Mediterranean Marine Science

Vol 14, No 3 (2013)

Vol 14, No 3 (2013) special issue

Spatio-temporal changes of Munida Rutllanti Zariquiey-Alvarez, 1952 (Decapoda: Galatheidae) in the North-Western Ionian Sea (Central Mediterranean)

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doi: 10.12681/mms.619

Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.619

This work was presented at the 10th Colloquium Crustacea Decapoda Mediterranea, held together with the Summer Meeting of The Crustacean Society in Athens, 3-7 June 2012.

Spatio-temporal changes of *Munida rutllanti* Zariquiey-Alvarez, 1952 (Decapoda: Galatheidae) in the north-western Ionian Sea (Central Mediterranean)

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Handling Editor: Maria Thessalou-Legaki

Received: 24 April 2013; Accepted: 10 September 2013; Published on line: 27 September 2013

Abstract

The spatio-temporal distribution pattern of *Munida rutllanti* in the north-western Ionian Sea has been studied. Data were collected during 14 experimental trawl surveys conducted from 1997 to 2010 as part of the international MEDITS project. The hauls were carried out during day-light hours between depths of 10 and 800 m in the spring season. A progressive increase in the abundance index (N/km^2) of *M. rutllanti* was observed from 2000 to 2008, then a sharp decrease was shown in the last two years. The greatest and lowest abundance indices were observed in the Apulian and central Calabrian sub-areas, respectively. The species was collected between 107 and 795 m in depth, with a significant increase and decrease over time in the maximum and minimum depth of finding, respectively. A highly significant increase over time in the mean carapace length was also observed in the whole study area. The widespread occurrence and increasing abundance of this species in the Ionian Sea could be related to the increase in temperature and the variation in hydrographic conditions which occurred in the Ionian basin during the EMT-BiOS phenomenon.

Keywords: *Munida rutllanti,* Crustaceans, Spatio-temporal distribution, Population structure, Ionian Sea, Mediterranean.

Introduction

Munida rutllanti Zariquiey-Alvarez, 1952 is an Atlanto-Mediterranean species, distributed in the eastern Atlantic from Portugal to Morocco and in the Mediterranean basin both on the western and eastern side (d'Udekem d'Acoz, 1999; Froglia, 2010). Starting from the first occurrence of this species along the Mediterranean coasts of North Africa (Zariquey Alvarez, 1968), for many years the presence of *M. rutllanti* in the Mediterranean has been scarcely recorded in the Alboran and Catalan Seas for the western basin (Garcia Raso, 1985; Abelló *et al*., 1988) and in the Aegean Sea for the eastern one (Koukouras *et al*., 1992; 1998). In the last decade, the increasing occurrence of the species along the Spanish coasts (Abelló *et al*., 2002) and its progressively abundant finding in the rest of the central and eastern Mediterranean have also been described (e.g. Koçak *et al*., 2001; 2008; Kocataş & Katağan, 2003; Froglia & Gramitto, 2005; Politou *et al*., 2005; Froglia *et al*., 2010). In the north-western Ionian Sea, the occurrence of *M. rutllanti* dates back to 1997 but it has been systematically and abundantly caught in this geographic area since 2000 (Maiorano *et al*., 2010).

This species is mainly distributed on the soft bottoms of the shelf and upper slope throughout the Mediterranean, although it has been occasionally collected down to 1209 m in the Alboran Sea (Garcia Raso, 1996). Its depth distribution is generally covered by commercial trawl fishing and it is often associated in the catch with the other two congeneric squat lobsters, *M. intermedia* A. Milne-Edwards & Bouvier, 1899 and *M. tenuimana* G.O. Sars, 1872 (Huguet *et al*., 2005; Politou *et al*., 2005). In recent years, *M. rutllanti* has become the most abundant squat lobster in some Mediterranean basins such as the northern Adriatic Sea where it also outnumbers the most common *M. intermedia* (Froglia *et al*., 2010). Moreover, a rapid and unexpected increase in the commercial trawl catch has also been reported by fishermen along the Apulian coast of the Ionian Sea (unpublished data).

