ABUNDANCE OF THE ALIEN SPIONID *STREBLOSPIO GYNOBRANCHIATA* IN RELATION TO SEDIMENT COMPOSITION ALONG THE SOUTHERN COAST OF THE CASPIAN SEA

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ABSTRACT

Seasonal and inter-annual variations in the density of the invasive polychaete *Streblospio gynobranchiata* were noted in the south Caspian Sea when sediment conditions were examined at five and 14 meters depths in 2005 and 2010. There was no clear trend in changing density in line one but in line two, in all seasons except summer, density of *S. gynobranchiata* decreased significantly. Maximum densities of 2,040 ind./m^{-2} and 1,013 ind./m^{-2} were obtained in 2005 and 2010, respectively. Although the percentage of total organic matter as a food resource increased from 2005 to 2010, the density of *S. gynobranchiata* decreased slightly in the same period. It seems that in this invasion phase the population of *S. gynobranchiata* has decreased to a balance condition. There is evidence that the changing density of this species is also being affected by other biotic/abiotic factors like intra/interspecific competitors and pollutants.

RÉSUMÉ: L’abondance des populations du polychète envahissant *Streblospio gynobranchiata* selon les caractéristiques du sédiment sur les côtes Sud de la Mer Caspienne.

Nous avons étudié les variations saisonnières et interannuelles de la densité des populations du polychète *Streblospio gynobranchiata* au sud de la Mer Caspienne selon les caractéristiques du sédiment aux profondeurs de cinq et 14 mètres en 2005 et en 2010. Aucune tendance claire n’a été identifiée pour la ligne un mais pour la ligne deux, la densité de *S. gynobranchiata* a baissé de manière significative durant toutes les saisons, excepté l’été. Les densités maximales ont été de 2040 ind./m^{-2} en 2005 et de 1013 ind./m^{-2} en 2010. Même si le taux de matière organique totale - source de nourriture - a été plus grand en 2010, la densité de l’espèce a baissé légèrement durant l’année 2010. Il semble que, durant cette phase d’invasion, les populations étudiées ont baissé aux valeurs d’équilibre. De même, il a été suggéré que les variations de la densité de cette espèce sont contrôlées par d’autres facteurs biotiques ou abiotiques tels la concurrence intra/interspécifique et la pollution.

REZUMAT: Abundența populațională a polichetului invaziv *Streblospio gynobranchiata* în funcție de caracteristicile substratului în zonele costiere sudice ale Mării Caspice.

S-au cercetat variațiile sezoniere și interanuale ale densității populațiilor polichetului invaziv *Streblospio gynobranchiata* în sudul Mării Caspice, în funcție de caracteristicile substratului, la adâncimile de cinci respectiv 14 metri, în anii 2005 și 2010. Nu s-a evidențiat o tendință clară în variațiile densității pentru linia unu dar, pentru linia doi, densitatea *S. gynobranchiata* a scăzut semnificativ în toate anotimpurile cu excepția verii, astfel încât densitățile maxime au fost de 2040 ind./m^{-2} în 2005 și 1013 ind./m^{-2} în 2010. Deși procentul de materie organică totală utilizată ca sursă de hrană a fost mai mare în 2010, valorile densității au fost ușor mai mici în 2010. Se pare că, în această fază a invaziei, populațiile studiate au scăzut până la valori de echilibru. De asemenea, s-a sugerat că variațiile de densitate ale acestei specii sunt controlate de alți factori biotici/abiotici, precum concurența intra/interspecifică și poluarea.

INTRODUCTION

The success of invasive aquatic organisms is aided by a variety of attributes such as high genetic variability, wide environmental tolerance, short generation time, high reproductive capacity, early sexual maturity and a broad diet.

Normally, following some period of time after its introduction, invasive species show an exponential population increase and expansion. Maintenance of the immigrant species at a high population level will be related to interspecific competition with native species and availability of habitat, and also the availability of food. Eventually, the immigrant population may decline, for instance due to increased predation pressure, parasite infestation or loss of genetic vigour (Essink and Dekker, 2002; Neideman et al., 2003).

