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Looking Back, Looking Ahead: The CIESM Atlas, Crustaceans

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Abstract

The 'CIESM Atlas of exotic species in the Mediterranean' galvanized attention and garnered recognition for the unique situation concerning bioinvasions in the Mediterranean Sea, and promoted documentation of the full extent of the diversity of 'exotic' species. The volume comprising decapod and stomatopod crustaceans was published in 2002, and has been accompanied by a popular digital edition, updated in 2008, listing 70 species, with an average of 7400 visits annually. Additional species have been recorded in recent years, few more were recorded prior of the temporal limits adopted in the Atlas. The full list of decapods (89) and stomatopods (2) recorded as 'exotic' in the Mediterranean Sea since the 1870 is presented. Recommendations as to terminology, taxonomic expansion and usage of innovative information and communication technologies are offered. The 'Atlas', intended to allow non-specialists to recognize the 'exotic' species recorded in the Mediterranean Sea, is the only open source for data focusing exclusively on the bioinvasion of the Mediterranean – a valued and irreplaceable resource.

Key words: CIESM Atlas, 'exotic' species, Mediterranean Sea, Decapoda, Stomatopoda

Introduction

In the late 1990s the 'Mediterranean Science Commission' (CIESM) undertook the challenge of assembling and validating many thousands of records of 'exotic' species in the Mediterranean Sea, and presenting them in a standardized, scientifically robust and user-friendly format. This pioneering endeavor resulted in the publication of the first 'Atlas' of 'exotic' species in the Mediterranean (http://www.ciesm.org/online/atlas/) – in fact, the first of its kind worldwide. The first three volumes of the 'Atlas' (a fourth is in late stages of production) galvanized attention and garnered recognition for the unique situation concerning bioinvasions in the Mediterranean Sea, promoted documentation of the full extent of the diversity of 'exotic' species, and provided information for management and conservation policies. Volume 2 (Crustaceans) was cited in over 130 scientific publications (*fide* Google Scholar, viewed August, 2014).

The volume comprising decapod and stomatopod crustaceans was published in 2002 (Galil et al. 2002). Recognition that crustaceans had been introduced into the Mediterranean from other parts of the world preceded that volume by more than a century. Already Darwin (1854, pp 162–163) remarked "… it should not be overlooked, that those species, as *Balanus tintinnabulum*, *amphitrite*, *improvises* (accepted today as *Megabalanus tintinnabulum* (Linnaeus, 1758), *Amphibalanus amphitrite* (Darwin, 1854), *A. improvisus* (Darwin, 1854) …. which seem to range over nearly the whole world … are species which are habitually attached to ships, and which could hardly fail to be widely transported". In 1873 the tri-masted *Karikal* arrived at Marseille from India carrying on its flanks a "...petite forêt d'êtres vivants était peuplée de Crustacés" (Catta 1876, p. 4),

including hundreds of specimens of *Plagusia squamosa*. Yet, though records of shipping- and mariculture introduced crustaceans kept appearing in the scientific literature, their number and impact were long considered negligible. It was the opening of the Suez Canal that focused scientific attention on the movement of marine species: the very first crustacean recognized straightway as an introduced species was the swimming crab *Portunus segnis* (as *Neptunus pelagicus*, Fox 1924), which had entered the Mediterranean through the Suez Canal - an augury of the invasion to come. By the 1980s the upper shelf communities along the Levant differed notably from communities elsewhere in the Mediterranean because of the thriving populations of species introduced through the Canal. While thermophilic species were pouring into the Levantine basin, vessel-borne species and commercially valuable species were introduced into ports and lagoons along the European coast of the Mediterranean.

