

As fast as a hare: colonization of the heterobranch *Aplysia dactylomela* (Mollusca: Gastropoda: Anaspidea) into the western Mediterranean Sea

Juan MOLES^{1,2}, Guillem MAS², Irene FIGUEROA², Robert FERNÁNDEZ-VILERT², Xavier SALVADOR²
and Joan GIMÉNEZ^{2,3}

(¹) Department of Evolutionary Biology, Ecology, and Environmental Sciences and Biodiversity Research Institute (IrBIO), University of Barcelona, Av. Diagonal 645, 08028 Barcelona, Catalonia, Spain

E-mail: moles.sanchez@gmail.com

(²) Catalan Opisthobranch Research Group (GROC), Mas Castellar, 17773 Pontós, Catalonia, Spain

(³) Department of Conservation Biology, Estación Biológica de Doñana (EBD-CSIC), Americo Vespucio 26
Isla Cartuja, 42092 Seville, Andalucía, Spain

Abstract: The marine cryptogenic species *Aplysia dactylomela* was recorded in the Mediterranean Sea in 2002 for the first time. Since then, this species has rapidly colonized the eastern Mediterranean, successfully establishing stable populations in the area. *Aplysia dactylomela* is a heterobranch mollusc found in the Atlantic Ocean, and commonly known as the spotted sea hare. This species is a voracious herbivorous with generalist feeding habits, possessing efficient chemical defence strategies. These facts probably promoted the acclimatation of this species in the Mediterranean ecosystems. Here, we report three new records of this species in the Balearic Islands and Catalan coast (NE Spain). This data was available due to the use of citizen science platforms such as GROC (Catalan Opisthobranch Research Group). These are the first records of this species in Spain and the third in the western Mediterranean Sea, thus reinforcing the efficient, fast, and progressive colonization ability of this sea hare. We have demonstrated that citizen science is a valuable tool for the early awareness of new colonizations as well as for monitoring the advance and settlement of new populations of cryptogenic species.

Résumé : Rapide comme un lièvre: le mollusque hétérobranche *Aplysia dactylomela* (Mollusca: Gastropoda: Anaspidea) colonise la Méditerranée nord occidentale. L'espèce cryptogénique marine, *Aplysia dactylomela*, fut décrite pour la première fois en Méditerranée en 2002. Depuis, cette espèce a rapidement colonisé la Méditerranée orientale, dans laquelle des populations stables se sont établies. *Aplysia dactylomela* est un mollusque hétérobranche qui habite les eaux de l'océan Atlantique, plus communément connu sous le nom de lièvre de mer ocellé. C'est un herbivore vorace au régime généraliste qui possède des stratégies de défense chimique efficaces. Cela a probablement facilité l'acclimatation de cette espèce aux écosystèmes méditerranéens. Nous rapportons trois nouvelles observations de *A. dactylomela* aux Îles Baléares et sur la côte catalane (NE de l'Espagne). Cette information a été obtenue grâce à l'utilisation de plateformes de science citoyenne telles que le GROC (Groupe de Recherche sur les Opisthobranches de Catalogne). Ces observations sont les premières rapportées en Espagne, et les troisièmes en Méditerranée occidentale, ce qui confirme la capacité de ce lièvre de mer à coloniser rapidement et efficacement de nouvelles zones. Nous avons démontré que les programmes de science citoyenne peuvent jouer un rôle capital dans la détection précoce de nouvelles colonisations ainsi que le suivi de l'avancée et de l'établissement de nouvelles populations d'espèces cryptogéniques.

