Final Project Report (to be submitted by 30th September 2016)

1. Contestant profile

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2. Project overview

Title:	Stepping ponds: enhancement of connectivity for amphibians in riverside gravel pits
Contest:	Spanish QLA
Quarry name:	Áridos Sanz S.A.
Prize category:	☐ Education and Raising Awareness ☒ Habitat and Species Research ☒ Biodiversity Management ☐ Student Project ☒ Beyond Quarry Borders

Abstract

Amphibians are one of the most globally threatened taxa. In Europe, amphibians decline is mainly linked to habitat reduction and fragmentation. Gravel pits and other mining activities create floodable holes in the ground, that could be used for restoration porpoises. These cavities provide habitat opportunity for amphibians. The aim of this project was to evaluate the potential of the Áridos Sanz gravel pit to house amphibians and to increase landscape connectivity for this taxonomic group.

75 water bodies were characterized in Áridos Sanz gravel pit and its surroundings. They were characterized based on 27 attributes related to physical and hydrological conditions, water quality, vegetation, fauna and terrestrial uses and shelters. We defined a habitat suitability index based on species tolerance for each habitat attribute and its importance according to species requirements (for Pelophylax perezi, Pelobates cultripes, Pelodytes punctatus and Triturus marmoratus). Afterwards, we characterized habitat suitability and landscape connectivity for every species and proposed habitat improvement measurements which were evaluated in terms of their effectiveness.

Results showed that gravel pit habitats are more suitable for more generalist species (as P. perezi), which also showed best habitat connectivity. Gravel pit suitability and connectivity were lower for the other species. Proposed improvement measurements are: (1) to increase habitat connectivity through the construction of corridors and (2) to increase the suitability of existing habitats.

Two corridors, formed by different types of water bodies (ponds, pond systems and water troughs), were designed to connect isolated water bodies around the gravel pit: (1) Watt corridor, using an abandoned railway; and (2) Amundsen corridor, which connects the core water bodies in the gravel pit to the fluvial system “Riberas del Duero y sus afluentes” SCI. Results indicated that Amundsen corridor is more effective in connecting isolated ponds than Watt corridor. The cost of each corridor is around 4000-5000 €.

The design of habitat improvement measurement should rely on acting on those attributes (1) more important for amphibian development and (2) whose modification is possible. The construction of shallow areas, the reduction of the slope of shores and the building of sand heaps near the water bodies enhanced connectivity in a greater proportion than the corresponding increase in maximum quality of the landscape. The presence of exotic red crayfish (Procambarus clarkii) clearly hampers amphibian development. Thus, improvement habitat measures should be focused on preventing habitat invasion by this exotic species. In this regard, we tested in the Áridos Sanz gravel pit some experimental measures oriented to avoid habitat invasion: (1) the insulation of ponds' bottom, to prevent the formation of red crayfish's burrows, and (2) the construction of a fence that allows the transit of amphibians but not red crayfishes. The cost to improve habitat suitability across the gravel pit is between 1200 and 1700 €.

In the specific case of Epidalea calamita (natterjack toad), we found that this species colonizes shallow and ephemeral water bodies without vegetation, which are not usable by other species. Therefore, we have proposed specific management measures for this species: (1) make shallow scratchings at the foot of gravel stocks in order to increase water accumulation; (2) minimize machinery transit by delimiting or indicating water bodies with tadpoles; (3) remove pioneer vegetation, to prevent the colonization of other amphibians different from natterjack toad. In Áridos Sanz gravel pit, this type of environment is created by usual activity of exploitation on the extraction face and under material stocks, when watered.

The proposed habitat improvement measures are easily applicable to broad types of gravel pits worldwide. Small efforts in activity management and restoration planning would result in favouring amphibian populations in gravel pits. Moreover, gravel pits might play a pivotal role in amphibian's conservation as the only suitable habitat in adverse landscapes for amphibians (e.g. crops). In addition, these proposals contribute to the fight against the decline of amphibian populations and transmit a commitment to preserve this taxon.