The south Caspian Sea, with its low diversity of macrofauna, has passed through a stressful condition during last decade. Because of the invasion of *Mnemiopsis leidyi* (Agassiz, 1860) and *Streblospio gynobranchiata* (Rice and Levin, 1998), macrofauna diversity and community structure has changed dramatically (Roohi et al., 2010; Taheri and Yazdani Foshtomi, 2011). Besides, different kinds of pollutants like heavy metals, microbial, rural and agricultural waste water are increasing in this part of the Caspian Sea (Karbassi and Amirnezhad, 2004; Fereidouni et al., 2006).

The presence of the *S. gynobranchiata* species has been found in the south-eastern United States in Florida and the Gulf of Mexico (Rice and Levin, 1998) for the first time. It was reported as an invasive species in the Black Sea (Boltacheva, 2008) and also in the Izmir Bay in 2003 (Cinar et al., 2005). In Izmir Bay (Alsancak Harbour) it became the dominant species and accounted for almost 100 percent of faunal population at some stations with a maximum density of 60,480 ind./m^{-2} (Cinar et al., 2005, 2006). In the autumn of 2004, it was observed at Noor Coast (Iran) in the south Caspian Sea and in a short time it reached 10,311 ind./m^{-2} at 30 meters depth and became the dominant species (Taheri et al., 2009; Taheri and Yazdani Foshtomi, 2011). At Gorgan Bay on the south-east coast of the Caspian Sea, in the spring of 2010 *S. gynobranchiata* represented 64.80 percent of the total density of Annelida with a maximum observed density of 3,617 ind./m^{-2} (Taheri et al., 2012).

Monitoring community structure is useful for coastal management and conservation. The aim of this study is to record the changing densities of *S. gynobranchiata* in the shallow water of the south Caspian Sea in the five years after its first report.

MATERIAL AND METHODS

Mazandaran Province is located in the south of the Caspian Sea along the Iranian coast. The province has a subtropical climate characterised by warm summers and mild winters. The gradient and structure of the seabed are uniform and there is almost no tidal current. The surface salinity down to 30 meters depth has negligible variations (Hadjizadeh Zaker et al., 2007). No major rivers exist in the vicinity of the sampling sites in this area though it is important to note there is rip current phenomenon in this area (Shafiei Sabet and Barani, 2011). Sampling was conducted on the Noor Coast (between Royan and Rostamrood) between 51°59’35” to 52°02’31” E and 36°35’25” to 36°36’29” N in 2005 and along the Noshahr Coast (between Royan and Noshahr) between 51°31’12” to 51°49’54” E and 36°39’28” to 36°35’11” N in 2010 (Fig. 1).

