

## Article

# Land Snail Assemblages of Olive Orchards in Crete, Greece

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**Abstract:** Land snail biodiversity research in agroecosystems is limited, if non-existent. Here we investigate the land snail assemblages of olive orchards in Messara plain, Crete, Greece. Land snails were collected from 16 olive orchards. In addition, we performed a literature survey and recorded all species reported in the surrounding area. We found 18 species in the olive orchards among the 37 species found in the area and reported in the literature. *Xerotricha conspurcata* (Draparnaud, 1801) and *Caracollina lenticula* (Michaud, 1831) are reported for the first time in the study area. Their presence is probably a result of human-mediated dispersal. Olive orchards proved to be an important refuge for land snail diversity as they host 43% of the species found in the surrounding area. We highlight the importance of olive orchards as habitats with increased land snail richness. We suggest that land snails should be included in future biodiversity research in agricultural areas.

**Keywords:** agroecosystem; gastropods; olive orchards; cultivated land; human impact



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## 1. Introduction

The island of Crete in southern Greece harbors several land snail species, including a number of endemics to the island and adjacent areas (e.g., [1–10]). Records of Cretan land snails date from 19th century publications (e.g., [11,12]), while recent research intensified after the 1950s (e.g., [1,13–16]). The PhD thesis of Vardinoyannis [17] is the first work that provides a complete list of species and distribution maps with records from field collections and the literature. Since then, several publications have contributed to our knowledge of Cretan land snails, e.g., by resolving taxonomic uncertainties [4,5,7–9], dealing with biogeographic and historical affinities [6] and working on phylogenetic relationships as well as species' phenology (e.g., [4,5,10,18]). Among the most recent and taxonomically complete works is the publication of Hausdorf and Sauer [8] on the Hellicelinae of Crete. These authors conducted a thorough field research of the island and combined their data with older museum samples/specimens in order to provide species distribution maps and an updated systematic key for the identification of 23 species from eight genera of the Hellicelinae. In addition, many works have been dedicated to the complex evolutionary history of the genus *Albinaria* Vest, 1867 in Crete (e.g., [19–21]). Specifically, Welter-Schultes [21] provided an extensive revision of the genus and summarized all the previous work. Another consolidated work investigated the genus *Metafruticicola* von Ihering (1892) in the Mediterranean, identifying eight (8) morphological species in Crete while stressing the need for molecular investigations [22]. Similarly, other groups of species that have been investigated include *Mastus* (Beck, 1837), *Monacha* (Fitzinger, 1833) and *Orcullela* (Steenberg, 1925) ssp. [7,9,15].

Welter-Schultes [23] in his book on non-marine mollusks, provided species maps for all known species living in Europe, including the land snails of Crete. Although the species distributions shown by Welter-Schultes [23] are rather imprecise, it is one of the most

up-to-date sources of information on the land snail fauna of Crete. Still, our knowledge of local land snail assemblages in Crete is limited with very few works dealing with faunas from typical Mediterranean habitats such as maquis and phrygana (e.g., [2,3]).

Similar to other habitats, cultivated land and its biodiversity face threats such as agricultural intensification, extensive synthetic chemical input use, habitat fragmentation in isolated patches and landscape homogenization [24,25]. As a consequence, diversity may be reduced with species losing or shrinking their habitats and distributions in conjunction with important agroecosystem services themselves being reduced (e.g., [26]). Thus, studying biodiversity of agroecosystems is of significant importance to conservation.

Agricultural land is rarely searched in terms of land snails (but see [25,27]), although examples from other animal groups indicate that cultivated land harbors a rich biota (e.g., [25,28–30]). In addition, land snails are a promising bio-indicator for monitoring agricultural land [27,31,32].

Crete is characterized by olive cultivation. Although about 20% of Crete's landscape is covered by olive orchards, our knowledge of the snail diversity in olive orchards is limited, if non-existent. So far, we are aware of one unpublished PhD thesis [33] dealing (amongst other taxa) with land snails in agroecosystems of Greece. Grammatikaki [33] recorded ten and seven land snail species during the investigation of olive orchards in Lesvos Island in the Aegean Sea and in Arta in northwestern Greece, respectively.

