

## The land snails of Lichadonisia islets (Greece)

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### Abstract

The Lichadonisia island group is located between Maliakos and the North Evian Gulf, in central Greece. Lichadonisia is one of the few volcanic island groups of Greece, consisting mainly of lava flows. Today the islands are uninhabited with high numbers of visitors, but permanent population existed for many decades in the past. Herein, we present for the first time the land snail fauna of the islets and we compare their species richness with islands of similar size across the Aegean Sea. This group of small islands, provides a typical example on how human activities in the current geological era, i.e., the Anthropocene, alter the natural communities and differentiate biogeographical patterns.

**Key words:** Anthropocene, biogeography, human impact, species–area relationship, volcanic islands.

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### Introduction

Land molluscs represent one of the most speciose groups of terrestrial animals on Earth, with approximately 23,000 recognized species (MolluscaBase 2021) and an estimated number of undescribed taxa varying between 11,000–40,000 (Lydeard *et al.* 2004; Rosenberg 2014). Land snails occupy almost all available habitat types such as deserts, forests, phrygana, maquis and alpine meadows and are found almost everywhere on Earth, including all continents except Antarctica (e.g. Cameron 2016). Although they are known for their poor active dispersal ability (e.g. Cameron 2013; 2016) and their low tolerance to saline water, land snails have managed to colonize even the most isolated islands and comprise an important component of global islands' biodiversity (e.g. Cowie 2004; Cameron *et al.* 2013; Proios *et al.* 2021). The first ever global inventory of island snails, based on the faunas of 727 islands, includes 11,139 species; that is approximately 48% of all known land snail species, with 75% of them being single-island endemics (Proios

*et al.* 2021). At the same time land snails represent one of the most threatened groups of terrestrial animals (Lydeard *et al.* 2004), representing the majority of currently known extinctions among all plants and animals (200 species out of 950, IUCN 2021). Most of the extinct species are island endemics, a pattern observed in other taxa as well (e.g. Whittaker *et al.* 2017).

The land snails of the Greek islands is one of the most well studied animal groups in Greece (see Vardinoyannis *et al.* 2018; Sfenthourakis *et al.* 2018), especially due to the systematic and extensive studies of the past four decades (Mylonas 1982; Vardinoyannis 1994; Botsaris 1996; Triantis *et al.* 2008). Thus, species lists are available for more than 200 islands and islets, especially from the Aegean Sea. Endemism levels across the Aegean islands are quite high, 35–45% (Triantis & Mylonas 2009) and in some cases, like Crete, it exceeds 60%, (Vardinoyannis 1994; Vardinoyannis *et al.* 2018). Many of these species are currently threatened with extinction and in imminent need for conservation measures (Neubert *et al.* 2019).

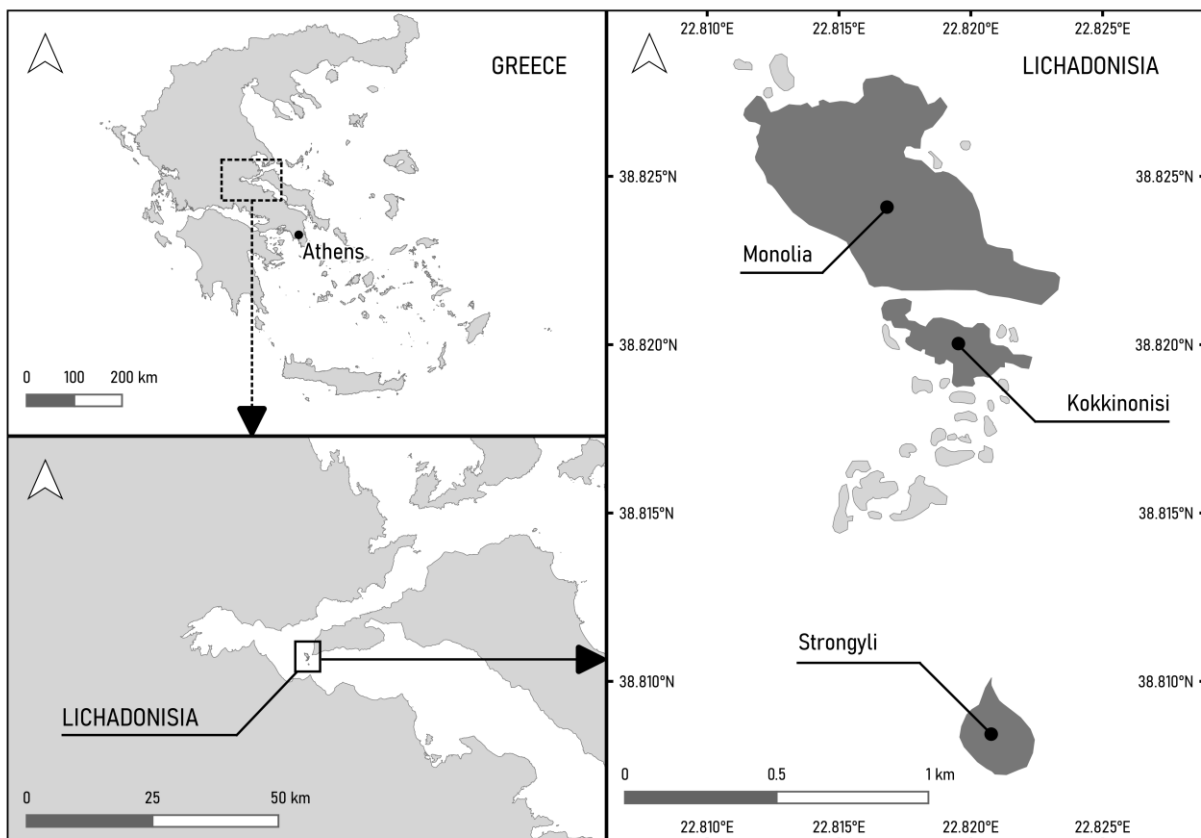
Destruction, alteration and/or fragmentation of their habitats due to human activities (e.g. tourism, road construction, urban expansion) are identified as the major threats (Vardinoyannis *et al.* 2018).