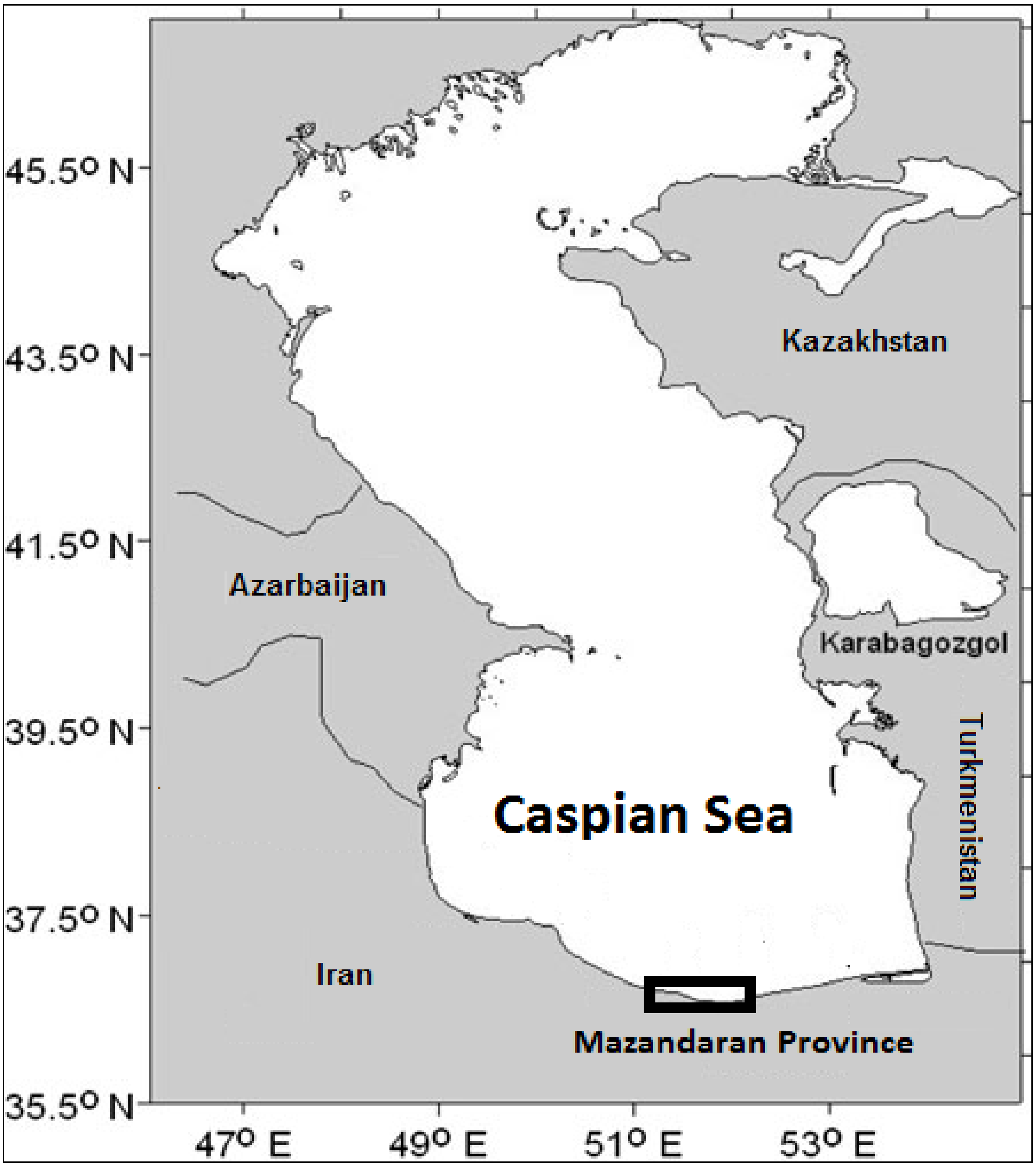

Figure 1: The map of the study area.

Seasonal samplings were carried out at two different depths (five m and 14 m) in four transects during 2005 and 2010. At each station for the macrofauna study, three replicate samples (12 samples in each depth) were collected using a Van Veen grab (250 cm^2). In the field, the contents of each grab were stored in separate plastic containers. Sediment from each container was gently sieved at the laboratory through a 0.5-mm mesh and the retained material was fixed in 4% buffered formalin and stained with Rose Bengal. Then, other macrofauna was separated off and the *S. gynobranchiata* was collected and counted under a stereomicroscope (Taheri and Yazdani Foshtomi, 2011). Another three replicate sediment samples were taken at each station to measure the percentage of the total organic matter (TOM), again using the Van Veen grab. The surface sediment (four cm) was sub-sampled and stored in clean plastic containers. Total organic matter was determined by loss weight on ignition (four hours at 550°C) after drying (24 hours at 90°C) to a constant weight (Taheri et al., 2012).

Our sampling design provided measurements in two years, four seasons in each year, and 12 samples at each depth. To test for differences in density (univariate) between different seasons and depths, a fully-crossed, three-factor-design was analysed using PERMANOVA. The design included the random factor replicate nested in the fixed factor season, and the fixed factor depth on year. A Euclidean distance-resemblance-matrix was used for similarity matrix. Whenever significant differences were observed, pairwise tests were performed to investigate differences. P-values were obtained from P perm and Monte Carlo P (MC) (Anderson and Robinson, 2003). These analyses were carried out using PRIMER v6 with PERMANOVA+ add-on. All figures were drawn using Excel. Furthermore, correlations between density and sediment variables were tested with Spearman's rank.

