SEASONAL CHANGE OF THE ALIEN BIVALVE ARCUATULA SENHOUSIA (Benson in Cantor, 1842) POPULATION OF THE VARANO LAGOON (GARGANO, CENTRAL ADRIATIC SEA, ITALY)

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Introduction

Numerous non-indigenous species were recorded in the area of the Adriatic Sea in last decades. One of these non-indigenous species in the Adriatic Sea is Asian mussel, *Arcuatula senhousia (Benson in Cantor, 1842).* It is small mytilid, with thin, oval and elongate shell attaining a maximum length of about 32 mm, but the common size is from 10 to 25 mm in length and up to 12 mm in width. Asian mussel is suspension-feeder that inhabits both, hard and soft substrata, where it lives, attached with its bissus, in intertidal and subtidal to 20 m deep. It is an opportunist, short-lived species (maximum life span is approximately 2 years), that grows quickly, suffers high mortality, but it could be very abundant within its native range of distribution or in the areas where it has been introduced. Its native range of distribution is Asian continent, from Siberian coast to Malay Peninsula, and in the Red Sea, but it was introduced in different parts of the world: western coast of North America, Australia, New Zealand, the Atlantic coast of Europe and the Mediterranean Sea. In the Mediterranean Sea the species was first recorded in the eastern part, in Israel and Egypt, then in the southern France, in Italy in the area of Ravenna in the northern Adriatic Sea, and Slovenia. Additionally, in the Adriatic Sea the species was found in the Trieste Gulf, along the northern part of the western coast, in Venezia, Sacca di Goro, Comacchio Bay and other areas of the Po River Delta, in the brackish-water lakes in Gargano National Park, and in the coastal waters. *A. senhousia,* was also recorded in the Taranto seas (north-western Ionian Sea), in the Tyrrhenian Sea (Olbia Gulf - Sardinia) and Ligurian Sea (Livorno port). In this paper the seasonal observations on the abundance, wet weight and frequency classes of non indigenous bivalve *A. senhousia* (Benson in Cantor, 1842) were presented in the Varano lagoon, Gargano National Park, the biggest lagoon in southern Italy, during a survey carried within the framework of the Regional Project FEP Apulia 2007/2013.

Materials and methods

Study area

The Varano lagoon is a Mediterranean coastal lagoon located along the northern of the Gargano (Central Adriatic Sea) National Park (**Fig. 1**). The lagoon covers an area of 6.500 ha, with a perimeter of 33 Km. The average depth is 2.5 m, with a maximum value of 6 m in the central zone. The lagoon is surrounded on three sides by steep hills while the north side which faces the sea is a bar of sand dunes. Two artificial channels (Capojale and Varano) at the east and west extremities of the sand bar provide a connection with the Adriatic sea. Salinity values are relatively stable for a lagoon, never dropping below 20 psu. Temperature extremes are 5°C and 30°C. The hydrological system consists of the lake itself, two channels to the sea, freshwater inputs from a small catchment basin drained. The main freshwater input (87.000 m^3 d^{-1}) is from karst springs on the southern shore but the lagoon also receives the outflow of urban wastewater treatment plants and the runoff from agriculture and zoo-technique activities. Due to low tide excursion and reduced exchange with the adjacent costal area, water time residence is very long and it is estimated to about 1.5 years. The lagoon and the neighbouring coastal marine area are exploited by mussel farming. Fish species are those typical of Mediterranean lagoon: seabass, seabream, eel, grey mullet, etc.

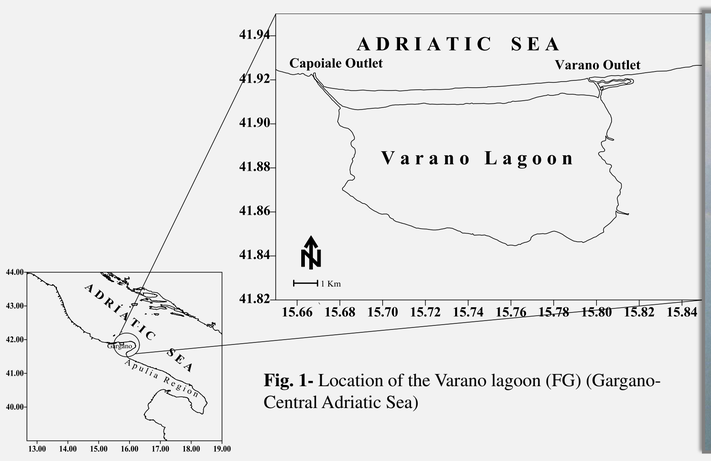

Fig. 1- Location of the Varano lagoon (FG) (Gargano-Central Adriatic Sea)

