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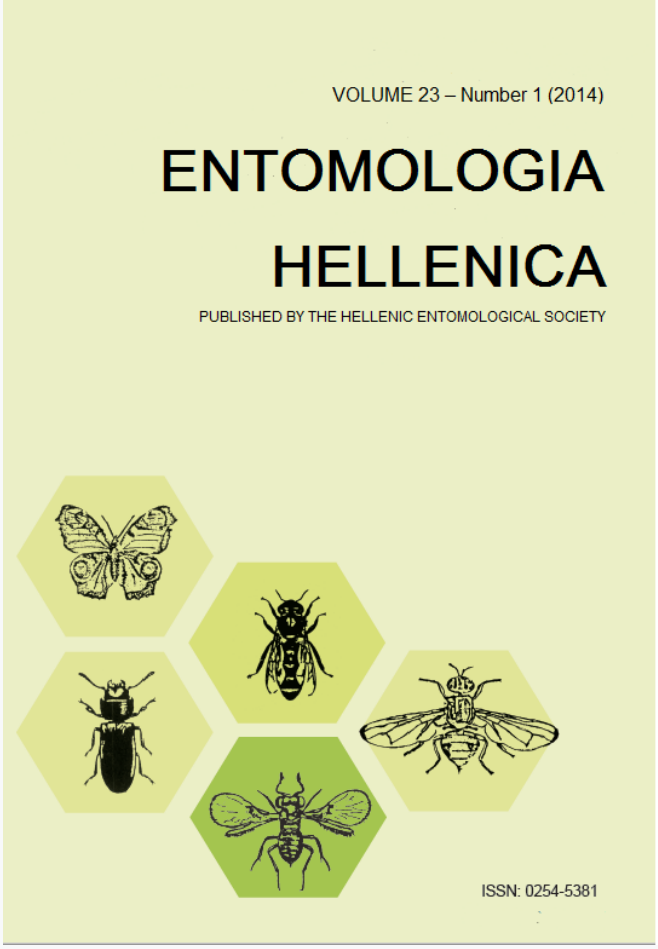

Δομή βιοκοινοτήτων εδάφους και βιοποικιλότητα σε ελαιώνες τριών νησιών της Αν. Μεσογείου

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Structure of soil biocoenosis and biodiversity in olive orchards of three eastern Mediterranean islands

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ABSTRACT

In this work the structure of soil arthropods' biocoenosis was compared among 11 olive orchards from six localities of Crete (three of the localities from Messara's valley, including two olive orchards each one, plus three localities near to Herakleion city) and other two ones each from the island of Kos and Cyprus. Pitfall traps were used and totally 35 taxa were captured. The order Coleoptera and the family Formicidae were the two main taxa at the 8 of the 11 olive orchards. Statistically significant differences in biodiversity were recorded among the orchards separating them in three groups, the first group included Messara's olive orchards, the second the olive orchards of the rest of the Crete and the third group the olive groves of the other two islands. Messara's group had higher biodiversity than the third group. By studying the similarities of biological communities, some pairs of Messara's olive groves, have the highest ones. Among the 15 highest values, the 14 belonged to pairs between Messara's olive orchards. Generally, biocoenosis in all 11 olive orchards of the three different islands follows a similar pattern, despite of differences in cultural practices and changes of climatic factors from a year to another.

KEY WORDS: Biodiversity, biological communities, olive orchards, pitfall traps.

Introduction

The culture of olive tree is very ancient in Greece. It has a noticeable contribution to the Greek exports and the economy of the country. Although is a very common crop, there are no many ecological studies of soil arthropods from olive orchards in Greece.

The structure of soil arthropods' biocoenosis in olive orchards of northern Greece was studied using pitfall traps (Hadjicharalampous et al. 2002). However, that study focused on only two groups (Coleoptera and Isopoda). There are also similar studies focused on only a single order, such as Coleoptera in Spain (Cotes et al. 2009). More groups of arthropods were examined in a work on southern Italy (Scalercio et al. 2009), by following the same trapping method.