Herein we present the terrestrial snail fauna of the Lichadonisia island group, one of the few groups of volcanic origin in Greece, and we provide a comparison of the group's species richness with other Aegean islands. We also discuss the potential effect of human activities.

## Materials and methods

### Study area

Lichadonisia is a group of approximately 30 small islets located at the interface of Maliakos and the North Evvoia gulfs, in central Greece (Figures 1 & 2). Closest distances are 0.72 km from Evvoia and 2.17 km from mainland Greece. A small population of monk seals (*Monachus monachus*) is hosted in the area, which is therefore included in the NATURA 2000 network (site code GR2420013). The three largest islets are: Monolia (0.599 km<sup>2</sup>, maximum elevation: 13 m), Kokkinonisi (0.082 km<sup>2</sup>; maximum elevation: 1 m) and Strongyli (0.071 km<sup>2</sup>; maximum elevation: 17 m).



**Figure 1.** Map of Lichadonisia islets between Evvoia and mainland Greece. The three islets we visited are dark coloured.

Lichadonisia is one of the few volcanic islands of Greece, along with the island groups of Thira, Nisyros and Giali (e.g. Sfenthourakis & Triantis 2017). They consist mainly of trachyandesite lava flows, lying over a magma chamber (Pe-Piper & Piper 2002; Karastathis *et al.* 2011; Kanellopoulos *et al.* 2019). All islets are nowadays uninhabited, but according to demographic data (Hellenic Statistical Authority), they used to host residents until the early '80s in Monolia and Strongyli (Table 1). More specifically, 70 residents were reported in 1928 in Monolia. The population slowly declined in the following decades and the last residents abandoned the islet after 1971. Strongyli hosted a maximum of six people for a shorter period of time; most being military personnel (Hellenic Statistical Authority). On the other hand, Kokkinonisi was never inhabited. During the past few years, though, Monolia and Kokkinonisi have been attracting a high number of tourists during summer.

**Table 1.** Population census data of the Lichadonisia islet group from 1928 until 2011 according to the Hellenic Statistical Authority.

Year	Monolia	Strongyli	Kokkinonisi	Total
1928	70	-	-	70
1940	34	3	-	37
1951	47	6	-	53
1961	20	5	-	25
1971	2	-	-	2
1981	-	5	-	5
1991	-	-	-	-
2001	-	-	-	-
2011	-	-	-	-



**Figure 2.** Lichadonisia panorama: photo taken from Monolia, with an abandoned building by the sea, Kokkinonisi in the front, and Strongyli at the end. In the background, the mountains of mainland Greece appear. Photo by P. Pafilis.

The vegetation and the topography of the three main islets vary considerably. The largest part of Monolia is covered by *Olea europaea* trees, while there are also some open spaces with extensive rock piles, most probably created as a result of the inhabitants' efforts to plant olive trees (e.g. drystone wall terraces). Today, a few abandoned buildings are still standing, while the island's sand beach is used for touristic activities during the summer. Kokkinonisi is flat and covered almost entirely by sand and it also hosts touristic activities. The vegetation consists mainly of lentisks (*Pistacia lentiscus*), small halophyte plants and shrubby sea-blite (*Suaeda vera*) (see also Pafilis *et al.* 2020). Strongyli is quite verdant and steep, especially for a small Aegean islet, and it is the only one of the three that doesn't host any touristic activities. A small chapel and a lighthouse still exist, the latter being abandoned.

