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Restoration Success Assessment of Mediterranean River Copses Based on Orthopteran Diversity

Ana M. Cárdenas*, Juan M. Hidalgo

Department of Zoology, Campus Rabanales, University of Córdoba, Córdoba, Spain
Email: *ba1cataa@uco.es, zo2himaj@uco.es

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Abstract

There is evidence that the development of plant communities determines the composition and structure of the orthoptera assemblages. This is the reason for using the orthoptera biodiversity as an indicator of environmental recovery processes in revegetated areas. This research is a part of the monitoring actions included in the Breña's Compensation Project, linked to the construction of the Breña II damp. It is aimed to assess the biodiversity of the Orthopteran assemblages settled in the restored river copses after nine years following (2007-2016). The results will be interpreted as an indirect measure of the success of the environmental improvement performed. In 2016, two forest farms named "Las Mesas" and "Cerro del Trigo" located in the Sierra de Hornachuelos Natural Park (Córdoba, Southern Iberian Peninsula) were selected for monitoring. These sampling sites were also selected in a previous following phase, which makes comparisons easier and more reliable. At each of these sampling sites, two revegetated enclosures corresponding to the environmental model "restored river copses" and their respective control areas were selected for the study. From the values of the specimen's number recorded in each sampling plot, the same population indices that in the previous phase (Richness, Abundance, Dominance, Shannon Diversity, and Evenness) were calculated. The diversity profiles using Rényi's family of uni-parametric diversity indices were also obtained. Differences in the indices were statistically tested by resampling bootstrapping for inferential statistics. Based on our results, the environmental differences between revegetated and control areas have not led to significant changes in the composition and structure of the orthopteran communities they host. In consequence, the environmental restoration carried out in the study area has not been as successful as could be expected and the previous environmental alterations have not been minimized nor have those derived from the environmental rehabilitation itself been compensated.

Keywords

Breña, Caeliferous, Ensiferous, Environmental Restoration, Hornachuelos Natural Park, Orthoptera, River Copses

1. Introduction

One of the main shortcomings of the environmental restoration projects carried out in the past decade is the lack of an adequate later following [1]. This monitoring phase is necessary to quantify the success of the environmental improvement and to determine whether it needs to be optimized in the long term. In this regard, the evaluation of the improvement effect is an essential task for the development of the ecological restoration [2]. However, carrying out an adequate following of environmental progress is a complex process, especially working at landscape scale [3]. It requires spending time collecting data in the field and, consequently, is economically expensive, and sometimes entails the involvement of specialists [4]. It also implies continuous management and follow-up to adjust this management in the case that restoration has not resulted in the expected recovery in terms of biological diversity [5], so much so that the environmental restoration actions suffering from a lack of the subsequent monitoring are more likely to fail to meet the initials project objectives [6].

As background for this study, it is worth mentioning that Mediterranean forests are biodiversity hotspots and being one of the most vulnerable ecosystems to harmful human activity and its consequences [7]-[9]. Hence, these are priority areas for the implementation of practices aimed at restoring forest landscapes [10].

In environmental improvement projects, whether they involve ecological restoration or environmental compensation, revegetation is considered one of the most effective actions because it facilitates ecological functions enhancing both biodiversity and ecosystem services, as well as carbon sequestration and soil recovery [11], and always requires the abovementioned long-term following program. Among the most frequent interventions is the implementation of linear landscape elements which facilitate the colonization process, the settlement and the survival of species in newly established habitats [12].

In the context of the foregoing, it should be mentioned that this research is a part of the monitoring of the compensatory measures included in the Breña's Compensation Project, linked to the construction of the Breña II damp [13] [14] These measures were devoted to offsetting the environmental disturbance caused by the flooding of part of the nature reserve Sierra de Hornachuelos Natural Park (southern Iberian Peninsula), and by the dam infrastructure itself [15].

The revegetation plan linked to the Breña Compensation Project corresponded to the "plantation type" [16] and consisted of the establishment of three different environmental models: 1) "Forest-islands" or patches of woody vegetation corresponding to the original forest species; 2) "Hedges," or alignments of tree, shrub, and grass species planted to increase connectivity between patches of relict forest; and 3) "River copses" or mixed plants formations consisting of deciduous trees and shrubs species typical of Mediterranean riverbanks [17]. Each model required a specific composition of plants, which were chosen agreeing to the projected ecological characteristics [18]. In the Project, the design and implementation of a medium- to long-term monitoring plan was also included to assess the functionality of these models. Full information on the overall improvement measures carried out is available [13].