RESULTS

In all seasons the percentage of total organic matter (TOM) increased with depth ($p = 0.00$). At a five-meters depth, the highest and lowest TOM values were obtained in summer and winter, respectively. At a 14-meters depth the highest value was observed in autumn while the lowest occurred in the summer. In 2010, although the percentage of TOM increased with depth, there were no seasonal differences at both depths. Inter-annual comparisons showed a clear increase in *S. gynobranchiata* at both depths in all seasons ($p = 0.00$).

During the 2005 sampling period the percentage of sand decreased with depth ($p = 0.00$). There were no seasonal differences in the amount of sand at the five-meters depth but at 14 meters the highest values of sand occurred in spring and summer and the lowest was in the winter. In 2010, sand was also found to decrease with depth ($p = 0.01$) and there were no seasonal differences. Inter-annual comparisons only showed variations in the amount of sand at the five-meters depth except in spring ($p = 0.01$).

The percentage of silt-clay did not show differences at the five-meters depth in 2005. The greatest amounts of silt-clay were obtained in the winter and autumn while the least amount was obtained in the summer. Furthermore, the amount of slit-clay decreased with depth ($p = 0.00$). In 2010, it decreased with depth ($p = 0.01$) with no differences due to seasonality. The inter-annual comparison only showed variations at the five-meters depth except in spring ($p = 0.01$, Tab. 1).

A significant difference in the density of *S. gynoranchiata* was observed in the different seasons during 2005. In line one, the maximum density (144.44 ind./m^{-2}) was observed in summer and autumn while the minimum density was observed (0 ind./m^{-2}) in winter. In line two, the lowest density was obtained in summer (825.93 ind./m^{-2}) and the highest density was obtained in spring. Also, *S. gynoranchiata* densities increased with depth ($p = 0.00$). In 2010 at both depths, the highest density occurred in summer (233.33 and 1,013.89 ind./m^{-2}) while the lowest density was found in the spring (0 and 11.11 ind./m^{-2}). With the exception of spring, density increased with depth in all seasons ($p = 0.00$). An inter-annual comparison in line one showed a higher value in winter 2010 ($p = 0.01$) and a lower value in autumn 2005 ($p = 0.00$) while in line two, except summer in other seasons, density was higher in 2005 ($p = 0.00$). The range of density in 2005 was between 0-144.44 ind./m^{-2} and 825.59-2040.74 ind./m^{-2} in five-and-14-meter depths respectively. In 2010 the range of density was between 0 to 233.33 ind./m^{-2} and 11.11 to 1,013.89 ind./m^{-2} in the similar depths. In general, total density decreased in 2010 (Fig. 2).

Table 1: Sediment variables during study; upper case letters show seasonal variation.

TOM	Year	Winter	Spring	Summer	Autumn
TOM 5 meters	2005 2010	1.66 ± 0.21 C 4.80 ± 0.71 A	2.32 ± 0.44 B 5.62 ± 1.21 A	2.73 ± 0.27 A 4.84 ± 1.22 A	2.35 ± 0.17 B 5.32 ± 0.94 A
TOM 14 meters	2005 2010	2.90 ± 0.92 AB 6.64 ± 1.37 A	3.38 ± 0.21B 6.33 ± 1.17 A	3.53 ± 0.15 C 6.30 ± 1.77 A	2.83 ± 0.14 A 5.83 ± 0.78 A
Sand 5 meters	2005 2010	97.46 ± 1.14 A 92.41 ± 5.11 A	97.46 ± 0.61 A 97.50 ± 2.07 A	97.59 ± 0.45 A 92.68 ± 4.24 A	97.70 ± 0.67 A 93.03 ± 5.48 A
Sand 14 meters	2005 2010	78.92 ± 14.49 C 75.95 ± 13.72 A	93.44 ± 0.89 A 89.60 ± 7.53 A	92.98 ± 1.61 A 87.67 ± 8.63 A	90.93 ± 1.39 B 96.15 ± 0.68 A
Silt-clay 5 meters	2005 2010	2.57 ± 0.61 A 6.95 ± 2.87 A	2.38 ± 0.35 A 1.57 ± 0.72 A	2.62 ± 0.90 A 5.16 ± 4.80 A	2.30 ± 0.26 A 6.26 ± 2.40 A
Silt-clay 14 meters	2005 2010	15.65 ± 7.62 A 20.32 ± 7.18 A	6.43 ± 0.80 AB 9.92 ± 3.88 A	5.48 ± 1.04 B 11.16 ± 4.49 A	7.39 ± 0.63 A 2.09 ± 0.50 A

