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ORIGINAL PAPERS

Biodiversity in Quarries - a Study Case from Iglicioara Quarry, Romania

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Abstract

The quarrying industry is an indispensable resource for human society, although it has a negative impact on biodiversity. Stone quarries, apart from the detrimental effect, generate new habitats, favourable for some species. We inventoried vertebrate diversity in an active quarry to evaluate its impact and importance. We identified 5 main habitat types. Among the species observed, 2 species of amphibians, 7 species of reptiles, 18 species of birds and 5 species of terrestrial mammals actively use the quarry area for feeding and/or breeding. The ruderal vegetation habitat with 25 species has the highest species richness. Modelling the species richness distribution throughout the quarry, we observed that a species richness hot-spot is in the ruderal vegetation habitat, where it intercepts temporary ponds and sterile deposits. Species accumulation curves and species richness estimators highlight that we have not reached a plateau and additional species might be present. The quarry, although active, creates new habitats and is a species rich spot. Thus, it is an example for conservation and biodiversity management.

Keywords*:* quarries, biodiversity, habitats, conservation, rehabilitation.

Introduction

Biodiversity is declining worldwide, the main cause being human activities. The Earth is under human pressure and the geologists suggest we have entered the Anthropocene Epoch. Although the exact period of the beginning of the Anthropocene is still under discussion, estimations of the rate of species extinction caused by human activities highlights that this is the epoch of the 6^{th} mass extinction [1, 2]. One of the most important factors responsible for biodiversity decline is habitat destruction, deterioration and fragmentation [3].

One such example of habitat change is represented by the quarrying industry. Surface mining is essential for the construction industry and, as world economy grows, it is easy to assume that the demand for this resource will grow [4]. Mining exploits a non-renewable resource, and thus no sustainable strategies of exploitation can be proposed. The extraction process of rock materials generates degraded areas with poor-quality soil, stripped vegetation, modified habitats and creates disturbances on an area larger than the original land surface because of the blasting operations, thus affecting the distribution of species in the surrounding region [5, 6].

One solution for the mitigation of quarry impact is restoration at the end of the exploitation period, with the purpose to re-establish plant communities with coherence to surrounding vegetation, if not similar to original state. In many cases such a solution might be unrealistic from both biodiversity structure and the economic points of view [7, 8]. One proposed action to be taken in quarry rehabilitation is to plan according to natural processes of spontaneous succession. Quarry rehabilitation can help create refuge for wildlife when it takes into consideration habitats created through the extraction processes and minimises disturbances by taking advantage of natural processes of species colonization of affected land [9, 10].

Surface mining can lead to the creation of new habitats, previously not present in the area, like aquatic habitats, which can favour mesophytic vegetation and invertebrates associated with these, but also amphibians [9, 11]. Birds can also benefit from habitats created by the mining activity: created cliffs may provide a safe nesting site and waterfowl may colonise the newly formed aquatic habitats [12].

Vegetation is more easily inventoried and provides valuable information on modified habitats re-colonisation. Animal species are more mobile and usually have wide home ranges and thus, little is known about animal colonization of a quarry environment, especially terrestrial vertebrates [6, 11, 12].

Since Iglicioara Quarry is an active site, no proper vegetation restoration steps have been taken, with the exception of a patch of planted *Populus* sp. In this study we proposed to: 1) inventory the main habitat types, especially newly created ones and 2) estimate species diversity in the quarry and the habitats they use.

Material and methods

Study area and site. The quarry is located in south-eastern Romania. The region is characterized by relatively warm, dry and windy climate, with a hill landscape dominated by loess steppe grasslands [13, 14].

