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ORIGINAL ARTICLE

Does the introduced polychaete *Alitta succinea* establish in the Caspian Sea?

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Abstract Members of the polychaete family Nereididae do not occur naturally in the Caspian Sea but are documented intentional human introductions that commenced in 1939. However, the identity of the species involved has been uncertain; material has been identified as both *Alitta succinea* and *Hediste diversicolor*. In this study, we confirm the presence of both species in the Caspian Sea. We discuss the distribution of both species, based on tolerance to physical factors, especially salinity. Although establishment of this partially predatory Nereidid, as a food reservoir could facilitate the recreation of commercially exploited fish stock, the consequences for native benthic communities are unclear and may be subject to unforeseen negative impacts.

Keywords Nereididae · *Alitta succinea* · *Hediste diversicolor* · Caspian Sea

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Introduction

Between 1939 and 1941, individual Nereididae worms were brought from the Sea of Azov into the Caspian Sea for acclimatization in order to increase the food resources for the commercial fish. Russian marine scientists introduced 6,100 specimens in different places of the Caspian Sea from the Sea of Azov (Zenkevitch et al. 1945). The northern Caspian was rapidly colonized, and the animals subsequently spread into the middle and southern parts of the sea. In autumn 1944, Nereididae worms were recorded for the first time in large quantities in the intestines of sturgeon from the Chechen Island (Spassky 1945). Initially, specialists thought the introduced species was *Alitta succinea*, but further examinations showed that the introduced species was *Hediste diversicolor,* and no specimen of *A. succinea* was recorded (Hartman 1960; Khlebovich 1963). Therefore, it was not clear whether *A. succinea* was established in the Caspian Sea or not Karpevich (1968, 1975), and most literature for the Caspian Sea has only reported *H. diversicolor* (Malinovskaja et al. 1998; Guseinov 2005; Karpinsky 2010; Roohi et al. 2010; Taheri and Foshtomi 2010; Taheri et al. 2011, 2012).

In 2010, during sampling of the macrobenthic community at shallow waters of the Mazandaran province, we observed some specimens with characteristics of *A. succinea*, especially based on paragnaths on region V of the eversible pharynx. This note confirms the presence of two introduced species, *H. diversicolor* and *A. succinea*, both occurring on soft substrates of shallow waters in the southern Caspian Sea. We will also discuss their life history and factors limiting the distributions of the species.

Both species are known under a variety of synonyms and have previously been referred to the genera *Neanthes* and *Nereis*. Here, we follow Bakken and Wilson (2005) and refer to them as *A. succinea* and *H. diversicolor*.

Materials and methods

Study area

Mazandaran province is located in the middle of the southern beach of the Caspian Sea (Mazandaran Sea) along the Iranian coasts. There is almost no tidal range, and the gradient and structure of the seabed are uniform. The surface salinity and temperature to 20 m depth vary negligibly (Hadjizadeh Zaker et al. 2007). No major rivers exist in the vicinity of the sampling sites, but the most important phenomenon in these areas is strong rip currents (Shafiei Sabet and Barani 2011). Besides floating fishing nets are widely used annually from December to June.