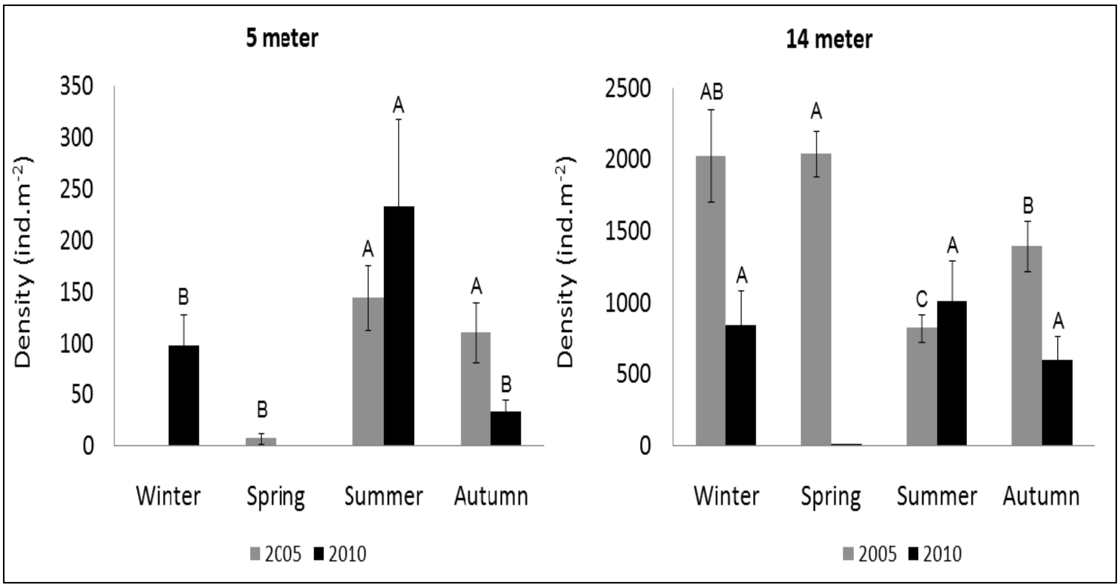

Figure 2: Density (mean ± SE) of *S. gynobranchiata* during the sampling periods. Upper case letters show seasonal variation.

In case of Spearman’s rank correlation coefficient between density of *S. gynobranchiata* with sediment variables (Tab. 2), variable TOM showed a relationship with density.

Table 2: Spearman’s rank correlation coefficient between density of *S. gynobranchiata* with sediment variables; *, P < 0.05, **, P < 0.01.

	Winter	Spring	Summer	Autumn
TOM 5 meters	0.632**	0.109	0.047	- 0.273
TOM 14 meters	- 0.457*	- 0.750**	- 0.040	- 0.454*
Sand 5 meters	0.462	0.472	0.065	0.067
Sand 14 meters	0.215	0.217	- 0.274	- 0.512*
Silt-clay 5 meters	0.330	0.287	- 0.095	0.066
Silt-clay 14 meters	0.156	- 0.131	0.162	0.397

DISCUSSION

Invasive species are considered a major global threat to the diversity and integrity of marine ecosystems (Norkko et al., 2011). It is often difficult to accurately assess the long-term effects of invaders because of the lack of data and the changing nature of ecosystems. However, existing historical information can be used to make a comparison with current conditions and generate hypotheses that can be tested experimentally (Crooks, 2001).