There are several elements to be considered when approaching a long-term monitoring program: 1) Adequate selection of the bioindicator group; 2) Sufficiently long time elapsed since the implementation of the improvement actions; and 3) To have available control areas where no environmental intervention has been made to be used for comparisons [19].

Regarding the selection of the indicator taxon, it should be supported on that the ecological requirements of the selected group are indicative of the state of the environmental conditions to be assessed during the monitoring phase [20]. Due to their sensitivity to changes in habitat structure, the Orthopterans are considered valid indicators of the effectiveness of restoration actions [21] [22]. This is because land management has a significant impact on microclimate and structure of vegetation [23] and these insects maintain a close relationship with vegetation through various aspects of their biology, particularly feeding, reproduction and dispersal power. So much so that the Orthopterans respond quickly to environmental changes [24] [25], disturbances [26], and habitat restoration [27] [28]. As a result, they are widely accepted bioindicators for detecting environmental changes linked to the landscape interventions [14] and effectiveness of habitat restoration [21] [22].

Concerning the time elapsed since the revegetation actions were carried out, in our case the implementation of each environmental model, planting was done in spring 2007. First assessment of short-term effects of the revegetation program on the Orthopteran's diversity was performed in 2012. Four years later (2016) the second monitoring phase was completed.

To have control areas, as baseline which would enable comparisons of conditions after the interventions equivalent areas were selected corresponding to the same environmental models but in which no intervention had been carried out (fully description available in Moyano *et al.* [14]).

Because predictive models suggest that drought is the main present and future threat in Mediterranean terrestrial ecosystems [8] and that riparian forests are particularly vulnerable to global change [29], this research has focused on the environmental model defined as "river copses". Moreover, riparian vegetation is more demanding from the point of view of water requirements so that vegetation associated with temporary watercourses is more difficult to implement and maintain. Consequently, its effects on animal communities should be greater and more evident.

Similar studies to the proposed here have been previously carried out also using the Orthopterans as bioindicators for habitat quality assessment, most of them focused on grasshopper inhabiting grasslands and rangelands [22] [23] [28] [30]. In addition, research on Orthopteran assemblages (concerning both Ensifera and Caelifera) from other types of habitats is also available [31] [32], including riparian corridors [33] [34], as is our case.

Considering that the maximum of Orthopteran diversity is estimated to be reached 3.5 - 5.5 years after restoration [34], we hypothesized that the maximum diversity should have been achieved before this second monitoring phase.

The aim of this study was to assess the biodiversity Orthopteran assemblages settled in the river copses after nine years of following (2007-2016); concretely, from the time of revegetation was carried out until the last recording faunistic data. The results will be interpreted as an indirect measure of the success of the environmental improvement achieved in the area.

To determine the restoration success in the research area the following two attributes from those proposed by the primer provided by the Society of Ecological Restoration International (SER) [35] were considered: diversity and community structure in comparison with reference sites; and the presence of indigenous or singular species.

2. Material and Methods

2.1. Research Area

Figure 1. Location of the research area.

Research was performed in the surrounding area of the Breña dam, in the Sierra de Hornachuelos Natural Park (province of Córdoba, Southern Iberian Peninsula), **Figure 1**. Here, the climate is of Mediterranean type; the relief shows moderate altitudes (250 - 725 m a.s.l.); and the landscape is dominated by a Mediterranean mixed sclerophyllous forest, whose vegetation is mainly constituted by evergreen trees and diverse scrubland plants. The most representative species are *Quercus ilex* subsp. *ballota* (Desf.) Samp. (1908-9), *Q. suber* L. 1753, *Pistacia lentiscus* L. 1753, *Asparagus albus* L. 1753 and different species of *Erica* and *Cistus* in the scrubs. Fully information about the research area is available [36] [37].

2.2. Sampling Area

In 2016, the forest farms named "Las Mesas" and "Cerro del Trigo" were selected for monitoring (**Table 1**). These sampling sites were also selected in the first phase of following, which makes comparisons easier and more reliable. At each of these sampling sites, two revegetated enclosures corresponding to the environmental model designated as "river copses" were selected for the study.

Another two nearby areas, which had not been restored, referred as "control areas" were also sampled. Following the Poniatowski and Fartmann criterium [38], the environmental models and the control areas had, insofar as possible, equivalent surfaces and similar vegetal composition. There was a between-plot separation distance > 10 m to avoid edge effects [39].

Table 1. Sampling sites nomination, municipal districts and UTM coordinates.