In another study conducted in Spain more taxa (17) were recorded (Garrido-Jurado et al. 2011), but was focused on Formicidae family, which was the most abundant one (88.5% of total captures).

Our aims were to investigate the similarities in biocoenosis' structure and biodiversity in the olive groves of areas of Crete, Kos and Cyprus.

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Materials and Methods

This study carried out on six olive orchards in three villages of Messara valley, three olive orchards from regions near the city of Herakleion in Crete and two more orchards each from the island of Kos and Cyprus. Pitfall traps were used with propylene glycol, both as trapping and as preservative liquid, in all the olive orchards. In each orchard about two traps per 1.000 m^2 were established very close to the trees' trunks. By this way was stronger the influence of olive tree in captures (i.e. protection during ploughing, shadow etc.). The collection of specimens and the replacement of the liquid were conducted once per week and the identification of captured invertebrates was made mainly at the order level. The unique exception, were the members of family Formicidae, which were placed separately from the other species of the order Hymenoptera.

The studied olive orchards were located near the villages Peri, Petrokefali and Kouses in Messara valley and were sampled from January 2005 to April 2006. In each locality an organically and a conventionally grown orchard was selected, except the non-organic orchard of Petrokefali, which was aligned to the standards of Integrated Management System. Other three olive orchards were selected at the locations Vasilies (conventional, summer 2012), Skalani (conventional, spring - summer 2010), and the farm of Technological Educational Institute Stavromenos (abandoned olive orchard, winter - spring 2011), all located nearby the city of Herakleion. In addition one olive orchard was situated on the island of Kos (conventional, summer 2012) close to the village Tigaki and a second one on Cyprus (conventional, spring - summer 2010) close to Deryneia. The effect of weed cutting in the recovering of arthropod numbers was searched in the orchard of Petrokefali which was cultivated under integrated management.

Our criteria for the selection of main taxa to be studied were based both on numbers of captures and on relative abundance. For statistical analysis ANOVA and four post hoc indices (Tukey, Duncan, Scheffe and LSD) were used. For the estimation of similarities between the experimental olive orchards the Shannon index for the biodiversity and the Jaccard similarity coefficient (Southwood 1978) were selected. The type for Shannon biodiversity index is:

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

where: H = the Shannon diversity index, p_j= fraction of the entire population made up of species j, S = number of species encountered. When diversity indices are used in ecology the types of interest are usually species, but they can also be other categories, such as genera, families, functional types or haplotypes (Okpiliya 2012).

The Jaccard similarity coefficient (J), for the attributes (in our case taxa) of two totals A & B is:

$$J=M_{11}/(M_{01}+M_{10}+M_{11})$$

where: M_{11} represents the total number of present taxa in both A and B, M_{01} represents the total number of taxa absent in A and present in B, M_{10} represents the total number of taxa present in A and absent in B. The Jaccard similarity coefficient is used in a large spectrum of biological issues, as Cell – Molecular Biology and mainly Ecology, but also to the other sciences as in Chemistry or Informatics and Social Networks (Willett et al. 1998, Duarte et al. 1999, Nekola and White 1999, Bank and Cole 2008).

Results and Discussion

During this study, from the 11 olive orchards of the three islands, totally 35 taxa of soil mesofauna and macrofauna, were captured, almost the double number of the study conducted by Garrido-Jurado et al. (2011). From these 35 taxa, 21 belonged to the insects and 6 to arachnids. Among them, the relative abundance of Coleoptera and Formicidae were the highest as these groups are plentiful in previous works in literature (Stork and Eggleton 1992, Redolfi et al. 1999, Santos et al. 2007). The total number of captures in our study was higher than 50,000 specimens for each of these taxa (Fig. 1). Generally, in biological communities, the order Coleoptera and the family Formicidae are very often two of the dominant taxa (Stork and Eggleton 1992).