S. gynobranchiata has recently been observed in the south Caspian Sea (Taheri et al., 2009) and after discovery it became the dominant species of macrofauna in that area (Taheri and Yazdani Foshtomi, 2011). The present study shows that the density of *S. gynobranchiata* decreased between 2005-2010 with densities of 2,040 and 1,013 ind./m^2 in 2005 and 2010 respectively. In Izmir Bay (Alsancak Harbour) *S. gynobranchiata* was a dominating species with a maximum density reported at 60,480 ind./m^{-2} (Cinar et al., 2005, 2006). The maximum density recorded reached to 10,311.11 ind./m^{-2} at a 30 meters depth along the Noor Coast. Generally, the density and biomass of *S. gynobranchiata* increased as the water became deeper while the amount of total organic matter and percentage of sand decreased (Taheri et al., 2009). *S. gynobranchiata* was the dominant species with 84.95 percent of the total density of macrofauna (Taheri and Yazdani Foshtomi, 2011). In spring 2010 at the Gorgan Bay (in the south east of the Caspian Sea), *S. gynobranchiata* was 64.80 percent of the total density of Annelida which represents its maximum density observed 3,617 ind./m^{-2}.

Seasonal density variations did not show a regular trend in both years, but with increasing water depth the density of *S. gynobranchiata* increased. In 2005, there was a significant correlation between the densities of *S. gynobranchiata* with the percentage of TOM but in 2010 there was a significant correlation only in winter.

After the invasion of *M. leidyi* in the southern Caspian Sea, biodiversity of phytoplankton has changed (Roohi et al., 2010) and chlorophyll levels have increased (Kideys et al., 2008). Because phytoplanktons are the most important source of TOM in the south Caspian Sea (Lahijani, 2004), increases in chlorophyll could be the cause of the increasing percentage of TOM in 2010. In both 2005 and 2010, the percentage of TOM increased as the water got deeper. Because *S. gynobranchiata* is a deposit feeder (Cinar et al., 2005), higher densities of it found in deeper water may be related to the increased percentage of TOM (as a food). Taheri et al. (2009) showed that the density of *S. gynobranchiata* is positively correlated with the percentage of TOM. Higher densities of *S. shrubsolii* and *S. benedictii* have also been reported with an increase in TOM (Rossi and Lardiccii, 2002; Garcia-Arberas and Rallo, 2004). But the strangest thing is why the density of *S. gynobranchiata* did not increase in 2010 while the percentage of total organic matter increased?

The south Caspian Sea has a lot of different pollutants like heavy metals (Karbassi and Amirnezhad, 2004), microbial pollutants (Fereidouni et al., 2006), and rural and agricultural waste water. These contaminants continue to increase in this part of the world and certainly pollution can have a bad effect on macrofauna. In the Gorgan Bay, there was no significant correlation between the density of Annelid and several environmental conditions (Taheri et al., 2011), so it seems there are other factors controlling benthic fauna in the south Caspian Sea.

The backwash power of a rip current has an effect on surface sediment and transports fine sediment (MacMahan et al., 2005). Rip currents can also wash the meiofauna and macrofauna out to deeper areas (McLachlan and Hesp, 1984), which can be a reason for higher densities in deeper water. Furthermore, rip currents can wash away TOM and indirectly affect the availability of organic matter used as food for macrofauna. Hence, it could be said that the effect of the rip current on sediment, TOM and washing macrofauna and their larvae is another reason explaining increasing density with increasing depth.

CONCLUSIONS

Although the percentage of total organic matter as a food source has increased since 2005, 2010 results show the density of *S. gynobranchiata* has decreased slightly since 2005. So it seems that in the invasion phase the population of *S. gynobranchiata* has decreased to a balance condition. Besides this, it is suggested that the changing density of this species is controlled by other biotic/abiotic factors like intra/interspecific competitions and pollutants. More information about the macrofauna community and environmental variables are needed, however, to increase our understanding of the changing population of *S. gynobranchiata.*

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