Only recently were 'exotic' species in the Eastern Mediterranean "…considered, in a figurative sense "welcome guests" (Por 1978, p. 123), even, to have "biologically enriched" the sea (Tortonese 1973, p. 327). Oliverio and Taviani (2003, p. 314) thought that " …the Levant Basin was and still is biologically under-exploited by marine life a growing legion of benthic organisms found and is still finding a sort of vacuum where many ecological niches are available". These notions have been greatly modified by the awareness that heavily invaded locales, such as the Levant coastline and coastal lagoons throughout the Mediterranean, are impacted by 'propagule pressure'. This composite measure of the number of viable individuals, the discrete introduction events, their frequency and duration, is recognized as the primary determinant of invasion success and a significant predictor of both 'invasiveness' and 'invasibility' (Colautti et al. 2006).

Over the dozen years since the volume appeared in press and on CIESM website (http://www.ciesm.org), changes have occurred not only in the tally of species and their spread, but in our own understanding of the phenomenon. Over this period electronic resources on non-indigenous species have proliferated: worldwide more than 260 websites on NIS have been recently listed (GISIN 2014), their geographical scope varying from global, to regional, national, or confined to a smaller geographic locale. The Atlas is singular in serving as a tool for identification of the 'exotic' species recorded in the Mediterranean Sea.

The present tally

Eighty nine decapod and two stomatopod species have been recorded as 'exotic' in the Mediterranean Sea (Table 1). All are littoral and sublittoral benthic or demersal species. The data are presumably quite accurate, as decapods and stomatopods are relatively large and conspicuous species which are easily distinguished from the native biota, as recent records have demonstrated (Abelló and Hispano 2006; Mizzan and Vianello 2009; Ben Hadj Hamida-Ben Abdallah et al. 2009; Froglia and Deval 2012; Rothman et al. 2013).

The date of the introduction of the *inoculum* is significant for management purposes and for the study of the patterns and processes of invasion, but is extremely difficult to ascertain for unintentional or undocumented intentional introductions. As research efforts vary greatly along the shores of the Mediterranean, and since even the better studied locales suffer temporal and taxonomical lacunae, we accept that the date of collection may be years behind the actual date of introduction. The number of 'exotic' species which had been recorded in the Mediterranean each decade over the past century increased in recent decades. The dramatic spike in the 1930s reflects the publication of the results of 'The Cambridge Expedition to the Suez Canal', whereas the rise in records in the last decade of the 20th century and since the turn of this century may reflect hightened scientific interest and rise in introductions. The number of 'exotic' species has doubled since the 1970s.

The 'exotic' biota shows strong geographical patterns: the largest number of established populations occur in the Levant and along North Africa (Research efforts vary greatly along the coasts of the Mediterranean; data are presumably most accurate for frequently sampled areas and where taxonomic expertise is readily available). Recently reported 'single records' may reveal a novel *inoculum* that given time may (or may not) establish a population; decades-old 'single records' bear witness to an unsuccessful introduction. Together with information on the deduced and ascertained prevailing pathways/vectors, this information distinguishes entry points and potential 'bridgeheads' of 'exotic' biota. It is not surprising that Turkey, Israel and Egypt, with the largest number of 'exotic' species, have also 'single records', both new and old, reflecting the intensity of the phenomenon.

Of the ninety one 'exotic' decapods and stomatopods recorded, 18 are considered to be 'widespread'. Swimming crabs and penaeid prawns

Table 1. Updated alphabetical list of 'exotic' decapod and stomatopod crustaceans recorded in the Mediterranean Sea since 1870. Asterisk (*) denotes species that may have autonomously entered the Mediterranean Sea through the Strait of Gibraltar.