1. Introduction

Human activity is making a large footprint on the planet. The impact is such that in the 35th International Conference on Geology (August 2016) it was settled that the Holocene must make way to a new geological period: the *Anthropocene* [**1**]. The term "Anthropocene" was proposed in 2000, because human modification of the global environment had become significant enough to warrant termination of the current Holocene [**2**]. These environmental changes were conceptualized as nine global priorities (e.g. global warming and oceanic acidification) that were called *Planet Boundaries* [**3**]. Four out of nine boundaries have been already exceeded and one of them is the loss of biodiversity [**4**]. Loss of plant and animal species due to human activities have been more rapid in the past 50 years than at any time in human history, increasing the risks of abrupt and irreversible changes to ecosystems [**4**]. Amphibians are one of the most endangered taxonomic groups [**5**] and populations decline has been noticed at the global scale [**6**]. Amphibian' species extinction is happening at an unprecedented rate [**5**], which has caused a global alarm and concern about the conservation of this group [**7**]. In Europe, the main cause of amphibian population decline is the loss of habitat [**5**].

However, it is possible to reverse the current global degradation [**8**], using a wide range of solutions. Conservation, ecological restoration or sustainable development are part of these initiatives that humans should bound to ecosystem use, to balance the need of natural resources against biodiversity conservation.

The environmental impacts of mining are really noticeable at local and regional scale because of geomorphology modification. The exploitation of geological resources, including gravels pits, deals with an essential need for society, but involves irreversible changes in the landscape. However, this activity also helps biodiversity due to its capacity to create new habitats [**9,10,11,12**]. This fact means new survival opportunities for some taxonomic groups as the amphibians. Pits and quarries may act as *oasis* for these animals when they are located in unfavourable landscapes (i.e. agricultural landscapes). In this way, pits and quarries could contribute to conservation of endangered animals like amphibians [**13**].

2. Objectives

Regarding gravel pits capacity as supporting for amphibian populations, we study the specific situation of Áridos Sanz Gravel Pit (La Cistérniga, Spain). The main objective is to evaluate the gravel pit potential to host amphibians and to contribute to landscape connectivity for these species. The specific objectives of this work, under the framework of the international contest *Quarry Life Award 2016*, are:

1. To identify the amphibian species living in the gravel pit and the adjacent areas.
2. To characterize their habitat requirements and to study the habitat suitability.
3. To evaluate the current connectivity in the gravel pit and its surroundings (that includes the "Riberas del Duero y sus afluentes" SCI), for each amphibian species.
4. To design specific connectivity enhancement measures in order to improve the connectivity during and after operations.
5. To develop a monitoring plan to evaluate the effectivity of proposed measures.
6. To elaborate a graphic report about the results from project in order to popularize and raise awareness of amphibian decline and its consequences[1].

[1] The graphic report "Guide for integrated management of amphibians in gravel pits" (hereafter **Amphibian Monitoring Guide** is available at https://goo.gl/shqu5v

3. Materials and methods

3.1. Project area

Gravel pit Áridos Sanz (La Cistérniga, Spain) is within an agricultural landscape, among industrial and peri-urban zones nearby Valladolid city, and "Riberas del Duero y sus afluentes" SCI (**Figure Annex 1**). The gravel pit is bounded on the north by Duero Canal and on the south by river Duero. It is settled in the river terraces. The climate is temperate continental Mediterranean with average temperature of 12,6 ºC and 433 mm of annual rainfall. In the northern part of the gravel pit, tertiary arkoses come to the surface, whereas in the southern part, the arkoses are covered by quaternary alluvial deposits, mainly quartzite gravels.

3.2. Identification and characterization of potential habitats for amphibians

All bowls were identified searching zones with a depth(m)/area(m^2) ratio >0,6 in a digital elevation model (DEM) of 5 m resolution. Each bowl was field checked to verify if it was a water body or it was not. After this process, 75 water bodies were found to be potentially used by amphibians.

Each water body was characterized by 27 attributes, grouped by six categories (**Table 1**). Attributes selection was based in their importance for amphibian reproduction and larvae development, according to specific literature.

