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# Spatial variation in biodiversity patterns of neuston in the Western Mediterranean and Southern Adriatic Seas

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ABSTRACT

Neuston - comprising a diverse assemblage of organisms living in the surface layer of the water column - plays a unique ecological role in marine life. Notwithstanding its importance, quantitative information on its spatial structure are still limited, in particular for the Mediterranean Sea.

Here, the spatial structure of neuston assemblage of the Western Mediterranean and the Southern Adriatic Seas was analysed, with particular emphasis on the biodiversity pattern in the two study areas. A total of 59 stations were sampled in an oceanographic cruise conducted in May–June 2013. Additional analyses were performed on data on 21 stations sampled in the Southern Adriatic in March 2015 in order to confirm the generality of the patterns observed in the 2013 cruise. Geostatistical analyses indicated that in 2013 in the Southern Adriatic the variation in taxonomic richness, abundance, and ecological diversity of the neuston across stations was characterized by a significant spatial autocorrelation. Conversely, in the Western Mediterranean a negligible spatial structure was observed. In addition, the taxonomic richness and ecological diversity of the neuston resulted significantly higher in Southern Adriatic than in the Western Mediterranean. Data collected in the 2015 cruise confirmed a high taxonomic richness and diversity for the Southern Adriatic; furthermore, a significant spatial autocorrelation was observed for both parameters. The present study represents an original insight into the structure of the neuston community in the Mediterranean Sea, providing strong evidence of the spatial variability of its diversity patterns. The influence of local and large-scale processes is discussed, and the need of more extended investigations is emphasized.

## 1. Introduction

The Mediterranean Sea, despite its relatively small size compared to the neighbouring Atlantic or Indian Oceans, is generally considered to be highly heterogeneous in terms of oceanographic and climate characteristics (Nieblas et al., 2014). This environmental heterogeneity is responsible for the distinctive diversification of the biota (Lejeusne et al., 2010) and justifies the title of "biodiversity hotspot" (Coll et al., 2010). The air-water interface is a unique physical and chemical environment (Hardy, 1982), particularly severe for the diversified assemblage of highly specialized organisms living there, collectively referred to as Neuston. The oceans cover 71% of the planet; thus, by living in the first few centimetres of the ocean's surface waters, neuston can reasonably be considered one of the most ubiquitous ecological communities. As it is located at the air-water interface, it may play a significant role in biogeochemical processes on a global scale despite the thinness of the layer (Engel et al., 2017). Moreover, given the abundance of larvae and juvenile stages, neuston appears to be a keystone biotope in the complex of biological processes involved in the reproduction of most marine organisms (Zaitsev, 1971; Abelló and Frankland, 1997; Olivar et al., 1998; Sabatés et al., 2015). In addition, the Surface Micro Layer (SML) is threatened by anthropogenic materials including oil spills, heavy metals, and micro-plastic debris (Ryan et al., 2009; Brennecke et al., 2016; Suaria et al., 2016).

In spite of the extensive efforts made in the past to characterize the neuston biodiversity of the Mediterranean Sea taxa (Holdway and Maddock, 1983a,b; Olivar and Sabatés, 1997; Collard et al., 2015), the recent increase in studies focused on the neuston is mainly due to the global problem of plastic debris accumulating on the sea surface (Ryan et al., 2009; Critchell and Lambrechts, 2016; Suaria et al., 2016), with only an indirect interest in the biology and biodiversity of the living communities populating the sea surface layer (García-Flor et al., 2008;

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Collignon et al., 2012, 2014; de Lucia et al., 2014; but see Bryant et al., 2016; Mincer et al., 2016).

Here, we analysed the community composition, abundance and biodiversity of the neuston characterizing the Western Mediterranean and the Southern Adriatic Seas, with particular attention to its spatial structure. Spatial heterogeneity is currently acknowledged to be an important feature of ecosystems rather than a statistical nuisance (Dale and Fortin, 2014); as it has deep implications for productivity, nutrient cycling and biological interactions, its estimation is necessary for an understanding the mechanisms regulating the complexity, structure, and functioning of ecological systems (James and Fortin, 2013). Pelagic systems are particularly interesting for investigating spatial patterns; in plankton ecology, specifically, the degree of horizontal spatial heterogeneity varies among sampling scales, and nested patchiness along a hierarchical continuum of scales has long been recognized to be a general feature of plankton populations in both marine and freshwater environments (Pinel-Alloul et al., 1995; Avois et al., 2000; Ludovisi et al., 2008; Grados et al., 2012; Bulit, 2014).

Specifically, in the present study we investigated the spatial autocorrelation of neuston biodiversity and abundance parameters using geostatistical techniques based on semivariogram analysis (Matheron, 1971) in order to verify the occurrence of a spatial structure, possibly influenced by oceanographic and environmental drivers. Analyses were performed on data obtained in the period May–June 2013; to corroborate the generality of the results, additional analyses were performed on the abundance and biodiversity of neuston in the Southern Adriatic Sea in winter 2015.