Those groups have been noticed, as amongst the most frequent, many times in the past in olive orchards (Chavres et al. 1999, Milakis et al. 2003). The combination of these two taxa presents the two higher relative abundances at the 8 of the totally 11 olive orchards of the current study. Also the relative abundance of each one, of these dominant groups, is higher than 10% in the eight out of eleven olive orchards (Fig. 2). In all the olive orchards except one (Stavromenos), the relative abundance of these two taxa, when combined, reached from 61.9% to more than 92% (Fig. 3). This phenomenon is commonly reported in related studies (Redolfi et al. 1999, Santos et al. 2007). Also the total percentage of the nine main taxa varied from 88% to 99%, among the studied olive orchards (Fig. 3).

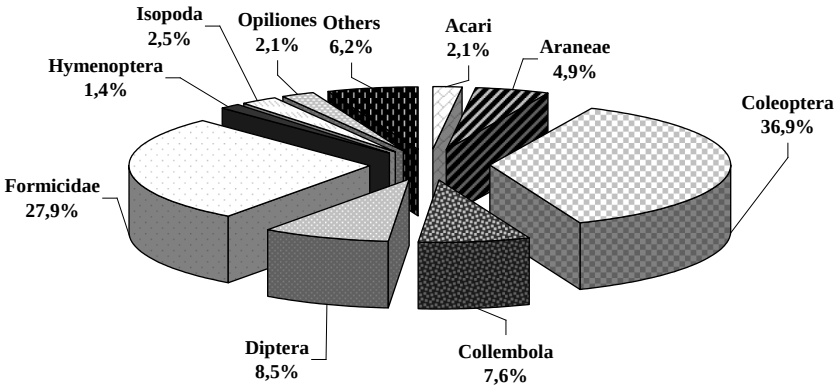

FIG. 1. Average of total relative abundance of the main taxa at the eleven olive orchards.

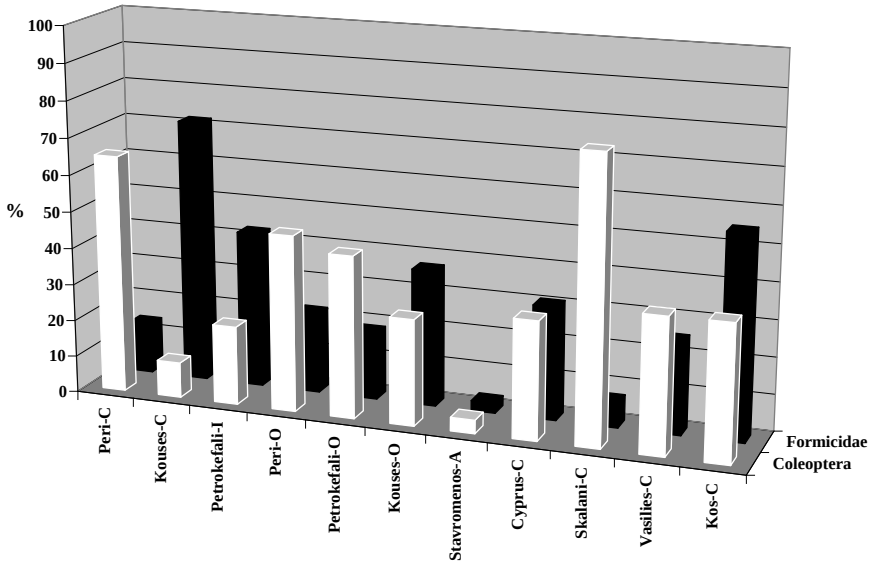

FIG. 2. Relative abundance (% of total captures) of the two main taxa (Coleoptera and Formicidae), in the eleven olive orchards of the study. "C" indicates conventional olive orchards, "O" organic, "I" integrated and "A" abandoned.

