A REVISION OF THE "NORTHERN GUEST" OSTRACODA (CRUSTACEA)
OCURRENCE IN THE QUATERNARY OF THE MEDITERRANEAN AREA

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ABSTRACT: Faranda C. & Gliozzi E., A revision of the "northern guest" Ostracoda (Crustacea) occurrence in the Quaternary of the Mediterranean area.

In this paper the revision of the "northern guest" ostracods widespread in the Mediterranean area during Quaternary time is proposed. The abundant literature on this topic lists up to twenty-three species. They have been critically revised and a list of only twelve true "northern guests" is provided: Acanthocythereis dunelmensis (NORMAN, 1865), Bythocythere turgida SARS, 1866, Bythocythere zeelandica (B. turgida) NORMAN, 1865, Cythere lutea Müller 1785, Cythere depressum (BRADY & NORMAN, 1889), Cytheropteron punctatum BRADY, 1868, Cytheropteron testudo SARS, 1870, Hemicythere vilosa (SARS, 1865), Paradoxostoma abbreviatum SARS, 1866, Paradoxostoma ensiforme BRADY, 1866, Paradoxostoma tenuissimum (NORMAN, 1869) and Semicytherura anguifera (BRADY, 1868). These species are generally rare, being found with few specimens and mainly in one locality. Only Cytheropteron testudo and Cytheropteron punctatum have been reported with a wide geographical distribution in Italy and in the Aegean Sea. The twelve "northern guest" ostracods entered the Mediterranean at different times, being more abundant in the Early Pleistocene Sicilian substage.

In this paper the revision of the "northern guest" ostracods widespread in the Mediterranean area during Quaternary time is proposed.

RIASSUNTO: Faranda C. & Gliozzi E., Revisione della presenza dell’ospite freddo Ostracoda (Crustacea) nel Quaternario dell’area mediterranea.

In questo lavoro viene proposta la revisione critica degli ostracodi “ospiti nordici” che si diffusero nel Mediterraneo durante le fasi climatiche fredde che caratterizzarono il Quaternario. L’abondante letteratura esistente su questo argomento, elenca ventitré specie di ospiti nordici, in seguito alla presente revisione questo numero è ridotto a sole dodici specie di ostracodi che possono essere considerati veri “ospiti nordici”: Acanthocythereis dunelmensis (NORMAN, 1865), Bythocythere turgida SARS, 1866, Bythocythere zeelandica (B. turgida) NORMAN, 1865, Cythere lutea Müller 1785, Cythere depressum (BRADY & NORMAN, 1889), Cytheropteron punctatum BRADY, 1868, Cytheropteron testudo SARS, 1870, Hemicythere vilosa (SARS, 1865), Paradoxostoma abbreviatum SARS, 1866, Paradoxostoma ensiforme BRADY, 1866, Paradoxostoma tenuissimum (NORMAN, 1869) e Semicytherura anguifera (BRADY, 1868). Queste specie sono generalmente rare sia nelle associazioni, dove spesso sono rappresentate da pochi specimini, sia come presenza nell’area mediterranea, essendo prevalentemente segnalate in una sola località. Solo Cytheropteron testudo e Cytheropteron punctatum sembrano avere una distribuzione geografica piuttosto ampia, sia nel Mediterraneo centrale (Italia) sia in quello orientale (Mare Egeo). Le dodici specie di ostracodi “ospiti nordici” migrarono nel Mediterraneo in tempi quaternari diversi e risultano più abbondanti in corrispondenza del sottopiano Siciliano. L’unico studio sulle ostracodfaune marine dell’ultimo Pleniglacial ha permesso di registrare la presenza di C. testudo anche nella parte alta del Quaternario. E’ possibile che a questa specie ne possano venire aggiunte almeno altre due (P. tenuissimum and B. turgida) le cui valve isolate, prive di parti molli, sono state rinvenute nel fondali del Mediterraneo insieme ad ostracodfaune viventi.

Keywords: Marine ostracods, northern guests, Mediterranean, Quaternary, stratigraphic distribution.

Parole-chiave: ostracodi marini. Ospiti nordici, Mediterraneo, Quaternario, distribuzione stratigrafica.

1. INTRODUCTION

At the 18th International Geological Congress (London, 1948), the lower boundary of the Quaternary Era (Tertiary/Quaternary boundary) was established “at the horizon of the first indication of the climatic deterioration in the Italian Neogene succession” (PILLANS & NAISH, 2004, p. 2272). Consistent with this recommendation, the basal part of the Quaternary included the “Calabrian”, a marine Mediterranean stage defined by Gig-noux (1910) at S. Maria di Catanzaro (Calabria, southern Italy) and originally assigned by this author to the Pliocene. In fact from the S. Maria di Catanzaro outcrop some “northern guest” molluscs such as Arctica islandica were collected, and their presence indicated a climatic cooling, as pointed out by Suess (1883-1909). Several studies followed in which numerous “northern guest” molluscs, foraminifers and ostracods were listed, and their appearance in the Mediterranean area occurred in different Pleistocene times (RUGGIERI, 1975, 1977,
1980; Ruggieri & Sprovieri, 1977; Malatesta & Zarella, 1986). Recently, through the stable isotope analysis of marine foraminifers, a first global cooling was detected in correspondence to the Marine Isotopic Stage 100 (Raymo et al., 1989), which falls about 60 ka after the Middle/Late Pliocene boundary (Piacenzian/Gelasian GSSP at Monte S. Nicola section (Sicily) (Rio et al., 1998). This discovery led the scientific community to discuss the possibility to move the Pliocene/Quaternary boundary down to the base of the Gelasian. After around twenty years of heated debates (Cita & Castadori, 1994 with references; Vai, 1996 with references; Sce et al., 1997 with references), in 2007 the INQUA and ICS stratigraphic commissions have jointly proposed a new stratigraphic assessment of Pliocene and Quaternary (OGG, 2007) (Fig. 1), ratified by the ICS Commission during May 2009 (Cita, 2009; Mascarelli, 2009). In this new global stratigraphic scheme, the Neogene/Quaternary boundary corresponds to the base of the Gelasian Stage (2.588 Ma), which represents the first stage of the Quaternary System and also the first stage of the Pleistocene series (Giibard et al., 2010). At present, the Quaternary system includes the ratified or proposed standard stages Gelasian, Calabrian, Ionian and Tarantian (Rio et al., 1998; Cita et al., 2006). Thus, in this paper, also the “cold” ostracods that entered the Mediterranean during the Gelasian are considered Quaternary “northern guests”, since, as redefined by Ruggieri (1977), a species can be considered a true Mediterranean “northern guest” if it is at present living outside the Mediterranean area during the “cold” global climatic oscillations. Moreover, we consider stratigraphically useful to maintain the subdivision of the Calabrian stage into the Santernian, Emilian and Sicilian Mediterranean regional substages, as defined by Ruggieri et al. (1984) for the Mediterranean.

