala & Boix (2005), Stichel (1955-1956), and Tamanini (1957). We can definitely expect records of additional species.

List of localities

Northern Portugal, Provincia do Viana do Castelo: 1) P. N. da Peneda-Gerês, **Lamas de Mouro** env., 15 km S of Lamas de Mouro, 3 km SE of Tibu (small village), along the river (41°55.926 N 8°13.797 W), 417 m a.s.l., 3.ix.2005, J. Skuhrovec lgt.
North-eastern Portugal, Provincia do Braganca: 2) Bragança env., 6 km N of Bragança, camp (41°48.242 N 6°44.982 W), 697 m a.s.l., 7.ix.2005, J. Skuhrovec lgt.
Southern Portugal, **Provincia do Algarve**, **Faro reg.: 3) Carrapateira-Amado**, 8.xi.2004, M. Mantič lgt. **4) Foia** 4 km W of Monchique**,** swamp, in water, 1.xi.2004, M. Mantič lgt. **5) Fonte Belamola** 2 km of Querenza, *Quercetum*, brook, 5.iii.2004, M. Mantič lgt. **6)** 12 km S of **Monchique** (Serra da Monchique), 43 m a.s.l. (37°14'05"N, 08°32'39"W), 14.-16.iv.2004, J. Skuhrovec lgt. **7a-b) Odelouca**, meadow, salt water: a) 5.iii.2004, M. Mantič lgt.; b) 5.xi.2004, M. Mantič lgt. **8) Porto de Lagos**, puddle on pasture, 5.xi.2004, M. Mantič lgt. **9) Quarteira** (37°03' N, 08°06' W), saline pool at margin of the sandy beach (ca 30 cm deep) (Fig. 1), 2.iii.2004, M. Mantič lgt. **10a-c) Trafal**: a) meadow, canal, fresh water, 2.iii.2004, M. Mantič lgt.; b) canal, in water, 10.xi.2004, M. Mantič lgt.; c) salt water on the beach, 10.xi.2004, M. Mantič lgt. **11a-b) Vilamoura**: a) meadow, in water, 29.ii.2004, M. Mantič lgt.; b) meadow, puddle, 1.xi.2004, M. Mantič lgt. **12) Vila do Bispo**, Pinetum, fresh water, 8.xi.2004, M. Mantič lgt. **13)** 1 km E of Junqueira, **Vila Real de Sto. António** env. (37°15'15"N, 07°27'37"W), 2.-4.iv.2004, J. Skuhrovec lgt.
Western Portugal, **Provincia do Santarém**, **Santarém reg.**: **14)** Parque Natural de la Sierra d´Aire en Candeiros, **Monsante** (20 km N of Santarém), at light, 19.-21.vi.2005, Z. Laštůvka lgt.

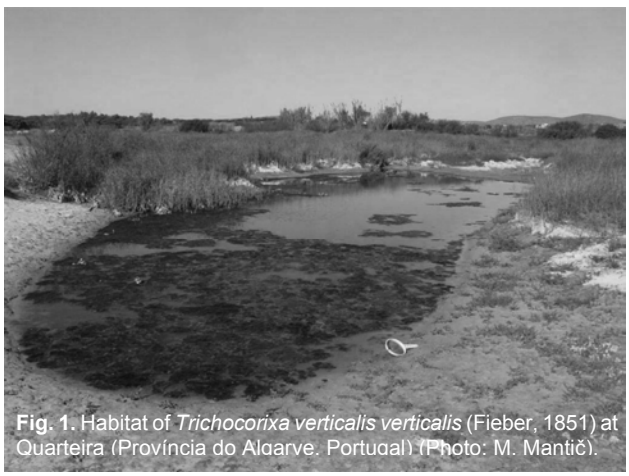

Fig. 1. Habitat of *Trichocorixa verticalis verticalis* (Fieber, 1851) at Quarteira (Província do Algarve, Portugal) (Photo: M. Mantič).

