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## Research Article

# First Records of *Onchidella celtica* (Gastropoda: Pulmonata) from Atlantic Rocky Shores of Morocco

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## Abstract

**Background:** The littoral pulmonate gastropod *Onchidella celtica* (Cuvier, 1817) known as the celtic sea-slug is for the first time reported from five littoral locations on the Atlantic coast of Morocco. **Methodology:** Specimens, 72 in total of different sizes of *O. celtica* were collected during a sampling survey of epibiontic communities associated with algal communities, during low spring tides in June, 2013 and July, 2014 on intertidal rocky areas of these locations. **Results:** Descriptions based on specimens as well as morphometric and distributional informations are presented and discussed. **Conclusion:** These new records extend the known Northern geographical distribution range of the species and contributes to enhance the knowledge on ecology and global distribution of *O. celtica* found to date, only on Atlantic European coasts between British shores in the North and the Western Mediterranean, Azores and Madeira islands in the South.

**Key words:** *Onchidella celtica*, mollusca, new records, NE Atlantic, rocky shores

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**Competing Interest:** The authors have declared that no competing interest exists.

**Data Availability:** All relevant data are within the paper and its supporting information files.

## INTRODUCTION

The shell-less pulmonate gastropod *Onchidella celtica* (Cuvier, 1817), belonging to the family Onchidiidae has never been reported from Atlantic coasts of Morocco. It is the only representative of its genus found, till date, on Moroccan shores and represents with *O. marginata* (Chouthouy in Gould, 1852)<sup>1</sup>, the species with the widest distribution among the *Onchidella* genus. Included in the order Stylommatophora of the Pulmonates, according to Anderson<sup>2</sup>, *O. celtica* is considered as a British non-marine mollusc closely allied to the land slugs<sup>3-5</sup> and it is believed to be a land mollusc snail that has reverted to a marine habitat and has colonised the shore<sup>2,3</sup>. The species is regarded as an air-breathing onchidiid marine slug predominantly found in intertidal marine habitats throughout many areas of the world<sup>6,7</sup>.

Regardless this evolutionary interesting aspect, Onchidiidae remains a poorly-known taxon in many regards, especially in species diversity and distribution<sup>8</sup> and little is known about their biology and ecology although they are common in some habitats<sup>9,10</sup>. In fact the ecology of the family has been largely neglected. Arey and Crozier<sup>11</sup> included observations of habitat in their description of the behavior of *Onchidium floridanum* (Dall, 1885) and Fretter<sup>12</sup> gave some ecological information in her study of the functional morphology and embryology of *Onchidella celtica*. Stringer<sup>13</sup> dealt with the aspects of the biology, distribution and life cycle of *O. nigricans* (Quoy and Gaimard, 1832). Various aspects of the ecology of *Onchidium verruculatum* (Cuvier, 1830)

were discussed by McFarlane<sup>14</sup>. The ecological role of defensive secretions by repugnatorial glands against predators was studied in the intertidal pulmonate *Onchidella borealis* Dall 1872 from San Juan island, Washington and Barkley Sound, Vancouver island, British Columbia<sup>15</sup>. The ecology and behaviour of *O. celtica* in the littoral of Cornwall were analysed in Tween's dissertation<sup>16</sup>. Recently, Cumming<sup>17</sup> and Cumming *et al.*<sup>1</sup> studied the evolutionary biogeography and patterns of dispersal of the intertidal slug *Onchidella* and dealt with aspects of *Onchidella's* ecology (specifically the effect of ecology and life history on dispersal patterns and the biogeography) in New Zealand, Australia, the subantarctic, Chile and the Falklands.

An examination of samples collected from rocky intertidal shores extended from El Jadida to Essaouira cities (North-Western Morocco) during June, 2013 and July, 2014, yielded a number of specimens identified as *Onchidella celtica*. The present study adds a new geographic region to its original reported distribution range. Additionally it confirms, again the occurrence of this species on North African coasts and represents its first report for the Moroccan Atlantic shores. In the present study, the first record of *O. celtica* from the Atlantic coasts of Morocco is highlighted.