Sampling sites	Municipal districts	UTM coordinates
Las Mesas	Córdoba-Almodóvar del Rio	30S 3231 41968
Cerro del Trigo	Almodóvar del Rio-Villaviciosa de Córdoba	30S 3234 41988

Once the sampling areas were demarcated, the surface of each enclosure (river copse) and those of its respective control plot were measured using a Bosch DLE 50 Professional laser meter (0.05 to 50 m ± 1.5 mm accuracy), and with a Garmin ETREX 32X GPS. The vertices, masts, etc. were geo-referenced (0.05 to 50 m ± 1.5 m accuracy). The average surface of the sampling enclosures was 666 ± 117 m^2.

2.3. Sampling Methods

Sampling design and working protocol were identical to those applied in the first monitoring phase. Sampling extended from April to September 2016, making it coincide with the most suitable time to quantify the Orthopteran abundance and diversity [14]. The unit of sampling effort was also similar to that of the previous phase. Concretely, Linear transects [40] with zig-zag paths over a time of 30 minutes/sampling plot/sampling day were carried out. The sampling procedures were a combination of direct observation, manual capture and sweeping of vegetation with a resistant sweep net. The specimens were identified in the field, censused, sexed and released. Developmental stage (nymph or imago) was also noted before releasing. Several specimens of the species that could not be identified directly in the field were preserved in 70% ethanol and transported to the laboratory for further study and classification.

2.4. Data Analysis

From the values of the specimen's number of the Ensiferous and Celiferous species recorded in each sampling plot, the same population indices that in the previous phase (Richness, Abundance, Dominance, Shannon Diversity, Equitability) were calculated. The diversity profiles using Rényi's family of uni-parametric diversity indices [41] were also obtained, which depend upon the parameter alpha: for alpha = 0, this function gives the total species number; alpha = 1 (in the limit) gives an index proportional to the Shannon index, while alpha = 2 gives an index which behaves like the Simpson index. These parameters jointly consider a family of diversity index to make sure that the diversity ordering is robust [42] allowing a scalable comparison of the diversity of the assemblages of two or more communities [43]. In addition, according to Abrams *et al.* [44], visualizing results in the form of diversity profiles facilitates the comparison of diversity between sites or across time. Concretely, these authors propose the application of the diversity profiles to monitor the diversity of a community over time and to assess the success of management, as it is our case.

However, if the profile lines cross, the diversities are non-comparable in this way [45]. For this reason, differences in the indices were also statistically tested by resampling bootstrapping for inferential statistics (at 95% confidence interval, based on 2.000 replications) [46].

Ecological indices were calculated and compared using the Past Paleontological software package [47].

3. Results

The faunistic results (list of species and specimens number censused in the restored copses and control areas) corresponding to the last monitoring phase are shown in **Table 2**.

3.1. Comparative Analysis between Environmental Models (Restored River Copses vs. Control Areas)

Starting from the Orthopteran data recorded in "Las Mesas" (**Table 2**), a first observation of the table shows a greater number of individuals and species in the restored copses than in the control areas. The diversity profiles obtained with the specific abundance values (specimens' number, **Table 2**) are displayed in **Figure 2**. It can be observed that for alpha ≈ 2, the lines intersect. Effectively, the graph initially shows that the revegetated river copses run above the unmanaged areas in terms of Diversity. However, along its path, the trends reverse finally indicating a more favourable condition in the control areas. So, this graph is not applicable to compare diversities [45].

Notwithstanding, if data shown in **Table 2** are analyzed in more depth, clear differences are observed between both environmental models. It is worth mentioning the better representation of Ensiferous (with 6 species and 25 specimens) compared to the control areas (2 species and 4 specimens). Overall, the restored environments almost double the control areas in terms of both, richness (species number) and abundance (**Table 3**).

Table 2. List of species and specimens number censused in the restored copses and control areas in "Las Mesas" and "Cerro del Trigo" sampling sites during the sampling period April - September 2016.