### Sampling

We visited the islet group twice, on May 3, 2019, as part of a scientific expedition by the Zoological Museum of the University of Athens, and on December 6, 2019. Sampling in two different periods covers the diverse biological cycles and habitat preferences of land snail species and thus enhance the credibility of snails' collection (e.g. Mylonas 1982; Triantis *et al.* 2008). Due to the islets' small size, sampling covered the whole area; we took samples from all the existing habitats on each islet and collected litter and soil under various plant species. Additionally, we recorded the vegetation and the human impact on each of the three islets. The collected specimens were in water for 24 hours and then preserved in 75% ethanol. Some of the individuals were preserved in absolute ethanol for future molecular analysis. The collected litter was sieved through 0.4–5 mm mesh and examined under a magnifying lens in the laboratory. GG, AP, CR and KAT identified all species. The specimens are deposited at the Zoological Museum of the National and Kapodistrian University of Athens (ZMUA).

### Species diversity comparisons

Snails depend on the availability of calcium, thus volcanic substrates that are usually calcium-poor might lead to reduced species richness and densities (e.g., Cameron *et al.*, 2016). In order to test if the three focal Lichadonisia islets have deviating or resembling numbers of land snail species in comparison to other Aegean islets of similar area, on account of their diverse geological background, we assembled species-richness data from 94 islets of the Aegean (see Appendix), smaller than 1.5 sq. km, belonging to the island groups of Astypalaia, Skyros, Kalymnos (Triantis *et al.* 2008), Kastellorizo (Mylonas *et al.* 2019) and the Saronikos Gulf (Botsaris 1996). Using the log-log species–area relationship model (e.g. Triantis *et al.* 2012) for those 94 islets, we calculated the estimated number of species for Monolia, Kokkinonisi and Strongyli, according to their area and then compared it to the number of species actually collected.

### Results

In total, 13 species were found on the three studied islets, all belonging to different genera. None of the species is endemic to the islet group. All species seem to maintain populations on the islets at low or very low densities, with the exception of *Lindholmiola lens* Férussac, 1832. The species found on each islet in the two surveys differ slightly, indicating that we have recorded the malacofauna of the islets in its entirety.

During the first survey, a single old shell of *Eobania vermiculata* Müller, 1774 was found on Kokkinonisi, but no other shells or individuals were found on any of the islets or during the next survey. Therefore, *E. vermiculata* is not included in the living malacofauna of Lichadonisia. Overall, 9 species were found on Monolia, the largest islet, 10 on Strongyli and 11 on Kokkinonisi (Table 2).

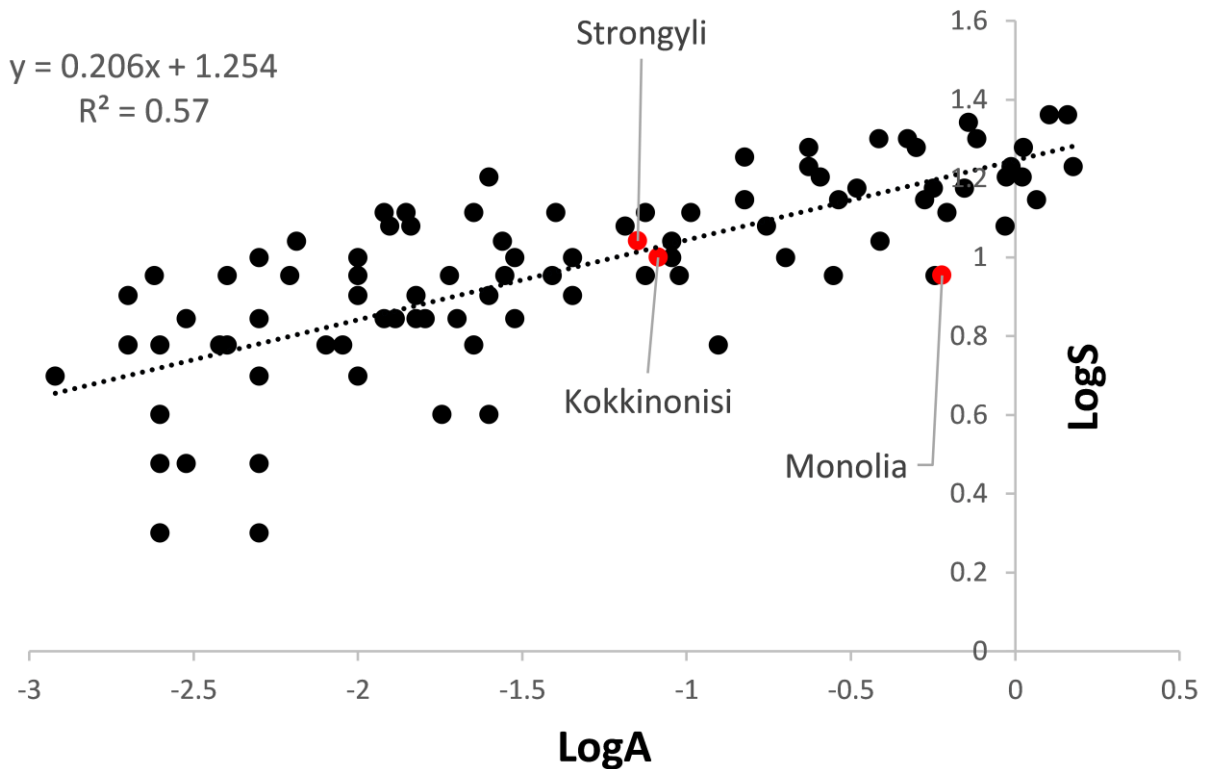
Based on the species–area relationship of 94 islets (Figure 3), we estimated the number of species expected to be found on the three islets of Lichadonisia (Table 3).