Data collection

Seasonal sampling was conducted on the Noshahr coasts at 16 stations along four different depths (2, 5, 9, and 13 m) within 51°31′11″ to 51°49′06″E and 36°35′10″ to 36°39′55″N (Fig. 1). At each station, three replicate samples were collected using a Van Veen grab with sampling area of 300 cm^2. In the field, the content of each grab was stored in separate plastic containers. In the laboratory, each sample was gently sieved over 0.5-mm mesh, and the retained material fixed in 4 % buffered formalin and stained with Rose Bengal. One replicate sample from rocky substrate (1 m depth) was collected with scraping a surface of 225 cm^2 (15 cm × 15 cm) and immediately thereafter washed through a 1-mm mesh sieve, fixed in a 4 % formalin solution, and preserved in 70 % ethanol. Macrofauna were separated and all Nereididae identified and counted under a Olympus stereomicroscope and a Carl Zeiss Jena Laboval 4 microscope, and photographed with CCD and Nikon digital cameras. Another three replicate Van Veen grab sediment samples were taken at each station for measuring percentage of total organic matter (TOM) and sediment grain size. Surface sediment (≈4 cm) was subsampled and stored in a cleaned plastic container. The TOM was determined by weight loss on ignition (4 h at 550 °C) after drying (24 h at 90 °C) to constant weight (Abrantes et al. 1999). Grain size analysis was performed using a particle size analyzer. Sediment fractions (sand and silt–clay) were reported as percentage and defined according to the Wentworth scale. Physical data (temperature and salinity) of the water were recorded in two meter depth by the moored buoy of the Noshahr Ports and Maritime Organization. All data from the four stations at each depth (totaling 12 replicate samples from each depth) were plotted separately (Fig. 1).

Results

Averages of salinity, temperature, percentages of total organic matter (TOM), sand, silt–clay, and species density (ind/m^2) in the sampling months are given in Table 1. On soft substrates, 74 specimens of the two species were collected: *Alitta succinea* (42 specimens) and *Hediste diversicolor* (8 specimens). A further 24 damaged and juvenile specimens could not be identified (Table 2). *A. succinea* was collected at all depths in both soft and rocky substrates, while *H. diversicolor* was collected only along lines 3 and 4 in March and September, in an habitat characterized relatively greater depth and higher TOM and silt–clay.

On rocky substrates, only *A. succinea* was present (48 specimens), typically among *Mytilaster lineatus*, *Balanus improvises,* and *Rhithropanopeus harrisii* communities. In this area, we observed the highest density of *A. succinea* (more than 2,100 ind/m^2) with more numbers of fishing net

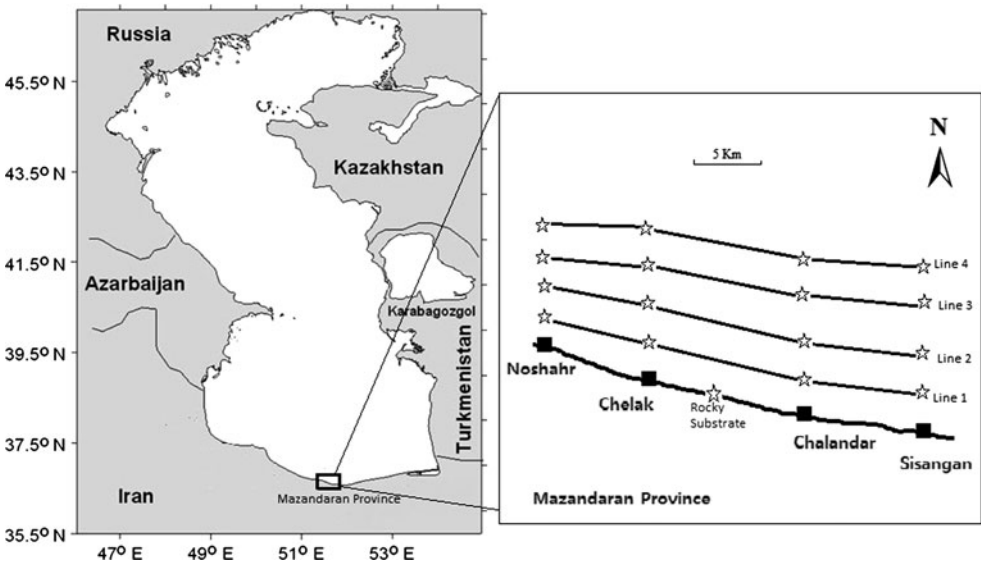


Fig. 1 Map of sampling area (*left*) and location of sampling stations in Mazandaran province with depth lines (*line 1* = 2, *line 2* = 5; *line 3* = 9 and *line 4* = 13 m)

