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First record of the acanthurid fish *Zebrasoma xanthurum* (Blyth, 1852) in the Mediterranean Sea, with some considerations on the risk associated with the aquarium trade

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Abstract

The occurrence of a single individual of yellowtail tang *Zebrasoma xanthurum* (Acanthuridae) from Sardinia island (Italy), probably released from an aquarium, is reported. This observation represents the first record of this species in the Mediterranean Sea. General information on the Acanthurid fishes and other non-native species in the Mediterranean is discussed in the light of the ongoing ecological change taking place on rocky reef ecosystems with consideration of implications on the aquarium trade.

Keywords: Non-native fishes, surgeonfish, Acanthuridae, accidental introduction, aquarium trade, ecosystem shifts, Tyrrhenian Sea, Italy.

Introduction

The Acanthuridae is a widespread teleost family, comprising of 84 species, with tropical and subtropical affinity (Eschmeyer, 2015). Within the acanthurids, the yellowtail tang, *Zebrasoma xanthurum* (Blyth, 1852), is distributed throughout the Western Indian Ocean, including the Red Sea, the Persian Gulf and Maldives (see Froese & Pauly, 2015). There have also been isolated, individual recordings from the marine waters off Boca Raton, Palm Beach County, Florida, US (Bartley, 2006) and off Hoi Ha Wan Marine Park, Hong Kong (Myers *et al.*, 2012).

Z. xanthurum is reported to occur on coral- and rocky-reefs (Sommer *et al.*, 1996) within the 2-20 m bathymetric range and between 24 and 28°C sea water temperature (Baensch & Debelius, 1997). It is a typical herbivorous grazer, generally feeding on benthic algae. Natural predators are primarily large serranids (e.g. genus *Cephalopholis*).

Z. xanthurum has a reported maximum length of 37 cm, however it is commonly observed around 10-20 cm (Froese & Pauly, 2015 and references therein). The body is blue in color with a yellow tail, the head displays numerous black spots, and in some locations black horizontal lines can be displayed along the sides of the body. Similarly to other species belonging to the *Zebrasoma* genus, the yellowtail tang is characterized by large dorsal and anal fins accompanied by an extended snout used to feed upon algae. The tips of the pectoral fins are often yellowish (Carpenter *et al.*, 1997).

There are no specific conservation measures in place for this species. The yellowtail tang is not commercially important for fisheries and is considered a minor species in the aquarium trade. Consequently, the IUCN has classified this fish as 'least concerned' (Myers *et al.*, 2012).

In this work we report the first known occurrence of *Z. xanthurum* (Blyth, 1852) in the Mediterranean Sea and discuss the ongoing changes in rocky reef ecosystems throughout the basin and implications of the aquarium trade.

Materials and Methods

On the 3rd of August, 2015, a single individual of *Zebrasoma xanthurum* was observed (L. Magnani) at Tavolara Island, in a site located within the borders (specifically in the buffer zone) of the Tavolara-Punta Coda Cavallo Marine Protected Area (Sardinia, Italy; Mediterranean Sea; Fig. 1; 40.884722° N; 9.709722° E). The specimen occurred on a rocky bottom covered by macroalgae interspersed with *Posidonia oceanica* patches at about 16-17 m depth. Identification was based on photographs performed while on SCUBA.

Subsequent to the first sighting, 33 dives (15 in August, 10 in September and 8 in October) at the same site were made (during daytime by the three authors of this ms) to identify behavioral traits (e.g. feeding and interactions with other fishes) via *in situ* observations, and by analyzing video footage and pictures. Three dives were made by the authors in August 2015 with HD video to

