1. Contestant profile

▪ Contestant name:	**Carlos Caballero Díaz**
▪ Contestant occupation:	PhD Student
▪ University / Organization	Universidad Autónoma De Madrid, Asociación Herpetológica Española
▪ Number of people in your team:	**5.** **With: Álvaro Iglesias Donoso, David Laorden Romero, Iván Gómez García, Pablo Cisneros Araujo**

2. Project overview

Title:	**Project Amphiquarry: Are abandoned quarries essential refugees to ensure amphibian connectivity?**
Contest: (Research/Community)	Research
Quarry name:	Arrigorriaga (Bilbao, Spain)

Abstract

Amphibians are the most threatened vertebrate group in the world. Habitat loss and fragmentation is one of the most important threats, as is the case of mining industry (e.g. quarries). In these places, numerous ponds are formed due to substrate impermeability, which could function as "Stepping ponds" with surrounding water bodies. Although there is little basic information about amphibian dynamics in quarries, the maintenance of an interconnected good-preserved pond network is essential for amphibians, which have physiological characteristics limiting dispersion. Therefore, in this study we aim to assess and model connectivity using Graph theory in Arrigorriaga´s quarries (Vasque Country, Spain) to then propose accurate conservation measures. To achieve this, we intensely sampled every water body in the quarries and their surroundings, we conducted C-M-R analyses with the help of the photo-identification in the principal ponds and we monitored *Pelophylax perezi* movements thanks to the placing of radio-trackers. We detected six amphibian species breeding in 38 water bodies with high abundances of *Bufo spinosus* and *Salamandra salamandra* outside the quarries, but strong dependence of *Triturus marmoratus*, *Alytes obstetricans* and *P. perezi* to breed in the quarries. We also achieved optimal population sizes of *A. obstetricans* and *P. perezi* using C-M-R data – which suggests interesting amphibian colonization– and a strong philopatry of *P. perezi*, with reduced home ranges and displacements. The connectivity results suggest the importance of improving the conservation status of nodes and to focus efforts in adapting and building new water bodies in the ecological corridors. Finally, we propose conservation measures that should be extrapolated to quarries in similar regions.

1. Introduction

Amphibians are the most threatened vertebrate in the world with more than a 40% of the species in decline [1]. This is due to numerous factors, as alien invasive species, pollution, emerging infectious diseases, climatic change and habitat loss and fragmentation [2,3]. In addition, amphibians are considerably vulnerable to every threat due to their physiological characteristics, their limited dispersive capacity and their biphasic life cycle. Firstly, larvae strictly need water to grow up and to complete metamorphosis; Secondly, juveniles and adults spend the most part of their lives in the terrestrial ecosystem where they feed on and look for shelter, although they visit every year the water sites to breed [4,5]. Therefore, amphibians are essential in food chains of terrestrial and aquatic ecosystems, as well as provide benefits for humans (controlling plagues or as environmental bioindicators) [5,6].