## MATERIALS AND METHODS

Specimens of *O. celtica* were found during a sampling survey of epibiontic communities associated with the new invasive brown seaweed *Sargassum muticum* (Yendo) Fensholt from five rocky intertidal shores along the Northwestern Moroccan coast (Fig. 1). More specifically,

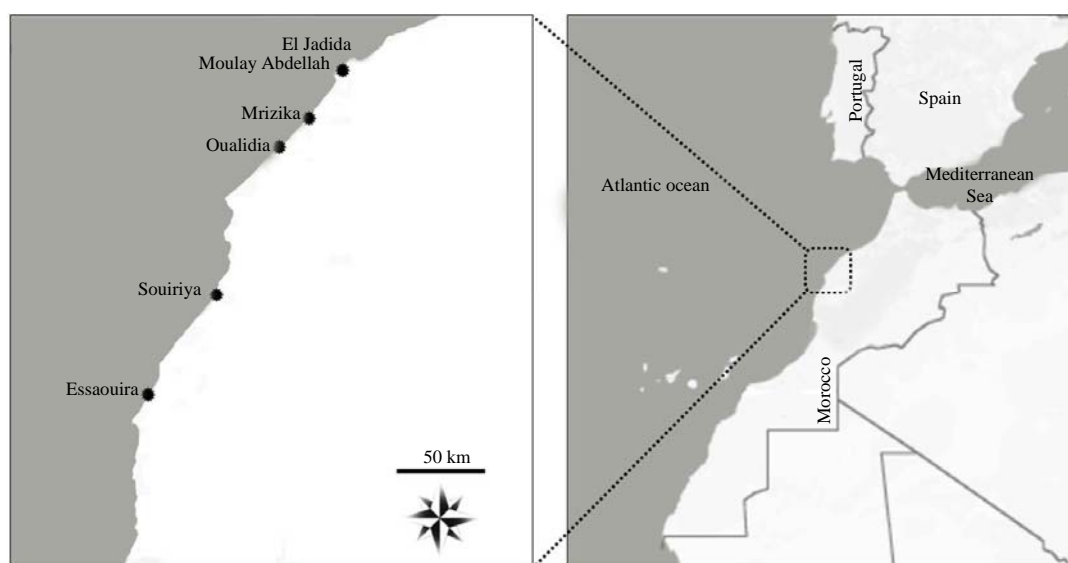


Fig. 1: Geographical position of the study area and sampling locations along the Northwestern coast of Morocco

samples were obtained from Moulay Abdellah-El Jadida "MA" (33°10' 50.2" N-8°36' 56.5" W), Mrizika "MZ" (32°43' 55.8" N-9°02' 57.6" W), Oualidia "OL" (32°43' 56.7" N-9°02' 60.0" W), Souiriya "SR" (32°03' 19.8" N-9°20' 22.9" W) and Essaouira "ES" (31°31' 14.6" N-9°45' 54.3" W).

Specimens of different sizes of *O. celtica* were collected during low spring tides in June, 2013 and July, 2014 on these intertidal rocky shores located approximately 10, 40, 76, 150 and 250 km, respectively to the South of the city of El Jadida (Fig. 1). These locations/sites were in fully marine rocky intertidal habitats, exposed to wave action and with a hard substratum (rock platforms/crevices) composed of a mix of bedrock and boulders of high slope (rock walls). Each location included many sampling points and 2-3 observers performed approximately 60 min searches across all microhabitats present on intertidal rocks. All sampled individuals were subsequently sorted and washed with seawater and fixed with 8% formaldehyde buffered with seawater and brought to the laboratory for taxonomical studies, after which specimens were preserved in 70% ethanol. The slugs were identified as *O. celtica* based on diagnostic characters indicated by many researchers<sup>12,18-21,7</sup>.