		"LAS MESAS"		"CERRO DEL TRIGO"	
		Restored copses	Control areas	Restored Copses	Control areas
CAELIFERA	*Pezottetix giornae*	60	30	66	41
	Calliptamus barbarus	5	-	2	-
	Aiolopus pouissanti	5	-	-	-
	Dociostaurus jagoi	15	12	6	21
	Anacridium, aegyptium	1	-	-	-
	Chorthippus vagans	-	1	3	11
	Oedipoda caerulescens	-	16	-	1
	Omocestus panteli	-	-	-	1
ENSIFERA	*Phaneroptera nana*	1	-	1	4
	Platycleis sabulosa	2	-	-	-
	Tylopsis liliifolia	5	3	2	1
	Tessellana tessellata	12	-	10	3
	Pterolepis spoliata	2	-	2	-
	Oecanthus pellucens	3	1	7	2

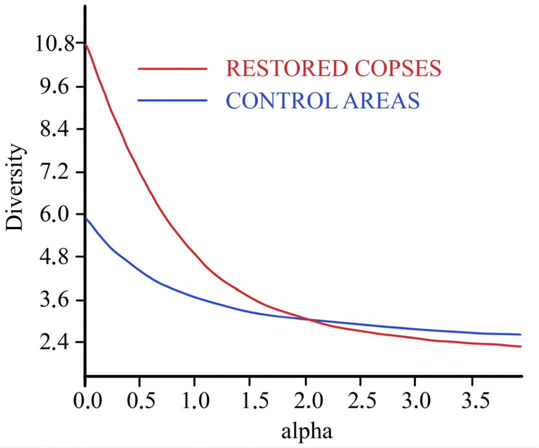

Figure 2. Diversity profiles of Orthopterans recorded in the restored copses and control areas sampled in "Las Mesas" sampling site.

Table 3. Ecological indices obtained for the Orthopteran assemblages recorded in restored river copses and control areas in "Las Mesas" sampling site.

Indices	Restored copses	Control areas
Number of species	11	6
Individuals	111	63
Dominance	0.329	0.330
Diversity (Shannon_H')	1.590	1.294
Evenness	0.445	0.6077

The statistical comparison of the ecological indices (**Table 4**) by the "bootstrapping" procedure only finds significant differences in terms of diversity, despite the discrepancy in values of richness (number of species) and abundance (censused individuals) **Table 3**.

Table 4. Significance of the statistical comparison (*P*-values) of Dominance, Diversity (Shannon_H') and Evenness indices obtained for the Orthopteran assemblages recorded in "Las Mesas" sampling plot; n.s.: not significant; * statistical significance at 95%.

INDICES	*P*-value	Statistical significance
Dominance	0.996	n.s.
Diversity (Shannon_H')	0.050	*
Evenness	0.090	n.s.

Applying the same procedure to the Orthopterans censused in "Cerro del Trigo", from the abundance values displayed in **Table 2**, the diversity profiles shown in **Figure 3** were obtained. It should be noted that the diversity profiles behave in a similar way, although along the course they tend to slightly move apart, becoming the line corresponding to control areas somewhat above that of the restored ones.

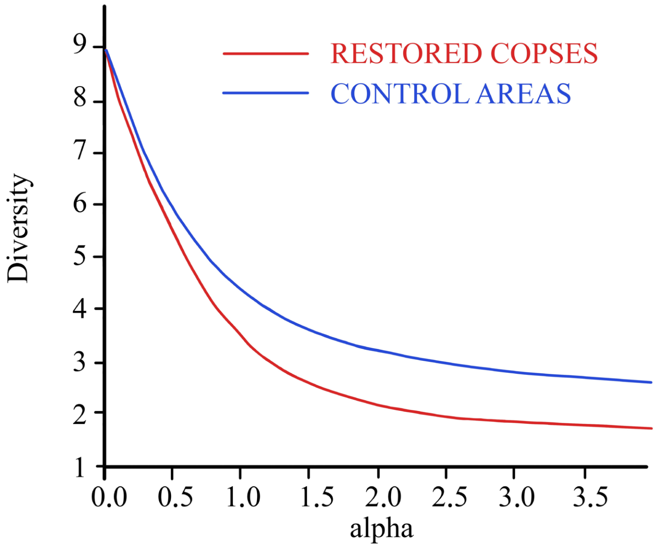

Figure 3. Diversity profiles of Orthopterans recorded in the restored river copses *vs.* control areas sampled in "Cerro del Trigo" sampling site.

In fact, in this sampling plots, the composition of the Orthopteran assemblages recorded in both environmental models are similar in terms of species richness and quite close in terms of abundance (**Table 5**).

Table 5. Ecological indices obtained for the Orthopteran assemblages recorded in restored river copses and control areas in "Cerro del Trigo" sampling site.

INDICES	RESTORED RIVER COPSES	CONTROL AREAS
Number of species	9	9
Individuals	99	85
Dominance	0.465	0.314
Diversity (Shannon_H')	1.284	1.469
Evenness	0.387	0.482

Indeed, the comparison of the indices does not find significant differences in diversity nor in terms of the other structural parameters of the community (dominance and evenness indices), **Table 6**.

