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Rapid Communication

Portent or accident? Two new records of thermophilic fish from the central Mediterranean

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Abstract

The blue tang *Acanthurus coeruleus* Bloch and Schneider, 1801 and the Red Sea bannerfish *Heniochus intermedius* Steindachner, 1893 are reported for the first time from the Maltese Islands, which also represents the first central Mediterranean record for both species. The new records are based on an individual of *A. coeruleus* observed in October 2013 and a specimen of *H. intermedius* caught in November 2014; no individuals of either species have been found since. The occurrence of these species in Malta may be due to a westwards range expansion in the Mediterranean, given that both species were previously recorded from the Levantine Sea, but they could also have been introduced directly in Maltese waters through the aquarium trade or by shipping, particularly since evidence for established populations in the eastern Mediterranean is lacking. The relevance of these new additions of thermophilic fishes to the central Mediterranean ichthyofauna is discussed in relation to ongoing biotic changes in this sea.

Key words: Acanthuridae, Chaetodontidae, Malta, non-indigenous species, range expansion

Introduction

An ongoing warming trend is clearly evident in both the surface and deep waters of the Mediterranean Sea (Lejeusne et al. 2010; Bianchi et al. 2012), and temperatures are expected to continue rising given that climate models predict that the Mediterranean region will be one of the hotspots of global climate change (Giorgi 2006; Diffenbaugh and Giorgi 2012). The increasing seawater temperature renders this sea more receptive to invasion by thermophilic species, especially by Red Sea biota entering through the Suez Canal (Raitsos et al. 2010; Galil and Goren 2014), but also by sub-tropical eastern Atlantic species extending their distribution range into the Mediterranean via the Strait of Gibraltar. Warmer temperatures also increase the survival chances for thermophilic alien species introduced intentionally or accidentally (Bianchi et al. 2013).

The appearance and spread of subtropical and tropical biota, together with seawater warming, are leading to what has been termed the 'tropicalization' of the Mediterranean Sea (Bianchi and Morri 2003; Bianchi 2007). Surgeonfish (Family Acanthuridae) and butterflyfish (Family Chaetodontidae) are examples of species contributing to this tropicalization. These subtropical and tropical fishes are typically found associated with coral reefs in the Atlantic, Pacific, and Indian Oceans (Froese and Pauly 2015). No acanthurid species are indigenous to the Mediterranean Sea, while one species of butterflyfish, *Chaetodon hoefleri* Steindachner, 1881, has on rare occasions been observed in the western basin, presumably having entered as a vagrant through the Gibraltar Strait (Psomadakis et al. 2012).

On the other hand, since the early 1980s, seven species belonging to these two families have been recorded as newcomers in the Mediterranean. Three species originate in the Atlantic Ocean: *Acanthurus monroviae* Steindachner, 1876, first recorded in 1981 in Spain (Crespo et al. 1987); *Acanthurus coeruleus* Bloch and Schneider, 1801,

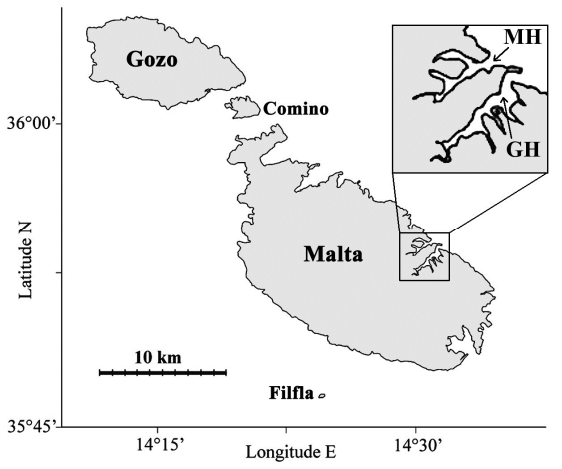

Figure 1. Map of the Maltese Islands showing location of the records of *Acanthurus coeruleus* (MH: Marsamxett Harbour) and *Heniochus intermedius* (GH: Grand Harbour).

Figure 2. Photograph of the *Acanthurus coeruleus* individual sighted in Marsamxett Harbour, Malta, in October 2013 (photograph © Debbie Adams).