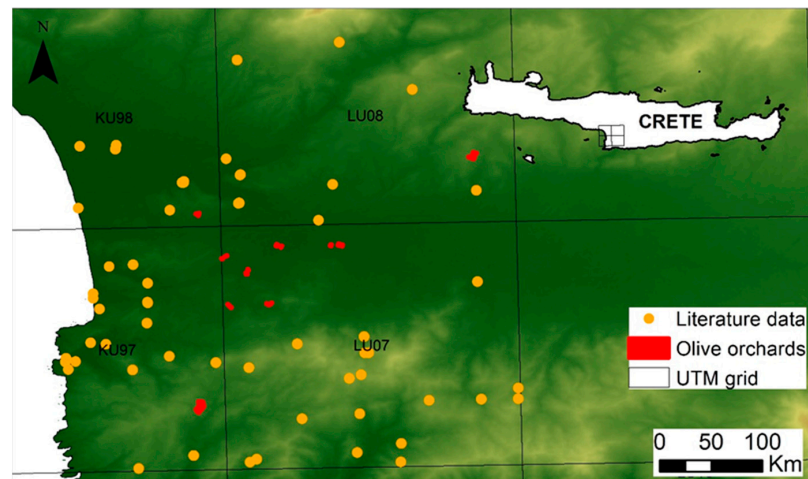
In this study, we record for the first time the land snail fauna of olive orchards located in southern Crete. In addition, we provide a species list from the literature of the snail fauna in the surrounding uncultivated natural area and compare it to the species diversity recorded from the orchards.

## 2. Materials and Methods

We sampled land snails on the western Messara plain on the island of Crete, Greece (Figure 1). Material was collected from 16 olive orchards for a year on a bimonthly basis. Sampling started in November 2019 and ended in October 2020. The selection of the olive orchards was based on previous research in the area [34–36]. The current research was also implemented in the framework of the project LIFE IGIC (<https://www.lifeigic.eu/> (accessed on 1 July 2022)). The ground floor, rocks, trees and any human construction/objects (e.g., stone walls, bags of fertilizer left on the ground) were searched for land snails until no new species were detected in the field (ca. after 45 min to 1 h). Litter and soil samples were taken during January–February 2020 and later sieved for small sized snails using different mesh sizes (5 to 0.5 mm).

Snails were identified to the lowest taxonomic level as possible. The nomenclature and classification followed MolluscaBase [37]. Based on their distribution, species were classified into four chorotypes: Palearctic (PAL), Mediterranean (MED), Aegean endemic (AEGend) and Cretan endemic (CREend) following Triantis et al. [38]. The collected material was preserved in 75% alcohol.

Land snail data from the broader study were compiled after a systematic bibliographic research. The bibliographic data are accompanied by a set of coordinates (if available) and the 10-km Universal Transverse Mercator (UTM) code of the grid cell they fall inside. If the exact coordinates were not available, they were estimated based on the description of the respective collection site. In case the information for the collection site was not precise, the data were directly assigned to a UTM grid cell without coordinates. The choice of UTM as a reference unit is in accordance with the two main sources of information on land snails of the study area (i.e., [8,17]). For the literature review, we considered the four UTM grid cells where the olive orchards are distributed. The four UTM grid cells cover an area of ca. 400 km<sup>2</sup>.



**Figure 1.** Map of the study area. The olive orchards are shown in red. The literature data are represented by orange dots. The study area is divided into the four (4) Universal Transverse Mercator (UTM) grid cells.

### 3. Results

In total, we recorded 18 land snail species from 16 olive orchards (Table 1, Figure 2). In addition, at least one other land snail species was found, but could not be identified to species level. Slugs were found in all olive orchards but are not considered in the current study. Two species are endemic to Crete (11%), two are endemic to the Aegean Archipelago (11%), 13 are Mediterranean species (72%) and one is a Palearctic species (6%) (Table 1). The highest number of recorded species in an olive orchard was 12 and the lowest was nine. Mean species richness was 9.8 species per olive orchard.

