

USING REPTILES AND SOIL ARTHROPODS AS INDICATORS FOR OPEN QUARRY RESTORATION IN MEDITERRANEAN-TYPE ECOSYSTEMS

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Materials & Methods

- Study plots

Natural undisturbed plot (A) -control

Vegetation covers 52.1% of plot
The rest is bare sand

Vegetation: *Juniperus oxycedrus*
ssp. macrocarpa (coverage
62.2%) & *Coridothymus*
capitatus (coverage 22.5%)



3 year old china clay quarry (B*)

Surface deposits of inert materials from a china clay quarry in an early phase of restoration

Vegetation (hydroseeded):

Ditrychia viscosa,
Artemisia absinthum,
Centaurea spinosa,
Atriplex alymus, *Tamarix*
sp. And other smaller
graminaceous plants

* For the arthropod study, **Bc**, an undisturbed phrygana plot right next to **B**, was used as control

8-9 year old perlite quarry-totally restored (C)

(Cs) Slope

- *Acacia cyanophylla*, *Myoporum lanceolatum*, *Medicago arborea*, *Tamarix* sp., (**all these plants were hydro seeded**) and the smaller *Satureja thymbra*, *Spartium junceum* that colonized the area later on.

(Cp) Plane

- *Cistus salvifolius*, *Cistus incannus*, *Satureja thymbra*, *Helichrysum italicum*, *Centaurea spinosa*, *Elymus farctus*, *Otanthus* sp., *Calycotome villosa*, *Genista acanthoclada*, *Sarcopoterium spinosum*.
- **None of these plants was hydro seeded**



Diversity

- **Herpetofauna:**

Transects (same time of the day/same observer):

(A) 70m x 4m

(B) 60m x 4m

(Cs) 234m x 4m

(Cp) 60m x 4 m

- **Soil arthropods:**

Pitfall traps (*20 traps/plot- except Bc that had 10 traps*)

→ **Index Species** →

**Population density
of index species**

Capture-recapture
&
transects



Results

a) Species records-Reptiles

Study plot	A (undisturbed)	B (3 year old)	C (Cs&Cp) (8-9 year old)
Species			
	Lizards		
	<i>Cyrtopodion kotschyi</i> <i>Ablepharus kitaibelii</i> <i>Podarcis milensis</i> <i>Lacerta trilineata</i> <i>hansschweizeri</i>	<i>Cyrtopodion kotschyi</i> <i>Ablepharus kitaibelii</i> <i>Podarcis milensis</i> <i>Lacerta trilineata</i> <i>hansschweizeri</i>	<i>Cyrtopodion kotschyi</i> <i>Ablepharus kitaibelii</i> <i>Podarcis milensis</i> <i>Lacerta trilineata</i> <i>hansschweizeri</i>
Total	4 species	4 species	4 species
	Snakes		
	<i>Macrovipera schweizeri</i> <i>Elaphe situla</i> <i>Telescopus fallax</i>		<i>Macrovipera schweizeri</i> <i>Elaphe situla</i>
Total	3 species	-	2 species



Soil Arthropods

A (undisturbed)	B (3 years old)	Bc (undisturbed)	C (Cs & Cp), (8-9 years old)
Opiliones	Opiliones	Opiliones	Opiliones
Araneae	Araneae	Araneae	Araneae
Acarina	Acarina	Acarina	Acarina
Isopoda	Isopoda	Isopoda	Isopoda
Chilopoda	Chilopoda	Chilopoda	Chilopoda
Collembola	Collembola	Collembola	Collembola
Thysanura	Thysanura	Thysanura	Thysanura
Dictyoptera	Dictyoptera	Dictyoptera	Dictyoptera
Orthoptera	Orthoptera	Orthoptera	Orthoptera
Hemiptera	Hemiptera	Hemiptera	Hemiptera
Ants	Ants	Ants	Ants
Coleoptera	Coleoptera	Coleoptera	Coleoptera
Insect larvae	Insect larvae	Insect larvae	Insect larvae
Pseudoscorpiones			Solifugae
Amphipoda			
Diplopoda			
Dermaptera			
Total 17	13	13	14