Most of the previous studies on *M. rutllanti* were related to its distribution and abundance within the crustacean assemblages (Koukouras *et al*., 1998; Abelló *et al*., 2002; Politou *et al*., 2005; Ungaro *et al*., 2005). Recently, the increasing occurrence of this species in different Mediterranean areas has improved the knowledge on its population structure (Huguet *et al*., 2005), reproduction (Sanz-Brau *et al*., 1998; Petrić *et al*., 2010) and growth (Petrić *et al*., 2010) but no studies on distribution or abundance over time are available. It has been assumed that the different patterns in the crustacean assemblages as well as the changes in the distribution of the squat lobsters recorded in most areas are related to variations in the environmental parameters that have occurred in recent decades (Huguet *et al*., 2005; Froglia *et al*., 2010). At the end of the 1980s the Mediterranean Sea underwent a major change that encompassed atmospheric, hydrological, and ecological systems and that led to new regime conditions (CIESM, 2000; 2008). The most important and evident phenomenon involved temporary changes in the circulation and thermo-haline structure of the water masses (the so-called Eastern Mediterranean Transient, EMT, and Bimodal Adriatic-Ionian Oscillations, BiOS) that lasted approximately 10 years until 1997 (Klein *et al*., 1999; Manca *et al*., 2003, 2006; Gacic *et al*., 2010). The shift in the water mass circulation primarily regarded the Ionian Sea, the Adriatic Sea and the Levantine basin where marked changes in temperature and salinity were also observed as a consequence.

Thus, the aim of this paper is to identify the spatio-temporal pattern of distribution and abundance of this species during 14 years of observations in the north-western Ionian Sea, and try to explain the dynamics of this species in relation to the EMT-BiOS phenomenon and environmental parameter changes.

Material and Methods

Data collection

Data were collected during 14 seasonal experimental trawl surveys conducted from 1997 to 2010 in the north-western Ionian Sea as part of the international MEDITS project (Bertrand *et al*., 2002). The area examined is between Cape Otranto (southern Apulia) and Cape Passero (south-eastern Sicily), and 4 geographical sub-areas (Apulia, north Calabria, central Calabria and south Calabria) were considered in this study (Fig. 1). The hauls were carried out during day-light hours in the spring season at depths between 10 and 800 m, adopting a depth-stratified sampling design. A commercial motor powered vessel, equipped with an experimental trawl net, with a stretched mesh of 20 mm in the codend (Bertrand *et al*., 2002) was hired for all surveys. The horizontal and vertical opening of the net were measured using the SCANMAR acoustic system (Fiorentini *et al*., 1999).

For each specimen of *M. rutllanti* the carapace length (CL) was measured from the post-orbital socket to the posterior-median edge of the cephalothorax, to the nearest millimetre. Sex was determined both under a stereo-microscope and macroscopically by the position of gonopores and the presence of the first and second pleopods: the first pleopods are absent in females while they are present and modified in males.