**Table 1.** List of species found in the 16 olive orchards under investigation and their chorotype (MED-Mediterranean, AEGend-Aegean endemic, PAL-Palearctic, CREend-Cretan endemic).

| Species   | Olive Orchards |           |           |           |           |          |          |           |           |          |          |          |          |           |           |          | Total Number of Presences | Chorotype |
|---|----------------|-----------|-----------|-----------|-----------|----------|----------|-----------|-----------|----------|----------|----------|----------|-----------|-----------|----------|---------------------------|-----------|
|   | 1o             | 2c        | 2o        | 3c        | 3o        | 4c       | 4o       | 5c        | 5o        | 8c       | 8o       | 10c      | 10o      | 11c       | 11o       | 7o       |                           |           |
| <i>Cornu aspersum</i>                               | +              | +         | +         | +         | +         | +        | +        | +         | +         | +        | +        | +        | +        | +         | +         | +        | 16                        | MED       |
| <i>Cantareus apertus</i>                            | +              | +         | +         | +         | +         | +        | +        | +         | +         | +        | +        | +        | +        | +         | +         | +        | 16                        | MED       |
| <i>Eopolita protensa</i>                            | +              | –         | –         | +         | +         | –        | –        | +         | +         | –        | –        | –        | –        | +         | +         | –        | 7                         | MED       |
| <i>Metafruticicola noverca</i>                      | +              | –         | –         | –         | –         | –        | –        | +         | +         | –        | –        | –        | –        | +         | +         | +        | 6                         | AEGend    |
| <i>Monacha syriaca</i>                              | –              | –         | –         | –         | –         | +        | +        | –         | –         | +        | +        | +        | +        | +         | –         | –        | 7                         | MED       |
| <i>Theba pisana</i>                                 | +              | +         | +         | –         | –         | +        | +        | +         | +         | +        | +        | +        | +        | –         | –         | +        | 12                        | MED       |
| <i>Cochlicella acuta</i>                            | –              | +         | +         | –         | –         | +        | –        | –         | –         | +        | +        | +        | –        | –         | –         | –        | 6                         | MED       |
| <i>Rumina saharica</i>                              | +              | +         | +         | –         | –         | –        | –        | +         | +         | –        | –        | –        | –        | –         | –         | +        | 6                         | MED       |
| <i>Ceriuella virgata</i>                            | +              | +         | +         | +         | +         | +        | +        | +         | +         | +        | +        | +        | +        | +         | +         | +        | 16                        | PAL       |
| <i>Pseudoxerophila bathytera</i>                    | +              | –         | –         | –         | –         | –        | –        | –         | –         | –        | –        | –        | –        | –         | –         | –        | 1                         | AEGend    |
| <i>Xerocrassa cretica</i>                           | +              | +         | +         | +         | +         | +        | +        | +         | +         | +        | +        | +        | +        | +         | +         | +        | 16                        | MED       |
| <i>Xerocrassa mesostena</i>                         | –              | –         | –         | +         | +         | –        | –        | –         | –         | –        | –        | –        | –        | –         | –         | –        | 2                         | CREend    |
| <i>Xeromunda candiota</i>                           | +              | +         | +         | +         | +         | +        | +        | +         | +         | –        | –        | –        | –        | +         | +         | –        | 11                        | MED       |
| <i>Xeropicta krynickii</i>                          | –              | –         | –         | –         | –         | –        | +        | +         | –         | –        | –        | –        | +        | –         | –         | –        | 3                         | MED       |
| <i>Eobania vermiculata</i>                          | +              | +         | +         | +         | +         | +        | +        | +         | +         | +        | +        | +        | +        | +         | +         | +        | 16                        | MED       |
| <i>Xerotricha conspurcata</i>                       | –              | +         | +         | +         | +         | –        | –        | –         | –         | –        | –        | –        | –        | –         | +         | –        | 5                         | MED       |
| <i>Caracollina lenticula</i>                        | –              | +         | +         | +         | +         | –        | –        | –         | –         | –        | –        | –        | –        | –         | –         | –        | 4                         | MED       |
| <i>Albinaria terebra</i>                            | +              | –         | –         | –         | –         | –        | –        | +         | +         | –        | –        | –        | –        | +         | +         | +        | 6                         | CREend    |
| <i>Mastus sp.*</i>                                  | p              | p         | p         | p         | p         | –        | –        | p         | p         | –        | –        | –        | –        | p         | –         | p        | 9                         |           |
| <b>Total number of species per olive orchard **</b> | <b>12</b>      | <b>11</b> | <b>11</b> | <b>10</b> | <b>10</b> | <b>9</b> | <b>8</b> | <b>12</b> | <b>12</b> | <b>8</b> | <b>8</b> | <b>8</b> | <b>8</b> | <b>10</b> | <b>10</b> | <b>9</b> |                           |           |