Number of species in May-July

	A (undisturbed)	B (3 years old)	Bc (undisturbed)	C (Cs & Cp), (8-9 years old)
Opiliones	1	1	1	1
Araneae	7	18	7	9
Acarina	1	1	1	1
Isopoda	1	1	1	1
Chilopoda	1	1	1	
Collembola	1	1	1	1
Thysanura	1	1	1	1
Dictyoptera	1	1	1	1
Hemiptera		4	1	3
Ants	7	8	11	6
Coleoptera	16	36	11	13
Insect larvae		1		
Total	37	74	37	37

Index species: *Podarcis milensis*

endemic lizard species in the Aegean Archipelago
(Milos, Kimolos, Polyaigos, Antimilos & small islets)



b) Population density of index species

Petersen (Caughley, 1980) $N = CM/R$ (1)

M = No of lizards marked in the first time
 C = Total No of lizards recaptured
 R = No of recaptured lizards that are marked
 $N/M = C/R$

For $R > 7$: Bailey (1952)
 $N = M(C+1)/R+1$ (2)

Correcting for edge effect

* Due to dense vegetation the capture-recapture method could not be used

Plot	Density	
	Transects	Capture-Recapture
A (undisturbed)	495 ind/ha	395.04 ind/ha
B (3 year old)	160 ind/ha	- *
Cs (8-9 year old-slope) Cp (8-9 year old-plane)	150 ind/ha 208 ind/ha	- * 303.3 ind/ha

Soil Arthropods

The three major groups in terms of number of species –
Coleoptera, Araneae, Hym. Formicidae – were chosen
as index groups