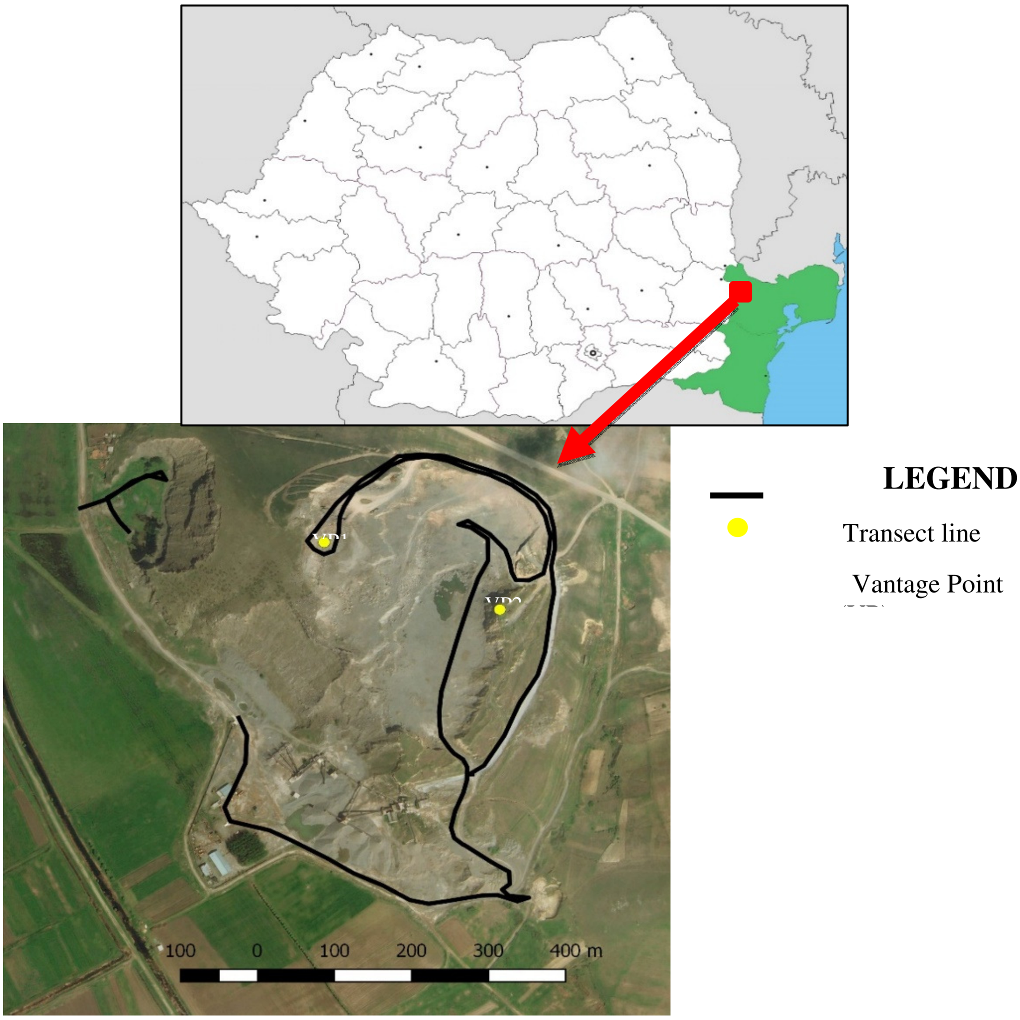

Fig.1. Top: position of Iglicioara Quarry (red square). Down: Transects (black line) and Vantage Points (VPs-yellow dots) used for biodiversity survey in the quarry.
(map sources: www.meteoalarm.eu and Microsoft Corporation Earthstar Geographics SIO)

Iglicioara Quarry is located in Tulcea County, Romania, 2 km east of the Danube and ca. 5 km west of Măcin Mountains(45°05'37.92"N, 28°11'12.47"E).The quarry is within the Natura2000 ROSPA0073 "Măcin-Niculițel" protected area and is in close range with ROSPA0040 "Dunărea Veche-Brațul Măcin", ROSCI0012 "Brațul Măcin" and ROSCI0123 "Munții Măcinului". The surrounding landscape is mostly loess steppe grasslands, and agricultural land. The quarry has been in operation since 1930 and now encompasses 22.4 ha extraction area and 12.56 ha of machineries and utilities area. The substrate is dominated by quartz porphyry and the bare ground consists of loess, rock and scree [15].