Table 1 Averages of salinity, temperature, percentages of total organic matter (TOM), sand, silt–clay, and species density (ind/m^2) in the sampling months (mean ± SD)

Date	March	June	September	November
Salinity (‰)	9.81 ± 0.17	10.29 ± 0.71	10.70 ± 0.3	9.91 ± 0.32
Temperature (°C)	9.68 ± 0.71	26.35 ± 3.05	27.36 ± 1.16	19.03 ± 0.7
TOM (%)	4.61 ± 1.119	5.17 ± 1.25	4.05 ± 0.59	5.03 ± 1.22
Sand (%)	87.69 ± 12.00	93.6 ± 7.54	92.33 ± 6.94	95.12 ± 4.38
Silt–Clay (%)	11.42 ± 11.43	6.16 ± 7.61	5.93 ± 6.08	3.92 ± 4.45
Alitta succinea	3.47 ± 12.38	0	11.81 ± 26.17	13.89 ± 23.65
Hediste diversicolor	1.39 ± 6.73	0	4.17 ± 13.09	0

Table 2 Number of individuals found at the different depth lines (line 1 = 2 m, line 2 = 5 m, line 3 = 9 m, and line 4 = 13 m depth)

Location	March	June	September	November
Alitta succinea				
Line1	0	0	0	4
Line2	1	0	4	4
Line3	3	0	6	7
Line4	1	0	7	5
Hediste diversicolor				
Line1	0	0	0	0
Line2	0	0	0	0
Line3	0	0	2	0
Line4	2	0	4	0
Indet. Nereidid				
Line1	0	0	0	0
Line2	0	0	0	0
Line3	1	0	7	0
Line4	7	0	9	0

rows along the coast line. The mean size of *H. diversicolor* was more than four times higher than that of *A. succinea* (Table 3).

The specimens fit well with the description and characteristics presented in Fauvel (1923), Kirkegaard (1992) and Bakken and Wilson (2005). *A. succinea* can be differentiated from *H. diversicolor* mainly in the following morphological aspects:(1) presence of paragnaths on region 5 of the pharynx, (2) larger dorsal notopodial ligules in the posterior parapodium, and (3) lack of fused falcigers which are characteristic of the genus *Hediste*. In addition, the species differ in life cycle: At sexual maturity, *A. succinea* undergoes an epitokal metamorphosis to a pelagic heteronereid form. These leave the sediment and swim up to the water surface for mass spawning. *H. diversicolor* lacks an epitokal stage (Kirkegaard 1992). Morphological differences between the species are compiled in Table 3.

Discussion

The geographical range of several species has been increased by human activities, both intentionally (e.g. aquaculture) and unintentionally (e.g. interconnection of water basins through canals; shipping activities) (Bij de Vaate et al. 2002). *Hediste diversicolor* and *Alitta succinea* have been intentionally introduced to the Aral Sea as food for commercially exploited fish (Proskurina 1980). Both species occur in the Sea of Azov, from which they were taken for introduction to the Caspian Sea. These worms are sufficiently similar that they are unlikely to have been distinguished on sample collection, and most likely, both species were gathered for introduction (Karpinsky et al. 2005). Other evidence suggests that *A. succinea* was present in the Caspian Sea as early as 1949: Birshtein (1952) reported that the gut contents of the clupeid *Alosa saposhnikovi* from the north Caspian were dominated by massive number of Nereidids in 1949. Since this fish feeds mainly on pelagic animals (Malkin and Andrianova 2008), it is highly probable that the prey consisted of heteronereids of *A. succinea*, rather than of *H. diversicolor* (Karpinsky et al. 2005). Thus, within several years of introduction to the Caspian Sea, *A. succinea* was present and reproducing (Belyaev 1952; Navozov-Lavrov 1948).