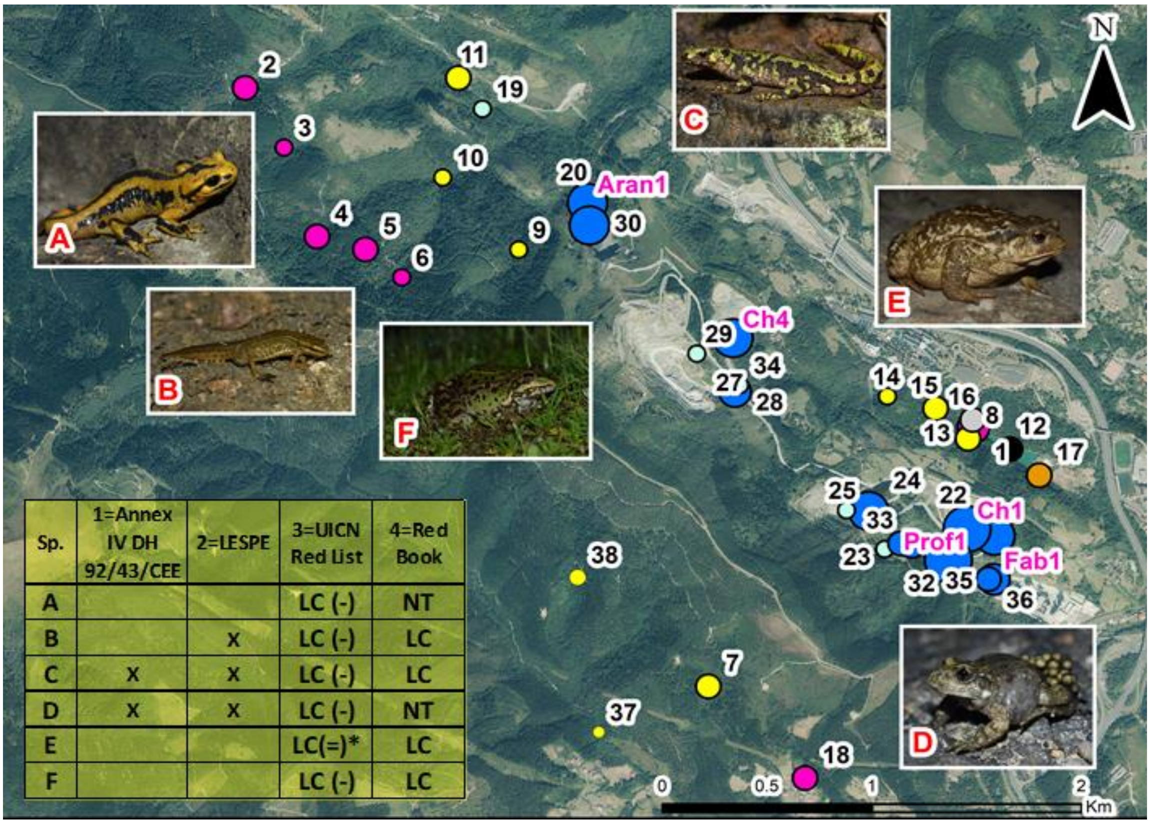
Due to the human population growth and the rising economical demand, large natural surfaces of land have been destroyed in favor of building cities, industrial areas or roads. This provokes the loss of available surface for animals, the deterioration of ecosystems and landscape fragmentation [7]. The same occurs with quarries – or open pit mining-: they destroy important forestry areas in order to extract minerals. When the exploitation finish, they become abandoned and then, they could entail important opportunities for amphibians, due to substrate impermeability, the easy accumulation of water and the abundance of refugee [8,9].

In modified landscapes, every water body could be essential for amphibian metapopulations. These sites function as “stepping ponds”, i.e., water bodies among further sites and where amphibians can successfully breed [9]. Due to the scarce dispersive capacity, it is essential to infer amphibian connectivity patterns at a fine scale, by detecting nodes (breeding sites) and ecological corridors to then apply conservation efforts [10]. To achieve this, we need to understand basic demographic aspects as population dynamics, dispersal or home ranges. However, the available information is very scarce.

Thus, in this study we tried to contribute to these basic aspects, as well as to model connectivity at a local scale in order to establish a paradigm in amphibian conservation in quarries. Hence, the principal aim of the study was to understand functional connectivity and amphibian population dynamics in Arrigorriaga´s quarries and afterwards, to propose accurate conservation measures. We established secondary objectives: 1) to characterize amphibian populations in Arrigorriaga´s surroundings and the main threats to which are subdued, 2) To quantify population sizes of two species in the principal ponds of the quarries, 3) to study movement dynamics and dispersal using radio-tracking, 4) to infer the main ecological corridors and the most important nodes and its relevance to assure connectivity among breeding sites, and 5) to propose conservation measures in Arrigorriaga and to extrapolate these results to other regions.

2. Materials and methods

Initial surveys. During April 2022, we sampled every water body in the quarries and surroundings (Figure 1). First, we obtained valuable cartographic information related to location of water bodies using online viewers Iberpix (https://www.ign.es/iberpix2/visor/) y google Earth (https://www.google.com/intl/es/earth/). Afterwards, we planned diurnal and nocturnal surveys during 14 days to quantify abundances. In the case of anuran, we visually/aural counted individuals; in the case of urodeles, we visually counted when possible and if not, we used dip nets to trap individuals. In the case of *A. obstetricans* and *S. salamandra* larvae, we also applied the latter. In those water bodies with two or more diary records, we chose the upper value. To avoid the transmission of pathogens, we disinfected the material using a bleach solution (1:10).