Sampling. The site was visited 11 times during April-October 2016 and February-August 2018, by teams of two researchers. The method of sampling consisted in two Vantage Point observations and a mix between transects and active search. The Vantage Point method was used mainly for ornithological observations: we chose the highest point available in both 2016 and 2018 (P1) and in 2018 we added another vantage point on the other side of the quarry (P2). For other vertebrate observations we followed a transect which covered almost all the quarry roads. Along the transect we carried out active search sessions of about 20 minutes each, with 15 m compass from the transect in order to cover more ground. This method was applied both during the day and at night (Figure 1). We recorded the presence of all vertebrate species using the quarry area for feeding or reproduction (from here on named active species). The birds observed in migration or resting were not considered as residents, because we could not properly estimate the importance of the quarry area for their activity. Bats also have not been included in the active species list, even though the acoustic recordings suggest they were feeding over the quarry area, we could not estimate the importance of the quarry for their feeding patterns.

Mapping habitat types. We used Google Earth Pro to create polygons with the habitats that we identified in the Iglicioara Quarry and to calculate the total area (ha) of each habitat type. Compared to the immediate surrounding area which is formed mainly by agricultural lands and steppe grasslands, and some wetlands near the Danube, in the quarry we encountered a mosaic of different habitats. For simplicity in mapping the habitat-species relationships we categorised them as such:

(1) Temporary ponds (0.7ha) – areas where surface mining made possible for either rain water to accumulate or for phreatic water to form surface accumulations. These areas are surrounded by hygrophytic species: *Phragmites communis, Eleocharis palustris, Agrostis stolonifera*.

(2) Deposits of sterile (4.4ha) – areas where mining operations form rock or gravel deposits. Most of these areas have no vegetation, with only some older rock deposits having few successful vegetal colonizers. These deposits seem to be permanent, as they were not removed since 2016.

(3) Cliffs (3.4 ha) – these are scree profiles formed by the mining operations. Soil and vegetation are patchy with mostly pioneer species, such as *Erodium cicutarium, Bassia prostrata, Alyssum allyssoides, Euphorbia seguieriana* and even shrubbery species such as *Rosa canina* and *Crataegus monogyna*.

(4) Steppe habitat (13.8 ha) – characterised by steppe grasslands and loess steppe grasslands species, such as Poaceae, Asteraceae, Lamiaceae and Crasulaceae. A cluster of *Paliurus spina-christi* is also present, a species characteristic for the Ponto-Sarmatic steppes habitat. This habitat is found mainly on the outskirts of the quarry.

(5) Ruderal vegetation (4.4 ha) – this is mostly the part along the roads and next to the operational buildings. Here we can find mostly herbs and a patch of planted poplars.

We marked and imported each habitat type into QGIS as a shape file (Figure 2). Although the total area covered by the quarry and the utilities associated is of 35 ha, our study area comprises of only 26.7 ha because we did not include inaccessible areas, the roads, nor a part of the utilities areas that are positioned on the Danube shore.

Mapping species occurrence. The field data records were created using Orux Maps app for Android and/or a Garmin GPS and then managed in Microsoft Excel. They were later introduced in Google Earth Pro where we created species datasets. These datasets were then imported into QGIS as shape files. To display species occurrence, we used heat map raster system with 8x8m grid system and linear interpolation of the records. The heat map was computed on yellow-red scale with 5 values from 0 to 13, based on all records of individuals.

Modelling species accumulation curves. The field data record was modelled using EstimateS9.1 software [16]. We analysed species occurrences for all recorded species based on number of field trips and of observations, but also on habitat type and importance of the quarry area to the ecological needs of the observed species.

The species accumulation curve was based on the number of field trips. We did two analyses, first with all the observed species (active and nearby species), next only the active species.

We estimated the total species richness using nonparametric estimators. A good estimator needs to be precise, unbiased and efficient [17]. Although no estimator meets all the criteria [17], we selected Chao2, ICE and Jackknife as best estimators for our data. Walther & Moore [18] conclude that Chao2 and Jackknife estimate better with most data sets than other parametric tests.