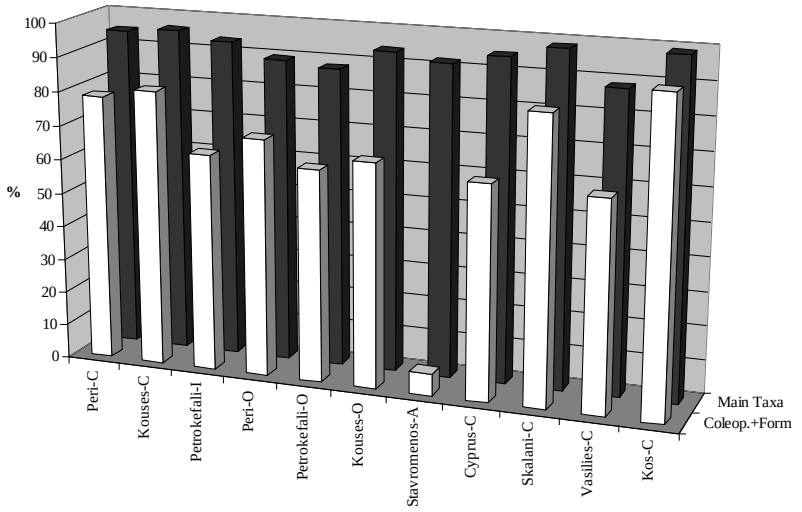

FIG. 3. Accumulative relative abundance (% of total captures) of the two most abundant (Coleoptera & Formicidae) and all the nine main taxa (Coleoptera, Formicidae, Collembola, Opiliones, Araneae, Acari, Isopoda, Diptera, and Hymenoptera). "C" indicates conventional olive orchards, "O" organic ,"I" integrated and "A" abandoned.

TABLE 1. Values of similarities, according to Jaccard index, between the eleven olive orchards. The 14 of the 15 higher values (bold characters) were recorded between olive orchards from Messara's valley. The four of the five lower values (underlined characters) were recorded between olive orchards from different islands. "C" indicates conventional olive orchards, "O" organic, "I" integrated and "A" abandoned.

	Kouses-C	Petrokefali-I	Peri-O	Petrokefali-O	Kouses-O	Cyprus-C	Skalani-C	Vasilies-C	Kos-C	Stavromenos-A
Peri-C	**0,931**	**1**	**1**	**0,933**	**0,965**	0,758	0,724	0,733	0,580	0,586
Kouses-C		**0,931**	**0,931**	0,866	**0,964**	0,814	0,777	0,724	0,566	0,629
Petrokefali-I			**1**	**0,933**	**0,965**	0,758	0,724	0,733	0,580	0,586
Peri-O				**0,933**	**0,965**	0,758	0,724	0,733	0,580	0,586
Petrokefali-O					**0,9**	0,7	0,666	0,677	0,531	0,586
Kouses-O						0,785	0,75	0,7	0,548	0,607
Cyprus-C							**0,954**	0,730	0,555	0,625
Skalani-C								0,692	0,576	0,652
Vasilies-C									0,666	0,538
Kos-C										0,48