Sp.	1=Annex IV DH 92/43/CEE	2=LESPE	3=UICN Red List	4=Red Book
A			LC (-)	NT
B		x	LC (-)	LC
C	x	x	LC (-)	LC
D	x	x	LC (-)	NT
E			LC(=)*	LC
F			LC (-)	LC

Figure 1. Map representing Arrigorriaga´s Quarries and surroundings. Amphibian species detected (Annex 1): A= Fire Salamander (*Salamandra salamandra*), B= Palmate Newt (*Lissotriton helveticus*), C= Marble Newt (*Triturus marmoratus*), D= Common Midwife Toad (*Alytes obstetricans*), E= Iberian Common Toad (*Bufo spinosus*), F= Green Frog (*Pelophylax perezi*). Numbers in the map represent amphibian breeding sites (see Annex 2 and 3). Size of dots indicates amphibian richness (from 1 to 6 species, from smallest to largest), and the color represents the type of water body: pink= cattle troughs, light blue= rain puddle, dark blue= artificial pond, black= dam, orange= channel, grey= ditch, yellow= streams. Legal protection figures: 1) Annex IV of Habitat Directive (92/43/CEE), 2) Species under special interest (RD 139/2011), 3) UICN Red List (including category of threat and population trend), 4) Red Book of Spanish Herpetofauna. Photos: Carlos Caballero Díaz

Photo-identification and Capture-Mark-Recapture analyses. We employed 26 nocturnal surveys to accurately quantify amphibian populations in the principal ponds (Fab1, Prof1, Ch1, Ch4, Aran1; Figure 1). In each survey and water site, we tried to capture every individual we detected (Max. time=30 min) using dip nets and carefully stored in fabric bags. We first geolocated each individual and then, we sexed (male, female), aged (juvenile, adult) and explored in search of scars or deformations to help in the subsequent identification. We also made a dorsal (for anurans) or ventral photo (for urodeles) with the help of a Huawei p20Lite mobile phone (20MP) and the incorporated flash (Figure 2). Once we finished, each individual was released in the same location where was previously found. To identify unique individuals and to be able to assign recaptures, we used the computer program Wild Id [11], which provided the 20 most similar photos when comparing with each uploaded individual. Then, we manually decided if the assignment was the correct. With this information, we obtained a maximum value of population sizes by species and pond by counting “Unique” individuals.

For 3 (Ch1, Ch4, Fab1) and 2 (Ch1, Aran1) breeding sites respectively for *A. obstetricans* and *P. perezi*, we performed Capture-Mark-Recapture analyses. We first discarded the rest of the species (due to absence of robust data) and for the target species, the discarded surveys with less than 3 and 4 individuals detected, to avoid statistical inconsistency. After building a presence/absence matrix (1 vs 0), we used Mark program [12] and POPAN Formulation [13], which models open populations (that contemplates entrance of individuals to the population due to recruitment or immigration and exits, due to deaths or emigration). Models combine four parameters: "φ" as the probability of survival between surveys, "p" as the probability of capture individuals in each survey, "pent" as the probability of new entrances before each survey, and "N" (Population Size) as the total number of individuals that have been in the population during the study period. We built models to estimate N with φ, p and pent varying depending on time (t) or being constant (.). The obtained models were ranked according to AICc value (Akaike Information Criterion for finite samples, [14], Annex 4).

Radio tracking monitoring. At early July 2022, we used radio-tracking BD-2X transmitters (Holohill, Ontario, Canada) in 13 individuals of *P. perezi* in two ponds, Ch1 (7 individuals) and Aran1 (6 individuals), a "Lightwight Yagi" antenna and a "TR-48S" receiver (both from WildLife Materials, Illinois, USA). Transmitters were programmed with unique frequencies between 150.010 and 150.463 Hz, which suit with the receiver frequencies. To place the radio trackers, we use an own-made harness to randomly captured frogs (Figure 2). The harness was compound of a surgical elastic micro tube surrounding the hip, and of a fishing line traversing the tube. We tied the transmitter to the fishing line at the back side of the hip and we placed the antenna of the transmitter oriented to the legs. We assure that frogs were not suffering damage and then we prove the movement amplitude. Afterwards, individuals were released into the wild in the same location where they were captured and we follow their movements during 10 consecutive nights, by geolocating their exact position with a GPS device (Garmin eTrex 30x). Once we finished the sampling, we conducted several surveys to try to remove the devices from frogs. With the obtained data, we inferred the maximum displacements, the average distances and the home ranges, calculated as the polygon which traverses the most external geolocations.

Figure 2. Photoidentification of *P. perezi* (left, up) and *A. obstetricans* (left, down), with recaptures belonging to the same individual. At the right side, an individual of *P. perezi* equipped with the harness and the radio-tracker.

Connectivity analyses. To design the amphibian connectivity analysis, we used the graph theory approach [17]). We selected as nodes the water sites where amphibians were found during fieldwork. Points that were closer than 50 m to each other were considered as one. We characterized habitat types using the Basque Country Habitat map 1:10,000 of 2019 and we assigned values of resistance to amphibian movement to the different habitats based on those given by [18]. We adapted these values to match the thematic resolution of this study according to fieldwork experience and expert criteria ANEX). To get the final resistance surface, we multiplied resistance values by 5 in the areas where the slope (DEM LiDAR from Eusko Jaurlaritza / Gobierno Vasco) was between 50-100% and by 10 in areas where the slope was greater than 100% (Annex 4).