\* *Mastus sp.* was only recorded as present (p) in the olive orchards and was not included in the total number of species per olive orchard. \*\* Only species noted with (+) were included in the total number of species per olive orchard.





**Figure 2.** Photos of some of the olive orchards under investigation (numbering follows Table 1). (A) olive orchard 2o. (B) olive orchard 3o. (C) olive orchard 5o. (D) olive orchard 5c. (E) olive orchard 11c. (F) olive orchard 11o.

We counted 37 species, three (3) subspecies and two (2) undescribed species during the bibliographic research distributed in the four UTM grid cells (Table S1). 16 of 37 species (43%) are also present in the orchards. Two species found in the olive orchards, i.e., *Caracolina lenticula* (Michaud, 1831) and *Xerotricha conspurcata* (Draparnaud, 1801) (Figure 3A,B), are recorded for the first time in the study area.



**Figure 3.** (A) *Caracollina lenticula* (Michaud, 1831), (B) *Xerotricha conspurcata* (Draparnaud, 1801). Scales bars correspond to 1 mm.

### 3.1. Taxonomic and Ecological Remarks

#### 3.1.1. Family Helicidae Rafinesque, 1815

*Cornu aspersum* (Müller, 1774), *Cantareus apertus* (Born, 1778) and *Eobania vermiculata* (Müller, 1774)—All three species were found in all searched olive orchards. *C. aspersum* and *E. vermiculata* were found in high densities, on the ground covered mostly with *Oxalis pes-caprae* during the survey period, on the olive tree trunks and under rocks. The species are considered anthropophilic [2] and were mentioned from the study area by other authors as well (see Table S1).

*Theba pisana* (Müller, 1774)—The species was collected from 12 olive orchards. The species is considered invasive and its current distribution in the Mediterranean is most probably shaped by anthropogenic activities [39].

#### 3.1.2. Family Enidae Woodward, 1903 (1880)

*Mastus* sp.—The species was found in nine out of 16 olive orchards on the ground and under piles of rocks at the edges of the orchards. The systematics of *Mastus* spp. occurring on Crete and its islets have been relatively well-studied using both conchological and anatomical characters [15,21] as well as molecular phylogeny [4,5]. However, the exact number of species occurring on the island is unclear as undescribed species still remain and not all parts of Crete have been thoroughly investigated. According to [15], an unnamed *Mastus* species occurs near Phaistos and Matala (i.e., in the study area). As no wet material of the unnamed *Mastus* species was available for the study of its reproductive system, Massen [15] refrained from providing a name for it. Vardinoyannis [17] mentions *M. etuberculatus* (Frauenfeld, 1867), *M. olivaceus* (Pfeiffer, 1846) and *M. turgidus* (Kobelt, 1877) living in the study area. However, according to [23], *M. etuberculatus* and *M. turgidus* do not live in Crete and *M. olivaceus* is so far considered to be restricted to Lefka Ori in the regional unit of Chania, western Crete (see also [5]). Finally, according to [40] the name *M. emarginatus turgidus* (Kobelt, 1877) is only accepted and the species does not live in Crete. Here we were only able to collect dry material from nine orchards, making the identification to species level impossible. However, based on the aforementioned observations, we hypothesize that the olive orchards in the study area host an endemic (possibly not yet described) *Mastus* species.