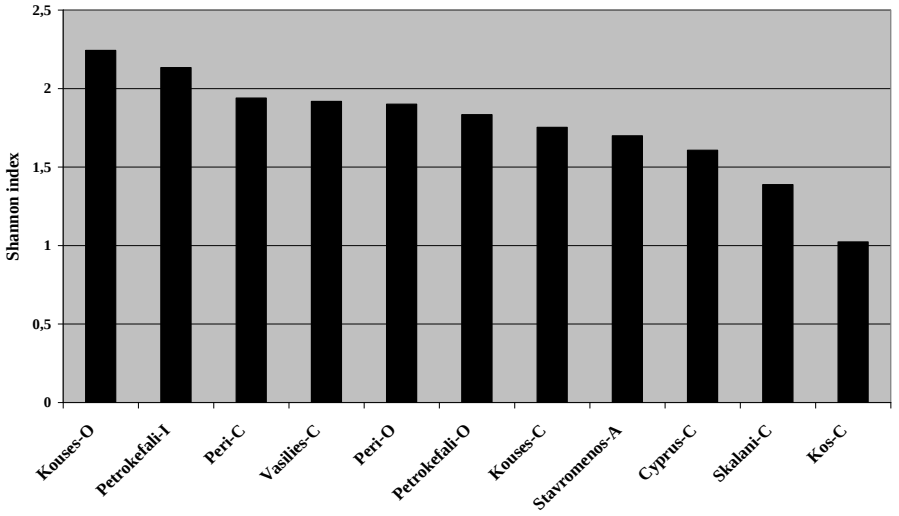

FIG. 4. Values of biodiversity, according to Shannon index, in the eleven olive orchards of the study. "C" indicates conventional olive orchards, "O" organic, "I" integrated and "A" abandoned.

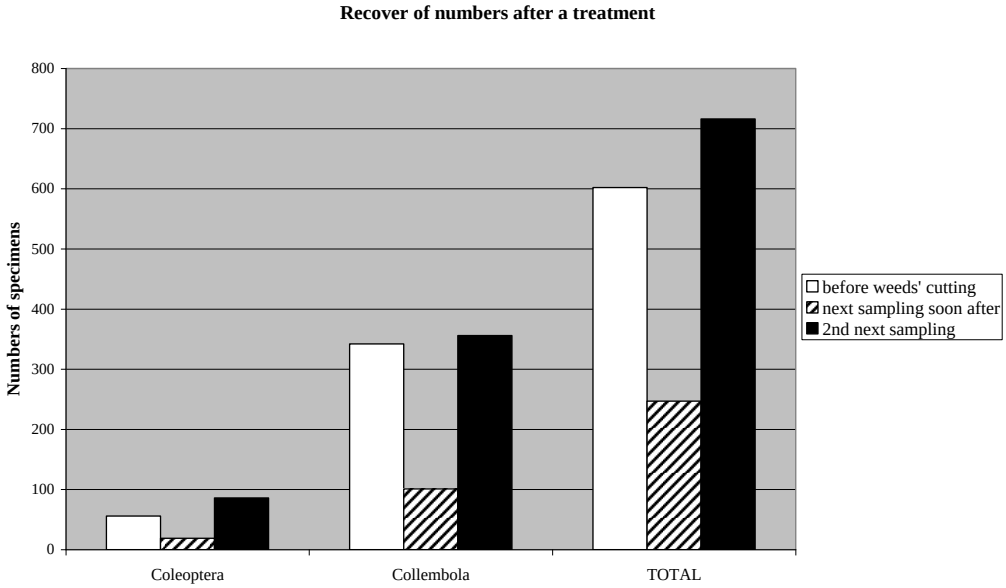

FIG. 5. Recover of numbers after a treatment (weeds' cutting) in the Petrokefali orchard grown under integrated management.

Other important taxa of soil fauna were Collembola, Opiliones, Araneae, Acari and Isopoda. Also, many specimens from two taxa of flying insect fauna (Diptera and Hymenoptera) were captured. The captured specimens in total, of all these taxa, ranged from 2,300 specimens, for the scarcest (Isopoda) to 40,500 for the most plentiful one (Diptera). By adding the relative abundance of these seven groups to the two most commonly recorded ones (Coleoptera and Formicidae), altogether accounted for 88% to 98.8% of the total abundance found in each respective olive orchards (Fig. 3). Many of these taxa are dominant in the soil fauna of all the types of ecosystems (Stork and Eggleton 1992, Giller 1996). The rest of the specimens captured, in our study belonged to 26 taxa, included in the "Others" category. The orders which contributed mainly to this group were four insect orders or suborders (Homoptera, Heteroptera, Dictyoptera and Psocoptera) and Gastropoda (Mollusca). In addition, there were taxa present in a statistically significant level and higher relative abundance in some regions, but probably a supplementary confirmation is needed.