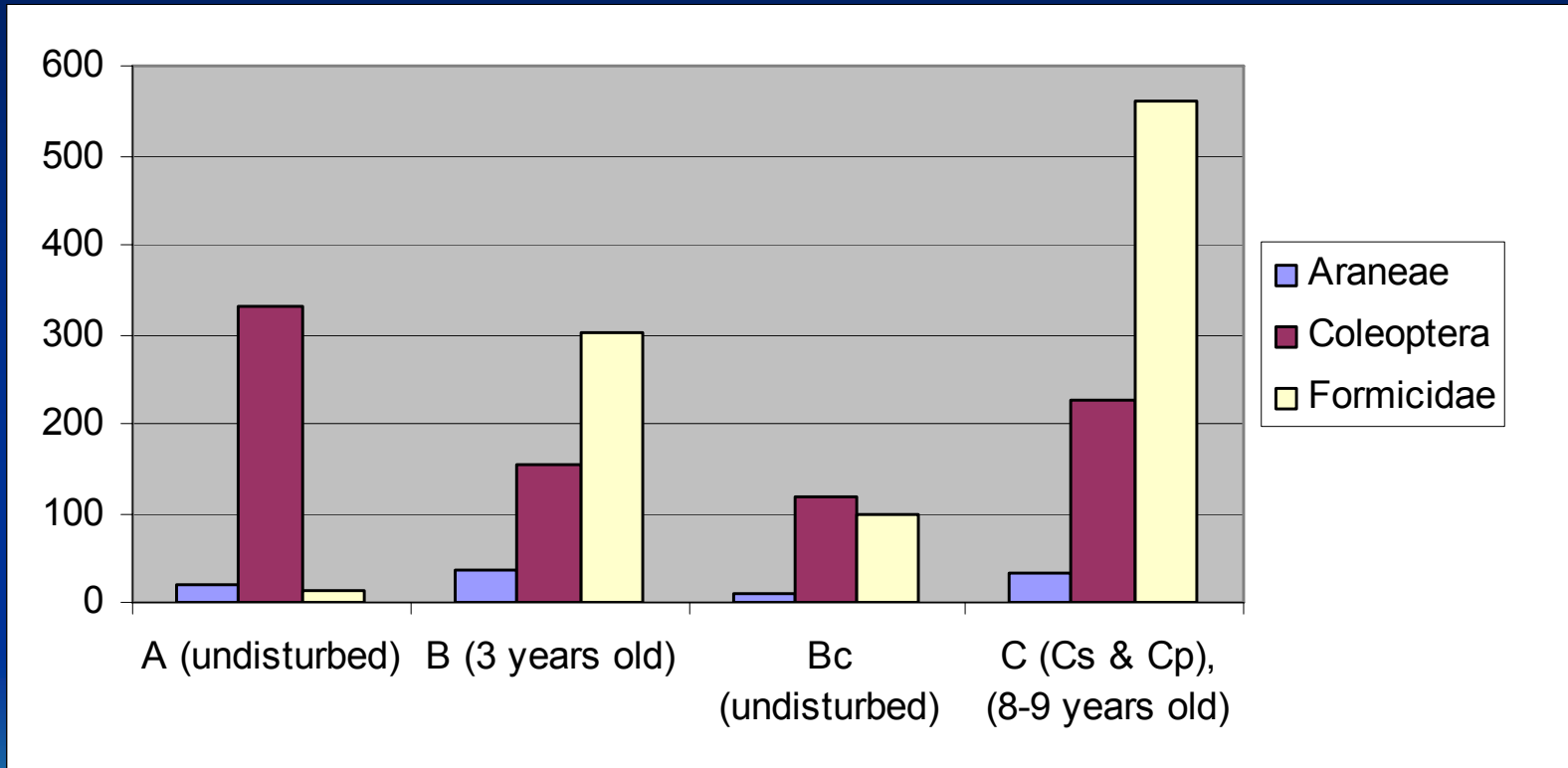


Mean number of individuals per trap per 60 days

	A (undisturbed)	B (3 years old)	Bc (undisturbed)	C (Cs & Cp), (8-9 years old)
Araneae	18.3	37.67	8.67	33
Coleoptera	330.33	153.33	119.33	227.33
Formicidae	14.3	302	100	560



Mean number of individuals per trap per 60 days



Numbers of species (total)

A (undisturbed) - C (Cs & Cp), (8-9 years old): No difference

Bc (undisturbed) – B (3 years old): Significantly more species in B



Numbers of species (Araneae, Coleoptera, Formicidae)

	Sites	Mann-Whitney U	p	Relations
Araneae	A - C	1.5	0.18	No difference
	B - Bc	0	0.049	More in quarry
Coleoptera	A - C	0	0.04	More in control
	B- Bc	0	0.046	More in control
Formicidae	A - C	3	0.049	More in quarry
	B-Bc	2	0.26	No difference

Number of individuals

A (undisturbed) > C (quarry) Mann-Whitney $U=0$, $p=0.049$)

Due to Coleoptera Tenebrionidae

B (quarry) > B (undisturbed) Mann-Whitney $U=0$, $p=0.049$)