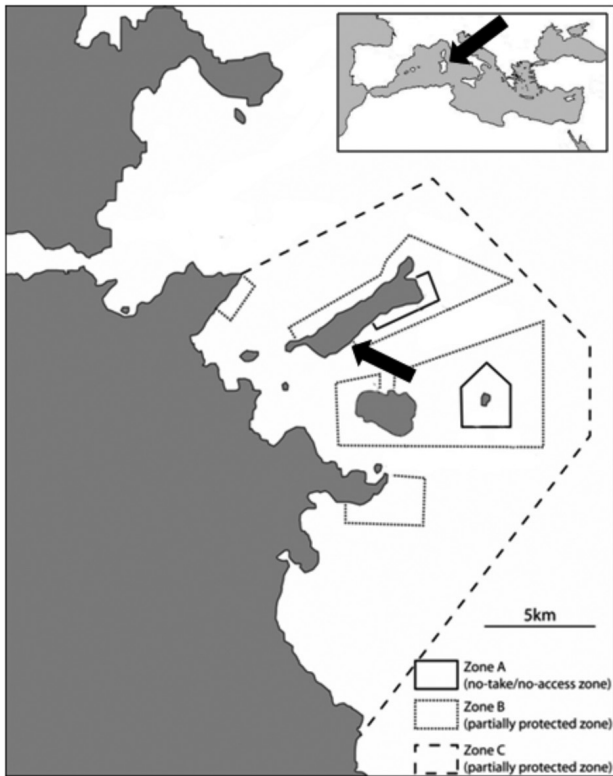


Fig. 1. Location of Tavolara Island (Sardinia, Italy; central Tyrrhenian Sea); the site where the specimen of *Zebrasoma xanthurum* was recorded.

help with fine-scale observations of behavior. The main behavioral features observed were: 1) location of the fish (where it was observed more frequently) and general patterns of movement; 2) events of interaction with other fishes; 3) events of feeding.

Results

The individual acanthurid observed at Tavolara Island had a total length (TL) of 11-12 cm, and the typical blue livery with yellow tail, yellowish tips of the pectoral fins, numerous black spots on the head, and some black horizontal lines on the body. The caudal fin had a linear margin and the soft portion of the dorsal fin was higher than the spiny portion (specific to the *Zebrasoma*). This combination of characteristics allowed for its univocal identification as a subadult *Zebrasoma xanthurum*. This result was further confirmed thanks to *in situ* observations, by analyzing pictures and videos, and with two experts of acanthurids (see Acknowledgements). During all observations, the specimen appeared to be in a good state of health. The individual actively moved over rocky bottoms covered by macroalgae, rich in boulders and crevices, and over patches of the seagrass *Posidonia oceanica*. Preference for these habitats suggest suitable refuge and food. The fish was always observed at one of two locations and each location was roughly ten square



Fig. 2. Photograph of the individual *Zebrasoma xanthurum* (~11-12 cm total length) that was observed swimming on rocky reefs and *Posidonia oceanica* patches at Tavolara (photo: L. Magnani).

meters. The individual regularly moved between the two locations found at 12-14 and 16-18 m depth. Movement patterns were 'stop-and-go', typical of many herbivorous fishes picking at (roughly every 10-15 sec.), and feeding from, benthic algae that settled on rocks and boulders. Furthermore, it also fed on epiphytic algae growing on the leaves of *P. oceanica* and on other large-sized macroalgae (e.g. *Codium bursa*).

Other fishes observed in the same locations included typical Mediterranean fish fauna associated with rocky reefs and *P. oceanica*. Fish communities of the Tavolara-Punta Coda Cavallo MPA has been surveyed annually since 2005 for which a more detailed description can be found at Di Franco *et al.* (2009). Based on our field observations, the specimen of yellowtail tang at Tavolara did not interact with other fishes except for pairs of the pomacentrid *Chromis chromis*, a species well known to actively defend their nests during the reproduction phase. Multiple observations (n=11 events observed) of defense behavior of individual *C. chromis* against approaches of the yellowtail tang resulted in the yellowtail tang to move elsewhere. Relatively large individuals of the serranid, *Epinephelus marginatus*, were present in the area with some observed within close range of the yellowtail tang. Although representing a potential predator, we did not observe any predatorial behavior, attraction, or interest towards the yellowtail tang. At times (n=6 events observed), the yellowtail tang would swim a few meters into the water column and angle its body at about 45°. This was assumed to be behavior aimed at attracting cleaning fishes. Nonetheless, this behavior never resulted in cleaning from *Symphodus melanocercus*, the only species present known to perform the function. With regard to interactions with divers, generally, the yellowtail tang at Tavolara was unaffected by diver presence allowing us to approach the fish for optimal observations.

The fish was last observed in the Tavolara-Punta Coda Cavallo MPA on September 21st, 2015. At that time water temperatures at the observation depth (15-20 m) was 23-24 °C.

Discussion and Conclusion

This observation represents the first record of the yellowtail tang in the Mediterranean and further confirmed by the species absence from a recent report of acanthurids by Langeneck *et al.* (2015). Including this this observation of the yellowtail tang, five species belonging to the Acanthuridae have, to date, been reported from the Mediterranean Sea. These species include: *Acanthurus monroviae* (Steindachner, 1876), *A. chirurgus* (Bloch, 1787), *A. coeruleus* (Bloch & Schneider, 1801), *Zebrasoma flavescens* (Bennett, 1828) and *Z. xanthurum* (Blyth, 1852). As noted by Langeneck *et al.* (2015), *Acanthurus monroviae* was, until recently, the only surgeonfish species reported from the Mediterranean Sea. However, in the last years, the list of acanthurid fishes recorded from the basin has increased significantly from one to five species (see above).

