

Marine Record

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Seawater warming favours the northward range expansion of Lessepsian species in the Mediterranean Sea: the cephalaspidean *Lamprohaminoea ovalis*

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Abstract

Monitoring the spread of non-indigenous species is fundamental to study global warming effects on marine biodiversity. A valuable tool is represented by the continuous updating of the geographic range expansion of non-indigenous species. *Lamprohaminoea ovalis* is a Lessepsian mollusc initially recorded in the Mediterranean Sea in 2001. This paper reports its range expansion over the last 20 years related to water warming. The first record of *Lamprohaminoea ovalis* from the Ligurian Sea (NW Mediterranean) is also reported. Two individuals (about 10 mm length) were observed on a sub-vertical rocky bottom at 26 m depth displaying potential trailing behaviour. This recent finding extends the currently known distributional range of *Lamprohaminoea ovalis*, representing the northernmost occurrence of this non-indigenous species in the western Mediterranean Sea.

As a result of global warming, the spread of non-indigenous species is one of the major drivers of change in marine ecosystems, with drastic consequences on their biodiversity (Bonanno & Orlando-Bonaca, 2019). Considering the number of non-indigenous species and the rate of introduction, the Mediterranean is one of the most affected seas by biological invasions (Zenetos *et al.*, 2010). Spatio-temporal information on non-indigenous species and monitoring their geographic range expansion represent valuable tools for conservation of marine ecosystems and biodiversity (Katsanevakis *et al.*, 2020).

Following a taxonomic revision of the Order Cephalaspidea, *Haminoea cyanomarginata* Heller & Thompson, 1983 was described from individuals of the Red Sea (Heller & Thompson, 1983; Dekker & Orlin, 2000) and initially considered junior synonym of *Lamprohaminoea cyanomarginata* (Oskars & Malaquias, 2019). Further taxonomic studies demonstrated that both *H. cyanomarginata* and *L. cyanomarginata* are junior synonyms of *Lamprohaminoea ovalis* (Pease, 1868; Oskars & Malaquias, 2020). This heterobranch, characterized by highly variable body colour pattern, was first described from Tahiti (French Polynesia, France). Nowadays it is widespread from the Red Sea to the Indo-West Pacific. Its fairly recent records from Greece, Turkey, Malta, Italy, Cyprus, Croatia and Spain, more than 20 years after its first finding in the Red Sea, suggest that it is an invasive Lessepsian species that entered and established in the Mediterranean Sea via the Suez Canal (Rizgalla *et al.*, 2018; Oskars & Malaquias, 2020). Nowadays, *L. ovalis* has been reported from the whole Mediterranean basin (Mifsud, 2007; Crocetta & Vazzana, 2009; Zenetos *et al.*, 2010; Fernández-Vilert *et al.*, 2018 and reference therein; Raghkousis *et al.*, 2020), except from the Gulf of Lion and the Ligurian Sea.

With the aim of investigating *L. ovalis* range expansion in the Mediterranean Sea in the last 20 years, all available records have been collected. The expansion rate of *L. ovalis* has been evaluated by measuring the geographic distances (kilometres) between the location of its first record in 2001 and the locations of the following new records from other Mediterranean areas. The expansion rate of the species has been compared with change in time of the sea surface temperature (SST), to evaluate if the spread of this non-indigenous species is a direct consequence of seawater warming. The first record of *L. ovalis* from the Ligurian Sea (NW Mediterranean) has also been reported.

The first occurrence of *L. ovalis* in the Mediterranean Sea was reported at Porto Germano (Greece) in 2001 (Zenetos *et al.*, 2003) (Figure 1A, Table 1). In the following years this species remained confined to the eastern basin of the Mediterranean, where Lessepsian species more typically settle (Gambi *et al.*, 2009). Since the second half of the 2010s the species crossed the 20° meridian East, reaching the westernmost portions of the Mediterranean, and since 2014 it



Table 1. List of records of *Lamprohaminoea ovalis* in the Mediterranean Sea (see also [Figure 1](#))