2. THE “NORTHERN GUEST” OSTRACODS IN THE LITERATURE: A CRITICAL REVISION

The first author who signalled the presence of “cold” ostracods in the Mediterranean was Ruggieri (1952a) who recovered a fragment of Cytheropteron testudo SARS 1870 from the lower Pleistocene grey sands of Imola (northern Italy). Since then, Ruggieri and other authors have discussed the presence of “northern guest” ostracods in several papers (Ruggieri, 1956, 1959, 1971, 1973, 1974, 1975, 1976, 1977, 1980; Ruggieri et al., 1976, 1977; Ruggieri & Sprovieri, 1977; Sissingh, 1976; Faranda & Gliozzi, 2008), giving a rather long list of species:

- Actinothyrineis dunelmensis (Norman, 1865)
- Argilloecia cylindrica SARS, 1866
- Bythocythere dromedaria SARS, 1866
- Bythocythere insignis SARS, 1869
- Bythocythere zetlandica Athersuch, Horne & Whittaker, 1983
- Clithia keiji Neale, 1975
- Cythere lutea Muller, 1785
- Cytheropteron depressum (Brady & Norman, 1889)
- Cytheropteron latissimum (Norman, 1865) = Cytheropteron sp. ex gr. C. latissimum (Norman, 1865)
- Cytheropteron punctatum Brady, 1868
- Cytheropteron testudo Sars, 1869
- Hemicythere virosa (Sars, 1866)
- Leptocythere macallana (Brady & Robertson, 1869)
- Macrocypris minna (Baird, 1850)
- Muellerina problematica (Seguenza, 1884)
- Muellerina sp. nov. cf. M. abissicola (Sars, 1866)
- Nereina (?) sp. ind.
- Paradoxoxtoma abbreviatum Sars, 1866
- Paradoxostoma ensiforme Brady, 1868
- Semicytherea angulata (Brady, 1868)
- Semicytherea producta (Brady, 1868)
- Thaerocythere (?) sp.
- Xiphichilus tenuissimus (Norman, 1869)

The validity as “northern guests” of some of these species was discussed in several papers by Ruggieri and by other authors. In particular:

- Argilloecia cylindrica Sars, 1866 - some valves recovered by Colalongo (1966) at Le Castella (Calabria, southern Italy) and referred to this northern species (Colalongo, 1966; Ruggieri, 1971) were subsequently revised by Greco et al. (1974 p. 174) and assigned to the species Zabathocythere antarctica (Maddocks), the specimens from Le Castella and Monasterace (Calabria, Southern Italy of Greco et al. (1974)) have been recently included by Aiello, Barra & Bonaduce (1996a) within their new species Anchistrocheles interrupta

- Bythocythere dromedaria Sars, 1866 - Ruggieri (1966) assigned to this species some juvenile valves from the Ṣanternian of Talignano (Parma, northern Italy) and from the Emilian of Sciacca (Sicily, near Bar Maddalena) afterwards, Ruggieri (1973) reported immature valves from Pliocene deposits (no localities are specified), thus, this author cancelled the species from its “northern guest” list. We have seen the Ruggieri Ostracod Collection (ROC) stored at the Paleontological Museum “G.G. Gemmellaro” (Palermo University), but, at present, it has not been possible to check the Pliocene specimens since they are not in the collection, whereas the specimen from Talignano (ROC No. 1651) is not a Bythocythere but a juvenile of Pseudocythere (Fig. 2).

- Bythocythere insignis Sars, 1869 - According to Ruggieri (1973), the valves recovered at Ficarazzi (Ruggieri, 1956) and Acqua dei Corsari (Palermo, Sicily) and referred to this species must be ascribed to Moioceratina mediterranea Sissingh, 1972

- Macrocypris minna (Baird, 1850) - Ruggieri (1973) doubtfully included this species in its list of “northern guests” because it was recorded only by Seguenza (1883-86) and never recovered again. Indeed, Seguenza dubitably referred an anterior fragment of a valve of Macrocyprididae to Macrocypris minna? and he did not provide any illustration.

- Muellerina sp. nov. cf. M. abissicola (Sars, 1866) - Ruggieri (1973) recognised a new species of Muellerina, from the Emilian of Foce del Verdura (Sciacca, Sicily) and compared it with the northern species M. abissicola (Sars 1866) suggesting that the Italian specimens could be either a subspecies of this taxon or a new species phylogenetically linked to it. Afterwards, Ruggieri (1975) referred Muellerina sp. nov. cf. M. abissicola to the fossil species Muellerina problematica
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Fig. 1 - Magnetostratigraphy, chronostratigraphy, biostratigraphy and oxygen isotope stratigraphy of the Quaternary System (isotopic scale from LOURENS et al., 2004).