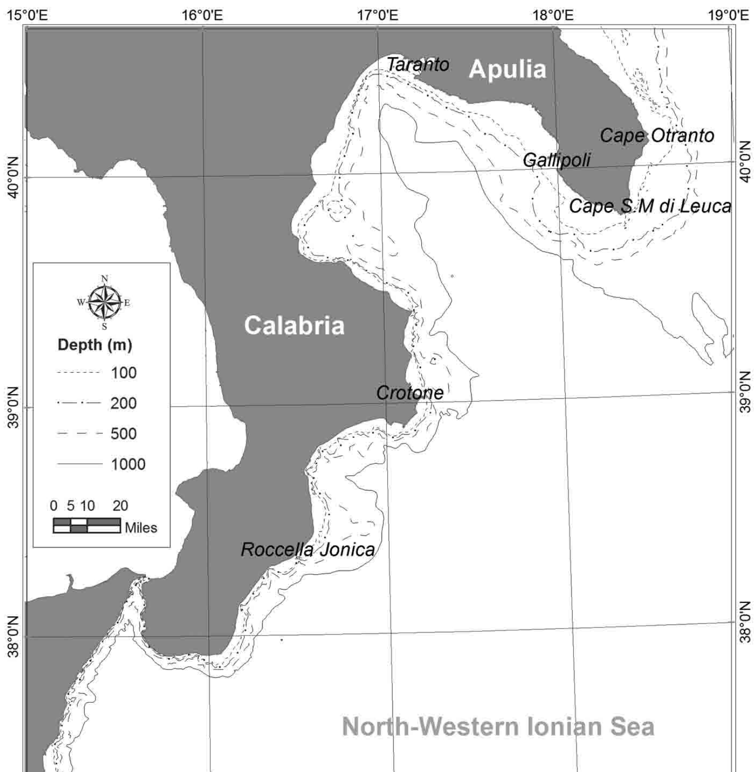

Fig. 1: Map of the study area.

Data processing

Abundance data were standardised to the 'swept surface unit' and the average density index (N/km^2) was computed by survey considering the whole area and geographical sub-areas. The density index of each haul was log transformed to minimize the negative effect caused by extreme values. Then, the change in abundance by depth was evaluated using linear regression. The length-frequency distribution was computed by sex for the whole investigated period and the median CL was calculated on the total population and by sex for each survey. The temporal trends in minimum and maximum depth of occurrence and mean CL throughout the investigated period were also tested using linear regression analysis.

Results

Abundance and distribution

Although *M. rutllanti* has sporadically occurred in the north-western Ionian Sea since 1997, an increase in its abundance was observed from 2000 to 2008 when the maximum average index of 1307 ± 654 N/km^2 (2008) was computed. Then, a sharp decrease was shown in the two successive years (Fig. 2).

Although the increase in abundance was observed in all investigated sub-areas, the greatest abundance indices for a more prolonged period were observed in the Apulian sub-area, where the abundance peak occurred in 2008. The lowest abundance indices for a restricted period of occurrence were computed for the central Calabrian sub-area (Fig. 3).

The species was collected in a wide depth range between 107 and 795 m during the study period although the greatest densities were mainly observed on the upper slope between 200 and 400 m. A significant decrease in abundance with depth was detected across the whole investigated area (Fig. 4). Moreover, a significant increase and decrease in the maximum and minimum depth of finding, respectively, were observed over time (Fig. 5).

Size structure

A total of 11340 females and 11858 males were caught in the whole study area throughout the investigated period. Carapace length ranged from 6 to 18 and from 6 to 20 mm in females and males, respectively. The median sizes in males were generally larger than females (Table 1). With respect to the size distribution in each geographical sub-area, the largest median sizes in both females and males were observed in South Calabria and East Sicily, and the smallest in Central Calabria (Table 1). The overall population structure obtained for the whole area, from 1997 to 2010, showed a bimodal distribution with the presence of both juvenile and adult individuals of both sexes (Fig. 6). A highly significant increase over time in mean carapace length was observed for the whole sampled population in the entire area (Fig. 7).

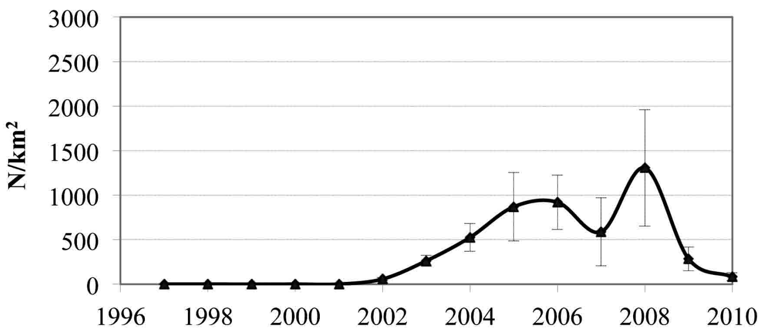

Fig. 2: Temporal trend of abundance (N/km^2) of *M. rutllanti* in the north-western Ionian Sea.