First record	Locality	Lat. (N)	Long. (E)	Reference	Author of the record
2001	Porto Germano, Greece	38.155064	23.222459	Zenetos <i>et al.</i> (2003; CIESM)	Ernesto Mollo
2002	Üç Adalar, Antalya, Turkey	36.459593	30.549790	Sea Slug Forum – http://www.seaslugforum.net	Adnan Buyuk
2002	Çeşme, Izmir, Turkey	38.326670	26.294391	Sea Slug Forum – http://www.seaslugforum.net	Namzi Kural
2003	Üç Adalar, Antalya, Turkey	36.459593	30.549790	Sea Slug Forum – http://www.seaslugforum.net	Baki Yokes
2004	Üç Adalar, Antalya, Turkey	36.459593	30.549790	Sea Slug Forum – http://www.seaslugforum.net	
2005	Çeşme, Izmir, Turkey	38.326670	26.294391	Sea Slug Forum – http://www.seaslugforum.net	Aziz Saltik
2005	Saronikos Kolpos, Greece	37.768312	23.895814	Sea Slug Forum – http://www.seaslugforum.net	Panaiotis Ovalis
2006	Rdum id-Delli, Malta	35.951865	14.338688	Mifsud (2007)	
2006	Fomm ir-Rih Bay, Malta	35.907289	14.339596	Mifsud (2007)	
2006	Ġnejna Bay, Malta	35.920942	14.342461	Mifsud (2007)	
2007	Cirkewwa, Malta	35.983213	14.332776	Sea Slug Forum – http://www.seaslugforum.net	Patricia Peels
2007	Schinaria, Plakias, Creta, Greece	35.166232	24.421272	Sea Slug Forum – http://www.seaslugforum.net	Jim Anderson
2007	Saline Joniche, Italy	37.937922	15.707796	Crocetta and Vazzana (2009)	
2008	Castellammare del Golfo, Italy	38.036258	12.876490	Stasolla <i>et al.</i> (2014)	Santo Tirnetta and Anna Macaluso
2009	Lazzaro, Italy	37.971763	15.662174	Crocetta <i>et al.</i> (2009)	
2009	Salamis, Attiki, Greece	37.934791	23.466596	NMR_Mollusca – http://www.marinespecies.org	Joop Trausel and Frans Slieker
2009	Golfo di Patrasso, Greece	38.317006	21.642224	Medslugs – http://www.medslugs.de	George Tryfonopoulos
2011	Scauri, Pantelleria, Italy	36.765097	11.969795	Stasolla <i>et al.</i> (2014)	Maria Ghelia and Francesco De Marchi
2012	Kalogrias Beach, Chalkidiki, Greece	40.177022	23.714886	Social media – Facebook	Nicholas Samaras
2013	Saline Joniche, Italy	37.937922	15.707796	Stasolla <i>et al.</i> (2014)	Domenico Tripodi
2013	Acicastello, Italy	37.554525	15.150620	Stasolla <i>et al.</i> (2014)	Alessandro Pagano
2013	Scilla, Italy	38.258340	15.715148	Stasolla <i>et al.</i> (2014)	Domenico Tripodi
2014	Mgarr, Gozo, Malta	36.027588	14.308428	Medslugs – http://www.medslugs.de	Silke Baron
2014	Baia di Puolo, Massa Lubrense, Italy	40.626660	14.341940	Katsanevakis <i>et al.</i> (2014)	Fabio Russo
2014	Acicastello, Italy	37.554525	15.150620	Social media – Facebook	Alessandro Pagano
2014	Casteldaccia, Palermo, Italy	38.057863	13.542987	Social media – Facebook	Dario Messina
2014	Palinuro, Italy	40.029065	15.266873	Tiberti <i>et al.</i> (2015)	Fabio Barbieri
2014	Uvala Travna, Šolta, Croatia	43.368852	16.267800	Social media – Facebook	Jakov Prkic
2015	Ammouliani island, Greece	40.313241	23.944508	Social media – Facebook	Yiannis Iliopoulos
2015	Praiano, Italy	38.930623	16.209802	Social media – Facebook	Raffaele Livornese
2016	Porto Ercole, Grotta Azzurra, Italy	42.370636	11.188660	Social media – Facebook	Gabriele Ziino

(Continued)

Table 1. (Continued.)