The average percentages from all the olive orchards for Coleoptera and Formicidae were 36.9 and 27.9 respectively (Fig. 1). We have compared our data with data from the study of Santos et al. (2007). The olive orchard from Portugal has some characteristics no different from the East – Mediterranean orchards used in our study. The most similar percentages remarked in Formicidae with 55.1 of Kos (Portugal 56.6), in Acari with 8.9 of Kouses' organic olive orchard (Portugal 9.9) and in Araneae with 1.1 of Skalani (Portugal 1.2). However, it has to be noticed that the percentage of Isopoda in Portugal (0.02) was much lower than in our work (0.1 to 7.2).

The biodiversity in the olive groves of our study (according to Shannon index) varied from a little higher than one (1.02) to clearly higher than 2 (2.24) (Fig. 4).

The value of Shannon index was 2-fold to 4-fold higher than in other olive orchards (Santos et al. 2007), as a consequence of the richest catalogue of taxa (35). From the three smallest biodiversity values, the two were recorded at the olive groves of the two more eastern islands and the third in Crete, in Skalani. We have unified the olive orchards in three groups, the first one was including Messara's olive groves, the second one was including the olive orchards of the rest of the Crete (all the three near the city of Herakleion) and the third group was including the olive groves of the other islands. The grouping of Messara's olive orchards includes three organic olive orchards as a first subtotal, two conventional and one integrated managed olive orchards as a second subtotal, but the geographical factor is much stronger than the applied production system. Special treatments as cutting of weeds, plowing etc., had instantly influences on the soil fauna, but this was disappeared soon after. The figure 5 presents a characteristic example.

By comparing these three groups of olive orchards, we have found that there are statistically significant differences among them. The group of Messara's olive orchards had higher biodiversity than the third group (this of other islands) at a level of 95% (ANOVA) (F=5.582, df=2, 8, P<0.03). This is indicated also by all used post hoc indices (Tukey, Duncan, Scheffe and LSD).

By studying the similarities of biological communities, some pairs of Messara's olive groves have the biggest ones (according to Jaccard similarity coefficient). High similarity there was also between the olive groves of Skalani and Cyprus. From the total of the 15 highest values of similarity (0.9 plus), all except one, belong to pairs between Messara's olive orchards. At the other end, four among the five lowest values (0.48-0.56) concerned pairs of olive orchards from different islands (Table 1).

As conclusion, we can remark that the structure of soil biocoenosis in olive orchards tested followed a similar pattern. Generally, the two most dominant groups were Coleoptera and Formicidae. The high similarity of olive orchards' biotic communities is very intense between pairs of olive orchards in Messara plain, as it is indicated by Jaccard index. The similarity is a fact, despite of differences in cultural practices. The pattern of soil' biocoenosis in olive orchards has two characteristics: a) The two dominant groups consisted 62% to 92% of the arthropod fauna, for the 10 of the eleven olive orchards b) Eleven main taxa accounting for 88-99% of the arthropod fauna for all the olive orchards, without exception.

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Δομή βιοκοινοτήτων εδάφους και βιοποικιλότητα σε ελαιώνες τριών νησιών της Αν. Μεσογείου