Figure 3. Photograph of the specimen of *Heniochus intermedius* caught from the Grand Harbour, Malta, in November 2014 (photograph © Raymond Caruana).

sighted in 2011 in Cyprus (Langeneck et al. 2012); and *Acanthurus chirurgus* (Bloch, 1787), recorded from off Elba Island, Tyrrhenian Sea in 2012 (Langeneck et al. 2015). Three species come from the Red Sea: *Heniochus intermedius* Steindachner, 1893, first found in 2002 in Turkey (Gökoglu et al. 2003); and *Chaetodon austriacus* Rüppell, 1836 and *Chaetodon larvatus* Cuvier, 1831, both recorded in 2011 from Israel (Goren et al. 2011; Salameh et al. 2011). Finally, one Pacific species, *Zebrasoma flavescens* (Bennett, 1828), was reported from the Balearic Sea, near Sitges (Spain), in 2008 (Weitzmann et al. 2015).

Here we report the presence of two of these species, the blue tang *Acanthurus coeruleus* and the Red Sea bannerfish *Heniochus intermedius*, in the Maltese Islands, which represents the first central Mediterranean record for both. The relevance of these additions to the central Mediterranean ichthyofauna to ongoing biotic changes in this sea is discussed.

Results and discussion

A surgeonfish was sighted during a scuba dive in Marsamxett Harbour (Figure 1) on 11th October 2013 (Debbie Adams and Bent Matusiak, personal communication, March 2014). The specimen was not caught but good quality photographs (Figure 2) enabled its unambiguous identification as the blue tang *Acanthurus coeruleus*. This species is characterised by bright yellow juveniles, which switch to a blue to purplish-grey coloration with grey longitudinal lines on the body as adults (Randall 2002); the specimen observed in Marsamxett represents the intermediate colour form with a bluish head and body but still possessing a yellow caudal fin. The bluish coloration and absence of spots, bands or other marks on the body (as found in other acanthurids; see Randall 2001, 2002) allow positive identification of *A. coeruleus* from photographs. The individual was observed over a rocky and boulder bottom in water 6–8 m deep. The divers estimated the fish to be between 100 mm and 120 mm in total length. The same individual remained in the area for at least two weeks (Bent Matusiak, personal communication, March 2014), but subsequent dives in the same place over a period of 5 months yielded no further observations of this species.

On 9th November 2014 a single specimen of *Heniochus intermedius* (Figure 3) was caught during recreational fishing by one of us (RT) in the Grand Harbour (Figure 1). The fish was kept

Table 1. Morphometric measurements, meristic counts and body mass of the specimen of *Heniochus intermedius* caught from the Grand Harbour, Malta, in November 2014.

Morphometric measurements	Absolute value (mm)	% of Standard Length
Total Length	115.0	116.8
Standard Length	98.5	100.0
Body depth	79.0	80.2
Body width	15.0	15.2
Head length	33.0	33.5
Snout length	12.0	12.2
Jaw length	6.5	6.6
Eye diameter	9.5	9.6
Dorsal fin base length	74.0	75.1
Dorsal fin length (4th spine)	117.0	118.8
Anal fin base length	36.5	37.1
Anal fin length	30.0	30.5
Pectoral fin base length	9.0	9.1
Pectoral fin length	26.0	26.4
Pelvic fin base length	8.5	8.6
Pelvic fin length	27.0	27.4
Caudal fin length	16.5	16.8
Caudal peduncle height	10.5	10.7
Meristic counts		
Dorsal fin rays	XI + 25	
Anal fin rays	III + 18	
Pectoral fin rays	16	
Pelvic fin rays	I + 5	
Caudal fin rays	23	
Total mass (g)	47.6	

alive in a marine aquarium for a few days but subsequently died and was preserved frozen. It occurred very close to the shore at a depth of around 3 m, on a bottom of large boulders covered with low-growing algae and turf algae. The fish was using the spaces between boulders to hide in. No other individuals of this species were observed in the area. Diagnosis was based on the following combination of characters which distinguish it from its congeners (see Pyle 2001): two broad black bands, the first extending from the front of the dorsal fin to the pelvic fins and including the eyes and pectoral fins; extremely elongated fourth dorsal spine; yellow pectoral fin, caudal fin and posterior part of dorsal fin. Selected morphometric measurements and meristic counts (Table 1) agree with those given by Randall (1983) and Golani et al. (2002).