Due to Araneae, Isopoda, Coleoptera, Formicidae



Diversity

Margalef index

Undisturbed sites have higher diversity than quarries

Mann-Whiney $U = 0$, $p = 0.049$ for both sets

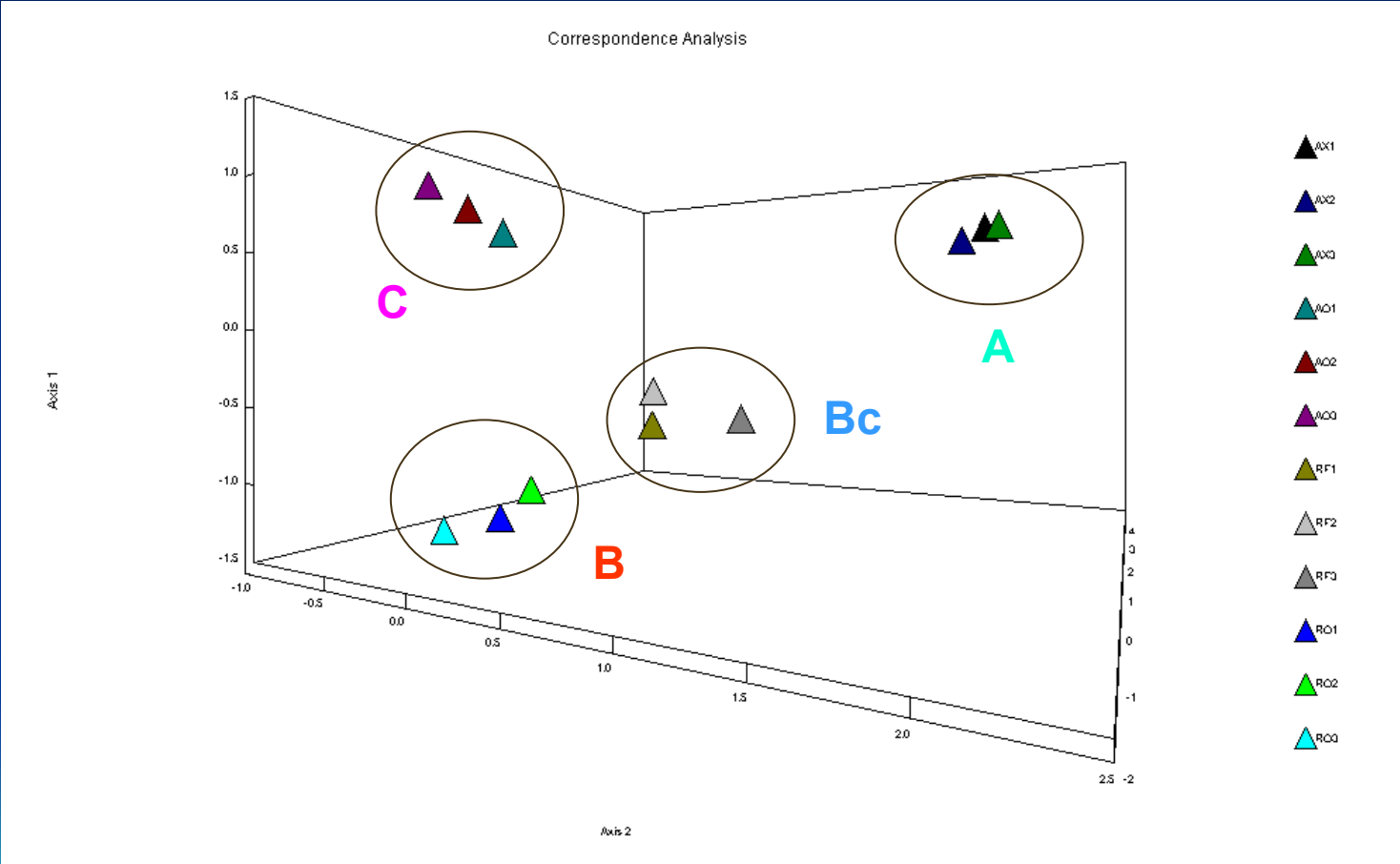
Shannon & Simpson

No differences

Mann-Whitney $U > 2$, $p > 0.27$



Discriminant analysis between sites



c) Qualitative results

Taxa	A	B	Bc	Cs	Cp
<i>Erodium orientalis</i> , <i>Dichomma dardanum</i> (Tenebrionidae)	+	-	-	-	-
<i>Dailognatha hellenica</i> , <i>Zophosis punctata</i> (Tenebrionidae)	-			+	+
Alleculidae, Staphylinidae	-	+	-	-	-
<i>Messor caducus</i> (Formicidae)	-	+	-	+	+
<i>Pheidole pallidula</i> , <i>Acantholepis</i> sp. (Formicidae)	-	+	-	-	-
<i>Cataglyphis</i> sp., <i>Plagiolepis pygmaea</i> (Formicidae)	-	-	-	+	+