## RESULTS AND DISCUSSION

### Systematics:

- Origin name: *Onchidium celticum* (Cuvier, 1816)
- Class: Gastropoda (Cuvier, 1797)
- Subclass: Heterobranchia (Schweigger, 1820)
- Superorder: Pulmonata (Cuvier, 1817)
- Order: Systellommatophora (Pilsbry, 1948)
- Superfamily: Onchidioidea (Rafinesque, 1815)
- Family: Onchidiidae (Rafinesque, 1815)
- Genus: *Onchidella* (M.E. Gray, 1850)
- *Onchidella celtica* (Cuvier, 1917)

Currently, the Onchidiidae contain 19 genera, one of which is *Onchidella*<sup>10</sup> are recognized within the Onchidioidea<sup>7</sup>. However, its phylogenetic position has been seriously debated during last decades. Researchers have considered them as Opisthobranchs<sup>12</sup>, Pulmonates<sup>22-35,16,7</sup>, Euthyneurans<sup>32,36-40</sup> or even as a separate order Onchidiida<sup>41</sup> and Silicodermatae<sup>42</sup>.

The species was recognized under several names and synonyms in the literature, *Oncidium celticum*, *Oncidiella celtica*, *Onchidium celticum* and *Onchidella celtica* as a valid name<sup>21</sup>. Moreover, five synonyms *Onchidella remanei* (Marcus Ev., 1956), *Onchidium celticum* (Cuvier, 1816),

Table 1: Length (L), width (W) and No. of specimen (N) collected from the five sampling locations along the Moroccan coast during June, 2013 and July, 2014

Location	L (mm)	W (mm)	N
MA	6.2-10.3	5-6	11
MZ	6.4-9.70	4-6	15
OL	8.3-11.0	4-7	23
SA	8.6-10.2	5-6	14
ES	10.0-12.0	5-7	9

MA: Moulay Abdellah-El Jadida, MZ: Mrizika, OL: Oualidia, SR: Souiriya, ES: Essaouira

*Onchidium nanum* (Philippi, 1844), *Onchidium tuberculatum* (Taslé, 1870) and *Peronia parthenopeia* (Delle Chiaje, 1841) are reported for the species. These scientific names are sometimes used but are not valid. Over 30 species are considered in the genus *Onchidella*<sup>16</sup> with a distribution straddling a wide range of latitudes.

**Material examined:** The number of slugs sampled throughout the study period varied from 9 individuals found in ES to 23 individuals in OL and with a total of 72. Individuals varied in size from 6-12 mm in length and from 3-7 mm in width (Table 1) without any significant differences among locations (one-way ANOVA,  $F = 5.336$ ,  $p = 0.093$  and  $F = 2.247$ ,  $p = 0.083$  respectively).

**Diagnosis/description:** The material examined was identified following descriptions provided by literature and fits well especially with the description of Joyeux-Laffaie<sup>43</sup>, Germain<sup>19</sup>, Barille-Boyer *et al.*<sup>21</sup> and Dayrat<sup>7</sup>.

The *O. celtica* as all onchidiaceans is naked (lacks a shell) in the adult state but it is developed and then shed during the capsular stage of development<sup>19</sup>. One of the most interesting diagnostic features of the Onchidiidae is the presence of a lung, which opens by a small pneumostome (pulmonary opening) at the posterior end of the body, slightly to the right of the ventral mid-line and behind the openings of the anus and vagina (protandrous hermaphrodite)<sup>12,19</sup>. The celtic sea slug has a solid, round to oval, body when crawling up to 14 mm in length and 6 mm in width with a broad, large fleshy elongated foot (flanked by the hyponotum) present on the ventral side of the body and a papillate or tuberculate notum. The notum is covered by a cuticle that may also contain siliceous spicules<sup>25,44-46</sup>. The notum covered with hemispherical pustules of different sizes, anterior pustules larger than posterior ones. The foot is surrounded on all sides by peripheral extensions of the mantle known as hyponotum. The latter is distinguished as per its location into the right, left, front and the hind hyponotum regions. The mouth is situated