The presence of *A. coeruleus* and *H. intermedius* in the Mediterranean may be linked to rising sea temperatures in the region. Such rising temperatures can facilitate the influx of subtropical or tropical species from the Gibraltar Strait or Suez Canal into the Mediterranean, as well as enhance the spread of already established thermophilic species from the Levantine Sea towards the west (Lejeusne et al. 2010; Bianchi et al. 2012, 2013).

The initial record of *H. intermedius*, based on a pair of individuals sighted in the Gulf of Antalya in Turkey in 2002, was originally attributed to shipping or aquarium release (Gökoglu et al. 2003), but individuals of this species were subsequently observed in Lebanon in 2005 and again in 2011. This suggests that immigration of this Red Sea species through the Suez Canal, aided by warming of eastern Mediterranean waters, is a more likely mode of introduction (Bariche 2012). It is not known whether the separate sightings are due to unrelated multiple introductions or to the presence of an established population in the Levantine area, but it is unlikely that this species could be overlooked given that it is very conspicuous and easily recognizable.

In the case of *A. coeruleus*, a climate-induced range expansion is less likely since it is primarily found in the western Atlantic Ocean; its occurrence in Cyprus was more likely due to direct human-mediated introduction, either through shipping or aquarium release (Langeneck et al. 2012). Between 2011 and 2014, juveniles of *A. coeruleus* were sighted in different locations along the southern coast of Cyprus, suggesting that this species may have become established in the region, even though there are no records of adult individuals (Langeneck et al. 2015).

The duration of the pelagic larval phase of *A. coeruleus* ranges from around 46 to 57 days (Rocha et al. 2002). While no information on that of *H. intermedius* is available, the mean pelagic larval duration of three congeneric species ranges between 32 and 41 days (Luiz et al. 2013). This provides ample time for these species to disperse to the central Mediterranean from elsewhere in the sea, so the new records of *A. coeruleus* and *H. intermedius* from the Maltese Islands may represent a westwards expansion from any populations already established in the eastern Mediterranean. On the other hand, the limited evidence for such established populations in the Levantine region, particularly in the case of *H. intermedius*, suggests that the two Maltese records could be due to separate direct introductions in the central Mediterranean.

Direct introductions may have occurred via aquarium release or shipping: both pathways have been suggested as likely modes of introduction of other exotic fishes in Maltese waters, e.g., *Scatophagus argus* (Linnaeus, 1766) (Zammit and Schembri 2011) and *Oplegnathus fasciatus* (Temminck and Schlegel, 1844) (Schembri et al. 2010). The intentional or accidental release of specimens imported via the aquarium trade was considered to be the most likely introduction pathway

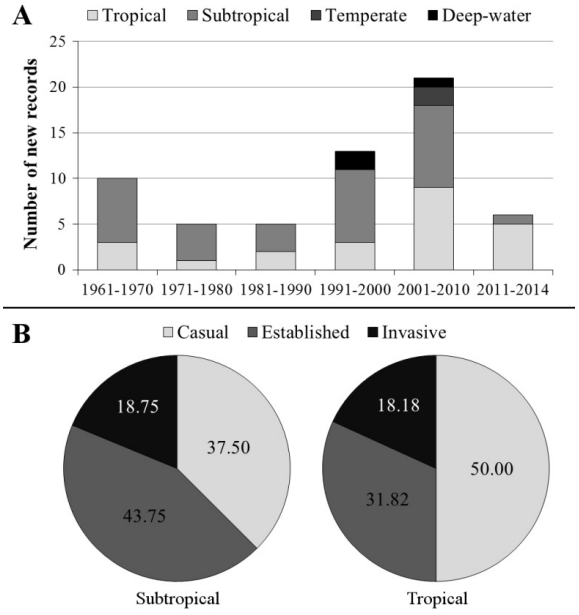

Figure 4. Newcomer fishes in the central Mediterranean region grouped according to their biogeographic affinity; A: number of new records per decade; B: establishment success (% number of species) of subtropical and tropical species.