Material examined

LN: Locality number

Species	LN	Specimens examined
Nepa cinerea Linnaeus, 1758	**2**	2 ♂♂ / 2 ♀♀
Naucoris maculatus Fabricius, 1798	**5**	1 ♀
	10b	2 ♂♂
Notonecta maculata Fabricius, 1794	**1**	1 ♂
	4	1 ♂
Anisops sardeus sardeus Herrich-Schaeffer, 1849	**10c**	1 ♂
Plea minutissima minutissima Leach, 1817	**10a**	4 exs.
Corixa affinis Leach, 1817	**10b**	3 ♂♂/12 ♀♀
Corixa panzeri Fieber, 1848	**10b**	8 ♂♂ / 1 ♀
Parasigara transversa (Fieber, 1848)	**12**	1 ♂ / 1 ♀
Sigara lateralis (Leach, 1817)	**7b**	1♀
	9	1 ♂
	10b	1 ♂
	10c	2 ♂♂ / 1 ♀
	11b	1 ♂
	12	2 ♂♂
	14	1 ♂ / 2♀♀
Sigara nigrolineata nigrolineata (Fieber, 1848)	**4**	1 ♂
	8	1 ♂
	12	1 ♂
Sigara selecta (Fieber, 1848)	**10b**	2 ♀♀
	10c	11 ♂♂ / 19 ♀♀
Sigara stagnalis stagnalis (Leach, 1817)	**9**	1 ♂/ 12 ♀♀
	10b	6 ♂♂ / 1 ♀
	10c	3♀♀
Trichocorixa verticalis verticalis (Fieber, 1851)	**7b**	1♀
	8	2 ♂♂
	9	9 ♂♂ / 7 ♀♀
	10b	1 ♂ / 3 ♀♀
	10c	12 ♂♂ / 3 ♀♀
	11b	2 ♂♂
	14	1 ♀♀
Hebrus pusillus pusillus (Fallén, 1807)	**3**	1 male
Mesovelia vittigera Horváth, 1895	**10b**	1 ♂ / 3 ♀♀ (all ap)
Hydrometra stagnorum (Linnaeus, 1758)	**6**	2 ♂♂ (mi)
	7a	2♀♀ (mi)
	13	1 ♀ (mi)
Aquarius najas (De Geer, 1773)	**1**	16 ♂♂ / 6♀♀ (all ap)
	5	2 ♂♂ / 2♀♀ (all ap)
	6	2 ♂♂ / 1♀ (all ap)
Gerris argentatus Schummel, 1832	**11b**	1 ♀ ma
Gerris lacustris (Linnaeus, 1758)	**5**	1 ♂ br
Gerris thoracicus Schummel, 1832	**11a**	1 ♀ ma

ap : apterous; mi : micropterous; ma : macropterous ; br : brachypterous

All the material was identified by the author and voucher specimens are deposited in the author's (National Museum, Praha, Czech Republic) and M. Mantič's (Hlučín, Czech Republic) collections.

Comments

***Trichocorixa verticalis verticalis* (Fieber, 1851)**

Trichocorixa v. verticalis, including synonyms *Trichocorixa verticalis fenestrata* Walley, 1930, and *T. verticalis verticalis* var. *sellaris* (Abbott,1913) (for synonymy see Jansson (2002)), is distributed along Atlantic cost of Canada (Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland, Labrador), the USA (Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Virginia, North Carolina, Georgia, Florida, Alabama, Louisiana, Mississippi, Texas, New Mexico), in Mexico (Campeche, Hidalgo, Jalisco, Michoacán, Sinaloa, Tamaulipas, Yucatán), Belize, and West Indies (Bimini Islands, Bermuda, Cayman Islands, Cuba, Grenada, Guadeloupe, Haiti, Jamaica, Puerto Rico, Virgin Islands) (Sailer 1948, Barber 1954, Polhemus *et al*. 1988, Jansson 2002). Three additional subspecies occur in the inland and on the Pacific coast of North America: *T. v. californica* Sailer, 1948 in coastal area of California, Oregon, Washington and British Columbia; *T. v. interiores* Sailer, 1948 in inland athalassic lakes in Alberta, Manitoba, Saskatchewan, Colorado, Idaho, Kansas, Minnesota, North Dakota, New Mexico, Nebraska, South Dakota, and Utah; *T. v. saltoni* Sailer, 1948 in southwestern California and adjacent part of Arizona (Sailer 1948, Polhemus *et al*. 1988, Kenner & Needham 2004). However, the subspecific identification of some specimens of *T. verticalis* may be problematical, e.g. in the sample from British Columbia Kenner & Needham (2004) found males corresponding to the description of *T. v. verticalis*, while females from the same sample fitted well to *T. v. californica*. For distinguishing characters of *T. v. verticalis* see Sailer (1948), Jansson & Reavell (1999) or Günther (2004).