The increasing number of non-native fishes in the Mediterranean (Zenetos *et al.*, 2012) demands consideration about pathways of introduction during climate change (thermophilous species). This will help to identify future scenarios and trajectories of Mediterranean marine ecosystems, and to eventually adopt appropriate measures for management or adaptation (Thresher & Kuris, 2004; Zenetos *et al.*, 2012; Katsanevakis *et al.* 2014).

Of the five acanthurids presently reported from the Mediterranean, *A. monroviae* (usually occurring from Angola to southern Morocco, Atlantic Ocean, and probably entered via Gibraltar), observations are sporadic and this species if considered as a 'vagrant' in the areas where it has been recorded (i.e. Algeria, Israel and NW Mediterranean ; Langeneck *et al.*, 2015 and references therein). Observations of the other four acanthurids (*A. coeruleus*, *A. chirurgus*, *Z. flavescens* and *Z. xanthurum*) have been sporadic, or from only a single record, indicating these to be related to intentional/accidental releases from tropical aquaria.

As a global and generally unregulated business, the aquarium trade is emerging as an important pathway of introduction of non-native marine species (Padilla & Williams, 2004). Padilla & Williams (2004) suggested that releases may take place intentionally or accidentally, via dumping of unwanted organisms, the deliberate release from captivity or by the draining of water containing adult organisms or their sexual (eggs, larvae) or asexual propagules.

The consequences of invasion (sometimes happening after introductions) of non-native species to marine ecosystems can result in serious ecological impacts and dramatic socio-economic costs. Some authors have stated that the probability for aquarium species to be released is higher in close geographical distance to large coastal cities (Johnston & Purkis, 2014). We suggest that in some regions, where

mega-yachts (often equipped with tropical aquaria) are frequent, releases from aquaria can also be frequent especially during high tourism seasons. From our best knowledge, there is has been no precedent in the scientific literature concerning introductions from mega yachts, however this is the avenue that we hypothesize for our recorded individual of *Z. xanthurum* in NE Sardinia.

Prevention of releases and possible invasions will require education and outreach, but also adequate legislation along with appropriate enforcement efforts to address aquarium amateurs, shops and industry (Padilla & Williams, 2004; Côté *et al.*, 2013). However, once an introduction has occurred, eradication or efficient population control through active removal may be considered the most effective actions, as natural ecosystems generally do not have the capacity to limit the expansion of non-native species (Côté *et al.*, 2013; Hackerott *et al.*, 2013). For instance, the example of the lionfish (*Pterois volitans* and *P. miles*) remains paradigmatic. The dramatic invasion of the Indo-Pacific lionfish to the western Atlantic and Caribbean has been attributed to the aquarium trade. Inter-specific ecological processes such as predation and competition with native fishes has not limit the lionfish expansion (Hackerott *et al.*, 2013). The success of the lionfish seems to be due to a combination of life history traits (e.g. early maturation/reproduction, ecological plasticity) and the characteristics of the recipient ecosystem (e.g. favorable climatic conditions, overfishing of native large predators; Côté *et al.*, 2013). Likewise, this successful invasion has had detrimental and rapid ecological impacts on native communities (see e.g. Côté *et al.*, 2013). Lionfish (*P. miles*) have recently been reported in the eastern Mediterranean. However, given the geographical proximity and connection with the Red Sea via the Suez Canal (where the lionfish is present), these records from the Levantine basin are attributed to lessepsian migration (Oray *et al.*, 2015 and references therein). Despite modelling studies that suggested invasion by the lionfish to the Mediterranean to be unlikely (Johnston & Purkis, 2014), new records of lionfish continue to occur (Oray *et al.*, 2015 and references therein) perhaps providing a warning signal that should be recognized before potential catastrophic damages occur to native Mediterranean species and ecosystems.

The yellowtail tang, *Z. xanthurum*, is not a predator like the lionfish, but rather a herbivorous fish. Until now, the accidental/deliberate introduction in herbivorous tropical fishes to the Mediterranean via the aquarium trade has not caused significant ecological impacts. Nevertheless, the possible consequences of the increasing number of observations, should be considered. Non-native herbivorous fishes (notwithstanding the pathway of arrival) have the potential to dramatically alter native Mediterranean communities. For instance, the invasion of rabbitfish (*Siganus* spp.) from the Red Sea to the eastern Mediterranean resulted in barrens; a phenomenon that generally arises from urchin over-graving (Sala *et al.*, 2011). Tropical fishes like acanthurids may find the Mediterranean temperatures during summer to be ap-

appropriate for survival. Surface waters in Sardinia during August 2015 were 26-28°C at surface, and 24-26°C at 16 m depth. These temperatures, unusual in the past but becoming more frequent in recent years, are probably related to climatic changes resulting in the warming of marine waters (Bianchi, 2007). This trend is likely to make Mediterranean waters increasingly suitable to receive thermophilous species (Raitsos *et al.*, 2010).