Keywords: Citizen science • Cryptogenic species • Sea hare • Marine ecosystems

Introduction

Anaspidean heterobranch molluscs are widely distributed worldwide, mostly found in shallow temperate and tropical waters (Carefoot, 1987). The spotted sea hare *Aplysia dactylomela* Rang, 1828, has been described from the Atlantic region, by externally displaying a yellowish colouration with large, black rings distributed all over the body (Rang, 1828). This species was considered to be distributed in both sides of the Atlantic (*i.e.* amphi-Atlantic) and in the Indo-Pacific Oceans. Nonetheless, the species is presently divided into two sibling species based on both molecular and morphological data (Alexander & Valdés, 2013): *A. dactylomela* and *A. argus* Rüppell & Leuckart, 1830, from the Atlantic and Indo-Pacific, respectively. The first record of *A. dactylomela* in the Mediterranean Sea was in the island of Lampedusa (central Mediterranean) in 2002 (Trainito, 2003). Since then, a plethora of new records popped out in the eastern and central Mediterranean basin, including Israel, Lebanon, Syria, Cyprus, Turkey, Greece, Croatia, Malta, and Italy (Schembri, 2008; Yokes, 2008; Crocetta & Galil, 2012; Crocetta et al., 2013; Valdés et al., 2013; Katsanevakis et al., 2014). Although this fast invader was firstly proposed to come from the Red Sea via the Suez Canal (*i.e.* Erythrean migration; Crocetta & Galil, 2012), later studies showing the atypical sequence of colonization of *A. dactylomela* and DNA data recover this species as a colonizer from the Atlantic via the Strait of Gibraltar (Valdés et al., 2013). Nonetheless, its Mediterranean introduction vector is not yet established with certainty, and therefore *A. dactylomela* has been cautiously considered as a cryptogenic species (Mannino et al., 2017).

The main aim of this study is to present the first records of *A. dactylomela* in the Spanish coast (western Mediterranean Sea) and discuss about the causes of such successful colonization in this area.

Material and Methods

Three new records were obtained from the online database of GROC (Catalan Opisthobranch Research Group; <http://www.opisthobranquis.org/>). All records were uploaded by certified divers currently involved in the association.

Systematics

Anaspidea Fischer, 1883
 Aplysiidae Lamarck, 1809
Aplysia dactylomela Rang, 1828
 (Fig. 1A-B)

Material examined

Three new specimens were recorded in the western

Mediterranean Sea (see Fig. 2). The first occurrence was photographed in Cap d'en Font (39°49'35"N-4°12'20"E; Minorca, Balearic Islands, Spain), on the 25th June 2016 by the underwater photographer Joop Werson. The individual measured 13 cm (Fig. 1A) and was found at 15 m depth. The second occurrence was photographed in Cala Secains (41°46'46"N-3°2'46"E; Sant Feliu de Guíxols, Catalonia, Spain), on the 20th June 2016 by the free-diver and underwater photographer Xavier Salvador. The individual measured 12 cm (Fig. 1B) and was found at 1 m depth. Finally, the third record was found in Cala Es Caials (42°17'7"N-3°17'47"E; Cadaqués, Catalonia, Spain), on the 18th August 2016 by the biologist Àlex Bartolí. The individual measured around 15 cm (Fig. 1C) and was found at 4 m depth.

Description

The three specimens photographed were beige to yellowish in colour, with black rings and a network of black lines all over the body (Fig. 1A-C). The parapodial lobes were high, joined low down near the posterior foot. The cephalic tentacles and rhinophores were broad and blunt. The animals secreted a purple defensive ink when molested.

Ecology

The three specimens were found at shallow waters on a photophilic, seaweed community: dominated by the red alga *Laurencia obtusa* (Hudson) J.V.Lamouroux, 1813 (Rhodomelaceae) and the brown alga *Dictyota* cf. *dichotoma* (Dictyotaceae), for specimen 1 (Fig. 1A); dominated by the red alga *Laurencia obtusa* and the brown algae *Cystoseira compressa* (Esper) Gerloff & Nizamuddin, 1975 (Sargassaceae) and *Padina pavonica* (Linnaeus) Thivy, 1960 (Dictyotaceae), for specimen 2 (Fig. 1B); and dominated by *Cystoseira mediterranea*, Sauvageau, 1912, *P. pavonica*, and the seagrass *Posidonia oceanica* (Linnaeus) Delile, 1813, for specimen 3 (Fig. 1C).

Discussion

Three new records of the spotted sea hare *A. dactylomela* in the western Mediterranean Sea are reported in this study. Our data together with the observations around Egadi Islands (Mannino et al., 2014) and the single record in a port in Monaco (Karachle et al., 2016) clearly reflect a fast and progressive colonization of the species in the western Mediterranean Sea (Fig. 2). Moreover, we also recovered this species in unperturbed ecosystems, thus reinforcing the ecological success of *A. dactylomela* for dispersion and habitat colonization.