#### 3.1.3. Family Hygromiidae Tryon, 1866

*Metafruticicola noverca* (Pfeiffer, 1853)—*M. noverca* was collected from six olive orchards. The species was found on the ground, under rocks and in shrubs/wild bushes inside the orchards. According to [17,22], two species, *M. noverca* and *M. sublecta* (Maltzan 1884) live in the study area. In the present study we did not find *M. sublecta* in the olive orchards. *M.*

*noverca* is one of the commonest snails of Crete [6,17]. *M. noverca* is also present in other Aegean islands (see [22] for a distribution map).

*Monacha syriaca* (Ehrenberg, 1831)—*M. syriaca* was collected from seven olive orchards. According to [17], the species is found in agricultural land and adjacent habitats and has been recorded in the study area. This species is distributed in the eastern Mediterranean region (see [23] for a range map).

Helicellinae spp.—*Xeromunda candiota* (Pfeiffer, 1849) was identified in 11 olive orchards. *Pseudoxerophila bathytera* (Westerlund and Blanc, 1879) was found only in one orchard, and *Xerocrassa mesostena* (Westerlund, 1879) and *Xeropicta krynickii* (Krynicky, 1833) in two and three orchards, respectively. *Xerotricha conspurcata* (Draparnaud, 1801), was collected from five olive orchards. This is the first record of the species in the Messara plain (see [8] for a distribution map). *Xerocrassa cretica* (L. Pfeiffer, 1841) and *Cerneuella virgata* (Da Costa, 1778) were present in all 16 orchards. Hausdorf and Sauer [8] recorded the same set of species, with the exception of *X. conspurcata*, in the area from several locations (see Table S1).

#### 3.1.4. Family Clausiliidae J. E. Gray, 1855

*Albinaria terebra* (L. Pfeiffer, 1853)—*A. terebra* was found in six olive orchards. The species was collected usually near piles of rocks and one individual was picked up from the ground. *A. terebra* lives in the lowlands around the Messara plain [23]. The genus *Albinaria* has a long research history in Crete (e.g., [10,41,42]), and the identification to species level can be challenging. Four species are present in the study area and its surroundings, *A. cretensis* (Rossmässler, 1836), *A. corrugata* (Bruguière, 1792), *A. terebra* (Pfeiffer, 1853) and *A. idaea* (Pfeiffer, 1850) [17,21,23]. All four are endemic to Crete and/or peripheral islets. Vardinoyannis [17] also mentions *A. inflata* (Olivier, 1801), which is now considered a subspecies of *A. corrugata* [43].

#### 3.1.5. Family Geomitridae C.R. Boettger, 1909

*Cochlicella acuta* (Müller, 1774)—The species was recorded in six olive orchards under rocks, on plants, on water pipes and shrubs. During summer, several individuals were attached on fallen and dry tree branches along with *T. pisana* and Helicellinae.

#### 3.1.6. Family Oxychilidae Hesse, 1927 (1879)

*Eopolita protensa* (Férussac, 1832)—*E. protensa* was collected from seven olive orchards. The species was found under rocks usually placed as boundaries at the edges of the orchards. It is a common species in central to eastern Crete [17] and it is considered anthropophilic [2].

#### 3.1.7. Family Achatinidae Swainson, 1840

*Rumina saharica* Pallary, 1901—*R. saharica* was present in six olive orchards. The species was collected under rocks and under decayed tree branches/trunks. Until recently the species has been misidentified as *R. decollata* (Linnaeus, 1758) [23]. It is common in areas affected by humans and in agricultural land [17,23].

#### 3.1.8. Family Trissexodontidae Nordsieck, 1987

*Caracollina lenticula* (Michaud, 1831)—The species was collected from four (4) olive orchards, under rocks or rock walls. It is not a common species in Crete and it is usually found near coastal habitats [23]. This is the first record of *C. lenticula* in the Messara plain. The species is anthropophilic [2] and is considered to be introduced to Crete [42].