For Kokkinonisi and Strongyli the estimated and the observed species numbers are almost identical, but Monolia hosts almost seven species less than what the model predicted, based on the islet's area. (Figure 3; Table 3). Results remain the same if only the islets of Saronikos Gulf, of similar isolation with the Lichadonisia islets, are used.

**Table 2.** Terrestrial land snail species found on the three islets.

Species	Chorotype	Monolia	Kokkinonisi	Strongyli
<i>Chondrula bergeri</i> (Roth, 1839)	Greek endemic	1	0	0
<i>Cochlicella acuta</i> (Müller, 1774)	Mediterranean	0	1	1
<i>Deroceras cf. panormitanum</i> (Lesson & Pollonera, 1882)*	Palaeartic	1	1	1
<i>Gittenbergia sororcula</i> (Benoit, 1859)	Mediterranean	1	1	1
<i>Isabellaria riedeli</i> Brandt, 1961	Greek endemic	0	0	1
<i>Lauria cylindracea</i> (Da Costa, 1778)	Palaeartic	1	1	1
<i>Lindholmiola lens</i> (Férussac, 1832)	Balkan	1	1	1
<i>Monacha claustralis</i> (Rossmässler, 1834)	Balkan	1	1	1
<i>Pomatias elegans</i> (Müller, 1774)	Palaeartic	0	0	1
<i>Trochoidea pyramidata</i> (Draparnaud, 1805)	Mediterranean	0	1	0
<i>Truncatellina callicratis</i> (Scacchi, 1833)	Palaeartic	1	1	1
<i>Vitrea contracta</i> (Westerlund, 1871)	Palaeartic	1	1	1
<i>Xerocrassa cretica</i> (Férussac, 1821)	Mediterranean	1	1	1
<b>Total Number of species</b>		<b>9</b>	<b>10</b>	<b>11</b>

\* see Wiktor (2001) and Hutchinson *et al.* (2014).



**Figure 3.** The species–area relationship for 94 islets of the Aegean Sea, of similar size with the islets of Lichadonisia, i.e. less than 1.5 km<sup>2</sup> and the respective position of the three islets presented with red dots.

**Table 3.** Estimated and observed number of species for the three islets of Lichadonisia studied.

Islet	Estimated number	Observed number
Monolia	16.13	9
Kokkinonisi	10.70	10
Strongyli	10.39	11

## Discussion

The Lichadonisia islet group is an exceptional case for the Greek islands; small in size, with minimum isolation, of volcanic origin and with a long and intense presence of humans. As expected, there are no endemic land snail species to the group and all species have a wider distribution, with the Palaearctic and the Mediterranean elements dominating.