Previous reports (Baensch & Debelius, 1997) have suggested that the optimal temperatures for *Z. xanthurum* range between 24 and 28°C. Thus, we believed that our observed individual at Tavolara would thrive during the summer, but mortality would ensue during winter's 12-14°C. Unfortunately we were unable to confirm this because the specimen disappeared from the study area at the end of September 2015, while the water temperature was still tolerable. The absence of the fish suggests that it moved elsewhere or that it had been successfully attacked by a predator.

Langeneck *et al.* (2015) stated that the absence of lessepsian acanthurids in the Mediterranean Sea was due to their close ecological association with coral reefs; a feature absent in the Mediterranean Sea (Goren *et al.*, 2011). Based on the preliminary observations from this study, the absence of coral reefs, *per se*, does not seem to prevent *Z. xanthurum* from surviving (at least temporarily) in the Mediterranean. Other coral-reef associated fishes have also displayed short-term survival in the Mediterranean (e.g. *Chaetodon austriacus* and *C. larvatus*; Goren *et al.*, 2011, Salameh *et al.*, 2011). Thus, it would seem that thermal barriers or local predators limit the expansion of many thermophilic fishes accidentally released in Mediterranean waters rather than the absence of coral-reefs. This is in agreement with Golani *et al.* (2013) who stated that Lessepsian migrants and thermophilic Atlantic species may display a significant rate of establishment and invasion success, while tropical species accidentally introduced (seldom become invasive).

Despite pathway or mechanism, more thermophilous fishes are entering the Mediterranean Sea and they are increasingly finding conditions conducive for their survival. They often establish in the warmer southern and eastern sectors of the Mediterranean basin, and occasionally expand north- and westwards (Azzurro, 2008). This phenomenon of geographical expansion encompasses a variety of thermophilic organisms including macroalgae, plankton, invertebrates and fishes (Bianchi, 2007; Galil *et al.*, 2014). Furthermore, these expansions are considered one of the most detectable indicators of climate change in the Northern hemisphere (Perry *et al.*, 2005 and references therein included).

In the last two decades the number of non-native fishes recorded in the Mediterranean has increased significantly (Azzurro, 2008; Golani *et al.*, 2013). Most are typically herbivorous, like *Siganus* spp. and the five Acanthuridae. In the areas where species of *Siganus* become established, rocky reef habitats have been dramatically and rapidly

degraded. Furthermore, profound ecosystem shifts occur where rocky reefs covered in macroalgae are converted to coralline barrens, a trajectory that is hardly reversible (Sala *et al.*, 2011; Guidetti *et al.*, 2014). In a recent study carried out at the Kos Island (Aegean Sea, Greece), Bianchi *et al.* (2014) has noted a dramatic regime shift occurring over the last 30 years. At this site they recorded a rise in sea surface temperatures 1-2°C, human pressures have increased significantly and multiple invasions by non-native species has occurred. These changes are further seen in the benthos where once flourishing macroalgal forests have been replaced by sponges and wide barrens. The authors (Bianchi *et al.*, 2014) attributed these profound changes chiefly to the overgrazing by non-native herbivorous fishes (*Siganus luridus* and *S. rivulatus*), whose establishment and spread have been probably favored by sea warming in combination with local human impacts (Bianchi *et al.*, 2014; Giakoumi, 2014). From this perspective, given that Acanthurid fishes are also herbivores, their potential introduction and spread across the Mediterranean coastal waters could increase the degradation of Mediterranean rocky reefs. The shift from macroalgal beds to barrens implies significant changes in biodiversity, 3-D architecture of habitats, and a number of ecosystem functions (including several goods and services provided to society) (Guidetti, 2006). This ecosystem shift is attributable to overfishing and other human impacts, climate change and the introduction of non-native herbivorous species (also including some invertebrates like the crab *Percnon gibbesii*; Evans *et al.*, 2015). In the worst case scenario, the increase of temperatures and continued biological introductions combined with human resource usage, will interact resulting in irreversible, negative consequences, especially for Mediterranean rocky reefs.

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