Fig. 2(a-d): *Onchidella celtica*, adult morphology. Live specimens from (a, d) Mrizika and (b, c) Oualidia locations. Dorsal and ventral views of specimens from (d) Mrizika. Scale bar: 10 mm

ventrally at anterior end of body between foot and front hyponotum. The species is a dark green-black inconspicuous slug with a mantle on the dorsal surface that is thickly covered in large, coarse, evenly spaced tubercles or body warts, to which sand grains often adhere. These tubercles come in a wide variety of forms, sizes and structures ranging from minute granules to large protuberances scattered all over the dorsal surface. When *O. celtica* is motionless, the mantle completely obscures the head and pale grey foot. The head bears a pair of short, thick, cylindrical black retractile optic tentacles carrying cephalic eyes at the tips and positioned in the antero-lateral corners of fleshy lobes surrounding the ventral mouth, called as labial palp. These are also known as oral lappets or oral lobes, regarded as main diagnostic characters, by which this pulmonate may be identified<sup>47</sup>. The head is only visible and extended from beneath the hyponotum when the animal is moving (crawling). Another key feature is the lack of the singular dorsal eyes characteristic of many tropical species<sup>16,18</sup>. An additional distinctive feature of *Onchidella* species is the presence of a radula (carrying radular teeth) in the buccal mass, varying with respect to structure, size and shape in all species of *Onchidella* (Fig. 2).

More morphologic characteristics and identifying striking features were described in detail by Joyeux-Laffuie<sup>43</sup>, Dall<sup>18</sup>, Germain<sup>19</sup>, Fretter<sup>12</sup>, Barille-Boyer *et al.*<sup>21</sup> and Dayrat<sup>7</sup>.

**Habitat preference:** In the present study conducted on the Moroccan coastline the species was mainly found in the

middle and high intertidal zone rocky beaches during the warmer part of the year ( $T^{\circ}$ : 26-32°C), which is in accordance with the statement of Joyeux-Laffuie<sup>43</sup>.

*Onchidella celtica* is now generally accepted as being a mid-shore species and it has been found between mid-tide and low water. It occurred a few feet down from the high-water mark, mainly in sloping crevices sheltered from wave action and from strong sunlight<sup>12</sup> although, it has been reported at very low levels and at very high levels. The species exclusively inhabited the lower mid-littoral level (microhabitat) along the coast of Palermo and Sicilia<sup>48</sup>.

The slug can be found on exposed rocks uncovered only at low tides, usually on sandy shores amongst mussels, barnacles and limpets in the mid-littoral (eulittoral) zone<sup>49</sup> and hiding in crevices between the rocks or in holes in the rocky platforms<sup>16</sup>. The species can be found in shallow waters until depths of 25 m on hard substrates (rockpools, boulders/crevices/overhangs, open rocks and rock platforms, sandstone rocks and rock walls), sandy bottoms or mostly associated to aquatic vegetation (inside macroalgal holdfasts). Davies<sup>50</sup> reported the occurrence of the species in low-shore pools and gullies. The species is quite specific in its habitat requirements (lives gregariously and prefers intertidal exposed, shaded rock walls/vertical surfaces and moist areas)<sup>21</sup> and is regarded in Great Britain as an obligate crevice-dweller during immersion but forages down the shore during emersion<sup>16</sup>, crawling on small algae and returns up the shore as the tide rises<sup>6,12,43,51</sup>. It is mainly observed between April and November<sup>12</sup>.