(SEGUENZA, 1884) but, because of its affinity with M. abyssicola, he continued to consider this species as a northern guest (RUGGIERI, 1977, 1980, 1991; RUGGIERI & SPROVERI, 1977) even if it is a fossil species. YASSINI (1979) recovered Muellerina latimarginata (SPEYER, 1863) (=M. problematica) in the Piacenzian-Gelasian of Algeria and, more recently CIAMPO (1992) recovered M. problematica at S. Todaro (Calabria, southern Italy) in the Zanclean (MP 3), thus, this species can no longer be considered a Quaternary “northern guest”.

Leptocythere macallana (BRADY & ROBERTSON, 1869) - RUGGIERI et al. (1976, 1977) included this spe-
In his paper of 1977, RUGGIERI changed the attribution in the Sicilian deposit of Acqua dei Corsari (Ficarazzi, 1865) to (Santernian). RUGGIERI (1977) and RUGGIERI & SPROVERI (1975) recorded the presence of the Mediterranean species Leptocythere levis (MÜLLER, 1894) as a younger synonym of this species. RUGGIERI & D'ARPA (1976) reported the presence of a younger synonym of this species, RUGGIERI (1977) himself stated that it could not be considered a true "northern guest" ostracod.

Unfortunately, Ruggieri did not clearly characterise it taxonomically, nor did he illustrate it. The slide of this species among the ostracod "northern guests" because it had been recovered from several Calabrian deposits of Calabria and Sicily (RUGGIERI, 1952b; RUGGIERI et al., 1976, 1977). Athersuch et al. (1989) consider the Mediterranean species Leptocythere levis (MÜLLER, 1894) as a younger synonym of this species. RUGGIERI & D'ARPA (1993) did not agree with this position. However, they recovered L. macallana in the Piacenzian of Altavilla (Sicily), thus the species cannot be included any more among the Quaternary "northern guests".

Cytheropteron latisimum (Norman, 1865) = Cytheropteron sp. ex gr. C. latisimum (NORMAN, 1865) - RUGGIERI (1975) records the presence of this species in the Sicilian deposit of Acqua dei Corsari (Ficarazzi, Sicily). In his paper of 1977, RUGGIERI changed the attribution of this species, considering it a species of Cytheropteron different although similar to C. latisimum. Unfortunately, Ruggieri did not clearly characterise it taxonomically, nor did he illustrate it. The slide of this species within the Ruggieri ostracod collection is empty.

Clithia kejii NEALE, 1975 - This species occurs for the first time in the Mediterranean area in the Calabrian (Santernian). RUGGIERI (1977) and RUGGIERI & SPROVERI (1977) included this species within the "cold species" which migrated into the Mediterranean in correspondence with the onset of the first Pleistocene cooling episode. RUGGIERI (1977) himself stated that it could not be considered a true "northern guest" since the species adapted to the Mediterranean climatic conditions and it is still living in this region. Clithia kejii was recovered by CARBONNEL & BALLESIO (1982) in the Piacenzian deposits of the Rhône valley, thus it cannot be considered as either a Quaternary "northern guest" nor a "émigrés du Nord attardés" sensu GIGNOUX (1913) (RUGGIERI, 1977). The specimen hosted as Clithia kejii (SARS, 1866) was recovered by CARBONNEL & BALLESIO (1982) in the Piacenzian of Altavilla (Sicily), (G.O.C. N° 2593C), from which it is impossible to confirm the identification. Thus, for the moment, the presence of S. producta in the Mediterranean during Quaternary is dubitative.

In conclusion, only the following 11 species, reported with the updated nomenclature, can be considered true "northern guest" ostracods: Acanthocythereis dunelmensis (NORMAN, 1865) - Bythocythere zelandica Athersuch, HORNE & WHITESIDE, 1983 - Cythere lutea MÜLLER, 1785 - Cytheropteron depressum (BRADY & NORMAN, 1889) - Cythereopteron testudo SARS, 1866 - Hemicythere villosa (SARS, 1866) - Paradoxostoma abbreviatum SARS, 1866 - Paradoxostoma erioforme BRADY, 1868 - Paradoxostoma tenuissimum (NORMAN, 1869) - Semicytherura angulata (BRADY, 1868) - Talignano (Parma). La barra corrisponde a 0.1 mm. This specimen is stored in the ROC slide N° 1651 under the name Bythocythere dromedaria - Talignano (Parma). This specimen is stored in the ROC slide N° 1651 with the name Bythocythere dromedaria - Talignano (Parma). The bar corresponds to 0.1 mm.

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Acanthocythereis dunelmensis (NORMAN, 1865) (Fig. 3)

In any case, the Sicilian valves are completely different from the Recent arctic species Thaerocythere crenulata (SARS, 1866). The same specimens cannot be referred to the arctic genus Nereina MANDELDSTAM, 1957 because the hinge is different, smooth in Nereina but with a crenulated bar in the Valle del Belice specimens. Thus, the doubtful attribution of these valves as a possible "northern guest" cannot be accepted.

Following our revision, the specimen hosted as Thaerocythere (?) in the Mediterranean area in the Calabrian (Norman, 1865) = Cytheropteron sp. ex gr. C. latisimum (NORMAN, 1865) - RUGGIERI (1975) records the presence of this species in the Sicilian deposit of Acqua dei Corsari (Ficarazzi, Sicily). In his paper of 1977, RUGGIERI changed the attribution of this species, considering it a species of Cytheropteron different although similar to C. latisimum. Unfortunately, Ruggieri did not clearly characterise it taxonomically, nor did he illustrate it. The slide of this species within the Ruggieri ostracod collection is empty.

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This specimen is stored in the ROC slide N° 1651 under the name Bythocythere dromedaria - Talignano (Parma). The bar corresponds to 0.1 mm.

3. STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION OF THE QUATERNARY "NORTHERN GUEST" OSTRACODS IN THE MEDITERRANEAN AREA

Acanthocythereis dunelmensis (NORMAN, 1865) (Fig. 3)

1865 Cythereis dunelmensis sp. n. - Norman, pp. 22, Pl. 7, Figs. 1-4.
1967 Acanthocythereis (?) dunelmensis (Norman) - Hazel, p. 34.
1969 Paradoxostoma tenuissimum (Norman) nov. comb. - Yasmini, p. 49.
1977 Acanthocythereis dunelmensis (Norman) nov. comb. - Ruggieri, p. 83, Fig. 1.
1989 Acanthocythereis dunelmensis (Norman) nov. comb. - Athersuch et al., pp.132-134, Fig. 52; Pl. 3, Fig. 10.
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Recent distribution: S. Baltic Sea, Öres, Bohuslän, N. Norway, Iceland and Arctic Seas, Shetlands, NE British Isles, East Greenland (ATHERSUCH et al., 1989; MALZ, 1989; HANSSON, 1998; FRENZEL et al., 2010); Hornsund (South Spitsbergen) (MACKIEWICZ, 2006); Laptev Sea (N. Russia) (STEPANOVA et al., 2003, 2007, 2010).

Ostracod bioprovince: Celtic - Arctic (Fig. 4)
Ecology: It inhabits the marine inner outer shelf environment (50-100 m), in polyhaline-euhaline conditions and water temperatures that range from -2 to 13 (19)°C (WILKINSON, 2005; STEPANOVA et al., 2007, 2010; FRENZEL et al., 2010).

Fossil distribution in the Mediterranean:
Calabrian (Sicilian): Belice, (Sicily) (RUGGIERI, 1977, 1980).

**Bythocythere turgida SARS, 1866**

(Fig. 5)

1866 Bythocythere turgida sp. nov. - SARS, p. 84, Pl. 107, Figs. 1-12.

*Bythocythere turgida* is a problematic species. The original drawings by SARS (1866, 1928) are the only available illustrations of this species. AITHERSUCH et al. (1983), revising the Bythocythere species from the British coasts, split this species into three different taxa: *B. turgida*, at present distributed only on the Norwegian coasts, *B. robinsoni* AITHERSUCH, HORNE & WHITTAKER, 1983, and *B. bradleyi* AITHERSUCH, HORNE & WHITTAKER, 1983, living only in the British waters. Unfortunately these Authors did not illustrate *B. turgida* s.s. MALZ & JELLINEK (1984) agree with AITHERSUCH et al. (1983) and discuss the possible attribution of their specimen to *B. turgida*. In the present paper we consider the specimen illustrated by MALZ & JELLINEK (1984) from the Calabrian (Emilian) of Peloponnesus (Greece) as males of…
Fig. 5 - *Bythocythere turgida*: (a) left valve from Breman, 1976; (b) present geographical distribution (dark grey line), early Pleistocene distribution in the Mediterranean area (black dot), Last Glacial Maximum distribution in the Mediterranean (white circle). Bar corresponds to 0.1 mm.

*Bythocythere turgida:* (a) valva sinistra da Breman, 1976; (b) distribuzione geografica attuale (linea grigio scura), distribuzione nel Meditarrenano durante il Pleistocene inferiore (punti neri) e durante il Pleniglaciale (cerchi bianchi). La barra corrisponde a 0.1 mm.

*B. puncticulata* RUGGIERI, 1976. Even the specimen from the Zanclean of Bou Isma il (Algeria) illustrated as *Bythocythere turgida* by Y ASSINI (1979) could be a female of the same species.

*Bythocythere turgida* specimen from Partanna (Sicily, early Calabrian) recovered in the ROC slide N° 2526 is not referable to this species but to a juvenile male of *B. puncticulata* RUGGIERI, 1976 (Fig. 6).

The inclusion of *B. turgida* within the list of the living Mediterranean species (AIELLO et al., 1995) is due to the recovery of some loose valves from the Adriatic and Tyrrenian seas (BONADUCE et al., 1976, 1983; BREMAN, 1976; ARBULLA et al., 2001, 2004). According to RUGGIERI (1976) the specimens collected by Breman in the Adriatic Sea must be considered as subfossil and referable to the Last Pleniglacial Maximum migration. We suppose that also the BONADUCE et al. (1976) specimens from the same sea were subfossil. ARBULLA et al. (2001, 2004) recover the few juvenile valves of *B. turgida* from La Maddalena (Sardinia) in a sample at 2-7 m of depth. Such shallow depth lead us to infer that these specimens too are subfossil.

In conclusion, we consider *Bythocythere turgida* as a true “northern guest”.


*Ostracod bioprovince:* Norwegian - Arctic (Fig. 4)

**Ecology:** According to Elofson (1941) it is a polyhaline-euhaline species that inhabits shallow to rather deep waters (20-140 m)

**Fossil distribution in the Mediterranean:**
- Gelasian: Castellarquato (Piacenza, northern Italy) (RUGGIERI, 1976)
- Tarantian (Last Pleniglacial): Adriatic Sea (BONADUCE et al., 1976; BREMAN, 1976)
- Tyrrhenian Sea (Maddalena Island) (ARBULLA et al., 2001; 2004)

Western Mediterranean Basin (near Algerian coast) (BONADUCE et al., 1983)

*Bythocythere zetlandica* AITHERSUCH, HORNE & WHITTAKER, 1983 (Fig. 7)

1983 *Bythocythere zetlandica* sp. nov. - Athersuch, Horne & Whittaker, p. 73, Figs. 5c, 41-n; Pl. 2, Figs. 5-8.

In the ROC slide N° 856 a broken juvenile specimen is stored labelled *Bythocythere* cf. *B. zetlandica* collected from the Gelasian Capocolle clays (Forlì, northern Italy) (Fig. 8). We have revised it and we prefer to leave it in open nomenclature since it does not seem a juvenile of *B. zetlandica*.

Recent distribution: Shetlands, N. Britain (ATHERSUCH et al., 1989; HANSSON, 1998).