Table 1*:Attributes for habitat characterizacion*

Physical attributes	(1) type; (2) slope; (3) maximum depth
Hydrological attributes	(4) regime; (5) stream speed
Water quality	(6) temperature; (7) pH; (8) conductivity; (9) turbidity; (10) nitrates; (11) phosphates; (12) COD
Vegetation	(13) shading; (14) shore with vegetation; (15) covered water sheet; (16) floating plants; (17) *Characeae*; (18) *Ranunculus*
Fauna	(19) red crayfish; (20) fishes; (21) birds
Surrounding elements	(22) number of shelters; (23) number of sandbanks; (24) % crops; (25) % grasslands; (26) % shrubs; (27) % forest

Slope and maximum depth were measured using ArcGis 10.0 and DEM of 5 m resolution. Water was sampled and analysed in the Environmental Analysis Area of Catholic University of Ávila and the Water Research and Technologic Development Centre, in order to measure the water quality attributes. Forest, shrub, grassland and crop cover was calculated within a buffer area of 40 m around the water bodies, using the land use map SIOSE2005, that was previously updated by hand, and ArcGis 10.0. Other attributes were scored during the field work.

3.3. Amphibian sampling

Tadpoles were sampled with a telescopic sleeve of 4 mm mesh size. Sampling was performed in different microhabitat within each water body, according to different depths, distance to the shore or vegetation. Captured tadpoles were identified in plastic trays and, after that they were released to their habitat. Adults were sampled at night, along transects by counting sightings and also by amphibian calls.

3.4. Habitat suitability calculation

A tolerance value (T_i) was defined for every attribute value on every habitat, according to specialized literature on considered amphibian species. Maximum tolerance was defined as 100 and minimum tolerance as 0 (**Figure Annex 2**). Moreover, the attribute importance for species development and breeding (I_i) was valuated between zero and one (**Figure Annex 3**). Then, habitat suitability was calculated for every species following **Equation 1**.

Equation 1. $$Id = \sum_1^{27} T_i \times I_i$$

3.5. Connectivity assessment

Connectivity analysis was done with ArcGis 10.0 and CONEFOR Sensinode 2.6 [**14**]. CONEFOR is based on two concepts: (1) *maximum quality* (Q) that represents the optimum connectivity condition, happening when all habitat plots are joint in a single one, and (2) *equivalent connected quality* (ECQ), that represents the real connectivity condition of the landscape.

Dispersion distance of species, one of the inputs to calculate connectivity, is fairly unknown for amphibian species in Iberian Peninsula [**15**]. Some studies in Europe show that dispersion distances vary widely [**16**]. For this reason, three dispersion thresholds were used (250, 500 y 1000 m) [**15**], in order to represent the best and worst case scenarios.

Connectivity was calculated for every species. It was estimated according to the current status of Áridos Sanz gravel pit, and according to different improved scenarios that were designed (i.e. landscape with corridors and with habitat suitability improvement), always in the dispersion threshold more restrictive (250 m). Connectivity contribution of isolated areas to whole landscape connectivity was compared to current situation to test corridor effectivity. Landscape maximum quality increment was compared to equivalent connected quality increment in order to test habitat suitability improvements.

4. Results: current scenario

4.1. Amphibians

Five species were found in the gravel pit and its surroundings (**Table 2**, **Figure Annex 4**)

Table 2*. Amphibians observed in Áridos Sanz gravel pit and its surroundings*

Scientific name	Common name	Number of water bodies	
		Within the gravel pit	Outside the gravel pit
Pelophylax perezi	Iberian water frog	8	12
Pelobates cultripes	Western spadefoot toad	2	9
Pelodytes punctatus	Common parsley frog	1	1
Triturus marmoratus	Marbled newt	1	2
Epidalea calamita	Natterjack toad	7	3

The natterjack toad (*Epidalea calamita*) is colonising specie that breeds in very ephemeral water bodies, as post-rainfall puddles [**17**]. This way of living hinders identifying potential habitats for this specie. Because of that we are not analysing connectivity for *E. calamita*, but a specific management proposal was designed (see **Section 6**).

4.2. Habitat suitability

Habitats in the gravel pit are mainly propitious to *P. perezi* (**Figure Annex 5a**). This result is consistent with the generalist livelihood of the specie. It has a great tolerance to permanent water bodies, steep shores and predator's presence [**18**], which are prevailing attributes in the gravel pit. Other species (*P. cultripes, P. punctatus, T. marmoratus*) that are specialist, find mainly suitable habitats outside of the gravel pit (**Figure Annex 5b, c and d**) and they could only use the floodable meadows inside the gravel pit. *P. cultripes* and *P. punctatus* prefer for breeding shallow temporary water bodies [**19,20**], but *T. marmoratus* needs permanent deep water bodies with proper vegetation [**21**], what compromised tadpole development in the gravel pit.