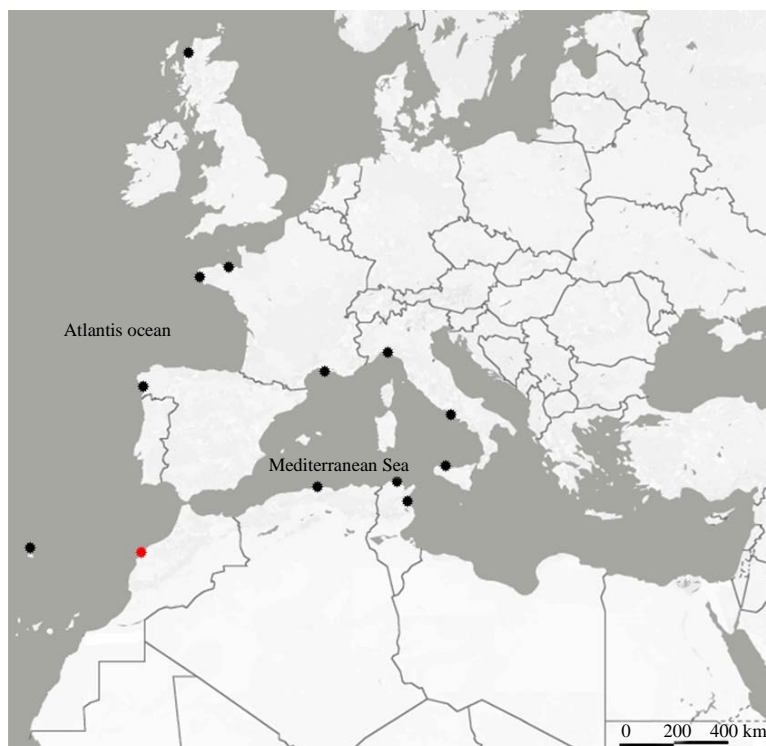


Fig. 3: Geographical distribution of *Onchidella celtica*, indicating new records reported from rocky shores surveyed in Morocco (red dot) and previous literature records around the world (black dots)

**Distribution:** Within the *Onchidella* genus, *O. celtica* have a wide distribution<sup>7</sup>. The species has been found throughout temperate waters of the Northeastern Atlantic ocean coasts<sup>52,53</sup>. The *O. celtica* is commonly known as the celtic sea-slug and was first identified and described (as *Oncidium celticum*) in 1817 by Cuvier, from the Brittany coast, France<sup>3</sup>. The first record of the species in Europe was made in Great Britain already<sup>12</sup> in 1835<sup>1</sup> where it was most probably transported by shipping<sup>21</sup>. The species is known to occur on many European shores (Fig. 3) from the Western coast of Scotland<sup>7,47</sup>, Britain<sup>2,54</sup> and British Isles<sup>16,55,56</sup>, British Cornwall<sup>3,16,50,57</sup>, Anglo-Normandy Isles and the Chausey Archipelago (Normandy-Breton Gulf, France)<sup>58-60</sup> along the coasts of Brittany<sup>3,24,61</sup>, Galician coasts on the Iberian Peninsula<sup>30,31,52,62</sup> and the Mediterranean Sea<sup>48,61-65</sup>, North Africa<sup>30,31,63,66</sup> including Azores and Madeira islands (Archipelagos)<sup>7,53,67-69</sup>.

**Dispersal and ecological remarks:** The present report is the first unequivocal record of *O. celtica* in the Moroccan coast ever, allowing the biogeographic range of the species/genus to be extended to the North African Atlantic coasts. The large range expansion of this subtropical/tropical species is suggested to be related with dispersal vectors, which

