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Letter to the Editor

The Suez Canal as a revolving door for marine species: a reply to Galil et al. (2016)

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Abstract

In this reply, we address the criticism directed recently to our work (Malaquias et al. 2016) by Galil et al. (2016) dismissing the hypothesis that the Suez Canal can act as a revolving door allowing marine species to move both ways between the Red Sea and the Mediterranean Sea. We reiterate that the presence in the Red Sea of the Indo-West Pacific sea slug *Chelidonura fulvipunctata* Baba, 1938 is most parsimoniously explained by an invasion from the Mediterranean and highlight several recent studies combing morphology and molecular phylogenetics where established views about the presence of alien Indo-Pacific / Red Sea species in the Mediterranean were proven wrong. Caution is suggested when assuming the conspecificity of species between these realms based solely on external features.

Key words: alien species, anti-Lessepsian migration, *Chelidonura fulvipunctata*, Gastropoda, Mediterranean Sea, Red Sea

In a recent paper (Malaquias et al. 2016), we postulated (using available DNA data, morphology, and geographical records) that the Indo-West Pacific species of sea slug *Chelidonura fulvipunctata* Baba, 1938, invasive and widespread in the Mediterranean Sea, did not enter this realm directly from the Red Sea (which would be Lessepsian immigration). Instead, it entered by a different route, and its occurrence in the Red Sea was a result of an anti-Lessepsian movement with specimens entering the Red Sea from the Mediterranean with the Suez Canal acting as a "revolving door" that allows species to move into and out of the Mediterranean Sea. Galil et al. (2016) commented on our paper and questioned our conclusions. In this reply, we address these concerns.

We fully agree with Galil et al. (2016) that "Identifying the geographic origin and the pathways of introduction are of major importance for management of bioinvasions" and that "… care should be taken to provide scientists, regulators and stakeholders with as accurate information as possible". And that is why we believe that conclusions and hypotheses have to be drawn from available facts and not from hypothetical arguments.

In their point E, Galil et al. (2016) insist on the idea that the Red Sea is a poorly studied basin as a putative argument to justify the lack of records of *C. fulvipunctata* in this realm and cites evidence from Yonow (2015) in which 73 species are documented for the first time in the period subsequent to the publication of the book "Sea slugs of the Red Sea" (Yonow 2008). As with almost any other large marine basin in the world, it is likely that new species records and even new species to Science will continue being found in the Red Sea, but this does preclude the fact that this marine basin has a long record of works dedicated to the study of sea slugs beginning in the late 18th century (see Yonow 2008:

pages 14–17). This work clearly continues to the present as the documenting of 73 new species records (Yonow 2015) most certainly demonstrates. Recent sea slug knowledge in the Red Sea does not result only from sporadic activities of amateur naturalists and divers who publish their underwater photographic images online but also comes from dedicate scientific activities such as those organized recently by the California Academy of Sciences and the King Abdullah University of Science & Technology in the Saudi Red Sea in 2013 (T Gosliner, California Academy of Sciences, San Francisco, CA, USA; personal communication) or the sampling program for opisthobranchs undertaken by the University of Tübingen, Germany between 2005–2007 in Mangrove Bay (central coast of Egypt) (N Anthes, University of Tübingen, Germany; personal communication). These last two examples did not generate monographs of Red Sea fauna like those of Yonow (2000, 2008, 2015); however, the results are included in revisions of specific groups or general identification guides of sea slugs from the Indo-Pacific region (e.g., Anthes et al. 2008; Gosliner et al. 2015).

Future research will certainly yield new species records for the Red Sea, but that is also the case in what is probably the best studied marine basin in the World—the Mediterranean Sea (Gosliner et al. 2008). In the Mediterranean Sea, species new to Science are still being found and described, including few recent examples of sea slugs: *Doto alidrisi* Ortea, Moro and Ocaña, 2010; *Doto caballa* Ortea, Moro and Ocaña, 2010; *Philine iris* Tringali, 2001; *Philinopsis miqueli* Pelorce, Horst and Hoarau, 2013; *Facelinopsis pacodelucia* Ortea, Moro and Caballer, 2014; *Piseinotecus soussi* Tamsouri, Carmona, Moukrim and Cervera, 2014; *Tritonia coralliumrubri* Doneddu, Sacco and Trainito, 2014; and *Tambja mediterranea* Domínguez, Pola and Ramón, 2015 (Tringali 2001; Ortea et al. 2010; Pelorce et al. 2013; Doneddu et al. 2014; Ortea et al. 2014; Tamsouri et al. 2014; Domínguez et al. 2015).

The only evidence confirming the occurrence of the conspicuous, shallow-water, sea slug *C. fulvipunctata* in the Red Sea consists of two photographic records made in the Gulf of Aqaba on the northernmost part of the realm (Koretz 2005; Lederman 2005a). And yet, the species is common across the Indo-West Pacific and has been already reported in the Mediterranean Sea nine times (see Malaquias et al. 2016 for details).