d) Morphometrics of index species *Podarcis milensis*

	SVL (mm)		
Plot	Mean (range)	t-test	
A (undisturbed)	<p>Males (n=46) 54.96 (47-65.5), SD=4.93</p> <p>Females (n=82) 49.01 (42-60), SD=4.93</p>	Males>Females p<0.0001	<p><u>A vs. Cp</u> No sign. dif. between males, t-test, p=0.000</p>
Cp (8-9 year old, plane)	<p>Males (n=25) 59.64 (55-64), SD=2.41</p> <p>Females (n=27) 54.18 (49-60), SD=2.85</p>	Males>Females p=0.000	



e) Predation pressure

A % of animals with regenerated tails	
May	July
Males...44 (n=...)	50 (n=...)

Cp	% of animals with regenerated tails	
	May (spring)	July (Summer)
Males	58.33 (n=12)	46.15 (n=13)
Females	45.45 (n=11)	50 (n=16)
Grouped	52.17	48.27



Recapitulation

a) Herpetofauna

(A) Undisturbed plot

Species record: 4 lizard species, 3 snake species
Population density: 395 ind/ha (capture-recapture), 495 ind/ha (transects)

(B) Restored 3 years ago

Species record: 4 lizard species, 0 snake species
Population density: 160 ind/ha (transects)

(C) Restored 8-9 years ago

Species record: 4 lizard species, 2 snake species
Population density:

Cs-slope 150 ind/ha (transects)

Cp-plane 303 ind/ha (capture-recapture), 208 ind/ha (transects)

Species record

No of species found follows restoration level.

Snakes not found in B maybe due to a) their cryptic behavior & restricted activity hours, b) the plot may not yet fulfill certain requirements (e.g. food, refuges, etc.)

Population density

Population density of index species follows restoration level. In B and Cs the smaller densities. In B due to early stages of restoration & dense vegetation and in Cs due to very dense vegetation

It seems that 3 years since restoration are enough for a good population of *Podarcis milensis* to be settled

b) Invertebrates

- The sites have characteristic species that are adapted to the special conditions at each study area

Ants

Both quarries: *Messor*

B (3 year old quarry): *Pheidole* & *Acantholepis*

C (8-9 year old quarry): *Cataglyphis* & *Plagiolepis*

- The 8-9 year old quarry is closer to the undisturbed site as far as Margalef diversity and some groups such as spiders, compared with the 3 year old quarry
- The soil arthropod community of the quarries is more similar to the phryganic undisturbed site than to the sandy undisturbed site



- The two quarries seem to have acquired communities that do not differ much from the undisturbed communities as far as diversity is concerned
- The difference of the soil community in the 3 year old quarry from the neighboring undisturbed site is bigger than the difference between the 8-9 year old quarry and its undisturbed neighbor



General conclusions

- The two quarries seem to be on the way to full restoration with the 8-9 year old quarry being closer
- The differences in vegetation and in soil substrate create different reptile and invertebrate communities
- It is possible that in the future, plants from adjoining natural areas will invade and remove these differences
- It is also possible that the alien plant species that have been used in some cases for restoration will negatively affect neighboring natural areas



We would like to thank

- Z. Goulioumi
- N. Vavasi
- M. Kourias

for assistance in the field

- The S&B mining company for permission to carry out the project in their quarries
- Mr G. Petrakis of S&B for the provision of data on the vegetation and history of the quarries
- The Ministry of Environment, Physical Planning and Public Works for financial assistance within the framework of the Environmental Protection and Sustainable Development Program