Species	Species
DECAPODA	*Merhippolyte ancistrota* Crosnier & Forest, 1973*
	Metapenaeopsis aegyptia Galil & Golani, 1990
Acantharctus posteli (Forest, 1963)*	*Metapenaeopsis mogiensis consobrina* (Nobili, 1904)
Actaea savignii (H. Milne Edwards, 1834)	*Metapenaeus affinis* (H. Milne Edwards, 1837)
Actumnus globulus Heller, 1861	*Metapenaeus monoceros* (Fabricius, 1798)
Alpheus edwardsii (Audouin, 1826)	*Metapenaeus stebbingi* Nobili, 1904
Alpheus inopinatus Holthuis & Gottlieb, 1958	*Micippa thalia* (Herbst, 1803)
Alpheus migrans Lewinsohn & Holthuis, 1978	*Myra subgranulata* Kossmann, 1877
Alpheus rapacida De Man, 1908	*Nikoides sibogae* De Man, 1918
Ashtoret lunaris (Forsskål, 1775)	*Notopus dorsipes* (Linnaeus, 1758)
Atergatis roseus (Rüppell, 1830)	*Ogyrides mjoebergi* (Balss, 1921)
Calappa hepatica (Linnaeus, 1758)	*Palaemon macrodactylus* Rathbun, 1902
Calappa pelii Herklots, 1851*	*Palaemonella rotumana* (Borradaile, 1898)
Callinectes danae Smith, 1869	*Panulirus ornatus* (Fabricius, 1798)
Callinectes sapidus Rathbun, 1896	*Paralithodes camtschaticus* (Tilesius, 1815)
Carupa tenuipes Dana, 1851	*Penaeus aztecus* Ives, 1891
Charybdis feriata (Linnaeus, 1758)	*Penaeus hathor* (Burkenroad, 1959)
Charybdis hellerii (A. Milne-Edwards, 1867)	*Penaeus japonicus* Bate, 1888
Charybdis japonica (A. Milne-Edwards, 1861)	*Penaeus merguiensis* De Man, 1888
Charybdis longicollis Leene, 1938	*Penaeus pulchricaudatus* Stebbing, 1914
Charybdis lucifera (Fabricius, 1798)	*Penaeus semisulcatus* De Haan, 1844
Coleusia signata (Paul'son, 1875)	*Penaeus subtilis* (Pérez Farfante, 1967)
Cryptosoma cristatum Brullé, 1837*	*Percnon gibbesi* (H. Milne Edwards, 1853)*
Cuapetes calmani (Tattersall, 1921)	*Pilumnopeus vauquelini* (Audouin, 1826)
Daira perlata (Herbst, 1790)	*Pilumnus minutus* De Haan, 1835
Dorippe quadridens (Fabricius, 1793)	*Plagusia squamosa* (Herbst, 1790)
Dyspanopeus sayi (Smith, 1869)	*Portunus sanguinolentus* (Herbst, 1783)
Elamena mathoei (Demarest, 1823)	*Portunus segnis* (Forsskål, 1775)
Eriocheir sinensis H. Milne Edwards, 1853	*Processa macrodactyla* Holthuis, 1952*
Eucrate crenata (De Haan, 1835)	*Rhithropanopeus harrisii* (Gould, 1841)
Eurycarcinus integrifrons De Man, 1879	*Rimapenaeus similis* (Smith, 1885)
Glabropilumnus laevis (Dana, 1852)	*Saron marmoratus* (Olivier, 1811)
Gonioinfradens paucidentatus (A. Milne-Edwards, 1861)	*Scyllarus caparti* Holthuis, 1952
Grapsus granulosus H. Milne Edwards, 1853	*Solenocera crassicornis* (H. Milne Edwards, 1837)
Guinusia chabrus (Linnaeus, 1758)	*Sphaerozius nitidus* Stimpson, 1858
Halimede tyche (Herbst, 1801)	*Sternodromia spinirostris* (Miers, 1881)
Hemigrapsus sanguineus (De Haan, 1835)	*Thalamita gloriensis* Crosnier, 1962
Herbstia nitida Manning & Holthuis, 1981	*Thalamita indistincta* Apel & Spiridonov, 1998
Hyastenus hilgendorfi De Man, 1887	*Thalamita poissonii* (Audouin, 1826)
Ixa monodi Holthuis & Gottlieb, 1956	*Thenus orientalis* Auctorum
Leptochela aculeocaudata Paul'son, 1875	*Trachysalambria palaestinensis* (Steinitz, 1932)
Leptochela pugnax De Man, 1916	*Urocaridella pulchella* Yokes & Galil, 2006
Libinia dubia H. Milne Edwards, 1834	*Xanthias lamarckii* (H. Milne Edwards, 1834)
Lucifer hanseni Nobili, 1905	
Lysmata kempi Chace, 1997	STOMATOPODA
Macrophthalmus graeffei A. Milne Edwards, 1873	
Matuta victor (Fabricius, 1781)	*Clorida albolitura* Ahyong & Naiyanetr, 2000
Menaethius monoceros (Latreille, 1825)	*Erugosquilla massavensis* (Kossmann, 1880)