Table 6. Significance of the statistical comparison (*P*-values) of Dominance, Diversity (Shannon_H') and Evenness indices obtained for the Orthopteran assemblages recorded in "Cerro del Trigo" sampling plots; n.s.: not significant; * statistical significance at 95%.

INDICES	*P*-value	Statistical significance
Dominance	0.370	n.s.
Diversity (Shannon_H')	0.202	n.s.
Evenness	0.239	n.s.

3.2. Comparative Analysis of the Environmental Models between Sampling Sites

In this section, the Orthopterans censused in "Las Mesas" sampling site are compared with the fauna recorded in "Cerro del Trigo", differentiating by environmental models (restored river copses and control areas), and by applying the same procedures of the previous section. The graph of the diversity profiles (**Figure 4**) suggests that the restored river copses located in "Las Mesas" run somewhat more favourable for the presence of Orthopterans than those of "Cerro del Trigo" (**Figure 4**).

In the control areas, this trend, which is also initially more noticeable, decreases and becomes null for alpha ≥ 2.5. To check the trends shown by the diversity profiles, the respective ecological indices were statistically compared resulting that there are no significant differences between any of the parameters considered (**Table 7**).

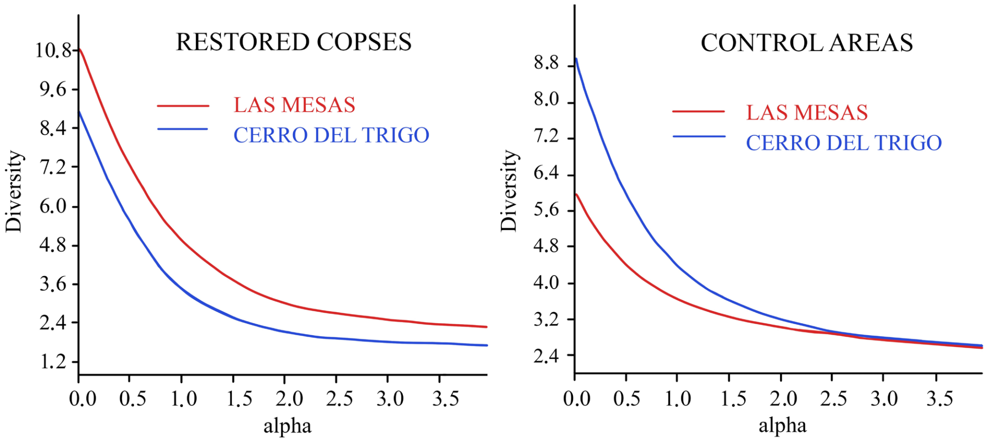

Figure 4. Diversity profiles of Orthopterans recorded in the restored river copses and control areas sampled in "Las Mesas" and "Cerro del Trigo" sampling sites.

Table 7. Significance of the statistical comparison (*P*-values) of Dominance, Diversity (Shannon_H') and Evenness indices obtained for the Orthopteran assemblages recorded in "Las Mesas" and "Cerro del Trigo" sampling sites; n.s.: not significant; * statistical significance at 95%.

LAS MESAS vs. CERRO DEL TRIGO	RESTORED COPSES	CONTROL AREAS
INDICES	*P*-value (significance)	*P*-value (significance)
Dominance	0.063 (n.s.)	0.787 (n.s.)
Diversity (Shannon_H')	0.061 (n.s.)	0.286 (n.s.)
Evenness	0.407 (n.s.)	0.161 (n.s.)

3.3. Time Course: Comparative Analysis of the Results Obtained in the First and Second Monitoring Phases

In this section, the results obtained in the environmental models defined as restored river copses and their respective control areas corresponding to the first monitoring phase (2012, [14]) and those of the present study are compared starting from data of abundance recorded in "Las Mesas" in 2012 and 2016 (**Table 8**).

Table 8. List of species and specimens number recorded in the restored copses and control areas in "Las Mesas" sampling site, during the sampling periods April-September 2012 and April-September 2016. Data for 2012 are used with permission of the authors.