Results

We identified 87 terrestrial vertebrate species: 7 reptile species, 2 amphibian species, 67 bird species and 11 mammal species. Out of these, active users of the quarry area were all reptile and amphibians, 18 bird and 5 mammal species. We did not take into consideration the other 52 species of birds identified since they were either in transit over the quarry or using the nearby agricultural and grassland areas. We have also left out from the analysis species such as *Monticola saxatilis* and *Oenanthe isabellina*, for which we observed mating behaviours, but we did not identify nests or juveniles during our two research years.

We recorded each individual seen, only in bird nesting colonies we estimated the number of adults (the case of *Merops apiaster* and *Riparia riparia* colonies). With a few exceptions, such as *Natrix natrix*, *Falco tinnunculus*, *Merops apiaster, Athene noctua, Riparia riparia, Oenanthe oenanthe, Passer* sp., *Apodemus* sp., *Lepus europaeus, Meles meles and Vulpes vulpes*all the other active species identified are included in the European Union Habitats and Birds

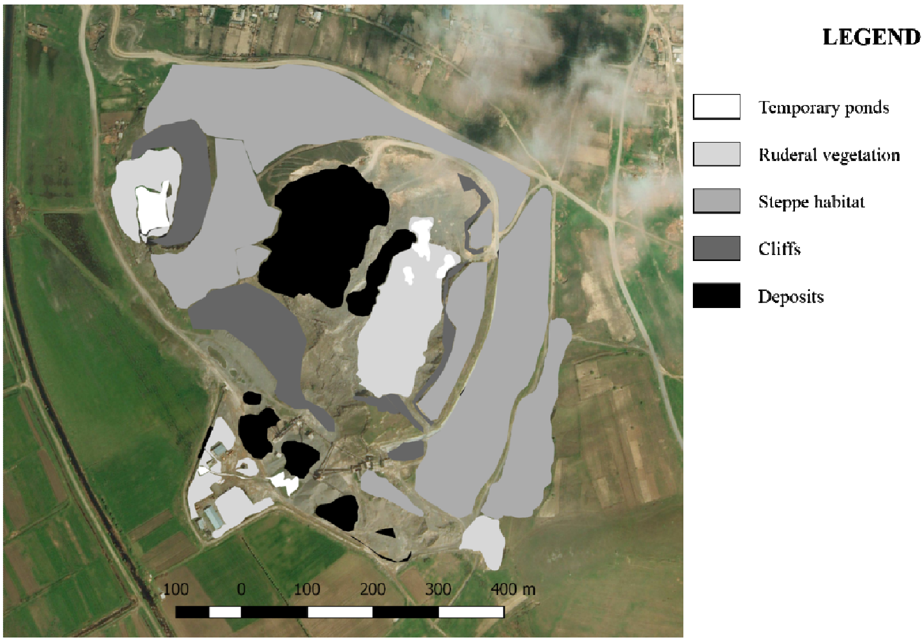

Fig. 2. Habitat types in the Iglicioara Quarry
(map source: Microsoft Corporation Earthstar Geographics SIO)

Table 1. Terrestrial vertebrates and the habitat type used in Iglicioara Quarry in 2016 and 2018

Systematic group	Species	Habitat type: Temporary ponds (0.7 ha)	Deposits (4.4 ha)	Cliffs (3.4 ha)	Steppe (13.8 ha)	Ruderal vegetation (4.4 ha)
Amphibia	*Bufotes viridis*	x				x
	Pelophylax sp.	x				x
Reptilia	*Natrix natrix*	x				x
	N. tessellata	x				x
	Dolichophis caspius				x	x
	Lacerta viridis		x		x	x
	L. trilineata		x			x
	Podarcis tauricus			x	x	x
	Testudo graeca		x		x	x
Aves	*Buteo rufinus*			x		
	Falco tinnunculus			x		
	Sturnus vulgaris				x	x
	Merops apiaster					x
	Corvus sp.					x
	Dendrocopos syriacus					x
	Riparia riparia		x			
	Oenanthe oenanthe		x			
	Athene noctua		x			
	Coracias garrulus					x
	Columba livia					x
	Streptopelia decaocto					x
	Pica pica					x
	Passer domesticus					x