for *A. coeruleus* in Cyprus (Langeneck et al. 2012), as well as for other recently introduced acanthurids: *A. chirurgus* (Langeneck et al. 2015) and *Z. flavescens* (Weitzmann et al. 2015). Aquarium release was also suggested as the initial mode of introduction for *H. intemedius* in Turkey (Gökoglu et al. 2003). However, shipping-related modes cannot be excluded given that the two new records were both made in harbours. The relatively long pelagic life of the larval stage of these species allows the larvae to be taken up together with ballast water in one place and subsequently discharged in another location. This would require a period of post-larval development in the destination port, so such a scenario would be more plausible if the new records were based on juvenile specimens. On the other hand, transport of sub-adult or adult fish can also occur in seawater-containing compartments, such as sea chests, enabling the long-distance translocations of large fish (see discussion in Schembri et al. 2010).

Irrespective of the exact mode of introduction, the occurrence of *A. coeruleus* and *H. intermedius* in the central (and eastern) Mediterranean can still be linked to the current climatic changes since warming sea temperature increases the likelihood that incoming warm-water species can survive in their new environment (at least long enough to be detected). Indeed, these two records add on to an increasing list of subtropical and tropical fishes that have been found in the Maltese Islands, including: *Abudefduf saxatilis* (Linnaeus, 1758); *Alepes djedaba* (Forsskål, 1775); *Cephalopholis taeniops* (Valenciennes, 1828); *Epinephelus malabaricus* (Bloch and Schneider, 1801); *Fistularia commersonii* Rüppell, 1838; *Ophioblennius atlanticus* (Valenciennes, 1836); *Oplegnathus fasciatus; Parablennius pilicornis* (Cuvier, 1829); *Scatophagus argus; Selene dorsalis* (Gill, 1863); *Seriola fasciata* (Bloch, 1793); *Siganus luridus* (Rüppell, 1829); and *Sphyraena chrysotaenia* Klunzinger, 1884 (Evans et al. 2015). Langeneck et al. (2015) also mention the sighting of another acanthurid (*Acanthurus monroviae*) in Malta, but this is based on a personal communication and is not substantiated by a photograph or specimen.

The central Mediterranean appears to be becoming more amenable to the occurrence of thermophilic species. To assess whether this is the case, a database (supplementary material Table S1) of non-indigenous species and other newcomers occurring in this region to date was compiled. For the purpose of this exercise, the "central Mediterranean" was considered to include south Sicily, Malta, Tunisia, Libya and the Ionian coasts of Greece, Albania and Italy. For each species, the climatic conditions in its native range (temperate/deep-water/subtropical/tropical), the country and date of first occurrence in the central Mediterranean (taken as "prior to" the date of publication when the actual date of the record was not indicated) and establishment success (casual/established/invasive) were recorded; questionable records were not included.

A total of 60 fish species were included in the list of newcomers in the central Mediterranean, with an increasing trend in the number of new records over the last two decades (Figure 4). Most of these species (90%) are of subtropical or tropical affinity, and the proportion of tropical newcomers appears to have increased (30% of newcomers in the 1960s vs 45% of newcomers in the 2000s). Overall, there has been a clear augmentation in the number of thermophilic fish species in the central Mediterranean, and the present records of *A. coeruleus* and *H. intermedius* are the latest in this ongoing trend.

Since only a single specimen each of *A. coeruleus* and *H. intermedius* was recorded from Malta, their presence in the central Mediterranean may be considered fortuitous, and it is unlikely that these species have established breeding populations at present. Nevertheless, when *A. coeruleus* was

first sighted in Cyprus, Langeneck et al. (2012) commented that it was "probably an accident: the establishment of this western Atlantic species in the Mediterranean seems unlikely", yet this species may have become established in Cyprus (Langeneck et al. 2015). Moreover, more than half of the subtropical/tropical species recently introduced into the central Mediterranean have established populations in the area, while nearly 20% are classified as invasive (Figure 4), clearly showing that some thermophilic newcomers do have the ability to become established. Furthermore, the possibility of multiple separate introductions, as may have occurred for *A. coeruleus* and *H. intermedius* in the Mediterranean, increases the chances that some of these species will eventually become established. Thus, while the present records of *A. coeruleus* and *H. intermedius* from Malta may be deemed an accident, they also portend further tropicalization of central Mediterranean waters. Given their location within the Sicilian Channel, the Maltese Islands are well sited to act as an observatory for these ongoing biogeographic changes.