First, we defined the links using least-cost modelling [19]. This approach estimates the single path between two nodes or amphibian breeding sites that implies the minimum effective distance. Therefore, least-cost paths have the most permeability and the highest probability of being used by amphibians in dispersion. We then computed least-cost paths and effective distances using the Linkage Mapper software [20]. Once the links and nodes were mapped, we identified those most important for connectivity. Focusing on the links, we aimed to identify: (1) currently important corridors to connectivity, as those that contribute most to maintaining dispersal flows and whose blockage would mean a high impact on connectivity; and (2) restoration corridors, whose restoration would implicate a relevant improvement in the overall connectivity (see more details in [21]). Focusing on the nodes, we also wanted to identify those currently most important in the amphibian connectivity network.

To achieve this, we used the probability of connectivity (PC) index (based on the habitat availability and graph theory approaches), which indicates to which extent two nodes are connected based on the probability of individuals to cross from one to another [22]. To calculate the PC value, we used the median dispersal distance (50m for *P. perezi*, see [23]) to indicate a probability of 0.5 for an individual to cross between nodes that are at that distance. We then multiplied this value by the mean resistance of the map to get the median dispersal effective distance. We used the total amphibian abundance in each water site as attribute in the analysis to weight the importance of each node or breeding site [21]. To identify the currently important corridors, we analyzed the impact of removing each link to check their contribution to overall amphibian connectivity by calculating the difference in PC.

To identify the restoration corridors, we measured how much the overall connectivity would increase in a situation in which dispersal habitat for amphibians is perfectly restored for each link. We used the Conefor software [24]) to compute the dPC values and their Link Removal and Change functions. To identify the most important nodes, we analyzed it in a similar way to the link removal method in order to obtain the dPC value. We also inferred the fractions of the total dPC: (1) the fraction Connector which measures the contribution of each breeding site (or node) as a connecting element or “stepping” ponds; (2) the fraction Flux which measures the amount of flux a breeding site emits or receives when it works as destination or source; and (3) the fraction Intra which measures the connectivity inside a node and equals the total amphibian abundance of each breeding site. Second, we used circuit theory (see [25]) with the software Circuitscape v4.0.5 [26]. To characterize links, depending on the resistance surfaces, they described as an amount of cells with high probabilities of being used. Circuit theory finds numerous pathways that connect nodes by previously finding multiple available dispersal routes including optimal and suboptimal ones.

3. Results

Initial surveys. Among the sampled water bodies, we located 38 breeding sites that are divided into streams (10; 26.3%), rain puddles (6; 15.8%), artificial ponds (12; 31.6%), cattle troughs (7; 18.4%), dams (1; 2.6%), ditches (1; 2.6%) and channels (2.6%) (Figure 1, Annex 2). We detected six amphibian species breeding in them: Fire Salamander (*Salamandra salamandra*; in 8 water sites, 21.1% of presence), Palmate Newt (*Lissotriton helveticus*; in 20 water sites; 52.6%), marble newt (*Triturus marmoratus*; in 7 sites, 18.4%), Common Midwife Toad (*Alytes obstetricans*; in 20 sites, 52.6%), Iberian Common Coad (*Bufo spinosus*; in 17 sites, 44.7%) and the Green Frog (*Pelophylax perezi*; 10 water sites, 26.3%) (Figure 1, Annex 2).

In ecological preference terms, we found that *S. salamandra* breed in streams (50%) or cattle troughs (50%); L. helveticus chose streams (15%), rain puddles (20%), artificial ponds (45%), cattle troughs (15%) and ditches (5%); *T. marmoratus* had preference for artificial ponds (100%); *A. obstetricans* chose streams (15%), rain puddles (5%), artificial ponds (50%), cattle troughs (20%) and channels (5%); *B. spinosus* breed in streams (29.4%), artificial ponds (47.1%), cattle troughs, ditches, dams and channels (5.9% each); *P. perezi* preferred artificial ponds (100%) (Annex 2). Relative to the surrounding abundances, we have to remark the important *S. salamandra* populations breeding in streams and *B. spinosus* ones in dams, channels and streams (with 1354 adults of the 1388 detected). In addition, we should point the important number of *A. obstetricans* adults found in artificial ponds (92.7% of the total encountered) (Annex 3).