Table 1. Number of individuals (N), minimum, maximum and median carapace length (CL) by sex of *M. rutllanti* caught in the north-western Ionian Sea from 1997 to 2010.

Geographical sub-area		**N**	**CL (mm)** min	max	median
South Calabria and East Sicily	Females	1049	8	18	14
	Males	1160	7	20	15
Central Calabria	Females	633	6	17	10
	Males	575	7	17	10
North Calabria	Females	1818	6	18	12
	Males	2815	6	20	13
Apulia	Females	7840	6	17	14
	Males	7308	6	19	14
Total area	Females	11340	6	18	13
	Males	11858	6	20	14

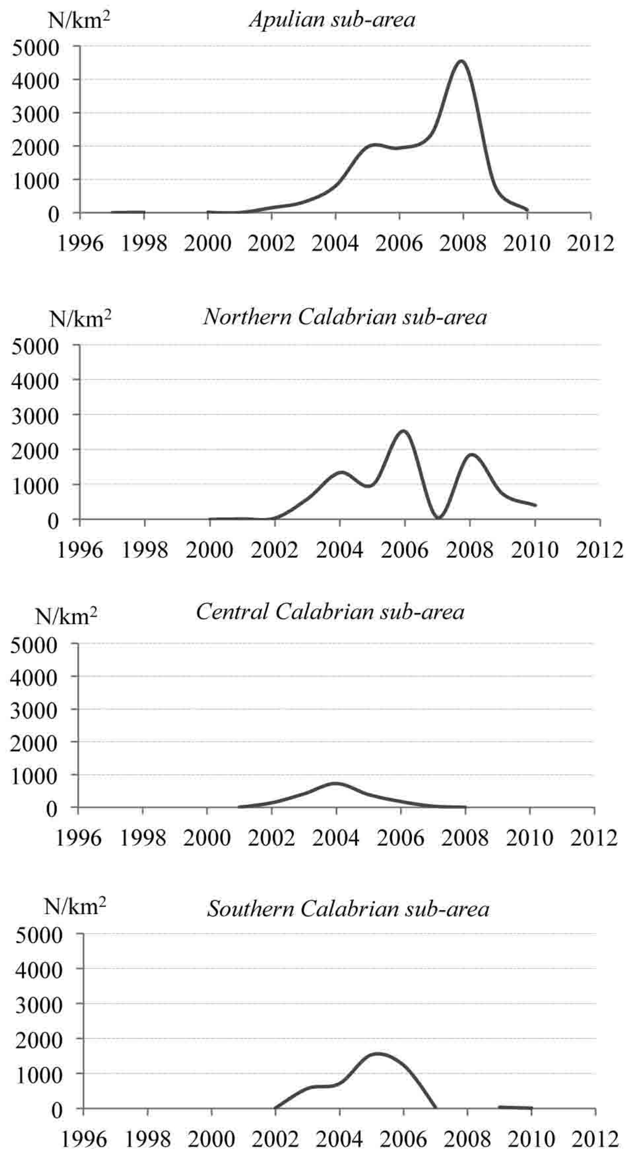

Fig. 3: Temporal trend of abundance (N/km^2) of *M. rutllanti* in four geographical sub-areas of the north-western Ionian Sea.