Together with the sympatrically occurring mosquito fish, *Gambusia affinis* (Baird et Girard, 1853) (Osteichthyes: Cyprinodontiformes: Poeciliidae), *T. v. verticalis* was introduced to New Caledonia (Jansson 1982) and South Africa (Jansson & Reavell 1999). In Spain it was collected for the first time in January 2004 on the brackish overflowed meadows at the eastern bank of the river Guadalquivir near the city Sanlúcar de Barrameda (Cádiz province) in southern Spain (Günther 2004). Millán *et al*. (2005) added a locality situated in the Doñana National Park. The first Portuguese records were published by Sala & Boix (2005) from puddles and temporary ponds in the Algarve province (environs of Faro, Vila do Bospo and Castro Marim) based on material collected in 1997-2003.

Several species of the genus *Trichocorixa* Kirkaldy, 1908, including *T. verticalis*, are known as inhabitants of brackish and saline waters (e.g., Hutchinson 1931, Sailer 1948, Howmiller 1969). Pearse (1932) described the habitat of *T. v. verticalis* (as *T. sellaris*) in Dry Tortugas Islands between Florida and Cuba. *T. v. verticalis* inhabited permanent ponds there as well as periodical pools with brackish water (salinity 8.51-73.32 g/l, i.e. 6-64 ‰) with the temperature oscillating between 25.4-42.8°C on the surface. The ponds had developed growth of higher plants (*Halodule*, *Sesuvium*), while there were only algae in the pools. *T. v. verticalis* proved to be able to endure wide variations in temperature and salinity. In such conditions, it was the dominant animal species in some of the water bodies. The entire life cycle of *T. v. verticalis* was described by Kelts (1979, as var. *sellaris*) in six pools in New Hampshire. Those pools were shallow (4.3-27.5 cm deep), affected by high spring tides, with oscillating salinity (1-160 ‰) and temperature (-1°C-40°C) throughout the year, and different vegetation cover. A quantitative study in one of the pools resulted in numbers of corixids ranged from 75.5-26,914.2 specimens/m^2 (average 3,906.6 specimens/m^2) in wide ranging salinities (12-45 ‰) and temperatures (12-38°C). In an experiment, the nymphs showed a somewhat greater salinity tolerance than adults. Salinities from 55 to 70 ‰ were lethal to all larval instars and adults.

The other subspecies *T. v. interiores* reproduced successfully in different athalassic saline lakes in Saskatchewan with conductivity range 2,240-51,400 µS/cm (at 25°C) and even maintained a small breeding population at 66,400 µS/cm (at 25°C) (Kelts 1979). Sala & Boix (2005) provided the only available European data on water chemistry in localities of *T. v. verticalis* (Lagoa do Pinhal de Sagres) – temperature 13-22°C (average 16°C), conductivity 800-1,700 µS/cm (average 1230 µS/cm) and pH 8.2-8.6 (average 8.4). Though this corixid can tolerate fresh water, it is found only in coastal marine environments. Since they are dependent on surface contact for air, unstable surface conditions and depth could likely be important limiting factors, preventing this insect from open ocean inhabitation (Kelts 1979). Live specimens of *T. verticalis* have been found in plankton tows in the waters of Delaware Bay (salinity 24.9-29.3 ‰) in association with typical marine organisms (Hutchinson 1931), and 16-32 km offshore of Louisiana and Mississippi (salinity 26.1-32.3 ‰) (Gunter & Christmas 1959). However, it has never been shown to reproduce in such habitats (Scudder 1977, Aiken & Malatestinic 1995). The osmoregulation ability of *T. v. interiores* was studied in detail by Tones & Hammer (1975), which proved its ability of both hypo- and hyper-osmotic regulation in saline waters. Jang & Tullis (1980) obtained similar results for related halobiont species *Trichocorixa reticulata* (Guérin-Méneville, 1857).