There are several factors that promote the broad dispersal potential of *A. dactylomela* into the

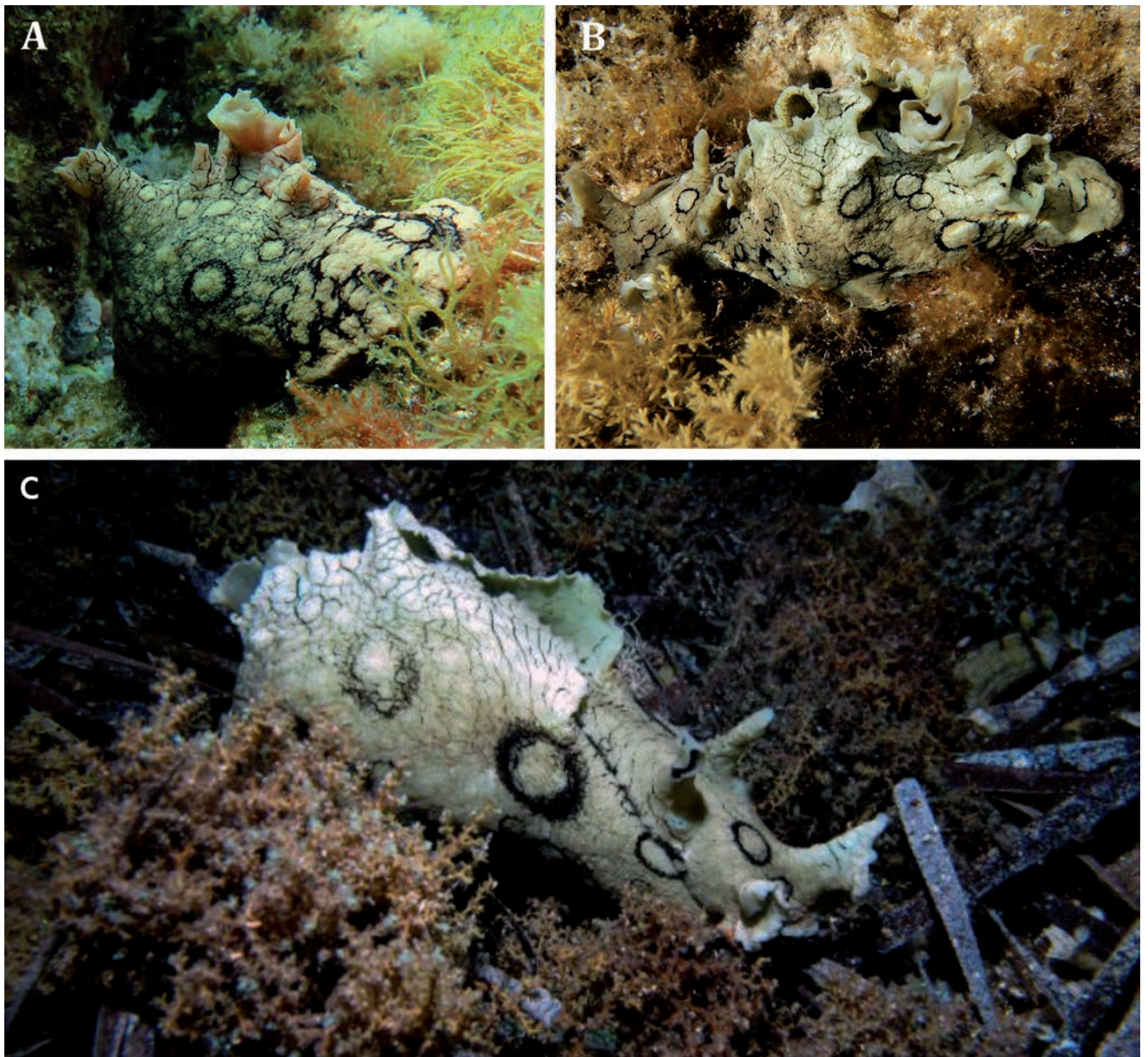


Figure 1. *Aplysia dactylomela*. Live, underwater photographs recorded from **A.** Cap d'en Font (Minorca, Balearic Islands, Spain) by Joop Werson. **B.** Cala Secains (Girona, Catalonia, Spain) by Xavier Salvador. **C.** Cala Es Caials (Girona, Catalonia, Spain) by Àlex Bartolí.