First record	Locality	Lat. (N)	Long. (E)	Reference	Author of the record
2016	Lago Faro, Italy	38.269288	15.637137	Vitale <i>et al.</i> (2016)	
2016	Munxar, Gozo, Malta	36.021566	14.218147	Social media – Facebook (Nudibranch lovers)	Vera Wittenberg
2016	Agios Minas, Greece	40.587246	22.881911	Underwater Photography in Greece – http://www.greeceme.com	Tasos Drosopoulos
2016	Costa Rei, Muravera, Sardegna, Italy	39.249898	9.579118	Social media – Facebook	Giorgio Zara and Silvia Crippa
2016	Nemesis wreck, Protraras, Cyprus	32.049633	34.0366	Yokes <i>et al.</i> (2018)	Fabio Crocetta and Vasilis Andreou
2016	Ammouliani island, Greece	40.313241	23.944508	Underwater Photography in Greece – http://www.greeceme.com	Yiannis Iliopoulos
2016	Greben Štit, southern side, Croatia	42.77166	17.33250	Chartosia <i>et al.</i> (2018)	Branko Dragicevic, Marija Despalatovic and Jakov Dulcic
2016	Capo Vaticano, Italy	38.618792	15.825806	Social media – Facebook	Francesco Pacienza
2016	Ustica, Italy	38.705300	13.196120	Social media – Facebook	Jonathan Cecchinel
2016	Ischia Island	40.737956	13.853602	Personal communication	Paolo Mariottini and Giulia Furfaro
2016	Secca della Formica, S. Flavia, Italy	38.083431	13.550167	Social media – Facebook	Giovan Ombrello
2016	Isola Reulino, AMP Tavolara, Italy	40.877310	9.673453	Present paper	Egidio Trainito
2016	Kašuni, Split, Croatia	43.510980	16.400696	Social media – Facebook	Jakov Prkic
2016	Praiano, Italy	38.930623	16.209802	Social media – Facebook	Francesco De Rosa
2017	Reggio Calabria, Italy	38.104215	15.626211	Social media – Facebook	Domenico Tripodi
2017	Porto Ercole, Grotta Azzurra, Italy	42.370636	11.188660	Social media – Facebook	Gabriele Ziino
2017	Argentario Promontory, Italy	42.400000	11.091666	Personal communication	Giulia Furfaro
2017	Capo Figari, Golfo Aranci, Italy	40.991111	9.6577778	Personal communication	Renato Romor
2017	Porto Santo Stefano, Italy	42.444388	11.114297	Social media – Facebook	Flavio Mattucci
2017	Punta Papa, AMP Tavolara, Italy	40.911873	9.743434	Present paper	Egidio Trainito
2017	Porto San Paolo, Italy	40.881635	9.637065	Present paper	Egidio Trainito
2017	Illa del Toro, Mallorca, Spain	39.462182	2.471748	Fernandez-Vilert <i>et al.</i> (2018)	Rubén Castrillo
2018	Tripoli, Lybia	32.854028	13.054639	Rizgalla <i>et al.</i> (2018)	
2019	Ibiza, Spain	39.899546	1.429359	Ragkousis <i>et al.</i> (2020)	Miquel Pontes, Fabio Crocetta and Ro Ba
2020	Nova Tabarca Island, Alicante, Spain	38.172250	-0.483639	Ragkousis <i>et al.</i> (2020)	Miquel Pontes and Fabio Crocetta
2020	Gozo, Malta			Social media – Facebook (nudibase)	Flow Curlebee
2020	AMP Tavolara, Italy	40.896533	9.707200	Present paper	Egidio Trainito
2021	Porto Ferraiolo, Elba Island, Italy	42.821707	10.328733	Present paper	Annalisa Azzola and Monica Montefalcone



Fig. 2. Individuals of *Lamprohaminoea ovalis* observed at: (a) Isola Rossa in 2016 (Sardinia, Tyrrhenian Sea), (b) Porto San Paolo in 2017 (Sardinia, Tyrrhenian Sea), (c, d) Elba Island (Tuscany, Ligurian Sea). Photo credit: Egidio Trainito (a, b), Lorenzo Moscia (c), Monica Montefalcone (d).



Fig. 3. An individual of *Lamprohaminoea ovalis* collected at 10 m depth at Cala Grande, Argentario (Tuscany, Tyrrhenian Sea) in October 2017 and photographed in laboratory. Photo credit: Giulia Furfaro.