## 4. Discussion

We present for the first time an account of the land snail fauna living in Cretan olive orchards in the largest plain of Crete, the Messara valley, located in central south Crete. To our knowledge, this is the first published study dealing with land snail faunas of olive orchards. Regarding the island of Crete comprehensive works such as [17,23] mention



the habitats that land snails of Crete are commonly found, however, no special survey or reference is made either to olive orchards or to the study area. Our study reveals that a significant subset (43%) of the land snail fauna found in the area occurs in the olive orchards under investigation. Their fauna consists mostly of Mediterranean species (13 of 18 species), which is in agreement with [33]. Other studies [44,45] also report that mollusk assemblages found in cultivated or formerly cultivated areas in the Aegean islands are dominated by Mediterranean species.

The presence of anthropophilic (e.g., *C. aspersum*, *C. apertus* and *E. protensa*) and introduced species in the olive orchards is not surprising [2,17] as the extended agricultural activity throughout Crete has facilitated the passive dispersal of land snails [46]. In particular, anthropophilic species contribute to the homogenization of the olive orchard fauna and can reduce faunal differences between collection sites in general [2,32].

The new records of the introduced species *X. conspurcata* and *C. lenticula* in the Messara plain are noteworthy. *Xerotricha conspurcata* was recorded for the first time in five locations in the northern part of Crete [8]. We assume that the species recent discovery in Crete, its patchy distribution and its presence in the olive orchards in southern Crete is a result of recent human-mediated dispersal. Yet, further investigation is required in order to confirm our findings. *C. lenticula* is found in a couple of locations across the coastal zone of Crete (see maps in [2,17,23]) and this is the first record of the species from an olive orchard. Its presence there is not unexpected as the species has been previously recorded from a coastal habitat in the proximity of the study area (see [2,17]).

Furthermore, our results reveal that at least four Aegean endemic species are present in the olive orchards, *X. mesostena* and *A. terebra* (Cretan endemics), *M. noverca* and *P. bathytera* (Aegean endemics). With the exception of *A. terebra*, the other three species are widespread in Crete [8,22,23]. Furthermore, the genera *Albinaria* and *Mastus*, which are mostly represented by endemic species in Crete, have already been reported from previously cultivated sites [2,45] and olive orchards [17,33]. However, the sporadic presence of *Mastus* sp. and *A. terebra* represented only by few specimens reflects the absence or limited availability of appropriate habitats such as calcareous rocks and stones [15,23].

## 5. Conclusions

Our study demonstrates that olive orchards are a valuable refuge for local land snail assemblages in Crete. Both widespread and endemic species live in the study sites, while anthropogenic activities have most probably facilitated the dispersal of certain species across the investigated olive orchards. Species richness in olive orchards may increase with the presence of stony micro-habitats [32], which favor the presence of micro-habitat specialists (e.g., *Albinaria* ssp.) or other rock-dwellers (e.g., *E. protensa*).

The results of our research highlight land snails as important biodiversity components of the olive agroecosystem. Agroecological studies aiming at the monitoring, management and/or conservation of biodiversity in the olive agroecosystem should include land snails among the studied taxa. In addition, we advocate that land snails should be considered when green infrastructure measures and related farming methods are implemented in agroecosystems. We anticipate that our work will set the beginning for research of land snail diversity in the olive agroecosystem and in cultivated habitats in general.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d14070565/s1>, Table S1: List of species records from the study area which were retrieved from the literature.

**Author Contributions:** Conceptualization, E.G., V.D.G. and E.M.K.; methodology, E.G., V.D.G. and E.M.K.; software, E.G.; validation, E.G., V.D.G. and E.M.K.; formal analysis, E.G.; investigation, E.G.; resources, E.G., V.D.G. and E.M.K.; data curation, E.G.; writing—original draft, E.G.; writing—review and editing, E.G., V.D.G. and E.M.K.; visualization, E.G.; supervision, E.G. and E.M.K.; project administration, E.M.K.; funding acquisition, E.G., V.D.G. and E.M.K. All authors have read and agreed to the published version of the manuscript.

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