In our opinion, the species has arrived via intentional introduction. It cannot be excluded that *A. succinea* had remained undetected before. Due to small population size during the period of arrival and establishment, an early detection of non-indigenous species is difficult. Probably, most introductions in the Caspian Sea were discovered only after populations had reached high abundances (e. g. the bivalves *Mytilaster lineatus* and *Abra ovate*) (Grigorovich et al. 2003).

There are several biotic and abiotic factors that may affect the abundance and distribution of the benthic community. Karpinsky (2010) suggested that fish grazing pressure is an important biotic factor influencing the benthic communities in the Caspian Sea. *A. succinea* and especially its planktonic heteronereid forms are significant prey for a variety of fish including Sturgeon (Karpinsky 2002; Karpinsky et al. 2005), *Alosa saposhnikovi* (Birshtein 1952), *Clupeonella engrauliformis* (Stark 1959; Surugiu 2006), *Mugil cephalus* (Bishop and Miglarese 1978), *Neogobius melanostomus* and *N. cephalarges* (Kvach and Zamora 2001). So, abundance and distribution of *A. succinea* may be controlled by fish predation and thus would

Table 3 Comparison of characteristics of *A. succinea* and *H. diversicolor* in the southern Caspian Sea

Characteristics	*Alitta succinea*	*Hediste diversicolor*
Maximal length (mm)	36	91
Mean length ± SD (mm)	12.2 ± 20.3	49.4 ± 34.4
Maximal width at chaetiger 10 (mm)	3.8	6.1
Mean width ± SD at chaetiger 10 (mm)	1.7 ± 2.5	4.9 ± 3.3
Maximal no. chaetigers	76	82
Extension of tentacular cirri	To chaetigers 3–8 (rarely 15)	To chaetigers 2–4
No. paragnaths on pharynx region 5	0–6 (usually 2)	Absent
No. paragnaths on pharynx region 6	A big one surrounded by 6–7 smaller ones	3–9
Dorsal cirrus	Longer than ligules, inserted distally	Much shorter than ligules
Dorsal notopodial ligules of posterior parapodia	Markedly enlarged and elongated	Not markedly enlarged
Fused falcigers	Absent	Present
Esophagus	Usually everted to ring 1	Not inverted at all
Color	Whitish to yellowish and brownish	Whitish to yellowish and greenish
Substrate/sediment type	All sediment types, epi- and infaunal	Soft sediments, infaunal
Epitokous stage	Present	Absent

increase when predation pressure declines. Reduced predation pressure may have resulted from overexploitation of the fish stock and/or invasion of the ctenophore *Mnemiopsis Leidyi* and, finally, may be expected to occur wherever fishing nets are deployed. Floating fishing nets are widely used in shallow waters (less than 15 m depth) from December to June when we found *A. succinea* to be most abundant.

Another possible biological factor affecting the abundance of *A. succinea* is the ctenophore *Mnemiopsis Leidyi*, which was also introduced to the Caspian Sea. Roohi et al. (2010) showed that the macrobenthic community shifted from the dominant filter feeding group of crustaceans (Gammaridae) in 1996 to deposit feeding annelids (*Hediste diversicolor* and oligochaetes) during 2001–2006. Roohi et al. (2010) observed the presence of Nereididae larvae during 2001–2006, which were absent in 1996. So, this ctenophore might have a positive impact on the presence of pelagic Nereidid larvae.

The major structuring abiotic parameter of the Caspian Sea is salinity (Aladin and Plotnikov 2004). The salinity in the surface mixed layer of the sampling area shows annual fluctuations around 10 ‰ (Table 1). The northern, middle, and southern parts of Caspian Sea differ in the salinity of their waters. The average salinities of the middle and southern are 12.7 and 13 ‰, respectively. Reduced values occur only in the deltas of the rivers Sulak, Atrek, Kura, and Sefidrud. The lowest salinity is observed in the northern part of the Caspian Sea. The average salinity of its waters is about 5–10 ‰. However, in certain areas adjacent to the deltas of the rivers Volga, Ural, and Terek, the water salinity is much lower and fluctuates within 2–4 ‰, and in the deltas of these rivers, the water can be considered fresh, since its salinity is less than 0.5 ‰ (Aladin and Plotnikov 2004).