"LAS MESAS"		RESTORED COPSES		CONTROL AREAS	
		2012	2016	2012	2016
CAELIFERA	*Pezottetix giornae*	187	60	138	30
	Calliptamus barbarus	-	5	-	-
	Locusta migratoria	1	-	-	-
	Oedipoda caerulescens	4	-	43	16
	Aiolopus puissanti	-	5	-	-
	Dociostaurus jagoi	198	15	146	12
	Omocestus panteli	15	-	-	-
	Chorthippus vagans	-	-	11	1
	C. apicalis	3	-	11	-
	Anacridium aegyptium	-	1	-	-
ENSIFERA	*Phaneroptera nana*	3	1	1	-
	Tettigonia viridissima	1	-	-	-
	Tylopsis liliifolia	-	5	-	3
	Platycleis sabulosa	-	2	-	-
	Tessellana tessellata	9	12	7	-
	Pterolepis spoliata	-	2	-	-
	Oecanthus pellucens	-	3	-	1

The results indicate that in the restored copses located in "Las Mesas" there has been an increase in the number of species inventoried in 2016 with respect to those of the previous period (2012), rising from 9 to 11. In **Table 8**, it can be observed that the increase corresponds to the incorporation of some Ensiferous species as *Tylopsis liliifolia* (Fab., 1793), *Platycleis sabulosa* Azam, 1901, *Oecanthus pelucens* (Scopoli, 1763) or *Pterolepis spoliata*. Rambur, 1939 Nevertheless, the total number of censused specimens has decreased remarkably mainly due to a decline in the relative abundance of the dominant grasshoppers, mostly *Dociostaurus jagoi*, Soltani, 1978 and *Pezzottetix giornae* (Rossi, 1794). Accordingly, the statistical comparison of the community descriptors (**Table 9**) confirms significant differences between the two monitoring periods in terms of abundance, diversity and dominance.

Table 9. Significance of the statistical comparison (*P*-value) of Dominance, Diversity (Shannon_H') and Evenness indices obtained for the Orthopteran assemblages recorded in the restored river copses sampled in "Las Mesas" in the first (2012) and the second (2016) monitoring periods. n.s.: not significant; * statistical significance 95%.

"LAS MESAS"	RESTORED COPSES		*P*-value	Significance
INDICES	2012	2016		
Number of species	9	11		
Individuals	421	111		
Dominance	0.420	0.329	0.004	*
Diversity (Shannon_H')	1.06	1.469	0.001	*
Evenness	0.320	0.4456	0.451	n.s.

Table 10. Significance of the statistical comparison (*P*-value) of the Dominance, Diversity (Shannon_H') and Evenness indices obtained for the Orthopteran assemblages recorded in the control areas sampled in "Las Mesas", in the first (2012) and the second (2016) monitoring periods. n.s.: not significant; * statistical significance at 95% probability.

"LAS MESAS"	CONTROL AREAS		*P*-value	Significance
INDICES	2012	2016		
Number of species	7	6		
Individuals	357	63		
Dominance	0.333	0.330	0.945	n.s.
Diversity (Shannon_H')	1.29	1.294	0.981	n.s.
Evenness	0.522	0.607	0.768	n.s.

Table 11. List of species and the specimens number recorded in the restored river copses and control areas in "Cerro del Trigo" sampling site, during the sampling periods April-September 2012 and April-September 2016. Data for 2012 are used with permission of the authors.

"CERRO DEL TRIGO"		RESTORED COPSES		CONTROL AREAS	
		2012	2016	2012	2016
CAELIFERA	*Pezottetix.giornae*	258	66	210	41
	Calliptamus.barbarus	1	2	3	-
	Oedipoda caerulescens	11	-	20	1
	Dociostaurus jagoi	259	6	152	21
	Omocestus panteli	-	-	-	1
	Chorthippus vagans	36	3	1	11
	C. apicallis	3	-	8	-
ENSIFERA	*Phaneroptera nana*	10	1	3	4
	Tettigonia viridissima	3	-	-	-
	Tylopsis liliifolia	1	2	2	1
	Tessellana tessellata	9	10	9	3
	Pterolepis spoliata	7	2	3	-
	Oecanthus pellucens	8	7	-	2

Table 12. Significance of *P*-value of Dominance, Diversity (Shannon_H'), and Evenness indices obtained for diversity comparison of the Orthopteran assemblages recorded in the restored sampled in "Cerro del Trigo", in the first (2012) and the second (2016) monitoring periods. n.s.: not significant; * statistical significance at 95%.

"CERRO DEL TRIGO"	RESTORED RIVER COPSES		*P*-value	Significance
INDICES	2012	2016		
Number of species	12	9		
Individuals	609	99		
Dominance	0.365	0.465	0.002	*
Diversity (Shannon_H')	1.301	1.248	0.695	n.s.
Evenness	0.3069	0.387	0.612	n.s.