Unlike most corixid species, *T. verticalis* hibernates in egg stage (Kelts 1979, Aiken & Malatestinic 1995 – *T. v. verticalis*, Tones 1977 – *T. v. interiores*). According to Kelts (1979) the winter eggs survive ice, hypersalinities (40-50 ‰), and high hydrogen sulphide production. The summer eggs are able to survive desiccation of pools. Undeveloped eggs found under mats of *Spartina* grass developed and hatched after reflooding (both in field and laboratory). Delayed egg development is an adaptation for population maintenance in alternately exposed and reflooded pools, and ensures that one reflooding does not cause all eggs to hatch (Kelts 1979). In *T. v. interiores* in Saskatchewan, Tones (1977) has shown that the eggs, which are laid in August when the temperature is high, do not develop immediately but require a period of diapause (approximately 2 months). Kelts (1979) reported *T. v. verticalis* laying eggs on *Spartina* stems, sticks, algal filaments as well as on the walls of aquariums; Tones (1977) observed *T. v. interiores* ovipositing on wooden trays as well as on stones. *T. v. verticalis* has 5 larval instars (common number in Corixidae), which may be distinguished according to its body length (Kelts 1979). In New Hampshire, the dormant eggs started to hatch in late April; there were two generations per year (Kelts 1979). The existence of two generations per year was confirmed by Campbell (1979) in New Jersey and Aiken & Malatestinic (1995) in New Brunswick. However, Günther (2004) found both adults and numerous larvae in southern Spain on 14th January and Sala & Boix (2005) collected adults in early December. Unfortunately, there is no information about the life cycle of *T. verticalis* in the southern part of its distributional range, but it could be similar to the situation described by Balling & Resh (1984) for *T. reticulata* in salt marsh ponds in San Francisco Bay. In this area, *T. reticulata* produced 3 generations (often largely overlapping) per year, both adults and larvae of the autumn generation overwintered. Among tropical corixids reproduction occurs year round (e.g., Peters & Ulbrich 1973). According to Aiken & Malatestinic (1995), males and females of *T. v. verticalis* mature sexually about 1 month after the last ecdysis, the first sexually mature females appearing 1 week before males. For most of the season, the numerical sex ratio is male-biased (Aiken & Malatestinic 1995). The adults are capable of flight, leaving pools when conditions become limiting (Kelts 1979). Campbell (1979) found that light trapping of adults showed negative correlation between abundance and the nocturnal ambient air temperature. This correlation indicated that *T. v. verticalis* dispersed on cooler nights to minimize water loss during flight (Campbell 1979).

Trichocorixa v. verticalis preys on certain animals (Chironomidae, Ceratopogonidae, Oligochaeta), and also on detritus and algae, so they are the important component of the food web (Kelts 1979). The study of gut contents of *T. v. interiores* in the saline lakes in Saskatchewan showed Chironomidae to be a main food (Reynolds & Swanson in Scudder 1977). Wurtsbaugh (1992) mentioned *T. v. interiores* praying on nauplii of *Artemia franciscana* (Kellog, 1906) (Crustacea: Anostraca: Artemiidae). In extreme ecosystems with a simple food web such as Great Salt Lake in Utah, *T. v. interiores* may play an important role of the only predator in the ecosystem. *Trichocorixa* specimens (especially larvae) serve as prey to various invertebrate (dragonflies, dytiscid and hydrophilid larvae, semiaquatic and shore bugs, neustonic lycosid spiders) and vertebrate predators (fish, birds). Gut analysis of mummichog, *Fundulus heteroclitus* (Linnaeus, 1766) (Osteichthyes: Cyprinodontiformes: Poeciliidae) (2-4 cm long) showed that 67 % of the food consisted of immature *Trichocorixa* specimens (Kelts 1979). It was also an important source of food of the needle fish, *Strongylura notata* (Poey, 1860) (Osteichthyes: Beloniformes: Belonidae), on Dry Tortugas (Pearse 1932). They made up 2.6-23.1 % of shorebird food too (Kelts 1979). The *Trichocorixa* specimens frequently occurred in mats of filamental algae, which proved to be good shelter from the fish and birds (Kelts 1979). Additional references concerning biology and ecology of *T. verticalis* are listed by Scudder (1977).

Millán *et al*. (2005) hypothesized that the introduction of *T. v.*

verticalis could potentially lead to a simplification of the macroinvertebrate communities of the saline and hypersaline habitats in Doñana National Park (Seville Province). This question is worth further studying.

Notes on other species: ***Sigara* (*Halicorixa*) *stagnalis stagnalis*** (Leach, 1817). Baena & Vázquez (1986) listed *S. stagnalis* from Portugal with references to papers by de Seabra (1941) and Serrao Nogueira & Azevedo e Silva (1970), in both cases with question mark. However, de Seabra (1941) listed only *S. lugubris* var. *Stali* (Douglas et Scott, 1865) based on older Lethierry's (1877) record of *Corisa Ståli* Fieber, which are in fact synonyms of *S. selecta* (see Jansson 1986, 1995). The first reliable record from Portugal (Vila do Bospo env.) was published by Sala & Boix (2005). ***Gerris* (*Gerris*) *argentatus*** Schummel, 1832 was recorded from Portugal by Lindberg (1962) and Nieser (1983), but later omitted from the list by Andersen (1995).

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