Mediterranean Sea. Firstly, *A. dactylomela* is known to be a fast grower, feeding on a wide variety of seaweeds (Carefoot, 1970): *Cladophora*, *Chaetomorpha*, *Enteromorpha*, *Gelidium*, *Hypnea*, *Laurencia*, and *Polysiphonia*. All of these algae are commonly found in shallow waters of the Mediterranean Sea (Guiry & Guiry, 2016); therefore these are putative areas of colonization for *A. dactylomela*. Secondly, *A. dactylomela* is chemically protected against predation, relying on a panoply of natural products mostly derived from algal prey (Kamio et al.,

2010). Undoubtedly, the high ecological success of this widely distributed species can be attributed to the ability to feed upon a wide variety of toxic seaweeds (e.g. *Laurencia* spp.), and use the consumed secondary metabolites for their own benefit, either by storing or transforming them (reviewed in Avila et al., in press). Overall, a rapid growth coupled with generalist feeding habits and an active defence against sympatric predation make this species an efficient cryptogenic invader. These facts are similarly shown in another invasive anaspidean, *Syphonota*

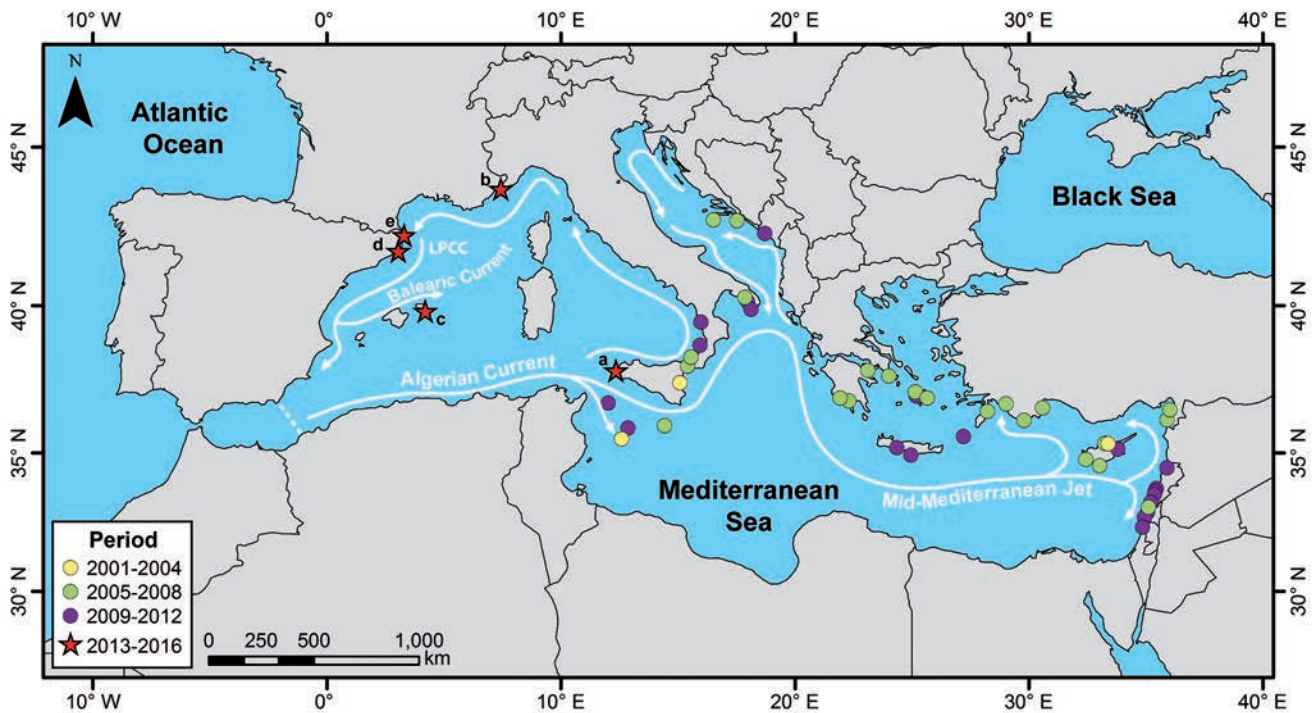


Figure 2. *Aplysia dactylomela*. Occurrences in the Mediterranean Sea. (a) Egadi Islands (Mannino et al., 2014); (b) Hercules harbour (Karachle et al., 2016); (c) Cap d'en Font; (d) Cala Secains; and (e). Cala Es Caials. Data from 2001 to 2012 were based on Valdés et al. (2013) review. Main Mediterranean Currents are illustrated, Almería-Orán Front represented by a white dashed-line. LPCC Liguro-Provençal-Catalan Current. Geographical data deposited in the EASIN database (<http://easin.jrc.ec.europa.eu/>).