Table 13. Significance of *P*-value of Dominance, Diversity (Shannon_H') and Evenness indices obtained for diversity comparison of the Orthopteran assemblages recorded in the control areas sampled in "Cerro del Trigo", in the first (2012) and the second (2016) monitoring periods. n.s.: not significant; * statistical significance at 95%.

"CERRO DEL TRIGO"	CONTROL AREAS		*P*-value	Significance
INDICES	2012	2016		
Number of species	10	9		
Individuals	411	85		
Dominance	0.401	0.314	0.031	*
Diversity (Shannon_H')	1.167	1.469	0.021	*
Evenness	0.32	0.482	0.209	n.s.

Proceeding in the same way with the control areas, the results (**Table 10**) indicate that these are somewhat more stabilized in terms of richness (or even loses a species), *i.e.* the Caelifera *Chortippus apicalis* (Herrich-Schäffer, 1840); this is accompanied by a significant decreasing in the records of the most abundant species as occurred in the restored copses. However, other ecological indices do not detect such differences, as the values of Dominance, Shannon diversity and Evenness obtained in 2016 were very similar to those of the previous monitoring phase, and the statistical comparison is not significant in any case.

From the abundance data recorded in the plots sampled in "Cerro del Trigo" in 2012 and 2016 (**Table 11**), the comparative results displayed in **Table 12** are obtained. Regarding the restored copses, there is a large discrepancy in the abundance of dominant species (*P. giornae* and *D. jagoi*) which is reflected in the significance of *P*-values of abundance and dominance. However, in terms of specific richness, evenness or diversity, the differences lack statistical significance.

Finally, for the unmanaged river copses located in "Cerro del Trigo", the statistical comparison found no significant differences in the qualitative component, but significant differences were obtained in terms of abundance, dominance and diversity (**Table 13**).

4. Discussion

There is substantial evidence that, at the local scale, plant community development determines the composition and structure of Orthopteran assemblages [21] [22] [48]. This is the rationale for using Orthopteran biodiversity as indicators of environmental recovery processes in revegetated areas affected by the compensatory measures linked to the construction of the Breña II dam. The short-term assessment of this recovery program performed in 2012 (after five years restoration), found structural similarity among the Orthopteran communities in the different habitats, whether improved or not, due to the high degree of vegetal homogeneity. The authors suggest that this could be because in the first monitoring phase, the development of the new plant cover had not yet achieved the expected achievement [14].

According to Mola *et al.* [49], four years later, the establishment and development of the plant restoration should have been consolidated. Considering that the maximum of Orthopteran diversity is estimated to be reached 3.5 - 5.5 years after restoration [34], it would be expected that the maximum in diversity would have already been reached in the first phase of monitoring. Nevertheless, the values of the community structural indexes (Dominance, Diversity and Evenness) are more balanced in the second monitoring period, suggesting that the recovery process of the Orthopteran fauna can take up for a longer period, exceeding seven years after revegetation tasks were done. In fact, this conclusion agrees with what Moyano *et al.* [14] pointed out in the sense that in the first phase of following, the Orthopteran assemblages found in the control areas were still best structured than in the improved zones.

The results obtained in the second monitoring phase, after nine years of restoration, indicate somewhat higher levels of abundance and diversity in restored river copses than in the control areas. These trends are observed in both study sites but acquire statistical significance only in terms of diversity in "Las Mesas", so it could be thought that environmental restoration has been slightly more successful in this sampling site. The highest abundance is explainable by the greater presence of certain generalist Caeliferous species as *P. giornae* to which corresponds almost 50% of the records in both environmental models. Kenyeres *et al.* [50] indicated that the habitat restoration resulted in a positive effect in the structure of Orthopteran assemblages, given that the parameters richness, density and relative frequency of species significantly increased after restoration. Nevertheless, these results contrast with those of Alignan *et al.* [22] who found that the Orthopteran abundance was significantly lower in the restored areas than in the original grasslands.

There is information indicating that the Orthopteran communities of unmanaged areas generally harbour lower diversity than those of managed sites [31]. Our results agree with this statement, in both phases of monitoring, since the specific richness is always higher in the revegetated river copses than in the control plots.