## 2. Material and methods

### 2.1. The study area

The investigation was performed is a sector of the Mediterranean Sea comprised between longitude (East) 4.24° and 19.23° and latitude (North) 37.41° and 43.03°; specifically, two study areas were selected in the Western Mediterranean Sea and in the Southern Adriatic Sea (Fig. 1). The South Adriatic was chosen for a more detailed study of neuston distribution in both space and time. The large-scale surface circulation of the Southern Adriatic is cyclonic and composed of two main coastal currents: the Eastern Adriatic Current (EAC) and the Western Adriatic Current (WAC). The EAC flows from the Ionian Sea northwards along the Balkan coasts, bringing relatively warm, salty and oligotrophic waters into the Adriatic (Zavatarelli et al., 1998; Godrijan et al., 2013). The WAC flows southwards along the Italian coasts and is constituted by relatively fresh and nutrient-rich waters (Betti and Grilli, 2015). The circulation is also characterized by the South Adriatic Gyre (SAd gyre), who's intensity varies seasonally (Russo and Artegiani, 1996). Since the Adriatic is embedded in the European continent, its oceanography is deeply influenced by the interplay of the hydrography of continental Europe with the Mediterranean Sea (Grbec et al., 2015). The effects of these juxtaposed forcing mechanisms are particularly pronounced in the southern part of the basin, influenced by the discharge of Albanian rivers as well as by marine water exchanges with the Ionian Sea through the Otranto Strait. In general, the Adriatic area exhibits a positive water balance, in contrast with the Western Mediterranean, which is characterized by a negative water budget. In this context, the amplitude of the seasonal cycle of river runoff plays a key role, leading to asymmetric evolution of the hydrology of the eastern and western Adriatic shores due to the absence of rivers on the Italian side. Compared with the Southern Adriatic, the oceanography of the Western Mediterranean is characterized by more diversified and complex patterns, where sub-basin and mesoscale processes are predominant (Robinson et al., 2001; Cuttitta et al., 2016).

### 2.2. Sample collection and analysis

Two oceanographic cruises were carried out on the research vessels *Urania* and *Minerva Uno* to collect samples in the study areas. In the first cruise (May–June 2013) neuston was collected at a total of 59 stations (Fig. 1) distributed around the Western Mediterranean and the South Adriatic. The South Adriatic stations were subjected to a replicated sample collection, to assess the variability in the neuston composition of samples from the same site. In total, 86 samples were collected in the first cruise.

The second cruise (March 2015) was conducted only in the South Adriatic area. A total of 21 stations were sampled, 13 corresponding to those of the first cruise (Fig. 1). The smaller number of sampled stations as compared with the 2013 cruise was mainly due to some countries

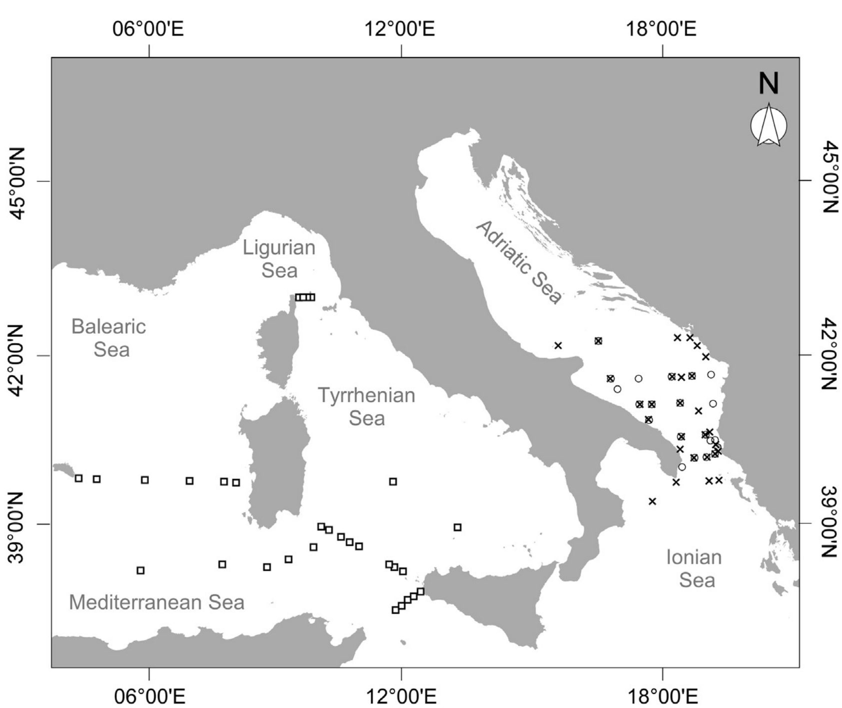


**Fig. 1.** Map of the sampling stations located in the Western Mediterranean (squares) and in the Southern Adriatic (crosses and circles). The stations sampled in the Southern Adriatic in 2013 are identified by crosses, while those sampled in 2015 are identified by empty circles.