*Ostracod bioprovince:* Celtic (Britannic) (Fig. 4)

Fig. 6 - *Bythocythere puncticulata*: left juvenile male valve. This specimen is stored in the ROC slide N° 2526, Partanna (Sicily, early Calabrian), labelled as *Bythocythere* cf. *B. turgida*. Bar corresponds to 0.1 mm.

*Bythocythere puncticulata:* valva sinistra maschile giovane. L'esemplare è conservato nella Collezione Ostracodi Ruggieri teca N° 2526, Partanna (Sicilia, Calabriano inferiore) con il nome *Bythocythere* cf. *B. turgida*. La barra corrisponde a 0.1 mm.
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Bythocythere zetlandica: (a) left valve from Monte Mario (Roma, Latium), Santernian age; (Gliozzi’s Ostracod Collection (GOC) slide N° M83/4/15). (b) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

Fig. 7 - Bythocythere zetlandica: (a) valva sinistra da Monte Mario (Roma, Lazio), età Santerniano; (Collezione Ostracodi Gliozzi teca N° M83/4/15). (b) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri) La barra corrisponde a 0.1 mm.

Ecology: inner circalittoral waters around British coasts (ATHERSUCH et al., 1989)

Fossil distribution in the Mediterranean:

Calabrian (Santernian): Monte Mario (Rome, central Italy), from the 2° A. islandica level (FARANDA & GLIOZZI, 2008).

Cythere lutea O.F. MÜLLER, 1785

1785 Cythere lutea sp. n. - O.F. MÜLLER, p. 65, Pl. 7, Figs. 3-4.
1818 Cytherina lutea (O.F. MÜLLER) nov. comb. - LAMARCK, p. 125.
1941 Cythere lutea O.F. MÜLLER - SYLVESTER-BRADLEY, p. 27, Figs. 15-18 (with full synonymy)

Recent distribution: Kieler Bucht, Öres, Bohuslän, Bergen, N. Norway, Iceland and Arctic Seas, Shetlands, SW British Isles, Scilly Isles, W France (HANSSON, 1998; FREIWALD et al., 1998; MACKIE-WICZ, 2006); Kent coast (Isle of Thanet) (BRUCE, 2002); North Yorkshire (HULL, 1998); from S. Norway to N France (ATHERSUCH et al., 1989); subfrigid to mild temperate waters of the Atlantic and Pacific Ocean (HANAI, 1977). A subspecies (Cythere lutea omotenipponica HANAI, 1959) reaches the warm temperate climatic zone along the Pacific coast of Japan (HANAI, 1977).

Ostracod bioprovince: Celtic - Arctic (Fig. 4)

Ecology: The species inhabits shallow waters (30-50 m) with sandy bottom or populated by coralline algae. It withstands meso- to euhaline salinities and a wide range of temperature (-2 to 22°C) (FREIWALD et al., 1998; FRENZEL et al., 2010).

Fossil distribution in the Mediterranean:

Calabrian (Santernian): Monte Mario (Rome, central Italy), from the 2° A. islandica level (FARANDA & GLIOZZI, 2008).

Cytheropteron depressum BRADY & NORMAN, 1889

1889 Cytheropteron depressum sp. n. - BRADY & NORMAN, p. 447, Pl. 34, Figs. 39-42.


Ostracod bioprovince: Celtic (Britannic) (Fig. 4)

Ecology: Inner circalittoral marine environment (ATHERSUCH et al., 1989)

Fossil distribution in the Mediterranean:

Calabrian (Santernian): Monte Mario (Rome, central Italy), from the 2° A. islandica level (FARANDA & GLIOZZI, 2008).

Fig. 8. Bythocythere sp.: left juvenile broken valve. This specimen is stored in the ROC slide N° 856 under the name Bythocythere cf. B. zetlandica - Gelasian Capocolle clays (Forlì, northern Italy). Bar corresponds to 0.1 mm.

Bythocythere sp.: valva sinistra giovanile rota. Questo esemplare è conservato nella Collezione Ostracodi Ruggieri teca N° 856 col nome Bythocythere cf. B. zetlandica - Gelasiano, argille di Capocolle (Forlì, Italia settentrionale). La barra corrisponde a 0.1 mm.
**Cytheropteron punctatum** BRADY, 1868

(Fig. 11)

1868 *Cytheropteron punctatum* nov. sp. - BRADY, p. 449, Pl. 34, Figs. 45-48.


Ostracod bioprovince: Celtic - Norwegian (Fig. 4)

Ecology: PENNEY (1993) collected this species from the silty bottom of the Norway Channel at a depth comprised between 190 and 270 m, bottom temperature between 6.5-7°C, and euhaline salinity.

Fossil distribution in the Mediterranean:

Calabrian: Tavoliere delle Puglie (southern Italy) (RUGGIERI, 1973).


Fossil distribution in the Mediterranean:

Cala Bianca (Marina di Camerota, Campania, Calabrian (Santernian): Valle del Tronto (Fig. 12)

Calabrian: Vrica (Calabria, southern Italy) (RUGGIERI, 1994).

Calabrian (Emilian): Vrica (Calabria, southern Italy) (COLALONGO & PASINI, 1980; PASINI & COLALONGO, 1994).

Calabrian (Sicilian): Le Castella (Calabria, southern Italy) (RUGGIERI, 1971).

Gelasian: M. S. Nicola (Sicily) at 68 m (sample 35) (AIELLO et al., 1996b, 2000; BONADUCE & SPROVIERI, 1984).


Rhodes (Greece, Aegean Sea) (MOSTAFAWI, 1989).

Zakynthos (Greece, Ionian Sea) (TSAPRALIS, 1981).

Calabrian (Santernian): Vrica (Calabria, southern Italy), about 10 m above the sapropel e (COLALONGO & PASINI, 1980; PASINI & COLALONGO, 1994).

Ribera (southern Sicily) (RUGGIERI, 1977).