Now analysing the effect of the time elapsed between the two monitoring periods over the Orthopteran assemblages, and firstly considering the abundance of species, an evident faunistic impoverishment is observed in both study sites and in the two environmental models (revegetated river copses and respective control zones). Significant differences uniquely refer to variations in the populations size of the most ubiquitous Caeliferous species such as *P. giornae*, or *D. jagoi*. These are pioneer species, r-strategists (*sensu* Price *et al.* [51]) which massively colonize the revegetated areas in the early stages of the succession, but whose populations subsequently became more balanced, the population peak observed in the first phase of monitoring having been dampened, resulting in a more structurally balanced community in the longer term. These trends have been observed in the revegetated areas of the two study sites and also, but to a lesser extent, in the control areas. So, it is not attributable to the effect of the improvement revegetation carried out.

Conversely, some Ensiferous, such as *Tessellana tessellata* (Charpentier, 1925), increase their presence in revegetated river copses while it is becoming scarcer or disappear in the reference models (controls) after four years following. This explains the significant differences in terms of abundance, diversity and dominance. Our results agree with those of Bieringer and Zulka [52] and Marini *et al.* [53] in the sense that the presence of shrubs is particularly detrimental to the Celiferous, whereas the Ensiferous seems to be less affected or even favoured, as in our case. Torma *et al.* [54] also observed that the density of woody vegetation along ditch banks had a negative effect on the total abundance and on the abundance of the most mobile species (Caeliferous).

Apart from the above factors, certain faunal impoverishment could be also attributable to the extreme thermal conditions recorded during 2015-2016 [55]. Accordingly, early and intense desiccation of grass vegetation, as consequence of high temperatures, could have stopped or shortened the life cycles of plants and animals. This may have affected even the species with greater ecological plasticity such as *T. tesellata* or *P. giornae* and prevented the presence of those with less environmental tolerance.

When interpreting the results, it is necessary to consider that from a conservation perspective, both community structural parameters and the presence of singular species are important [56] because of the indicative value of the exclusive species to each type of environment.

No singular species have been found in this second phase of the study, nor even those that due to their hydrophilic character would be expected, such as *Xya variegata* (Latreille, 1809). This species, commonly colonizing the riparian vegetation growing between sand bars and the water's edge [57], was exclusively located in the control areas and during the initial phase of the study. This observation agrees with Fartmann *et al.* [31] in the sense that the more stenotopic species are often restricted to undisturbed habitats. Disturbances linked to the revegetation tasks could be so detrimental to the organisms that initially occupy the land [39] that could prevent their presence in subsequent recolonization.

5. Conclusions and Implications for Conservation

Based on our results, the environmental differences between revegetated and unmanaged river copses have not led to significant changes in the composition and structure of the Orthoptera communities they host. Regarding the temporal evolution in both, revegetated river-copses and control areas, the most recent data reveal a certain positive evolution, likely by the effect of the improvement in the vegetation cover, which is beginning to become somewhat evident at other levels of the ecosystem. This recovery is expressed by the greater biodiversity, despite the population decrease is evident in all the areas sampled, but which in no case reaches the expected levels or includes the species with the greatest indicator potential.

From the results, it can be inferred that the environmental restoration carried out in the study sites has not been as successful as could be expected, and that the previous environmental alterations have not been minimized, nor have those derived from the environmental rehabilitation itself been compensated. In our opinion, it is necessary to make a greater effort in the initial planning phase of the strategies to be followed in the environmental improvement plan before their implementation in nature to ensure that their effects have a successful impact on the biodiversity of the affected territory. Among these improvement strategies, it would be considered a more precise selection of the plots to be revegetated, prioritizing soil quality, water availability, nutrient content and shade degree, to ensure a good progress of the new planted vegetation.

Given that revegetation is one of the main actions for supporting biodiversity by restoring habitats and providing food sources for wildlife as well as protecting and improving existing ecosystems, the main efforts of a restoration program should be focused on a good revegetation approach in its initial stages.

Due to the arid climate of the study area, it would have been essential to incorporate effective irrigation mechanisms and to guarantee their functioning, in order to ensure plants survival in the first stages after planting, even under the extreme summer conditions. It would be also advisable to select varieties of plants resistant to drought and to frequent pathologies in the area, as well as to replant the specimens that have not progressed successfully.

Special attention should also be paid to prevent herbivory by means of functional enclosures that allow access to Orthopteran and other small fauna but prevent entry to wild ungulates and extensive livestock. To confirm the project is on track, it’s also necessary to monitor vegetation progress continually.

Finally, it is worth mentioning that good long-term monitoring, both of the vegetation and of other bioindicators (in our case the Orthopteran), is economically costly but indispensable for good environmental management and should be intended in the total financing of the project.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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