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Snake overboard! Observations of marine swimming in *Malpolon monspessulanus*

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The ability to swim is widespread in snakes and not restricted to aquatic (freshwater) or marine species (Jayne, 1985, 1988). A high tolerance to hypernatremia (i.e., high concentration of sodium in the blood) enables some semi-aquatic freshwater species to use brackish and saline habitats. In coastal populations, snakes may even forage at sea (Tuniyev et al., 2011; Brischoux and Kornilev, 2014). Terrestrial species, however, are rarely observed in the open sea. While snakes are particularly resistant to fasting (Secor and Diamond, 2000), long trips in the marine environment are metabolically demanding (prolonged locomotor efforts entail substantial energy expense) and might be risky (Lillywhite, 2014). Limited freshwater availability might compromise the hydromineral balance of individuals, even in amphibious marine species (Bonnet and Brischoux, 2008; Lillywhite et al., 2012). Nonetheless, the capacity to travel long distances at sea offers new opportunities for dispersal.

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The diversity of fundamentally terrestrial snake species that colonised islands worldwide, including remote ones (e.g., the Galapagos Archipelago), shows that these reptiles repeatedly achieved very long and successful trips across the oceans (Thomas, 1997; Martins and Lillywhite, 2019). However, we do not know how snakes reached remote islands. Did they actively swim, merely float at the surface, or were they transported by drifting rafts? We also ignore the mechanisms that enable terrestrial snakes to survive during long periods at sea and how long they can do so. Terrestrial tortoises travel hundreds of kilometres, can float for weeks in ocean currents, and can sometimes survive in hostile conditions without food and with limited access to freshwater (Gerlach et al., 2006). Such events are rare, at least for human observers, and remain largely undocumented in terrestrial snakes. Therefore, even fragmentary information such as records of terrestrial snakes swimming in the open sea may provide additional insights into this topic.

Recent photographs of adult Western Montpellier Snakes, *Malpolon monspessulanus* (Hermann, 1804), taken in southeastern France (Var District) show that this terrestrial species can actively swim in the open sea (Fig. 1A). One individual was photographed near Port-Cros Island in August 2009 (exact date unknown) during a touristic tour, several hundred meters offshore of Port-Man Bay. Another snake was photographed in the main harbour of Porquerolles Island (Fig. 1B) on 28 May 2020. The snake was swimming towards the shore. These observations, which may represent the first documented instances of such behaviour in this species, motivated us to collect additional information. We therefore summarised other anecdotal observations, both from personal and online sources, and we suggest that *M. monspessulanus* occasionally ventures into the sea (Table 1). The coast guards of the Port-Cros National Park also reported instances of the species swimming in rather rough sea. In total, at least ten individuals of *M. monspessulanus* have been observed swimming in

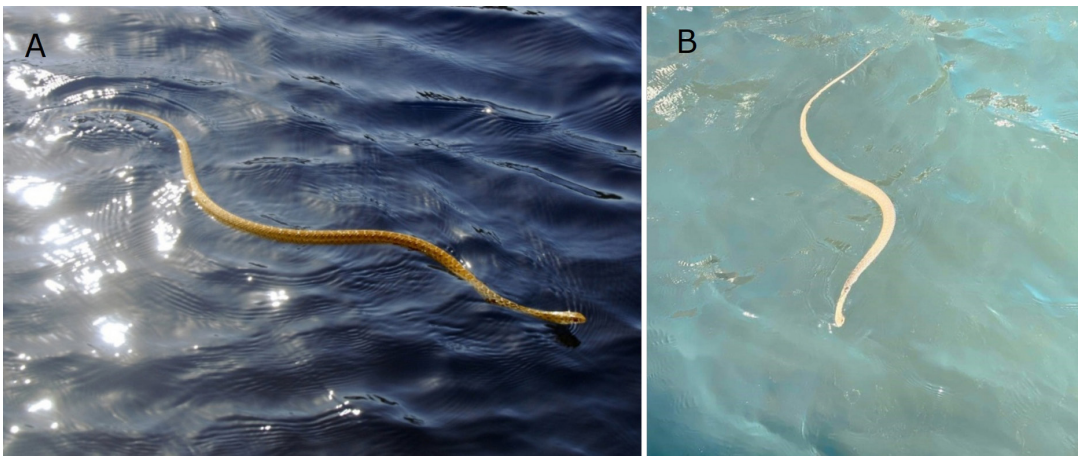

Figure 1. (A) An adult *Malpolon monspessulanus* spotted at sea near Port-Cros Island (Var, France), several hundred meters away from the shore. It was swimming towards Port-Man. (B) An adult *M. monspessulanus* swimming in the sea near the main harbour of Porquerolles Island (Var, France). Photos by Richard Destatte (A) and Thibault Cros (B).

the open sea. Although not all observations could be validated by photographic evidence, these anecdotal observations provide supporting evidence about the marine swimming behaviour of this terrestrial snake. Observers never reported any signs suggesting that the snakes were facing difficulty, such as uncoordinated movement or lack of balance.