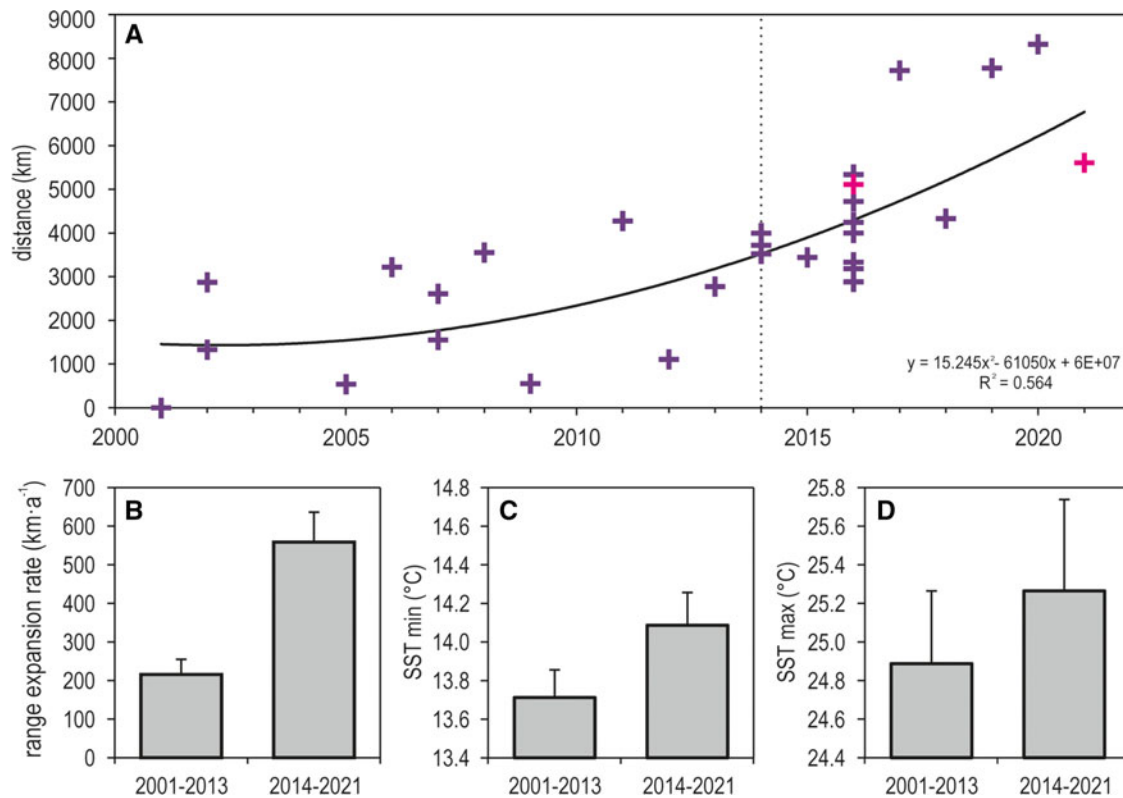


Fig. 4. Expansion rate of *Lamprohaminoea ovalis* in the Mediterranean Sea since its first record in 2001 (a). Mean range expansion rate in the two investigated time periods: 2001–2013 and 2014–2021 (b). SST minimum (c) and maximum (d) yearly mean in the two investigated time periods 2001–2013 and 2014–2021.

that its spread is mainly favoured by seawater warming. In the coldest Mediterranean sectors, where the yearly mean SST is still around 18°C or lower, this species is not yet widespread. Nevertheless, the first observation of *L. ovalis* in the Ligurian Sea reported in this paper represents the northernmost record of occurrence of this non-indigenous species in the Western Mediterranean Sea, providing further important evidence of the ongoing global water warming also in the coldest sectors of the Mediterranean.

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Conflict of interest. The authors declare that they have no competing interests.