geographica (A. Adams & Reeve, 1850), which its survival in the Mediterranean seems to be tighten to the presence of its prey, and thus its chemical defences obtained for defence (Mollo et al., 2008). Therefore, we expect that *A. dactylomela* will likely establish stable populations in the western Mediterranean, similarly to the already well-established populations in the eastern side.

Our study reinforces the hypothesis of a Mediterranean colonization by Atlantic populations of *A. dactylomela*. Valdés et al. (2013) suggested that the veliger larvae of *A. dactylomela* successfully traversed the Almería-Orán front during mild-winters; subsequently being transported to the central and eastern Mediterranean by the Algerian Current and the Mid-Mediterranean Jet, respectively. Lately, several colonisations towards the central Mediterranean have been reported (Schembri, 2008; Yokes, 2008; Crocetta & Galil, 2012; Valdés et al., 2013; Mannino et al., 2014). This hypothesis, therefore, would predict a potential colonization of the western Mediterranean by *A. dactylomela*, following the main Mediterranean currents. Our data is in clear accordance with this fact, and we suggest that the Liguro-Provençal-Catalan and the Balearic Currents have transported the species to the Catalan and Balearic coasts, respectively (Fig. 2). Overall, the main

driving force of migration of the species in the Mediterranean is the seawater circulation, which may be especially effective in the pelagic larval stage of *A. dactylomela*. Early warning evidences of the species may facilitate the elucidation of the colonization patterns of the species and its settlement in the Mediterranean Sea.

Citizen science programs, as the one carried by the Catalan Opisthobranch Research Group (GROC, 2016), assist to monitor and detect new records of heterobranchs, which can serve as an early warning alert to scientists and managers. Overall, we encourage scientists from other regions to settle platforms such as GROC to enhance citizen science monitoring, thus gaining insight on the ecology of heterobranchs and rapidly detecting colonization events and alien invasions.

Acknowledgments

We would like to thank Joop Werson and Àlex Bartolí, who kindly uploaded the new occurrences in the online database of GROC and provided the underwater photographs. We are indebted to the nearly 200 citizen collaborators of GROC that regularly monitor the Catalan coast and adjacent waters. Thanks are also given to I. Afán and D.

Aragonés (LAST-EBD-CSIC) for helping with map design and P. Gauffier for her help with the translation of the abstract to French. This is the study #2 of the GROC Association.