Galil et al. (2016) presented several examples of what they consider cases similar to *C. fulvipunctata*; including species described from the Mediterranean Sea later found to be widespread in the Red Sea and even Indo-Pacific (point D of their Letter). It might be the case that future studies will demonstrate that *C. fulvipunctata* is widespread and native in the Red Sea, but our work (Malaquias et al. 2016) is based on the most parsimonious interpretation of the facts at hand and tries to avoid speculation. As putative comparable examples, Galil et al. (2016) mentioned the nudibranch *Melibe viridis* (Kelaart, 1858) until recently only known from several localities in the Indo-Pacific and Mediterranean Sea, but not from the Red Sea. Thus it was concluded to have invaded the Mediterranean by other sources other than a Lessepsian migration (Zenetos et al. 2003). Yet, because this species has recently been found in the Red Sea (reported in Yonow 2015), Galil et al. (2016) presumed it to be native in the latter realm and explained its presence in the Mediterranean since the 1980's as the result of an invasion from the Red Sea. This is a personal interpretation of the authors (Galil et al. 2016) who offer no solid evidence that would lead one to reject the hypothesis that *Melibe viridis* could have entered the Red Sea from the Mediterranean. In this particular case, we are talking about a large species (10–20 cm long) that occurs in shallow waters among seagrass and, therefore, easily accessible to divers and researchers. Another example invoked by the authors is the colorful cephalaspid *Haminoea cyanomarginata* Heller and Thompson, 1983 described in 1983 from the Sudanese coast in the central part of the Red Sea (Heller and Thompson 1983) and reported later in the northern part of this basin at least seven times (Lederman 2005b, c, d; Koretz and Koretz 2005, 2006), therefore spread over a vast area of the Red Sea and known to be present in the Mediterranean since 2004 (Yokeş and Rudman 2004). It is difficult to understand how can this compare with the case of *C. fulvipunctata*, a species described from Japan (Baba 1938), and as mentioned earlier, widely distributed in the Indo-West Pacific and also in the Mediterranean Sea where it was first reported in 1961 (Swennen 1961; Malaquias et al. 2016), and yet only observed in the Red Sea twice during 2005 on the northernmost part of the realm (Gulf of Aqaba).

Galil et al. (2016; point A of the Letter) have apparently misinterpreted the goal of our molecular phylogenetic analysis, which never intended to support or refute the Mediterranean origin of the Red Sea specimens of *C. fulvipunctata*, but only to yield evidence for the conspecificity of the Mediterranean and Indo-West Pacific specimens.

Moreover, caution is necessary prior to assumption of the conspecificity of biological entities between Red Sea / Indo-Pacific and Mediterranean faunistic elements because of cryptic speciation and pervasive polychromatic patterns. The latter is well documented

in heterobranch gastropods (sea slugs *sensu lato*; Ornelas-Gatdula et al. 2011; Padula et al. 2016). Most comparisons of alien fauna between these realms are based on morphological similarities, but there are several recent examples of sea slug "species" that look very similar but actually are different entities. Pertinent to this geographical context is the recent case of the "alien" nudibranch species *Anteaeolidiella indica* (Bergh, 1888) reported in the Mediterranean Sea and broadly distributed across the Indo-Pacific (Zenetos et al. 2003; Carmona et al. 2014). Based on external morphology, this "species" was considered to be a single entity with a global distribution, and its presence in the Mediterranean Sea was assumed to be the result of transport on ship hulls moving from the Indian Ocean. Yet, recently, Carmona et al. (2014) using anatomical and DNA characters showed that *A. indica* is a complex of species and that the Mediterranean form is a different biological entity from those inhabiting the Indo-Pacific. Another example is the *Berthellina citrina* (Rüppell and Leuckart, 1828) species complex. This strikingly colored (orange-red), large, shallow-water sea slug species with type locality in the Red Sea has been reported several times from the Mediterranean (Eales 1970; Thompson 1976; Barash and Danin, 1977; Cattaneo-Vietti 1986; and more recently by Yonow 2008: 110), but Cervera et al. (2004) suggested these records actually are misidentifications of the similar eastern Atlantic-Mediterranean species *B. edwardsii* (Vayssière, 1897). Recently Moustafa et al. (2016) showed, with anatomical and molecular phylogenetic data, that the Red Sea harbors two distinct species of orange-red pleurobranchid sea slugs (*B. citrina* and *B. delicata* (Pease, 1861)) that are distinct from the Mediterranean orange-Red Sea slug *Berthellina* (= *B. edwardsii*).

In summary, we stand by our conclusion that the presence of *C. fulvipunctata* in the Red Sea is "…more parsimoniously explained by an expansion from the Mediterranean into the Red Sea rather than dispersal from the Indo-West Pacific to the Red Sea" (Malaquias et al. 2016). Nevertheless, in the last paragraph of the discussion of our original paper, we left room for alternative scenarios and went further to explain how competing hypothesis could be tested, highlighting simultaneously the difficulties of doing it at present because of lack of samples from the Red Sea.

It is critical that scientists, regulators, and stakeholders, is this specific case those concerned with the movement of species across the Suez Canal and its ecological implications, be provided with reliable and accurate information rooted in high quality taxonomic practice based ideally on integrative approaches rather than simple comparison of external resemblances. Moreover, in a period of global climate change characterized by rising water temperatures in many locations (Bianchi 2007), the scientific community must remain alert to the possible "revolving door" effect of the now enlarged Suez Canal and bidirectional movements of species between the Mediterranean and Red Sea.

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