Cosenza (Calabria, southern Italy) (RUGGIERI, 1952b).

Imola (northern Italy) (RUGGIERI, 1952a, 1975).

Mar Piccolo (Taranto, southern Italy) (CAMPO, 1971).

Porto Recanati (Ancona, central Italy) (RUGGIERI, 1971).

Località “il Carmine” (Crotone, Calabria, southern Italy) (RUGGIERI, 1952a).

Località in destra del Verde (Sciaccu, Sicily) (RUGGIERI, 1971).

Calabrian (Sicilian): Le Castella (Calabria, southern Italy) (COLALONGO & PASINI, 1980; PASINI & COLALONGO, 1994).

S. Maria di Catanzaro (Calabria, southern Italy) (SISSINGH, 1973a).


Mar Piccolo (Taranto, southern Italy) (CAMPO, 1971).

Porto Recanati (Ancona, central Italy) (RUGGIERI, 1971).

Località “il Carmine” (Crotone, Calabria, southern Italy) (RUGGIERI, 1952a).

Località in destra del Verde (Sciaccu, Sicily) (RUGGIERI, 1971).

Pizzo Longo (Crotone, Calabria, southern Italy) (this paper, together with G. truncatulinoides excelsa).

Tarantean (Last Pleniglacial): Gulf of Taranto (MONCHARMONT-ZEI et al., 1985)

Adriatic Sea (BREMAN, 1976)

**Hemicythere villosa** SARS, 1866

(Fig. 13)

1866 *Hemicythere villosa* nov. sp. - SARS, p. 173, Pl. 105, Fig. 1.

Recent distribution: Lofoten, Spitsbergen, Koster Channel, Hardangerfjord (HANSSON, 1998); Laptev Sea (N. Russia) (STEPANOVA et al., 2003); Sarsenby Sound, W Greenland (WATLEY et al., 1996; MACKIEWICZ, 2006); Murray Island (E Greenland), Newfoundland (BENSON et al., 1984), Norwegian coast down to the Skagerrak (RUGGIERI, 1971, 1973, 1977). The report of this species in the Bay of Biscay (YASSINI, 1969) concerns only loose valves. The possible distribution of C. testudo in the Southern Hemisphere is discussed by several authors (SWANSON & AYRESS, 1999; DIXON, 2006; JELLINEK et al., 2006) but this problem is beyond the topic of the present paper.

Ostracod bioprovince: Norwegian - Arctic (Fig. 4)

Ecology: It is a rather deep species. It has been reported from Norway at depths comprised between 80 and 240 m (FREIWALD et al., 1998) and down to 300 m (PENNEY, 1993) at bottom temperatures comprised between 7.0 and 7.4°C. ELOFSON (1941) reports C. testudo from Skagerrak at 270 m of depth and from Spitsbergen at 150 m at bottom temperatures from -2° to 10°C.

Fossil distribution in the Mediterranean:

Gelasian: M. S. Nicola (Sicily) at 68 m (sample 35) (AIELLO et al., 1996b, 2000; BONADUCE & SPROVIERI, 1984).


Rhodes (Greece, Aegean Sea) (MOSTAFAWI, 1989).

Zakynthos (Greece, Ionian Sea) (TSAPRALIS, 1981).

Calabrian (Santernian): Vrica (Calabria, southern Italy), about 10 m above the sapropel e (COLALONGO & PASINI, 1980; PASINI & COLALONGO, 1994).

Mar Piccolo (Taranto, southern Italy) (CAMPO, 1971).

Porto Recanati (Ancona, central Italy) (RUGGIERI, 1971).

Località “il Carmine” (Crotone, Calabria, southern Italy) (RUGGIERI, 1952a).

Località in destra del Verde (Sciaccu, Sicily) (RUGGIERI, 1971).

Calabrian (Sicilian): Le Castella (Calabria, southern Italy) (COLALONGO & PASINI, 1980, 1994).

S. Maria di Catanzaro (Calabria, southern Italy) (SISSINGH, 1973a).


Mar Piccolo (Taranto, southern Italy) (CAMPO, 1971).

Porto Recanati (Ancona, central Italy) (RUGGIERI, 1971).

Località “il Carmine” (Crotone, Calabria, southern Italy) (RUGGIERI, 1952a).

Località in destra del Verde (Sciaccu, Sicily) (RUGGIERI, 1973).

Pizzo Longo (Crotone, Calabria, southern Italy) (this paper, together with G. truncatulinoides excelsa).

Tarantean (Last Pleniglacial): Gulf of Taranto (MONCHARMONT-ZEI et al., 1985)

Adriatic Sea (BREMAN, 1976)

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Fig. 9 - Cythere lutea: (a) right valve (transmitted light), (b) right valve under SEM from Sperone locality (Palermo), Calabrian (Sicilian) (ROC slide N° 1623); (c) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

Cythere lutea: (a) valva destra in luce trasmessa, (b) valva destra in scansione elettronica dalla località Sperone (Palermo, Sicilia), Calabriano (Siciliano) (Collezione Ostracodi Ruggieri teca N° 1623); (c) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.

Fig. 10 - Cytheropteron depressum: (a) left valve from Monte Mario (Roma, Latium), Santernian age; (GOC slide N° M114/1/5); (b) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

Cytheropteron depressum: (a) valva sinistra da Monte Mario (Roma, Lazio), età Santeniano; (Collezione Ostracodi Gliozzi teca N° M114/1/5); (b) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.
Fig. 11 - *Cytheropteron punctatum*: (a) right valve from Monasterace (Calabria), Sicilian age; (ROC slide N° 2313). (b) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

*Cytheropteron punctatum*: (a) valva destra dalla località Monasterace (Calabria, Italia meridionale), età Siciliano; (Collezione Ostracodi Ruggieri teca N° 2313). (b) distribuzione stratigrafica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.