	Passer hispaniolensis					x
	Passer montanus					x
	Anas platyrhynchos	x				
	Tadorna ferruginea	x				
Mammalia	*Apodemus* sp.					x
	Lepus europaeus		x	x	x	x
	Mustela sp.					x
	Meles meles					x
	Vulpes vulpes		x			x
TOTAL NUMBER OF SPECIES		**6**	**8**	**4**	**6**	**25**

The hot-spot of species diversity is the ruderal vegetation habitat, near the administrative buildings of the quarry, where the temporary ponds and rock deposits overlap. Ruderal vegetation habitat holds by far the highest species richness: 50% of total active species observed in the quarry, although the surface covered is only 16% of total area studied (Table 1, Figure 3).

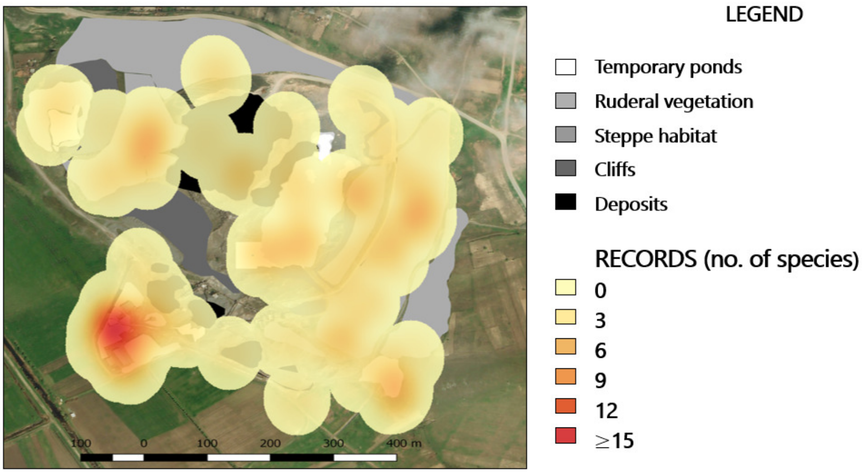

Fig.3. Species density map overlaid with the 5 habitat types identified

The species accumulation curve for all species observed, active and occasional in the quarry area, does not reach an asymptote, indicating that not all species present were inventoried. All estimators of species richness predict that there still are undetected species: Chao2 predicts another 18 possible species, ICE another 33 species and Jackknife another 39 species (Figure 4).

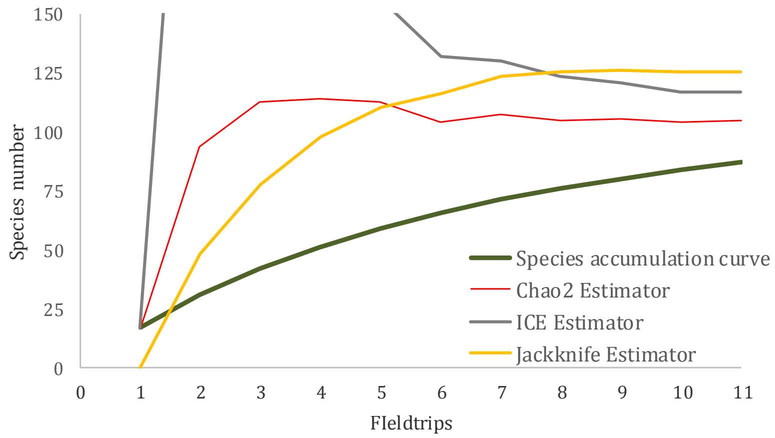

Fig.4. Species accumulation curve and estimators – for all species observed

When analysing species richness only for the active species, based on each type of habitat used, all the estimators indicated that more species are expected in each habitat type, from 2 new species on cliffs (ICE and Jackknife estimators) to 12 new species on rock deposits (ICE estimator) (Table 2, Figure 5).