Sampling and data analysis

The samples were collected seasonally (May-July-October) during 2015, in 12 stations arranged along three transepts perpendicular to the coastline (**Fig.2**). The sampling was carried out by professional hydraulic dredge, with an opening of 55 cm and a sack of 7 mm per side on a sampling surface of approximately 5 m^2**.** The stations were placed on different bathymetries (1, 2, 3, 4 mt), for each station was assessed of the abundance (ind/m^2) and wet biomass (gr/m^2). Collected samples were screened in situ by sieve with mesh of 1 mm. For each transept, random specimen were collected by *A. senhousia* and on which the length (mm) and the wet weight (gr) were measured and length-wet weight correlations by the ratio of the minimum squares regression and distribution of length classes were calculated. Spatial and temporal variability of abundance and size classes (length) were evaluated by the ANOSIM test. In addition to biological sampling, in two stations CTD profiles were detected

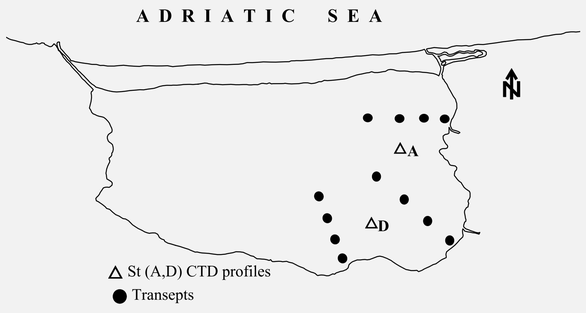

Fig. 2 - Map showing the sampling sites

Fig. 3 - Professional hydraulic dredge

Results

Environmental data (T°C, Salinity, O%) showed a typical seasonal pattern. The temperature varied from a minimum of 15.59±0.30 °C (May) to a maximum of 30.05±0.43 °C (July) detected in the **St.D**. Salinity ranged from a minimum of 19.48±0.69 psu (May) to a maximum of 24.85±0.47 psu (October). Dissolved oxygen (% saturation) showed average values close to saturation. In July, close to the base in **St.A**, low oxygen concentrations (22.46%) were found near hypoxia condition (**Fig. 3**). The average abundance and wet weight ranged by a minimum (67±146 ind/m^2; 16±44 gr/m^2) in October to a maximum (1266±1416 ind/m^2; 411±423 gr/m^2) in July, respectively (**Fig. 4**). The highest average lenght (20.81±5.34mm) was found in July, instead the smallest average lenght (12.82±5.41 mm) in October. There was a trend of decreasing abundance with time at all sites..(**Tab. 1**). Significant differences (ANOSIM test) on abundance between sampling dates (R=0.250; p<0.001). Pooled length-frequency histograms for the population *of A. senhousia* showed two cohort (bimodal) structure for most of samples (**Fig. 5**). In May and October, the population shows a bimodal structure, characterized by two cohorts. In May the most frequent lenght was between 9-15 mm (63%) and a small number of between 27-30 mm (8%). In October the most frequent lenght was between 6-9 mm (28%) and 18-21 mm (20%) . While in July the population showed a modal structure characterized by a single cohort, the most frequent lenght was between 18-24 mm (42%). The lenght showed significant differences (ANOSIM test) between transepts (R=0.082; p<0.001), stations (R=0.11; p<0.001) and sampling dates (R=0.261; p<0.001).

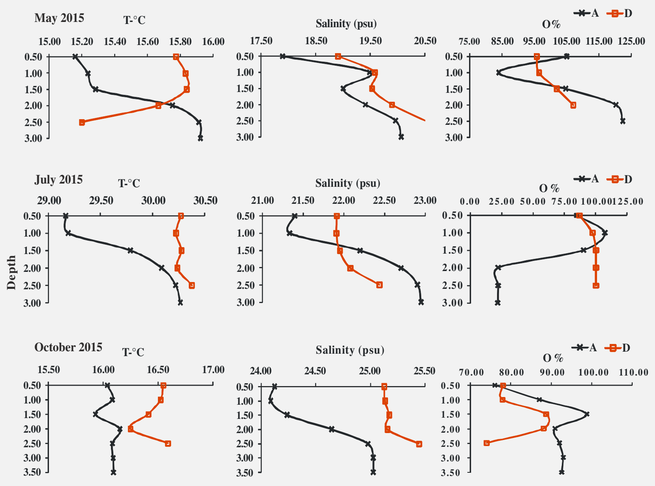

Fig. 3- CTD profiles detected during the three sampling periods

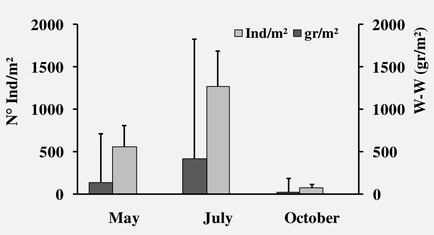

Fig. 4 - Abundance (ind/m^2) and Wet Weight (gr/m^2) in the three sampling periods