Fig. 12 - *Cytheropteron testudo*: (a) right valve (transmitted light), (b) right valve under SEM from “il Carmine” locality (Crotone, Calabria), Emilian age; (ROC slide N° 924). (c) present geographical distribution (dark grey line), early Pleistocene distribution in the Mediterranean area (black dot), Last Glacial Maximum distribution in the Mediterranean (white circle). Bar corresponds to 0.1 mm.

*Cytheropteron testudo*: (a) valva destra in luce trasmessa, (b) valva destra in scansione elettronica dalla località “il Carmine” (Crotone, Calabria), età Emiliano; (Collezione Ostracodi Ruggieri N° 924). (c) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri) ed il Pleniglaciale (cerchi bianchi). La barra corrisponde a 0.1 mm.
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**Fig. 13** - *Hemicythere villosa*: (a) right valve in transmitted light, (b) left valve under SEM from Sperone (Palermo) (ROC slide N° 1640); (c) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

*Hemicythere villosa*: (a) valva destra in luce trasmessa, (b) valva sinistra in scansione elettronica dalla località Sperone (Palermo, Sicilia) (Collezione Ostracodi Ruggieri teca N° 1640); (c) distribuzione stratigráfica attuale (linea grigio scura) e distribuzione nel Mediterra no durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.

**Ecology:** It inhabits marine very shallow to shallow waters with vegetated sandy bottoms and water temperatures that range from 0 to 22°C in mesohaline-euhaline conditions (ELOFSON, 1941; AThERSUCH et al., 1989; FRENZEL et al., 2010).

**Fossil distribution in the Mediterranean:**

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**Paradoxostoma abbreviatum SARS, 1866**

(Fig. 14)

1866 Paradoxostoma abbreviatum sp. nov. - SARS, p. 94

Recent distribution: S. Baltic, Öres, Bohuslän, Holland, Bergen, Shetlands, British Isles, N France, ‘Bay of Biscay (HANssON, 1998); British Isles, Norway, Baltic, Helgoland and N France (ATHERSUCH et al., 1989); North Yorkshire (HULL, 1998).

Ostracod bioprovince: Celtic (?Gasconyan) - Norwegian (Fig. 4)

**Ecology:** *P. abbreviatum* is typical of mesohaline to euhaline very shallow to shallow waters (0.2 to 20 m) with vegetated and highly oxygenated sandy bottoms, and water temperatures that range from 2 to 5°C (ELOFSON, 1941; AThERSUCH et al., 1989; FRENZEL et al., 2010).

**Fossil distribution in the Mediterranean:**
Calabrian (Santerian): Monte Mario (Rome, central Italy), from the 2° A. islandica level (FARANDA & GLOZZI, 2008).

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**Paradoxostoma ensiforme BRADY, 1868**

(Fig. 15)

1868 Paradoxostoma ensiforme sp. nov. - BRADY, p. 460, Pl. 35, Figs. 8-11.


Ostracod bioprovince: Celtic (?Gasconyan) - Norwegian (Fig. 4)

**Ecology:** The species inhabits mesohaline to euhaline very shallow to shallow waters (5 to 18 m on vegetated bottom and down to 50 m on detritic sands), and a wide range of water temperatures (ELOFSON, 1941; AThERSUCH et al., 1989; FRENZEL et al., 2010).

**Fossil distribution in the Mediterranean:**
Calabrian (Santerian): Monte Mario (Rome, central Italy), from the 2° A. islandica level (FARANDA & GLOZZI, 2008).
Paradoxostoma abbreviatum: (a) right valve from Monte Mario (Roma, Latium), Santernian age; (GOCollection slide N° T30/1). (b) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

Paradoxostoma abbreviatum: (a) valva destra proveniente da Monte Mario (Roma, Lazio), età Santerniano; (Collezione Ostracodi Gliozzi teca N° T30/1). (b) distribuzione stratigrafica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.

Paradoxostoma ensiforme: (a) left valve from Monte Mario (Roma, Latium), Santernian age; (GO slide N°T30/2). (b) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot). Bar corresponds to 0.1 mm.

Paradoxostoma ensiforme: (a) valva sinistra proveniente da Monte Mario (Roma, Lazio), età Santerniano; (Collezione Ostracodi Gliozzi teca N°T30/2). (b) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.

Paradoxostoma tenuissimum (NORMAN, 1869) (Fig. 16)

1869 Bythocythere tenuissimum sp. nov. - Norman, p. 294.
1870 Xiphichilus tenuissimum (Norman) - Brady, p. 369, Pl. 12, Figs. 6-9.
1889 Machaerina tenuissima (Norman) - Brady & Norman, p. 238, Pl. 21, Figs. 13-14.
1985 Paradoxostoma tenuissimum (Norman) - Home & Whitaker, p. 182, Figs. 30A-E, 31A-F, 32A-E, 44D-E, 45D-E

Recent distribution: British Isles from Scotland and Shetlands (HANSSON, 1998; ATHERSUCH et al., 1989). Ostracod bioprovince: Celtic (Britannic) (Fig. 4)

Ecology: P. tenuissimum is considered one of the most deep species of the genus, inhabiting waters down to 50-100 m (ATHERSUCH et al., 1989).

Fossil distribution in the Mediterranean:
Calabrian (Emilian): Cosenza (Calabria, southern Italy), together with Hyalinea balthica (RUGGIERI, 1975).
Calabrian (Sicilian): Casa Schifo (between Gela and Vittoria, Sicily) (RUGGIERI, 1975).
Tarantian (Last Pleniglacial): Adriatic Sea (BONADUCE et al., 1976; BREMAN, 1976)

Semicytherura angulata (BRADY, 1868) (Fig. 17)

1868 Cytherura angulata sp. nov. - Brady, p. 440, Pl. 32, Figs. 22-25.
1957 Semicytherura angulata (Brady) - Wagner, p. 84, Pl. 39.