Lichadonisia are volcanic islands with calcium-poor soils, which leads to low population densities. Nevertheless, a comparison of each islet's species richness with the number of species predicted based on 94, mainly calcareous, Aegean islets of similar area, gave very similar values for Kokkinonisi and Strongyli (Figure 3; Table 3). This is most probably the outcome of the low isolation of the system which allows the continuous flow of dispersing individuals from the nearby mainland Greece and Evvoia to Lichadonisia, leading to either the addition of new species or to the “rescue” of existing populations, i.e. rescue effect (e.g. Whittaker & Fernández-Palacios 2007). However, the largest islet of the group, Monolia, stands as an exception. Although on the other two islets, Kokkinonisi and Strongyli, human presence was limited, Monolia had a long and intense, for its size, presence of humans, which re-shaped its natural landscape. Numerous piles of relocated volcanic rocks, along with the olive trees groves that expand all over the area, have significantly reduced the islet's environmental heterogeneity. Furthermore, although Monolia and Kokkinonisi are separated by a small channel, Kokkinonisi has a more similar fauna to Strongyli than to Monolia (see Table 2), providing another piece of evidence for the effects of human pressure on Monolia's fauna.

The small Lichadonisia islet group forms an exemplary case of how human activities in this new geological era, often referred to as the Anthropocene, alter natural ecosystems and confound naturally occurring biogeographical patterns (e.g. Graham *et al.* 2017; Whittaker *et al.* 2017).

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## Appendix

Area in km<sup>2</sup> and respective species richness of land snails for 94 islets of the Aegean Sea (Greece).

Island	Area (A) (km <sup>2</sup> )	Number of species (S)
Agia Marina	0.0012	5
Diapori	0.0020	8
Thalia	0.0020	6
Pera (salamina)	0.0024	9
Markelos inner	0.0025	6
Ydrousa inner	0.0025	4
Ydrousa outer	0.0025	4
Aliki (Poros)	0.0025	3
Ksera (Kyra)	0.0025	2
Neda (Poros)	0.0025	2
Ag. Fokas	0.0030	7
Daskalio (poros)	0.003	7
Kavouri (katramonisi)	0.003	3
Kavouronisi	0.0038	6
Psomi	0.0040	6
Krevvati	0.0040	9
Galenthi	0.005	10
Markelos A outer	0.005	7
Gaidaros	0,005	5
Fleves (very small)	0.005	3
Prasonisi	0.005	2
Lazareta (Poros)	0.0062	9
Peristeri East	0.0065	11
Kourmoulades (north islet)	0.008	6
Molathi	0.009	6
Agios Georgios	0.0100	10
Psoradia	0.0100	8
Nekrothiki	0,0100	5
Peristeri 2	0.01	9
Agrielia	0.0120	13
Arxi	0.012	7
Lagonisi	0.0125	12
Tselevinia west	0,013	7
Kourmoulades (central islet)	0.014	13
Kanakia	0.0145	12
Prasou	0.015	8
Makronisos (small)	0.015	7

Lakkonisi	0.0160	7
E. Diavatis	0.0180	4
Fteno	0.0190	9
Pontikonisi	0.02	7
Alonissos (Agkistri)	0.0225	13
Bourtzi	0.0225	6
Traheili	0.025	16
Plateia (Poros)	0.025	8
Nisida (Aigina)	0.025	4
Pahaki	0.0275	11
Flevopoula	0.028	9
Sari	0.0300	7
Ag. Andreas	0.0300	10
M. Diavatis	0.0390	9
Spalathronisi	0.04	13
Kourmoulades (west islet)	0.045	10
Panagitsa	0.045	8
Ydrousa	0.065	12
StrongyliLic	0.0710	11
Tigani	0.0750	13
Ledou	0.075	9
Kokkinonisi	0.0820	10
Fokionisi S.	0.0900	11
Pahi	0.09	10
Stahtoroi	0.095	9
Petronisi	0.103	13
Plateia (Aigina)	0.125	6
Ag. KyriakiKAL	0.1500	18
Safonidi	0.1500	14
Modi	0.15	14
Evraios	0.15	14
Eleousa	0.175	12
Tragonisi	0.2	10
Lianos	0.2350	19
Makronisos	0.235	17
Ag. Kyriaki	0.2550	16
Kalavros	0.2800	9
Koulouri	0.2900	14
Doroussa	0.33	15
Chondros	0.3850	20
Sliki	0.388	11
Koutsomytis	0.4700	20
Nera	0.5000	19
Erinia	0.5300	14
Psili	0.563	15
Fokionisi	0.5700	9

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Monolia	0.5990	9
Platia	0.6200	13
Platourada (Sofiko)	0.7	15
Plati	0.7200	22
Arsidas	0.763	20
Strongyli	0.9300	12
Agios Thomas	0.94	16
Pontikousa	0.9700	17
Kyra	1.05	16
Moni	1.06	19
Agios Ioannis	1.1625	14
Fleves	1.27	23
Kounoupoi	1.4450	23
Ro	1.5000	17

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