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References

Bariche M (2012) Recent evidence on the presence of *Heniochus intermedius* (Teleostei: Chaetodontidae) and *Platycephalus indicus* (Teleostei: Platycephalidae) in the Mediterranean Sea. *BioInvasions Records* 1: 53–57, http://dx.doi.org/10.3391/bir.2012.1.1.12

Bianchi CN (2007) Biodiversity issues for the forthcoming tropical Mediterranean Sea. *Hydrobiologia* 580: 7–21, http://dx.doi.org/10.1007/978-1-4020-6156-1_1

Bianchi CN, Morri C (2003) Global sea warming and 'tropicalization' of the Mediterranean Sea: biogeographic and ecological aspects. *Biogeographia* 24: 319–327

Bianchi CN, Morri C, Chiantore M, Montefalcone M, Parravicini V, Rovere A (2012) Mediterranean Sea biodiversity between the legacy from the past and a future of change. In: Stambler N (ed), Life in the Mediterranean Sea: A Look at Habitat Changes. Nova Science Publishers Inc., New York, pp 1–55

Bianchi CN, Boudouresque CF, Francour P, Morri C, Parravicini V, Templado J, Zenetos A (2013) The changing biogeography of the Mediterranean Sea: from the old frontiers to the new gradients. *Bollettino dei Musei e degli Istituti Biologici dell'Università di Genova* 75: 81–84

Crespo J, Rey JC, García A (1987) Primera cita de *Acanthurus monroviae* Steindachner, 1876 y de *Diodon eydouxii* Brissout de Barneville, 1846, para la ictiofauna europea. *Miscellania Zoologica* 11: 271–275

Diffenbaugh NS, Giorgi F (2012) Climate change hotspots in the CMIP5 global climate model ensemble. *Climate Change* 114: 813–822, http://dx.doi.org/10.1007/s10584-012-0570-x

Evans J, Barbara J, Schembri PJ (2015) Updated review of marine alien species and other 'newcomers' recorded from the Maltese Islands (Central Mediterranean). *Mediterranean Marine Science* 16(1): 225–244, http://dx.doi.org/10.12681/mms.1064

Froese R, Pauly D (2015) Fishbase. http://www.fishbase.org (Accessed 10 April 2015)

Galil BS, Goren M (2014) Metamorphoses: bioinvasions in the Mediterranean Sea. In: Goffredo S, Dubinsky Z (eds), The Mediterranean Sea: its history and present challenges. Springer Netherlands, pp 463–478, http://dx.doi.org/10.1007/978-94-007-6704-1_27

Giorgi F (2006) Climate change hot-spots. *Geophysical Research Letters* 33: L08707, http://dx.doi.org/10.1029/2006GL025734

Gökoglu M, Bodur T, Kaya Y (2003) First record of the bannerfish (*Heniochus intermedius* Steindachner, 1893) from the Mediterranean Sea. *Israel Journal of Zoology* 49: 324–325, http://dx.doi.org/10.1560/016E-U41T-H5KQ-6F9U

Golani D, Orsi-Relini L, Massuti E, Quignard JP (2002) CIESM atlas of exotic species in the Mediterranean. Vol. 1 – Fishes. http://www.ciesm.org/atlas/appendix1.html (Accessed 10 April 2015)

Goren M, Gvili R, Galil BS (2011) The reef-associating butterfly fish *Chaetodon austriacus* Rüppell, 1836 in the Mediterranean: the implication of behavioral plasticity for bioinvasion hazard assessment. *Aquatic Invasions* 6 (Suppl. 1): S143–S145, http://dx.doi.org/10.3391/ai.2011.6.S1.032

Langeneck J, Marcelli M, Simak HC (2012) Unexpected alien species in Cyprus waters: *Acanthurus coeruleus* (Actinopterygii: Acanthuridae). *Marine Biodiversity Records* 5: e116, http://dx.doi.org/10.1017/S1755267212001042

Langeneck J, Boyer M, De Cecco PG, Luciani C, Marcelli M, Vacchi M (2015) First record of *Acanthurus chirurgus* (Perciformes: Acanthuridae) from the Mediterranean Sea, with some distributional notes on Mediterranean Acanthuridae. *Mediterranean Marine Science* 16: 427–431, http://dx.doi.org/10.12681/mms.1239