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ΠΕΡΙΛΗΨΗ

Σε αυτήν την εργασία μελετήθηκε η πανίδα του εδάφους με παγίδες παρεμβολής (pitffal traps) και συγκρίνονται τα αποτελέσματα από έξι ελαιώνες σε τρία χωριά της Μεσαράς (Πέρι, Πετροκεφάλι, Κουσές), σε άλλους τρεις ελαιώνες της Κρήτης σε Βασιλιές, Σκαλάνι, και Αγρόκτημα ΤΕΙ (όλοι πέριξ της πόλης του Ηρακλείου) και σε δύο ελαιώνες άλλων νησιών, ενός από την Κω και ενός από την Κύπρο. Συνολικά συνελήφθησαν 35 taxa, από τα οποία τα 21 ανήκουν στα έντομα και τα 6 στα αραχνίδια. Στις βιοκοινότητες κυριαρχεί το ζεύγος των ομάδων Κολεόπτερα και Μυρμήγκια (οικ. Formicidae) στους οκτώ από τους ένδεκα συνολικά ελαιώνες. Στους 10 από τους ένδεκα οι δύο αυτές ομάδες καταλαμβάνουν από 61-62% έως 91-92%. Άλλες σημαντικές ομάδες αποτελούν τα Δίπτερα, τα Υμενόπτερα, τα Κολλέμβολα, τα Φαλάγγια, οι Αράχνες, τα Ακάρεα και τα Ισόποδα. Αν προσθέσουμε τα ποσοστά αυτών των επτά ομάδων στις δύο πρώτες, συνολικά οι εννέα ομάδες αρθροπόδων καλύπτουν από 88 έως 99%. Οι τιμές βιοποικιλότητας κυμαίνονται (σύμφωνα με το δείκτη Shannon) από λίγο άνω της μονάδας (1,02) έως άνω του 2 (2,24). Χαμηλότερες βιοποικιλότητες εμφανίζουν οι δύο ελαιώνες εκτός Κρήτης, μαζί με τον ελαιώνα του Σκαλανίου. Ομαδοποιήσαμε τους ελαιώνες της Μεσαράς ως μία ομάδα, τους ελαιώνες της υπόλοιπης Κρήτης ως δεύτερη και τους ελαιώνες των άλλων νησιών ως τρίτη. Σύμφωνα με την ANOVA οι διαφορές είναι στατιστικά σημαντικές σε επίπεδο 95% και οι ελαιώνες της Μεσαράς εμφανίζουν στατιστικά σημαντικά μεγαλύτερη βιοποικιλότητα από τους ελαιώνες των άλλων νησιών (Κύπρου, Κω), σύμφωνα και με τους τέσσερις post hoc δείκτες που χρησιμοποιήσαμε (Tukey, Duncan, Scheffe, LSD). Σε ότι αφορά ομοιότητες βιοκοινοτήτων, ορισμένοι από τους ελαιώνες της Μεσαράς εμφανίζουν μεταξύ τους τις μεγαλύτερες (σύμφωνα με το δείκτη Jaccard). Υψηλή ομοιότητα εμφανίζει και ο ελαιώνας του Σκαλανίου με αυτόν της Κύπρου, αμφότεροι συμβατικοί. Μεταξύ των 15 υψηλοτέρων τιμών ομοιότητας (0,9 και άνω), οι 14 αφορούν ζεύγη ελαιώνων της Μεσαράς. Οι τέσσερις στις πέντε χαμηλότερες τιμές (0,48-0,56) αφορούν ζεύγη ελαιώνων από διαφορετικά νησιά. Υπάρχουν ζωικές ομάδες που εμφανίζονται σε στατιστικά σημαντικά μεγαλύτερα ποσοστά σε ελαιώνες ορισμένων περιοχών, ωστόσο χρειάζεται περαιτέρω μελέτη για την επιβεβαίωση αυτής της ένδειξης. Μπορούμε να συμπεράνουμε ότι οι ελαιώνες σε ότι αφορά τόσο στη δομή, όσο και στη βιοποικιλότητά τους, είναι από τα αγροοικοσυστήματα τα λιγότερο επηρεαζόμενα από τις καλλιεργητικές διεργασίες, όπως προκύπτει από την σχεδόν πλήρη ταύτιση των κύριων ομάδων και από τις τιμές του δείκτη ομοιότητας μεταξύ συμβατικών και βιολογικών καλλιεργειών.