Photo-identification and Capture-Mark-Recapture analyses. Thanks to photo-id and the geolocation of individuals, we obtained maximum displacements of 88m for *P. perezi*, 202m for *A. obstetricans* and 248m for *B. spinosus*. We did not detect movements for the rest of species. Using Mark program and POPAN formulation, Na estimates seem somewhat solid. For *A. obstetricans*, in pond Ch1 (see pond characteristics in Annex 5) we estimated a `population size of 25 adults (95% Confidence Interval, 17-56), in pond Ch4 a total of 118 adults (95% CI, 56-180) and in pond Fab1, 23 adults (95% CI, 20-46). For P. *perezi*, in Aran1 we obtained an estimate of 139 adults (95% CI, 86-272), while in Cha1 the population size was estimated in 153 (CI 95%, 123-183). The models were ranked by the AICc (Annex 5).

Radio tracking monitoring. The percentage of located individuals using radio-tracking was very high (96.15%) and constant in time, i.e., the number of occasions in which we succeed locating individuals did not diminish according to the passing of time.

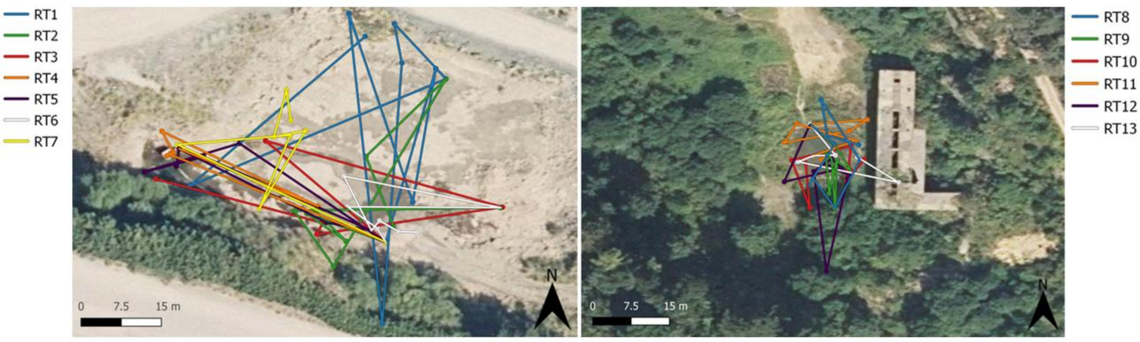


Figure 3. Diary movements (t=10 days) of the 13 *Pelophylax perezi* individuals (“RT”) in, Ch1 (left) and Aran1 (right).

Concerning displacements, we registered movements between 55.1 and 392.7m in the study period (10 days), with similar average distances between males (141.6m) and females (137.7m). Home ranges were bigger for females (481.1m^2) than for males (428.8m^2). The maximum registered home range belonged to a female, with a total surface of 2.027m^2. The maximum displacement of a frog in a day was inferred in 61.4m. Concerning microhabitat use, the two most frequent habitats used by frogs were rocks (32% of the occasions) and bulrush (32%) (Figure 3, Annex 7)

Connectivity analyses. Results from the connectivity analysis show all least-cost paths (links) among the water sites were predicted in the same valley where the quarries are established, with no links crossing the mountain ridge to the southwest neither AP-68 highway in the northeast (Figure 4). Inside this area, while many links happen across the quarries, especially in the southernmost ones (Ch1 and Prof), several links were predicted over natural covers, with quarries Aranz and Ch4 having no links inside.

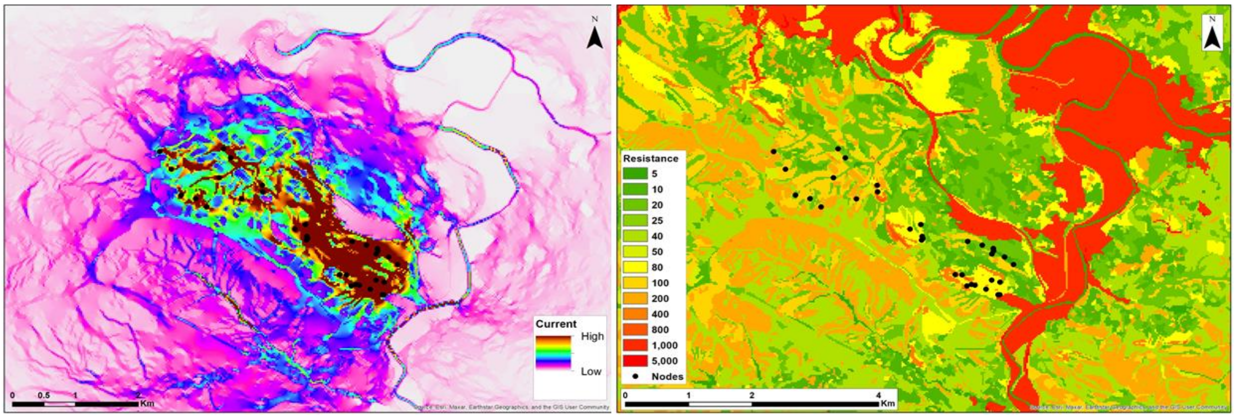


Figure 4 . Ecological corridors (left) and resistance layer (right). Resistance to movement values are included (Annex 4).