Discussion

The *Munida* genus is present in the north-western Ionian Sea with 4 species, *M. curvimana, M. intermedia, M. rutllanti* and *M. tenuimana* showing different distribution, abundance and frequency of occurrence (Maiorano *et al*., 2010). In particular, *M. intermedia* was more abundant and frequently occurring than *M. tenuimana* while *M. curvimana* was recordeded only once during the study period. The first species was generally caught on the continental slope and the second one exhibited a wider depth range of distribution, between 142 and 1500 m in depth (Company *et al*., 2004; Maiorano *et al*., 2010). Despite the many trawl surveys carried out in the last 25 years in the north-western Ionian Sea, the finding of *M. rutllanti* in this geographic area only dates back to 1997 and refers to the Apulia sub-area only. The fast spreading of this species in the Ionian basin together with the significant increase over time in depth range of occurrence and size seem to demonstrate a population outburst of *M. rutllanti* in this Mediterranean basin. The available time series on distribution, abundance and population structure reported here is in agreement with the dynamic processes characterizing this squat lobster in the Mediterranean (Abelló *et al*., 2002; Huguet *et al*., 2005; Froglia *et al*., 2010). Its fast increase in the whole north-western Ionian Sea shows a marked geographical pattern. The record of the greatest abundance for several years in the Apulian sub-area seems to present a temporal display quite similar to the adjacent Adriatic Sea (Froglia & Gramitto, 2005; Froglia *et al*., 2010). Presently, *M. rutllanti* is considered a common species in the eastern Mediterranean (Koçak & Katağan, 2008; Koçak *et al*., 2008) and there are well-established populations in the western Mediterranean (Abelló *et al*., 2002; Huguet *et al*., 2005). More recently, *M. rutllanti* has been recorded for the first time in the Ligurian Sea, extending its distribution to the northernmost area of the western Mediterranean (Orsi Relini & Garibaldi, 2012). This subtropical species has been spreading from its original distribution in the warm south-eastern Atlantic into the warmest Mediterranean areas (d'Udekem d'Acoz, 1999) and it has then been increasing rapidly, probably favoured by variations in environmental parameters in the last decades, as assumed by Huguet *et al*. (2005) and Froglia *et al*. (2010). The recent spread of warm-water species is an indication of the relationship between climate change and distribution patterns of Mediterranean biodiversity. Indeed, the warming of the Mediterranean and the tropicalisation of this basin (Bianchi, 2007) has already been observed in different areas where various thermophilic organisms belonging to macroalgae, plankton, invertebrates and fishes, are extending their distribution towards northern areas (Golani *et al*., 2002; CIESM, 2008). An increasing trend of some thermophilic taxa has recently been recorded in the Central Mediterranean where critical changes, mostly regarding coastal or pelagic fish, were recorded in the late 1990s and early 2000s (Azzurro *et al*., 2011). Indeed, the EMT-BiOS-related regime shift recorded in the early 1990s involved sea surface temperature, sea level pressure, surface and deep circulation of water masses, salinity and nutrient changes, primarily regarding the Ionian and Adriatic Seas and the Levantine basin (Civitarese *et al*., 2010; Conversi *et al*., 2010; Vilibić *et al*., 2012).

In the Ionian Sea, the new occurrence of tropical species (Mastrototaro *et al*., 2007; Sion *et al*., 2008) and the increasing abundance of *Sphoeroides pachygaster* has been suggested as being a consequence of the water mass variations occurring in the Ionian basin during EMT-BiOS (Maiorano *et al*., 2010). Moreover, it has also been suggested that the changes in demersal species abundance and faunal assemblage structure is a result of the abovementioned variation in hydrographic conditions as well as fishing pressure (Maiorano *et al*.,