References

- Betti F, Giuliano M and Mojetta A (2011) *Il regno dei nudibranchi: Guida ai molluschi opisthobranchi della riviera del Conero*. Imola, Italy: Editrice La mandragora.
- Bianchi CN (2007) Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia* **580**, 7–21.
- Bianchi CN, Azzola A, Bertolino M, Betti F, Bo M, Cattaneo-Vietti R, Cocito S, Montefalcone M, Morri C, Oprandi A, Peirano A and Bavestrello G (2019) Consequences of the marine climate and ecosystem shift of the 1980–90s on the Ligurian Sea biodiversity (NW Mediterranean). *European Zoological Journal* **86**, 458–487.
- Bianchi CN, Caroli F, Guidetti P and Morri C (2018) Seawater warming at the northern reach for southern species: Gulf of Genoa, NW Mediterranean. *Journal of the Marine Biological Association of the United Kingdom* **98**, 1–12.
- Bianchi CN and Morri C (2003) Global sea warming and “tropicalization” of the Mediterranean Sea: biogeographic and ecological aspects. *Journal of Integrative Biogeography* **24**, 319–329.
- Bonanno G and Orlando-Bonaca M (2019) Non-indigenous marine species in the Mediterranean sea – myth and reality. *Environmental Science and Policy* **96**, 123–131.
- Chartosia N, Anastasiadis D, Bazairi H, Crocetta F, Deidun A, Despalatovic M, Martino V, Dimitriou N, Dragičević B, Dulčić J, Durucan F, Hasbek D, Ketsilis-Rinis V, Kleitou P, Lipej L, Macali A, Marchini A, Ousselam M, Piraino S, Stancanelli B, Theodosiou M, Tiralongo F, Todorova V, Trkov D and Yapici S (2018) New Mediterranean biodiversity records (July 2018). *Mediterranean Marine Science* **19**, 398–415.
- Crocetta F, Renda W and Vazzana A (2009) Alien Mollusca along the Calabrian shores of the Messina Strait area and a review of their distribution in the Italian seas. *Bollettino Malacologico* **45**, 15–30.
- Crocetta F and Vazzana A (2009) First record of *Haminoea cyanomarginata* (Gastropoda: Haminoeidae) in the Italian seas. *Marine Biodiversity Records* **2**, e11.
- Dekker H and Orlin Z (2000) Check-list of Red Sea Mollusca. *Spirula* **47**, 3–46.
- Fernández-Vilert R, Giménez J, Mas G, Figueroa I and Moles J (2018) First records of the Red Sea alien mollusc *Haminoea cyanomarginata* (Gastropoda: Heterobranchia: Cephalaspidea) in the western Mediterranean. *Journal of Natural History* **52**, 1817–1823.
- Gambi MC, Barbieri F and Bianchi CN (2009) New record of the alien sea-grass *Halophila stipulacea* (Hydrocharitaceae) in the western Mediterranean: a further clue to changing Mediterranean Sea biogeography. *Marine Biodiversity Records* **2**, e84.
- Heller J and Thompson TE (1983) Opisthobranch molluscs of the Sudanese Red Sea. *Zoological Journal of the Linnean Society* **78**, 317–348.
- Katsanevakis S, Acar Ü, Ammar I, Balci BA, Bekas P, Belmonte M, Chintiroglou CC, Consoli P, Dimiza M, Fryganiotis K, Gerovasileiou V,