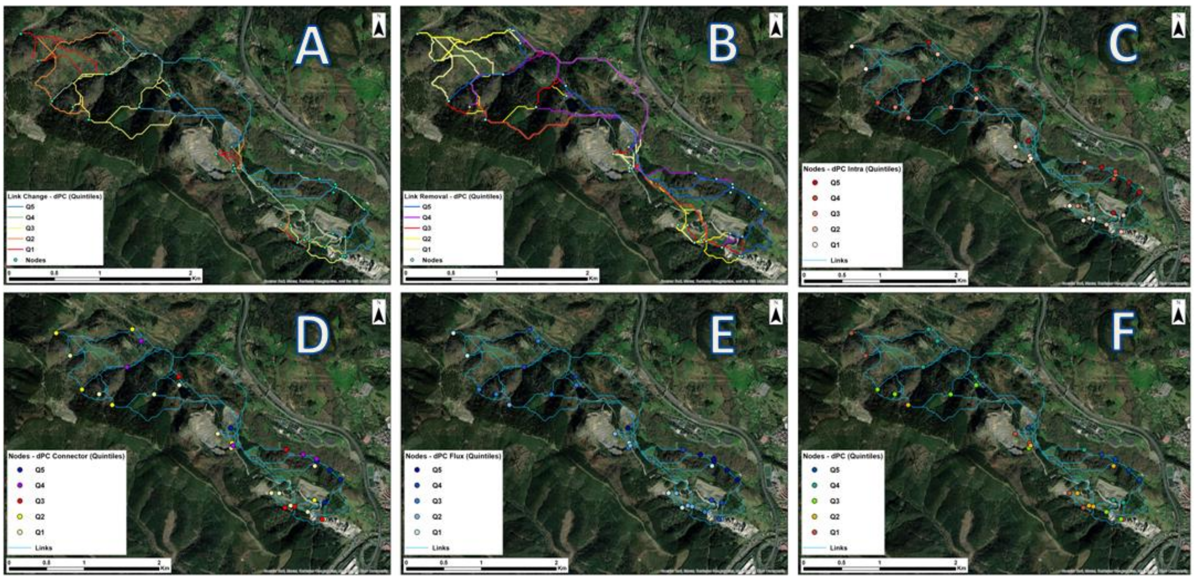


Figure 5. Connectivity analyses results concerning least-cost paths Graph Theory. A= Contribution of links to connectivity conservation (dPC Link Removal); B= Potential links to contribute to conservation of connectivity if they were restored (Dpc Link Change); Fractions of nodes dPC: Intra (C), connector (D) and flux (E). F= Contribution of nodes to connectivity conservation (dPC total). Individual maps are available in Annex 8.

Of these links, the most important ones for the amphibian connectivity network were estimated to be those connecting water sites in the reservoir (Embalse de la Dinamita) with sites in Ch4, Ch1 and Fab, and also one link connecting Ch4 with Aranz quarry and another following a small valley in the north of the area (Figure 5, A). For the links with the most potential for restoration, the situation is very similar being estimated to be those connecting water sites located in the reservoir and the quarries mentioned above (Figure 5, B). Circuit theory results also indicate high dispersal flows inside and in the surroundings of the quarries. However, some alternative pathways were predicted in the adjacent valley and others through the Nervión River on the other side of highway AP-68 (Figure 4, left). The most important nodes for amphibian connectivity in this landscape are located by the reservoir with the only exception being a water site located in quarry Ch4 (Figure 5, F). The same water sites are also among the most important in all dPC fractions (Figure 5, C, D and E).

4. Discussion

Our results suggest that remarkable amphibian richness exists in the quarries. The target species use a certain variety of water sites, although the artificial ponds originated due to mineral extraction develop as very important for amphibian connectivity. In addition, ponds harbor optimal population sizes, being the unique breeding sites for some species and suggesting perfect colonization. In the same way, dispersion results show high philopatry and connectivity models indicate the possible existence of ecological corridors connecting the ponds in the quarries with the surroundings. This suggests the necessity of applying conservation measures concerning the improvement of existing nodes and the construction of new ones.