The individuals pictured here (Fig. 1), were likely swimming near their home island, Port-Cros or Porquerolles. However, we cannot exclude that they originated from the mainland, several kilometres away (the minimal Euclidean distance between the mainland and Porquerolles Island is about 2.6 km; between successive islands distances range from 0.5–9 km). Indeed, in Report 7 (Table 1), snakes were spotted approximately halfway between the mainland and the Frioul Islands, a small archipelago 2.7 km offshore. The archipelago is free of established populations of *M. monspessulanus*, although the species has been sporadically observed there.

We have no information regarding the snakes' motivation to leave the mainland and enter the sea and can only speculate on this issue. Perhaps snakes escaped predation (proficient swimmers are more likely to flee in water rather than continue on land; Shine et al., 2003), attempted to disperse, or even used the seawater to cool down their body temperature. *Malpolon monspessulanus* feeds exclusively on terrestrial prey and is very unlikely to forage at sea, which most likely rules out this possibility (Pleguezuelos, 2017).

Several characteristics of *M. monspessulanus* may predispose this species to regularly enter the sea. This large, diurnal snake exhibits typical racer traits: high velocity, high visual acuity, behavioural boldness, and a marked*f* swimming ability (Garzon, 1974; Monrós, 1997; De Haan, 1999: 735–738). These features, shared with other species of the genus, may explain why *Malpolon* colonised nearly all small offshore islands of the Mediterranean basin. However, surprisingly, the entire Apennine peninsula between Istria and Western Liguria represents a major gap in the otherwise circum-Mediterranean Malpolon distribution (cf.: Carranza et al., 2006; Mangiacotti et al., 2014; Sillero et al., 2014). We wish to note that natural colonisation should be distinguished from human-driven processes that have enabled four snake species, including *M. monspessulanus* and the ladder snake, *Zamenis scalaris* (Schinz, 1822), to invade the Balearic Islands (Silva-Rocha et al., 2015).

Malpolon monspessulanus exhibits an eclectic diet, a feature that may facilitate the exploration of novel environments and promote successful colonisation of novel island habitats (Oro, 1994; Pleguezuelos, 2017). Interestingly, *Z. scalaris*, another large terrestrial snake species with a stocky build, is well represented both in the Hyères Islands and the nearby mainland but has never been observed swimming in the sea (Ballouard et al., 2016). This species is secretive, mostly slow-moving and often nocturnal, partly fossorial and, although an active forager, appears to be much more shy than *M. monspessulanus* (Pleguezuelos et al., 2007; Cluchier,

Table 1. Anecdotal observations of *Malpolon monspessulanus* swimming in the open sea (Mediterranean Sea and Atlantic Ocean). Details on exact locations (when available) and region (e.g., island name) are provided in the Locality column. Observers are reported by their initials when available, with all reports communicated to us personally unless otherwise noted. Fabienne Destatte (FD), Richard Destatte (RD), Odile Lahire (OL), Cyrielle Cavator (CC), Clelia Moussay (CM), Thibault Cros (TC), Gilles Garnier (GG), Florian Junac (FJ), Alexandre Cluchier (AC), Alain Mante (AL), Anonymous (AN).

No.	Year	Country	Locality	Observer	Image
1	2009	France	Port-Man, Port-Cros	FD, RD, OL	Yes
2	2019	France	South Beach, Port-Cros	CC	No
3	2017	France	Courtade Beach, Porquerolles	CM	Yes
4	2020	France	Port, Porquerolles	TC	Yes
5	2015	France	Courtade Beach, Porquerolles	GG	Yes
6	NA	France	Langoustier, Porquerolles	FJ	No
7	NA	France	offshore near Marseille	AC[1]	No
8	2003	France	Jarre Island, Calanques	AL	No
9	2019	Spain	Samil Beach, Vigo	AN[2]	Yes
10	2020	Spain	Benitatxell	AN	Yes

[1]Cluchier, 2010; [2]Faro de Vigo, 2019

2010; De Haan, unpublished). This lack of observation probably reflects an actual difference between terrestrial species in their respective tendency to swim at sea. Indeed, the ability for an observer to spot a snake already at sea is likely more dependent on an individual's body size rather than the species' activity pattern. Future studies should examine to what extent terrestrial active racers differ in their propensity to venture into the sea compared to secretive, less active species.

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