- Gnisci V, Gülşahin N, Hoffman R, Issaris Y, Izquierdo-Gomez D, Izquierdo-Munoz A, Kavadas S, Koehler L, Konstantinidis E, Mazza G, Nowell G, Önal U, Özen MR, Pafilis P, Pastore M, Perdikaris C, Poursanidis D, Prato E, Russo F, Sicuro B, Tarkan AN, Thessalou-Legaki M, Tiralongo F, Triantaphyllou M, Tsiamis K, Tunçer S, Turan C, Türker A and Yapici S (2014) New Mediterranean biodiversity records (October, 2014). *Mediterranean Marine Science* 15, 675–695.
- Katsanevakis S, Poursanidis D, Hoffman R, Rizgalla J, Rothman SB-S, Levitt-Barmats Y and Espinosa Torre F (2020) Unpublished Mediterranean records of marine alien and cryptogenic species. *BioInvasions Records* 9, 165–182.
- Mifsud C (2007) *Haminoea cyanomarginata* Heller and Thompson, 1983 (Gastropoda, Haminoeidae), a new invader for the Maltese Islands. *Novapex* 8, 29–30.
- Oskars TR and Malaquias MAE (2019) A molecular phylogeny of the Indo-West Pacific species of *Haloa* sensu lato gastropods (Cephalaspidea: Haminoeidae): tethyan vicariance, generic diversity, and ecological specialization. *Molecular Phylogenetics and Evolution* 139, 106557.
- Oskars TR and Malaquias MAE (2020) Systematic revision of the Indo-West Pacific colourful bubble-snails of the genus *Lamprohaminoea* Habe, 1952 (Cephalaspidea: Haminoeidae). *Invertebrate Systematics* 34, 727–756.
- Osland MJ, Stevens PW, Lamont MM, Brusca RC, Hart KM, Waddle JH, Langtimm CA, Williams CM, Keim BD, Terando AJ, Reyier EA, Marshall KE, Loik ME, Boucek RE, Lewis AB and Seminoff JA (2021) Tropicalization of temperate ecosystems in North America: the northward range expansion of tropical organisms in response to warming winter temperatures. *Global Change Biology* 27, 3009–3034.
- Parravicini V, Mangialajo L, Mousseau L, Peirano A, Morri C, Montefalcone M, Francour P, Kulbicki M and Bianchi CN (2015) Climate change and warm-water species at the north-western boundary of the Mediterranean Sea. *Marine Ecology* 36, 897–909.
- Pisano A, Marullo S, Artale V, Falcini F, Yang C, Leonelli FE, Santoleri R and Buongiorno Nardelli B (2020) New evidence of Mediterranean climate change and variability from sea surface temperature observations. *Remote Sensing* 12, 132.
- Ragkousis M, Abdelali N, Azzurro E, Badreddine A, Bariche M, Bitar G, Crocetta F, Denitto F, Digenis M, El Zrelli R, Ergenler A, Fortič A, Gerovasileiou V, Grimes S, Katsanevakis S, Koçak C, Licchelli C, Loudaros E, Mastrototaro F, Mavrič B, Mavruk S, Miliou A, Montesanto F, Ovalis P, Pontes M, Rabaoui L, Sevingel N, Spinelli A, Tiralongo F, Tsatiris A, Turan C, Vitale D, Yalgin F, Yapici S and Zenetos A (2020) New Mediterranean biodiversity records (October 2020). *Mediterranean Marine Science* 21, 631–652.
- Rizgalla J, Fridman S, Ben Abdallah A, Bron JE and Shinn AP (2018) First record of the nonnative sea snail *Haminoea cyanomarginata* Heller and Thompson, 1983 (Gastropoda: Haminoeidae) in the southern Mediterranean Sea. *BioInvasions Records* 7, 411–414.
- Stasolla G, Riolo F, Macali A, Pierri C and Crocetta F (2014) Further spreading in the Italian seas of already established non-indigenous mollusc species. *Marine Biodiversity Records* 7, e120.
- Tiberti L, Barbieri F and Gambi MC (2015) Osservazioni sulla presenza di specie aliene lungo le coste della campania: un esempio di conoscenza ecologica locale e “cittadinanza scientifica”. *Notiziario SIBM* 67, 23–29.
- Vitale D, Giacobbe S, Spinelli A, De Matteo S and Cervera JL (2016) “Opisthobranch” (mollusks) inventory of the Faro Lake: a Sicilian biodiversity hot spot. *Italian Journal of Zoology* 83, 524–530.
- Yokeş MB, Andreou V, Bakiu R, Bonanomi S, Camps J, Christidis G, Crocetta F, Giovos I, Gori A, Juretić T, Karhan SÜ, Katsanevakis S, Kytinou E, Langeneck J, Lipej L, Maximiadi M, Michailidis N, Mitsou E, Nicolaidou A, Petović S, Prado P, Santín A, Teneketzis K, Thasitis I, Tirelli V, Trkov D, Troplini E, Tsiamis K and Vannucci A (2018) New Mediterranean biodiversity records (November 2018). *Mediterranean Marine Science* 19, 673–689.
- Zenetos A, Gofas S, Russo G and Templado J (2003) CIESM ATLAS of exotic species in the Mediterranean. *Molluscs CIESM* 3, 376 p.
- Zenetos A, Gofas S, Verlaque M, Cinar ME, Garcia Raso JE, Bianchi CN, Morri C, Azzurro E, Bilecenoglu M, Froglija C, Siokou-Frangou I, Violanti D, Sfriso A, San Martín G, Giangrande A, Katagan T, Ballesteros E, Ramos-Esplá A, Mastrototaro F, Ocaña Ó, Zingone A, Gambi MC and Streftaris N (2010) Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union’s Marine Strategy Framework Directive (MSFD). Part I. Spatial distribution. *Mediterranean Marine Science* 11, 381–493.