Table 2. Species richness estimators for active species, based on each habitat identified in the quarry area

Habitat type	Active species - observed -	Estimated maximum number of species		
		Chao2	ICE	Jackknife
Ruderal vegetation	25	27.7	28.4	32.7
Deposits	8	12.5	20	17
Steppe vegetation	6	6.9	7.3	9.5
Temporary ponds	6	6.9	8.9	9.7
Cliffs	4	4.4	6.8	6.7

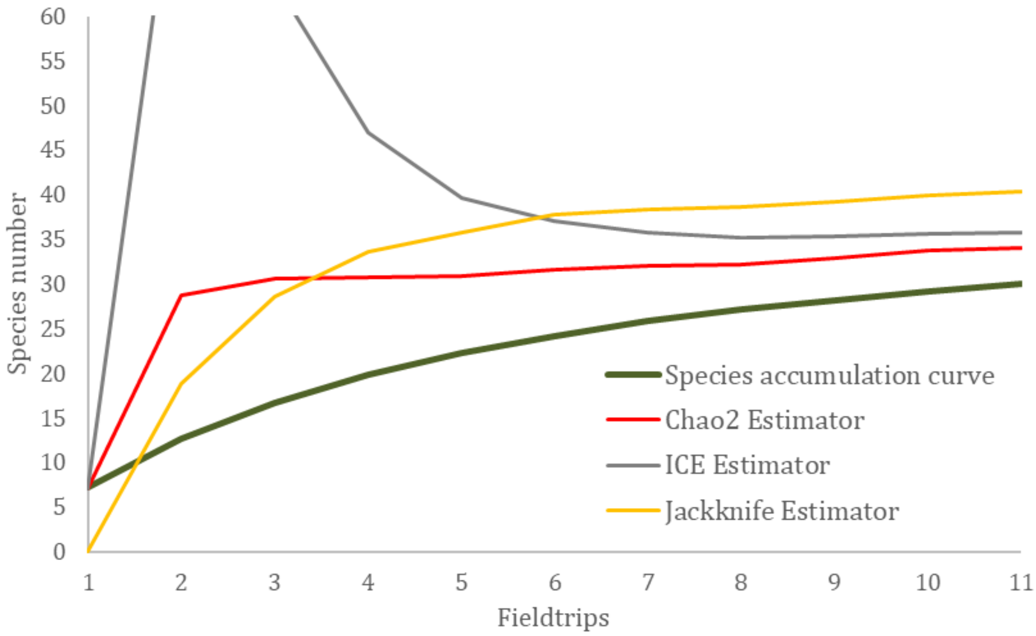

Fig. 5. Species accumulation curve and estimators - for all active species observed.

Discussion

Our study has highlighted that even an active quarry supports a high number of terrestrial vertebrate species, contains newly formed habitats and is thus important for conservation.

While reptiles and amphibians use both natural and man-made habitats, nesting birds are mostly localized in the man-made habitats: cliffs, deposits and ruderal vegetation areas, as shown in Table 1. Feeding birds prefer mostly the temporary ponds and the ruderal vegetation areas. Mammals, with the exception of foxes and hares, stick to the ruderal vegetation.

Areas with ruderal vegetation have the highest diversity. This habitat is characterised by the highest number of species (25) and heterogeneity. The “hot-spot” of species richness is also found in the ruderal habitats. A factor which might explain the high richness of the ruderal habitat, despite its rather small area cover is that is comes in contact with the other four habitat types. This supports the well-known fact that a higher diversity of habitats supports higher species richness [19, 20, 21].

The species richness estimators and the species accumulation curves indicate there are still undetected species in the quarry area. One explanations is that we might have not observed the behaviour to categorise the species as active users of the quarry (as in the case of *Monticola saxatilis*or that of bats). Another issue is that this is still an active quarry, and the disturbance provoked by the rock-extraction and processing restricts the activity and thus detectability of some species.

In an area where historically only agricultural land and grasslands existed [15], the surface mining activity at Iglicioara Quarry has caused a diversification of habitats. Constant digging has changed the landscape and generated new habitats which can host a large number of species. Long-term population studies in quarries are important to quantify the response of the animal communities to human impact and propose the best actions for a successful restoration process

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