References

- Alexander J. & Valdés A. 2013.** The ring doesn't mean a thing: molecular data suggest a new taxonomy for two Pacific species of sea hares (Mollusca: Opisthobranchia, Aplysiidae). *Pacific Science*, **67**: 283-294.
- Avila C., Núñez-Pons L. & Moles J. in press.** From the tropics to the poles: chemical defensive strategies in sea slugs (Mollusca: Heterobranchia). In: *Chemical ecology: the ecological impacts of marine natural products* (M.P. Puglis-Weeningi, M.A. Becerro & V.J. Paul eds). Taylor & Francis Group.
- Carefoot T.H. 1970.** A comparison of absorption and utilization of food energy in two species of tropical *Aplysia*. *Journal of Experimental Marine Biology and Ecology*, **5**: 47-62.
- Carefoot T.H. 1987.** *Aplysia*: its biology and ecology. *Oceanography and Marine Biology - An Annual Review*, **25**: 139-568.
- Crocetta F. & Galil B.S. 2012.** The invasive spotted sea hare *Aplysia dactylomela* (Mollusca: Gastropoda: Aplysiidae) - New records and spread pattern in the Mediterranean. *Vie et Milieu*, **62**: 43-46.
- Crocetta F., Zibrowius H., Bitar G., Templado J. & Oliverio M. 2013.** Biogeographical homogeneity in the eastern Mediterranean Sea - I: the opisthobranchs (Mollusca: Gastropoda) from Lebanon. *Mediterranean Marine Science*, **14**: 403-408.
- GROC. 2016.** Grup de Recerca d'Opistobranquis de Catalunya. World-wide electronic publication. <http://www.opistobranquis.org/>
- Guiry M.D. & Guiry G.M. 2016.** AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>
- Kamio M., Grimes T.V., Hutchins M.H., van Dam R. & Derby C.D. 2010.** The purple pigment aplysioviolin in sea hare ink deters predatory blue crabs through their chemical senses. *Animal Behaviour*, **80**: 89-100.
- Karachle P.K., Angelidis A., Apostolopoulos G., Ayas D., Ballesteros M., Bonnici C., Brodersen M.M., Castriota L., Chalari N., Cottalorda J.M., Crocetta F., Deidun A., Đodož, Dogrammatzi A., Dulčić J., Fiorentino F., Gönülal O., Harmelin J.G., Insacco G., Izquierdo-Gómez D., Izquierdo-Muñoz A., Joksimović A., Kavadas S., Malaquias M.A.E., Madrenas E., Massi D., Micarelli P., Minchin D., Önal U., Ovalis P., Poursanidis D., Siapatis A., Sperone E., Spinelli A., Stamouli C., Tiralongo F., Tunçer S., Yaglioglu D., Zava B., Zenetos A. 2016.** New mediterranean biodiversity records (March 2016). *Mediterranean Marine Science*, **17**: 230-52.
- Katsanevakis S., Acar Ü., Ammar I., Balci B.A., Beka P., Belmonte M., Chintiroglou C.C., Consoli P., Dimiza M., Fryganiotis K., Gerovasileiou V., Gnisci V., Gülşahin N., Hoffman R., Issaris Y., Izquierdo-Gómez D., Izquierdo-Muñoz A., Kavadas S., Koehler I., Konstantinidis E., Mazza G., Nowell G., Önal U., Özen M.R., Pafilis P., Pastore B., Perdikaris C., Poursanidis D., Prato E., Russo F., Sicuro B., Tarkan A.N., Thessalou-Legaki M., Tiralongo F., Triantaphyllou M., Tsiamis K., Tunçer S., Turan C., Türker A., Yapici S. 2014.** New mediterranean biodiversity records (October, 2014). *Mediterranean Marine Science*, **15**: 675-695.
- Mannino A.M., Balistreri P. & Yokeş M.B. 2014.** First record of *Aplysia dactylomela* (Opisthobranchia: Aplysiidae) from the Egadi Islands (western Sicily). *Marine Biodiversity Records*, **7**: 1-4.
- Mannino A.M., Parasporo M., Crocetta F. & Balistreri P. 2017.** An updated overview of the marine alien and cryptogenic species from the Egadi Islands Marine Protected Area (Italy). *Marine Biodiversity*, **47**: 469-480.
- Mollo E., Gavagnin M., Carbone M., Castelluccio F., Pozzone F., Roussis V., Templado J., Ghiselin M.T. & Cimino G. 2008.** Factors promoting marine invasions: a chemoecological approach. *Proceedings of the National Academy of Sciences*, **105**: 4582-4586.
- Rang S. 1828.** Histoire naturelle des Aplysiens. Première famille de l'ordre des Tectibranches. Didot: Paris.
- Schembri P.J. 2008.** Occurrence of the alien sea hare *Aplysia dactylomela* Rang, 1828 (Opisthobranchia, Aplysiidae) in Malta. *Mediterranean Marine Science*, **9**: 111-114.
- Trainito E. & Doneddu M. 2003.** *Mediterranean Harlequins. A field guide to Mediterranean Sea slugs*. Taphros: Olbia, Italy. 192 pp.
- Valdés Á., Alexander J., Crocetta F., Baki Yokeş M., Giacobbe S., Poursanidis D., Zenetos A., Cervera J.L., Caballer M., Galil B.S. & Schembri P.J. 2013.** The origin and dispersal pathway of the spotted sea hare *Aplysia dactylomela* (Mollusca: Opisthobranchia) in the Mediterranean Sea. *Aquatic Invasions*, **8**: 427-436.
- Yokes M.B. 2008.** *Aplysia dactylomela*: an alien opisthobranch in the Mediterranean. *Marine Biodiversity Records*, **1**: 1-3.