provide marine organisms with a relatively high potential to be introduced and become established at new regions. In fact, the present record raises interesting questions on dispersal vectors and particularly the vector of arrival of this North European species<sup>24</sup> in the Moroccan Atlantic coasts, which could be strictly connected with many factors (storms, currents, shipping or ballast water release). The broad distribution and contrasting life histories of the intertidal slug *Onchidella* make it a particularly useful group to address questions of dispersal and displacement between isolated and divergent coastal ecosystems<sup>17</sup>. Accordingly, knowledge of dispersal mechanisms allowing individuals to move large distances is essential to understand spatial population and community dynamics<sup>70,71</sup> predict spread of invaders<sup>72,73</sup> and manage biodiversity<sup>74</sup>. These mechanisms can include many forms of organism dispersal among of which is rafting as a passive form<sup>71</sup>. The latter is considered as a mechanism by which individuals move for long distances on detached algae or other material<sup>75-77</sup>. Rafting has been recognized as a common mode of redistribution for marine organisms<sup>71,75,78</sup> and structuring intertidal communities<sup>77</sup>. Particularly passive rafting on macroalgae is thought to enable movement over longer distances than those achieved by planktonic dispersal<sup>79</sup>.

In fact it has previously been suggested that the widespread distribution of the direct-developing *Onchidella* species can be related with passive rafting dispersal<sup>13,80</sup> with transoceanic rafting potentially linking their oceanically isolated populations (maintaining genetic connectivity)<sup>1</sup>. However, in spite of their direct development, *Onchidella* are able to disperse long distances associated to macroalgae (ecological association with kelp) by passive rafting via ocean currents or in ballast waters. Especially for species lacking larval dispersal stages, rafting allows individuals to move well outside their possible active dispersal range<sup>81,82</sup>. According to Cumming<sup>17</sup>, despite lacking a means of autonomous dispersal, *Onchidella marginata* surprisingly ranges over the broadest scales (up to >8000 km), which might be facilitated by rafting on macroalgae (*Durvillaea* spp.) through ocean currents.

Intertidal taxa that forego a planktonic larval phase, which could be regarded relevant for displacement over long distances along the ocean and instead have direct development are often expected to show limited dispersal capabilities. Nevertheless direct-developing pulmonate slugs of the genus *Onchidella* inhabit several marine coasts. This is the case of *O. celtica*. The wide distribution of this direct-developing species<sup>12,13,15</sup>, seems even more surprising given that it apparently lacks a mean of autonomous dispersal to explain its broad range. This biogeographic pattern could be attributed to the concept known as the "Paradox of Rockall" whereby direct-developing taxa are able to maintain a broader distribution than one having a pelagic larval phase by drifting or rafting<sup>80,83</sup>. Furthermore, *Onchidella* are excellent rafting candidates because they can both breathe air (pallial lung) and respire, while submerged (via the mantle), spend prolonged periods without feeding by reducing activity levels<sup>12,84</sup> and have potent chemical defenses via repugnatorial glands (defensive structures), which might serve to repel predators<sup>19,85</sup>. These capacities potential could have allowed *O. celtica* to disperse from North European populations (cool-temperate latitudes) and colonize North African shores (moderate-temperate latitudes).

*Onchidella celtica* was considered among temperature-sensitive rocky intertidal species in Great Britain<sup>56</sup> and further among some common rocky shore species in the British Isles that are expected to respond to climate change in UK waters<sup>29,86,87</sup>. As a matter of fact, it is suggested that, under warming climate conditions, this celtic slug might extended its geographical distribution from cool-temperate latitudes (Northern Europe) to warm-temperate latitudes (Southern Africa)<sup>88</sup>.

## CONCLUSION

In this study, the littoral pulmonate gastropod *Onchidella celtica* known as the celtic sea-slug is for the first time reported from five locations on the Atlantic coast of Morocco. These new records extend the known Northern geographical distribution range of the species drastically and importantly contributes to knowledge of the biogeography of this species, found to date, only on Atlantic European coasts between British shores in the North and the Western Mediterranean, Azores and Madeira islands in the South. We suggest that this species may also occur at other localities from the Mediterranean and North Africa and provide additional information on the spatial distribution, morphology and other ecological data of the species.

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