Recent distribution: Kieler Bucht, Belt Sea, Bohuslan,
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Hölland, Hardanger Fjord, Iceland, Shetlands and SW British Isles (HANSSON, 1998); British Isles and Northern Europe (ATHERSUCH et al., 1989); Bay of Biscay (YASSINI, 1969).

Ostracod bioprovince: Celtic (Britannic) - Norwegian

Ecology: The species inhabits mesohaline to euhaline very shallow to shallow waters (5 to 10 m) in marine and estuarine conditions, with vegetated bottom, and a wide range of water temperatures (ELOFSON, 1941; Ather SUCH et al., 1989).

Fig. 16 - Paradoxostoma tenuissimum: (a) broken left valve from Cosenza (Calabria), Emilian age; (ROC slide N° 745); (b) present geographical distribution (dark grey line), early Pleistocene distribution in the Mediterranean area (black dot), Last Glacial Maximum distribution in the Mediterranean (white circle). Bar corresponds to 0.1 mm.

Paradoxostoma tenuissimum: (a) valva sinistra rotta proveniente da Cosenza (Catabria, Italia meridionale), età Emiliana; (Collezione Ostracodi Ruggieri teca N° 745); (b) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri) e il Pleniglaciale (cerchi bianchi). La barra corrisponde a 0.1 mm.

Fig. 17 - Semicytherura angulata: (a) right valve in transmitted light, (b) right valve under SEM from Digerbato well (Marsala), Emilian or Sicilian age; (ROC slide N° 2622); (c) present geographical distribution (dark grey line) and early Pleistocene distribution in the Mediterranean area (black dot), Bar corresponds to 0.1 mm.

Semicytherura angulata: (a) valva destra in luce trasmessa, (b) valva destra in scansione elettronica proveniente dal pozzo Digerbato (Marsala, Sicilia), età Emiliana o Siciliana; (Collezione Ostracodi Ruggieri teca N° 2622); (c) distribuzione geografica attuale (linea grigio scura) e distribuzione nel Mediterraneo durante il Pleistocene inferiore (punti neri). La barra corrisponde a 0.1 mm.
4. DISCUSSION AND CONCLUSION

The critical revision of the "cold" ostracods recovered in the Mediterranean Quaternary proposed in this paper reduces the number of the true "northern guest" from the 22 species reported in literature only to 12 confirmed taxa. They are generally rare within their assemblages, often represented only by a single specimen from a single locality. Only *C. testudo* and *C. punctatum* have been reported with a wide Mediterranean geographical distribution in Italy and in the Aegean Sea. Almost all the "northern guest" ostracods have their present southernmost distribution in the Celtic bioprovince except *B. turgida* and *C. testudo* that are more northern species, presently widespread only from the Norwegian to the Arctic bioprovince. Data on the ecological requirements of the listed "cold" ostracods lead to divide them into three groups on the basis of the water depth: the shallow (infralittoral) species (*C. lutea*, *H. villosa*, *P. abbreviatum*, *P. ensiforme*, and *S. angulata*); the circalittoral species (*A. dunelmensis*, *B. turgida*, *B. zetlandica*, *C. depressum*, and *P. tenuissimum*); the circalittoral-upper epibatial species (*C. punctatum* and *C. testudo*). Temperature ranges are known only for few species, but two groups can be recognized: eurythermal species, such as *C. lutea* and *H. villosa*, and cold stenothermal species as *C. punctatum*, *C. testudo* and *P. abbreviatum*. The temperature ranges of this latter group (-2 to 10°C) does not fit neither the monthly mean temperatures of the Mediterranean superficial waters for January and July 2011 (Fig. 18) nor the mean annual temperature of the Mediterranean superficial waters as inferred by Kühlemann et al., 2008 for the Last Glacial Maximum (Fig. 19). Their presence in the Quaternary Mediterranean deposits can be explained by their settlements in deeper habitats, in search of lower temperatures: *C. punctatum* and *C. testudo* have been recovered in the Mediterranean in associations with lower epibathial species, whereas the epiphytal inner infralittoral *P. abbreviatum* moved towards the outer infralittoral bottoms. On the contrary, in the Quaternary, the eurythermal species occurred in the Mediterranean in the same range of depths as present.

The conclusion reached with this revision leads to a comparison with the "northern guest" molluscs (Malatesta & Zarlinga, 1986). Quaternary "northern guest" ostracod species are fewer than mollusc species (twelve against fifty-three) but in both cases they are generally rare within their assemblages. In fact also among molluscs, very few species can be considered common (> ten localities: *Pseudamussium septemradiatum* (Müller, 1776), *Arctica islandica* (Linnaeus, 1767)).
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Like the "northern guest" molluscs, also ostracods entered the Mediterranean at different times (Fig. 20), being more abundant in the Sicilian substage. "Northern guest" molluscs were reported also from the Last Glacial Maximum deposits of Cap Créus (MARS, 1958), confirming that the migration of "cold" species into the Mediterranean followed the cyclic cold climate oscillations. "Northern guest" ostracods have been mainly recorded in the lower Quaternary sediments, but one study on the Last Glacial Maximum ostracods (MONCHARMONT-ZEI et al., 1985) reports the presence of *Cytheropteron testudo* in deposits of the Ionian Sea. Additionally, in some papers dealing with modern Mediterranean ostracod faunas some other "cold" species are listed, recovered as loose valves. For example, BREMAN (1976) and BONADUCE et al. (1976) reported loose valves of *Cytheropteron testudo*, *Bythocythere turgida* and *Paradoxostoma tenuissimum*, whose presence in the Adriatic Sea could be better linked to reworked remains of the Last Glacial Maximum.

In conclusion, this revision of the "northern guest" ostracods suggests that they could be a valuable tool for interpreting cold climatic events in a sedimentary succession, but further studies are needed to improve the knowledge of the Quaternary "cold" ostracod contingent in the Mediterranean.

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