In the water bodies located in the quarries and surroundings, we detected a considerable number of species (6). Despite quarry ponds were formed only various decades ago, amphibians have shown a high colonization capacity and they find in the quarries favorable refugees to settle viable populations. In addition, amphibians seem to show high adaptive capacities to breed in this type of landscapes, which matches con previous studies [8,9]. However, the species choose very differently the water bodies where they breed. For example, *S. salamandra* opts for breed in streams or small-dimensions cattle troughs to avoid predation in larvae [27], while *B. spinosus* forms enormous populations in dams [28], although in our study showed high prevalence to colonize artificial ponds in quarries. On the other side, the strong dependence of *P. perezi* and *T. marmoratus* to breed in the quarries is highly remarkable. Although we sampled water bodies in the surrounding areas and both species are abundant in the region [29,30], we only detected breeding populations inside the artificial ponds of quarries. This could be explained by an important colonization of vegetation in most of the ponds, which is a remarkable ecological preference of both species [27,31]. The case of *A. obstetricans* or *L. helveticus* is different: both species are very abundant in the north of Spain [29,30] and show good adaptabilities to different type of breeding sites. We found both species in more than the half of the breeding sites, although *A. obstetricans* showed an upper preference to breed in artificial water bodies, which has been assessed in Mediterranean landscapes [8]. Thus, these results implicate that conservation measures and the restoration of habitat to assure connectivity and population viability should be focused separately for the species, and taking into account their different habitat preferences.

The use of photo-identification has been key for indifferently identifying captured individuals. In addition to obtaining the maximum number of unique individuals (ANNEX), we were able to estimate population sizes and to detect some displacements. The estimates indicate that *A. obstetricans* and *P. perezi* are in good conservation status, forming populations which are perfectly adapted to quarries. However it is necessary to improve habitat conditions in some ponds. This is the case of Fab1 (elimination of waste and restoration of vegetation), which needs the colonization of plants to then favor species as *P. perezi* or *T. marmoratus*. For *A. obstetricans*, which inhabits in the vicinities of water bodies all year around and does not expend (except larvae) plenty of time in the aquatic ecosystem, it is also necessary to continue avoiding the nocturnal traffic in the surroundings of the quarries. However, as the species disperses little [32] it can be permitted the traffic in the principal paths. It is strongly recommended to monitor populations by taking into account the phenology of the species, to maximize efforts and to avoid discarding sampling sessions in order to aim statistical consistence.

On the other side, the radio-tracking monitoring suggests interesting and novel results. We found a strong dependence of *P. perezi* to remain in the water bodies and to conduct scarce and short displacements, only to move inside the ponds and to shelter in the pond shore. Home ranges and average dispersive movements suggest a high philopatry; however, these data should be taken with caution due to monitoring was not conducted in the maximum-dispersive period (usually in autumn). The radio-tracking methodology worked perfectly and we were able to accurately locate animals, although the frequency signal has been lower than expected, probably due to the size of transmitters (it could not exceed more than the 5% of the individual weight [33]). To our knowledge, this is the first study concerning radio-tracking in *P. perezi* in the region and this could open further research. We suggest to use this method in other periods (e.g. autumn) and to use heavier transmitters (if the % of weight allows it), which last longer periods of time and could be detected from further areas. The information of habitat use and dispersion in amphibians is scarce and very difficult to obtain; thus, radio-tracking could give response to this knowledge gap.

Connectivity models indicate that there is connection between plenty of quarry ponds and with the surrounding sites, but also there are important barriers (as roads or quarry/mountain slopes) limiting dispersion [34]. The most recommended measures of the models concern the improvement of habitat quality in ecological corridors. As amphibians have limited dispersive capacity, nodes (breeding points) should stay under good-preserve and should not distance more than 1 or 2km each other. For example, models show some interesting sites (Q5 or Q4, Figure 5) for connectivity (p12, Ch4 and Fab1, Figure 5 D and E, Annexes 2 and 3) and their disappearance could strong damage the connectivity in the area. Thus, it is necessary to improve the conservation status of some of them (as cleaning and restoring vegetation in Fab1) and to conduct monitoring in the rest. Concerning links, there are some that could be strongly used by amphibians in their movements and where the construction of new water sites could be essential to assure genetic flow (see Figure 5 A). This map could also explain the abundances of some species in Ch1 and Ch4, due to there are good-ranked (Q5 or Q4) links which could have allowed the first displacements to the quarries decades ago (as from p12 to Ch1 or Ch4). However, it seems to be more difficult the connection between the latter and Aran1, where only a good-preserved population of *P. perezi* was detected. Thus, it is essential to improve abundances (main attribute in the connectivity models), which could be achieved by adapting water bodies to the ecological preferences of the species and diminishing the pressure of threats.