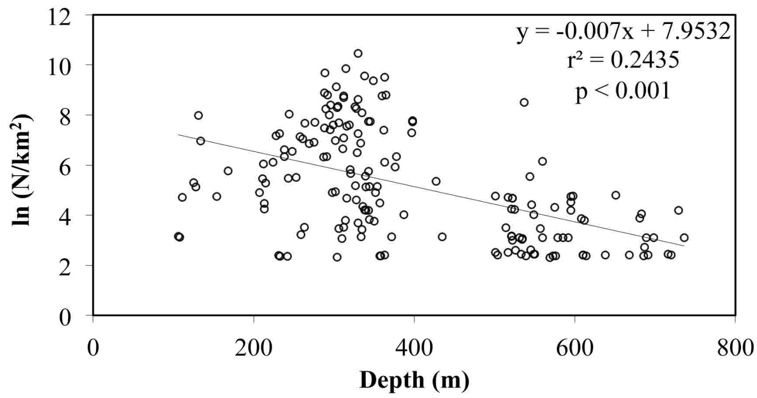

Fig. 4: Scatter plot of abundance (log N/km^2) by depth of *M. rutllanti* caught in the north-western Ionian Sea from 1997 to 2010.

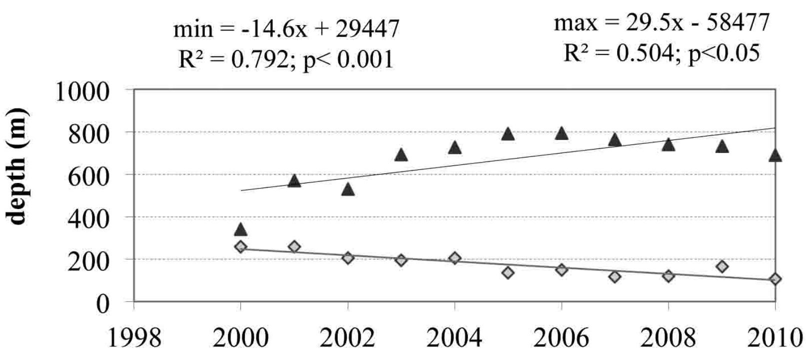

Fig. 5: Minimum and maximum depth of occurrence of *M. rutllanti* in the north-western Ionian Sea.

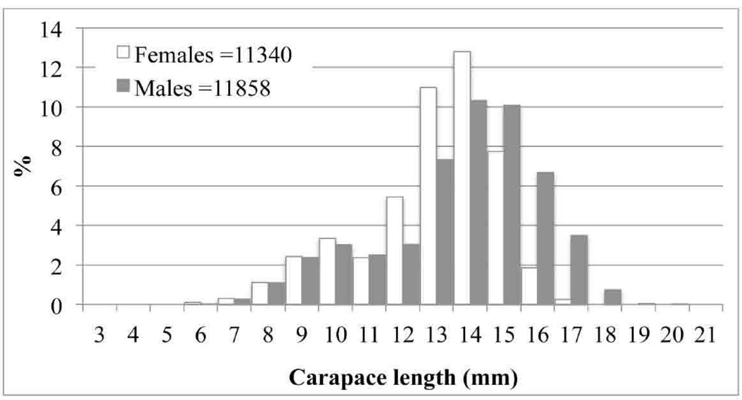

Fig. 6: Length-frequency distribution by sex of *M. rutllanti* caught in the north-western Ionian Sea from 1997 to 2010.

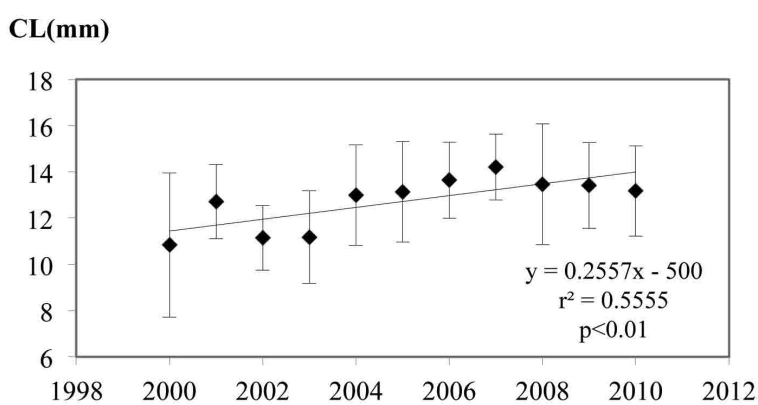

Fig. 7: Temporal trend of the mean length, with relative standard deviation, of *M. rutllanti* caught in the north-western Ionian Sea from 1997 to 2010.