Tab.1- Statistical parameters

	Length (mm)		
	May	July	October
N	600	572	215
Mean	15.74	20.81	12.82
St.Dev.	6.19	5.34	5.41
Median	13.67	20.80	13.09
Mode	Multiple	22.33	Multiple
Max	33.13	33.10	24.50
Min	5.79	6.77	3.80
Range	27.34	26.33	20.07

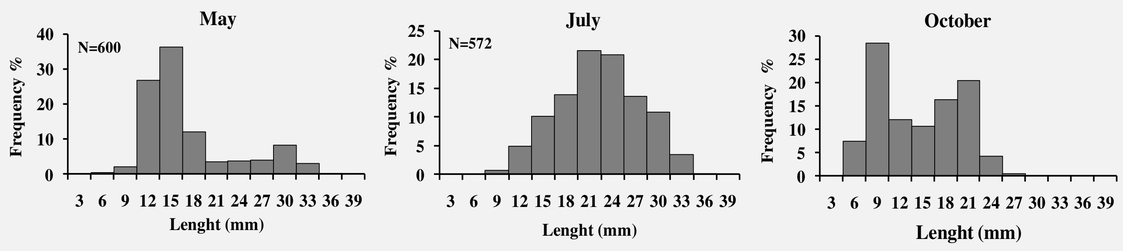

Fig. 5 - Length-frequency distributions at each date of *A. senhousia* in the three sampling periods

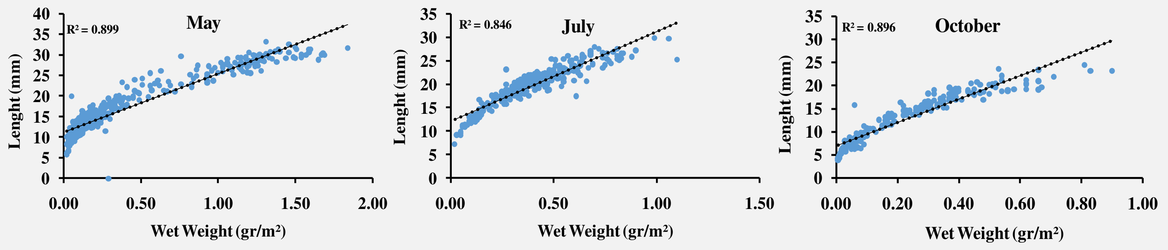

Fig. 6 - Correlations length-wet weight

Significantly positive correlations length-wet weight were found for all sampling periods (R^2=0.899; R^2=0.846; R^2=0.896).

Discussion and conclusion

Environmental data (T°C, Salinity, O%) showed a typical seasonal pattern. The massive decrease in the abundance of the *A. senhousia* detected in October, it could be related to different factors like overheating of the water, during summer and the low oxygen concentrations (22.46%) near hypoxia condition (July). Infact the temperature and low oxygen concentrations has an important influence on the physiological and biochemical attributes of bivalves.

The population growth in the Varano lagoon was extremely rapid, providing yet another example of the explosive potential of Asian date mussel populations in a Mediterranean lagoon. Abundance data and morphometric relationships confirm the presence of a stable population of the *A. senhousia* and well-structured and well-adapted to the Varano lagoon environment. Average abundance data of *A. senhousia* found during this study in the Varano lagoon (Central Adriatic Sea) are comparable with the abundance data found for the same species in the north-eastern Adriatic Sea (Sacca di Goro), Tyrrhenian (Gulf of Olbia) and Ionian (Mar Piccolo) coastal areas. At present, introduction way of the bivalve *A. senhousia* into Varano lagoon is unclear, but it could hypotyze her presence may be attributable to spontaneous penetration from near Adriatic Sea and introduction of larvae and juveniles brought to lagoon with the seed of *M. galloprovincialis* bought from Northern Adriatic Sea farms. *A. senhousia* seems well adapted to Varano lagoonal habitat, and has all the characteristics of a formidable opportunistic invader. Information found may be useful for understanding the rapid spread that specie has had in Adriatic Sea and, in particular, in transitional water ecosystems.

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