Lejeusne C, Chevaldonné P, Pergent-Martini C, Boudouresque C, Pérez T (2010) Climate change effects on a miniature ocean: the highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology & Evolution* 25: 250–260, http://dx.doi.org/10.1016/j.tree.2009.10.009

Luiz OJ, Allen AP, Robertson DR, Floeter SR, Kulbicki M, Vigliola L, Becheler R, Madin JS (2013) Adult and larval traits as determinants of geographic range size among tropical reef fishes. *Proceedings of the National Academy of Sciences of the United States of America* 110: 16498–16502, http://dx.doi.org/10.1073/pnas.1304074110

Pyle R (2001) Chaetodontidae. Butterflyfishes. In: Carpenter KE, Niem VH (eds), FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 5: Bony fishes part 3 (Menidae to Pomacentridae). FAO, Rome, pp 3224–3265

Psomadakis PN, Guistino S, Vacchi M (2012) Mediterranean fish biodiversity: an updated inventory with focus on the Ligurian and Tyrrhenian seas. *Zootaxa* 3263: 1–46

Raitsos DE, Beaugrand G, Georgopoulos D, Zenetos A, Pancucci-Papadopoulou AM, Theocharis A, Papathanassiou E (2010) Global climate change amplifies the entry of tropical species into the Eastern Mediterranean Sea. *Limnology and Oceanography* 55:1478–1484, http://dx.doi.org/10.4319/lo.2010.55.4.1478

Randall JE (1983) Red Sea Reef Fishes. IMMEL Publishing, London, 192 pp

Randall JE (2001) Acanthuridae. Surgeonfishes (tangs, unicornfishes). In: Carpenter KE, Niem VH (eds), FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Vol. 6: Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals. FAO, Rome, pp 3653–3683

Randall JE (2002) Acanthuridae. Surgeonfishes. In: Carpenter KE (ed), FAO species identification guide for fishery purposes. The living marine resources of the Western Central Atlantic. Vol. 3: Bony fishes part 2 (Opistognathidae to Molidae), sea turtles and marine mammals. FAO, Rome, pp 1801–1805

Rocha LA, Bass AL, Robertson DR, Bowen BW (2002) Adult habitat preferences, larval dispersal, and the comparative phylogeography of three Atlantic surgeonfishes (Teleostei: Acanthuridae). *Molecular Ecology* 11: 243–252, http://dx.doi.org/10.1046/j.0962-1083.2001.01431.x

Salameh P, Sonin O, Edelist D, Golani D (2011) First record of the Red Sea orangeface butterflyfish *Chaetodon larvatus* Cuvier, 1831 in the Mediterranean. *Aquatic Invasions* 6 (Suppl. 1): S53–S55, http://dx.doi.org/10.3391/ai.2011.6.S1.012

Schembri PJ, Bodilis P, Evans J, Francour P (2010) Occurrence of barred knifejaw, *Oplegnathus fasciatus* (Actinopterygii: Perciformes: Oplegnathidae), in Malta (central Mediterranean) with a discussion on possible modes of entry. *Acta Ichthyologica et Piscatoria* 40: 101–104, http://dx.doi.org/10.3750/AIP2010.40.2.01

Weitzmann B, Mercader L, Azzurro E (2015) First sighting of *Zebrasoma flavescens* (Teleostei: Acanthuridae) and *Balistoides conspicillum* (Teleostei: Balistidae) in the Mediterranean Sea: two likely aquarium releases. *Mediterranean Marine Science* 16: 147–150, http://dx.doi.org/10.12681/mms.963

Zammit E, Schembri PJ (2011) An overlooked and unexpected introduction? Occurrence of the spotted scat *Scatophagus argus* (Linnaeus, 1766) (Osteichthyes: Scatophagidae) in the Maltese Islands. *Aquatic Invasions* 6 (Suppl. 1): S79–S83, http://dx.doi.org/10.3391/ai.2011.6.S1.018

Supplementary material

The following supplementary material is available for this article:

Table S1. List of recent new records of ichthyofauna from the central Mediterranean region, including non-indigenous species and Atlantic species that have recently extended their range to reach the central Mediterranean.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2015/Supplements/BIR_2015_Evans_etal_Supplement.xls