The diversity of species, population sizes and connectivity found in Arrigorriaga´s quarries remark the good conservation of amphibians. This is needed to be taken into account and awards important value to the quarries, due to amphibians are very good environmental bioindicators and their conservation status reflect correct actions by the surrounding companies.

How can we favor connectivity?

Conservation actions	How?	The case of Arrigorriaga	When?	Price
Improvement and adaptation of water bodies	To improve the entrance and exit of individuals, to increase the quantity of vegetation and refugee, to protect against animals and cattle, to place education boards.	To increase vegetation in Fab1, Ch1, refugee in Fab1, and to improve access and exit of amphibians in Prof1 and Fab1. Placing of semi-fences in Aranz1.	The conservation measures shoukld be applied after the summer, when the majority of ampphibians have left the water body.	Between 400-500€ per intervention.
Creation of new water bodies	Digging, placing a waterproof plastic or ground layer, filling the basin, positioning of refugee (rocks), vegetation and fence.	We propose new ponds in: 1)43.2144, -2.9133; 2)43.2121, -2,9135; 3)43.2221, -2.9169; 4)43.2196, -2.9205, 5)43.2186, -2.9145.	Better after the summer or in the early winter, especially in continental regions .	Average cost: 5500€ per pond
Erradication of threats	Elimination of alien invasive species, wastes, rubbish. Reduction of speed in roads and paths and employ efforts in education.	Rubish and wastes should be eliminated from Fab1 and to control the loss of water in the surroundings of Ch1. To avoid traffic in the surroundings of the principal ponds.	Is better to act at the end of summer, but in case of emergency, in any moment. Education in schools should be conducted during the entire year, specially before the breeding season .	Average cost per intervention: 250€.
Monitoring	Anual monitoring of adults and tadpoles.	C-M-R should be conducted using photo-id (very cheap), and a anual surrounding survey is needed.	During march, april and may, once a week .	2500€ per year of monitoring.

5. Conclusions

1. The results of sampling the quarries and surroundings suggested that amphibian richness is optimal. In several sites, amphibians form very important populations, which could contribute migrants to other breeding sites. The detected species have shown very different ecological preferences depending on the type of r site.

2. The photo-identification and the C-M-R analyses suggest good colonization and positive population dynamics. However, some species are far from settling, which imply the necessity of focusing differently for each species. In addition, there are water bodies in the quarries with not-well preserved, which become into poor abundances.

3. Radio-tracking has function for P. perezi and allowed us to detect short displacements and a high philopatry to their breeding sites. However, these results should be taken with caution due to monitoring has been done out from the more dispersive period.

4. The connectivity analyses indicated that exist connection between the majority of the ponds of the quarries and with some important surrounding ponds, from where first colonization was possibly done. The models suggested the importance of focus efforts in adequate ecological corridors (by improving or creating new nodes); thus, amphibians could perfectly disperse all around the quarries and avoiding the high slopes.

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Project tags (select all appropriate):

This will be use to classify your project in the project archive (that is also available online)

Project focus:

- ☐Beyond quarry borders
- ☒Biodiversity management
- ☐Cooperation programmes
- ☐Connecting with local communities
- ☐Education and Raising awareness
- ☐Invasive species
- ☒Landscape management
- ☐Pollination
- ☐Rehabilitation & habitat research
- ☒Scientific research
- ☐Soil management
- ☒Species research
- ☐Student class project
- ☐Urban ecology
- ☐Water management

Flora:

- ☐Trees & shrubs
- ☐Ferns
- ☐Flowering plants
- ☐Fungi
- ☐Mosses and liverworts

Fauna:

- ☒Amphibians
- ☐Birds
- ☐Insects
- ☐Fish
- ☐Mammals
- ☐Reptiles
- ☐Other invertebrates
- ☐Other insects
- ☐Other species

Habitat:

- ☒Artificial / cultivated land
- ☐Cave
- ☐Coastal
- ☐Grassland
- ☐Human settlement
- ☐Open areas of rocky grounds
- ☐Recreational areas
- ☐Sandy and rocky habitat
- ☐Screes
- ☐Shrub & groves
- ☐Soil
- ☐Wander biotopes
- ☒Water bodies (flowing, standing)
- ☒Wetland
- ☐Woodland

Stakeholders:

- ☒Authorities
- ☒Local community
- ☐NGOs
- ☐Schools
- ☒Universities