comprise the largest number of the 'widespread' species. Attempts at predicting which species are more likely to be successfully introduced, and thus candidates for the keenest monitoring and surveillance, have shown that the most reliable indicator is past performance, i.e., widespread 'exotic' species are likely to disperse further.

The Suez Canal is the single most important pathway for introduction of 'exotic' decapod and stomatopod crustaceans in the Mediterranean, though the relative importance of pathway/ vectors varies among countries. Nearly all the 'exotic' species recorded along the coasts of the Levant are considered to have entered through the Suez Canal. Whereas vessel and culture-introduced 'exotic' species are more common in Italy, France and Spain.

Looking ahead

Updating metrics

Terminology

CIESM defined 'exotic' as a species 'relative newcomer to the Mediterranean Sea', one that had not been recorded in the Sea before the 1920s if it was considered to have been introduced through the Suez Canal, otherwise not recorded before the 1950s. The term 'alien' was reserved for 'species that have only one or few reliable records with no evidence of self-sustaining populations'. Since 2002 the study of marine bioinvasions has thrived and spawned a profusion of specialized terms. A computerized search of scientific databases disclosed a surfeit of synonyms, partial synonyms and neologisms (Occhipinti-Ambrogi and Galil 2004).

An harmonized terminology is desirable in order to facilitate communication. In this context, the definition set out in Annex 1 of the European Union Marine Strategy Framework Directive (MSFD) merits consideration ('Non-indigenous species introduced by human activities', Annex 1, the European Union Marine Strategy Framework Directive (EC 2008)). Cryptogenic species, *sensu* Carlton (1996), were excluded from our tally, but in preparing Table 1 we have expanded the temporal limits adopted in the 'Atlas' as of 1870 onward.

Taxonomic expansion

An updated version of the decapods and stomatopod crustacean 'Atlas' is in preparation and we hope it will be available on the CIESM website in 2015. But over 40 'exotic' crustacean species, other than decapods and stomatopods, (including Copepoda, Cirripedia, Amphipoda, Isopoda, etc.) have been recorded in the Mediterranean Sea and should be added in a separate volume.

Figure 1. *Ixa monodi* Holthuis and Gottlieb, 1956. In: CIESM Atlas of Exotic Crustaceans in the Mediterranean Sea. http://www.ciesm.org/atlas/Ixamonodi.php

‘APP smart’: a touch screen window to the bioinvasion of the Mediterranean Sea

The CIESM Atlas early recognized the benefits of public knowledge and open participation. The digital draft edition of the crustacean Atlas was placed on the CIESM website eliciting comments from members of the CIESM community ahead of publication. The digital crustacean ‘Atlas’ edition proved immensely popular, with an average of 7400 visits annually. Increasingly affordable innovative information and communication technologies (e.g., widely used global positioning systems (GPS) and smartphone apps) encourage participatory science and provide access to large amounts of data such as online searchable databases. This data should be scrutinized and validated by taxonomists.

Balancing accessibility with scientific rigor, while using the statistical power provided by large amounts of data, is the challenge facing the CIESM Atlas. It is the only open source for data focusing exclusively on the bioinvasion of the Mediterranean Sea that provides also tools for the identification of the recorded species – a valued and irreplaceable resource.

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