Dean and Mazurkiewicz (1975) fertilized eggs of *A. succinea* at 20 ‰ and then exposed them to varying salinities and temperatures. They found normal development of embryos at 10, 15, and 20 ‰, except for the combination of 10 ‰ and 10 °C. Kuhl and Oglesby (1979) suggested survival limits of *A. succinea* at 1 and 80 ‰, while successful fertilization and development can only occur between 10 and 45 ‰. Kristensen (1988) found that the distribution of this worm in a Danish estuary was restricted by salinities lower than 10 ‰. High worm densities were found less than 400 meters away in water of more than 16 ‰. Fong (1991) maintained *A. succinea*at 5 ‰ for 10–12 months; epitokal metamorphosis took place only after exposure to higher salinities. In contrast, larvae of *H. diversicolor*, from low-salinity Finnish waters (Tvärminne) developed within a salinity range of 5–15 ‰ (Smith 1964). Larvae from the west coast of Sweden (Kristineberg) where salinity is higher showed optimal development at 19 ‰ and a lower limit of fertilization at about 6 ‰. Belyaev (1952) reported that in the northern Caspian Sea, reproduction of *H. diversicolor* is limited by salinity of lower that 5.6 ‰ and that major colonies of *H. diversicolor* exist at salinities between 5 and 13 ‰. Thus, salinity values may cause limitations to *A. succinea*, especially in the northern Caspian Sea, while *H. diversicolor* may be able to disperse to the regions with salinities lower than 10 ‰. Moreover, *H. diversicolor* may be restricted to the fresher regions of the Caspian Sea by the presence of *A. succinea*.

The water temperature in the Caspian Sea ranges from 0 °C or less in winter in the northern part, which can be

partially covered with ice, to 30 °C in midsummer in the southern Caspian Sea. Both *A. succinea* and *H. diversicolor* are apparently able to tolerate the temperature range of the Caspian Sea. Both species survive and reproduce successfully in the Sea of Azov at winter water temperatures as low as 0 °C similar to the northern Caspian Sea (Stark 1959). Kuhl and Oglesby (1979) have shown that temperatures as high as 34 °C do not have any marked effect on adult survival and reproduction of *A. succinea*. However, higher temperature may have a synchronizing effect on epitokal metamorphosis in *A. succinea* (Fong 1991).

In the sampling area, *A. succinea* was collected at all depths in both soft and rocky substrates, while *H. diversicolor* was collected only along lines 3 and 4 in March and September, in an habitat characterized relatively greater depth and higher TOM and silt–clay. In the Gorgan Bay, which is characterized by soft silty substrate, only *H. diversicolor* is recorded (Taheri et al. 2011, 2012). Stygar and Mutysheva (2000) reported locally high abundances of *H. diversicolor* in the Uralsk Trench in the eastern part of north Caspian Sea, which has a greater depth and a higher percentage of silt–clay. For the Isefjord, Rasmussen (1973) suggested that the locally abundant *A. succinea* is a predator which mainly preys on quite large prey, like *H. diversicolor*. As *H. diversicolor* seems to be rare where *A. succinea* is common (Smith 1963), *H. diversicolor* may be restricted mainly to the soft bottoms at greater depth by the presence of *A. succinea*.

Although the establishment of this Nereidid as an additional food source could facilitate the recreation of commercially exploited fish stocks, the consequences for native benthic communities remain unclear and might be subject to unforeseen negative impacts. So, further studies are required to monitor potential impacts of *A. succinea* on the benthic communities in the Caspian Sea.

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