2010; D'Onghia *et al*., 2012). Thus, the widespread occurrence and increasing abundance of *M. rutllanti* in the Ionian Sea could be related to the same environmental processes. Its abundance peak in 2008 indicates a more delayed effect compared to the abovementioned species. However, the phenomenon of competitive realease due to the harvest of commercial species, mostly along the Apulian coast, cannot be excluded.

The population outburst of exotic species in other areas of the Central Mediterranean seems to show the same temporal pattern as *M. rutllanti* in the Ionian area (Azzurro *et al*., 2011). In particular, it is worth noting that the fish *Fistularia commersoni*, after its first occurrence in 2000, showed a fast increase in the Strait of Sicily starting from 2003-2004 and then a sharp decrease in the following years, with the same increasing temporal display as *M. rutllanti* (Azzurro *et al*., 2011). Furthermore, despite the important changes in water circulation in the Mediterranean basin as a whole, it is possible that their direct effects on several marine ecosystem components are detected differently at local geographic level. Indeed, the highest density of *M. rutllanti* observed in the Apulian sub-area could be supported by the local hydrodynamic regime with a main deep current flowing from the Adriatic Sea into the northern Ionian, providing a continuous supply of nutrients and particulate organic matter to the Apulian Ionian area (Budillon *et al*., 2010).

The wide depth range of finding reported in this study shows a distribution of *M. rutllanti* in the north-western Ionian basin that is deeper than in other Mediterranean areas, even though the highest densities have been confirmed for this species on the upper slope (Abelló *et al*., 2002; Huguet *et al*., 2005; Politou *et al*., 2005). Several studies suggest that climate change generally causes shifts in species range distributions and, particularly in response to warmer conditions, marine fishes and invertebrates tend to shift their distribution into deeper waters and/or to higher latitudes (Doney *et al*., 2012). Moreover, the present results could also be related to the change in the abundance and distribution of congeneric species with respect to the appearance and the outburst of *M. rutllanti* in the Ionian basin. In the first year of its occurrence, this squat lobster was only recorded on the upper slope and successively on deeper bottoms but, however, within the limit of its distribution in the other Mediterranean areas (Abelló *et al*., 2002; Politou *et al*., 2005). Starting from 2003, the fast increasing abundance of *M. rutllanti* outnumbers the previously most common *M. intermedia* and was followed by a significant decrease of both the other two squat lobsters *M. intermedia* and *M. tenuimana*, generally covering a wider bathymetric range. These last two species have almost been replaced by *M. rutllanti*, which has probably occupied part of their ecological niches, enlarging its bathymetric distribution towards the limits of its spatial niche boundaries. Thus, the competitive release could have regarded the species of *Munida* genus distributed in the north-western Ionian Sea. The probably shorter life span of *M. rutllanti* compared to the other *Munida* species, its early maturation and multiple spawning (Sanz-Brau *et al*., 1998; Froglia & Gramitto, 2005; Huguet *et al*., 2005; Petrić *et al*., 2010) could have favoured its demographic outburst in the Ionian Sea.

As regards the size structure, the present results are in agreement with previous studies confirming a wider spectrum of size in males than in females and the presence of few modal components in both sexes (Huguet *et al*., 2005; Petrić *et al*., 2010). Moreover, the largest median sizes were recorded in both sexes in the Southern Calabrian East Sicily sub-area where the smallest fishing pressure in the whole north-western Ionian Sea is observed, together with the presence of two marine protected areas.

Acknowledgements

This study benefited from data recorded during the MEDITS project financed by the Italian Government and the EU DG MARE project. Elaborations were carried out as part of the Italian PRIN OBAMA project (Ministry of University and Research-MIUR) and CoCoNet EU 7FP.

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