4.3. Connectivity

Landscape connectivity is greater for *P. perezi*, followed by *P. punctatus, P. cultripes* and finally, *T. marmoratus* (**Table 3**). Long distances with water bodies outside the gravel pit and low suitability of the habitats inside the gravel pit are significantly diminishing connectivity for the three specialist amphibians.

***Table 3**. Landscape connectivity the amphibians detected. Q=maximum quality; ECQ_{250}=equivalent connected quality with 250 m; ECQ_{500}= equivalent connected quality with 500 m; ECQ_{1000}= equivalent connected quality with 1000 m.*

Species	Q	ECQ_{250}	ECQ_{500}	ECQ_{1000}
Pelophylax perezi	5974	4183	4668	5128
Pelobates cultripes	5276	3582	4024	4459
Pelodytes punctatus	5492	3747	4205	4652
Triturus marmoratus	5099	3495	3918	4330

5. Assessed proposals

According to the scenario in **Section 4**, two action lines were proposed: (1) habitat creation in order to close the gaps between the gravel pit and isolated water bodies in the surroundings; (2) suitability improvement in water bodies in the gravel pit, to enhance its efficiency as connexion points for amphibians.

5.1. Habitat creation

Two corridors were designed (**Figure 1**): *Watt* corridor[2] *and Amundsen* corridor[3]. They are formed by different structures and actions (**Table 4**), more detailed described in the **Amphibian Monitoring Guide** (https://goo.gl/shqu5v), that are located 250 m apart one from each other. *Watt* corridor runs in east-west direction because it is designed over an old railway. If it is constructed, it would be necessary the collaboration with ADIF, the Spanish National Administrator of Railway Infrastructures. *Amundsen* corridor runs from the main concentration of water bodies in the gravel pit to the south, where “Riberas del Duero y sus Afluentes” SCI is located.

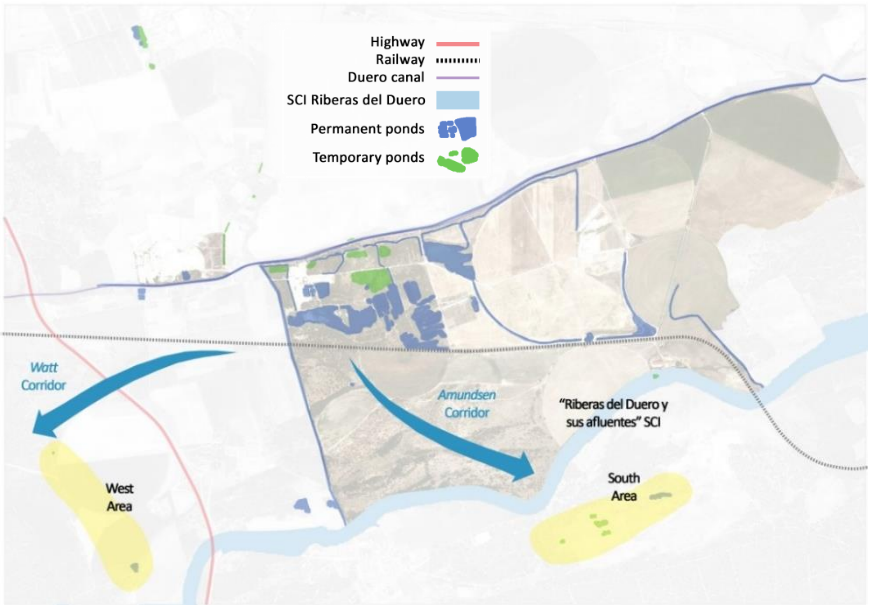

***Figure 1**. Watt corridor and Amundsen corridor. In yellow, isolated water bodies whose connectivity would be improved*

[2] Named for the inventor of water steam engine James Watt
[3] Named for Roald E. G. Amundsen, the man who led the expedition that first reached South Pole

Table 4. Structures and actions that form the corridors. The construction methods are described in the ***Amphibian Monitoring Guide*** *(https://goo.gl/shqu5v)*

		Watt	*Amundsen*
Pond systems	Set of three ponds: a seasonal pond, a semi-permanent pond and a permanent pond		✓
Ponds	A seasonal or semi-permanent pond, where space constrains do not allow to build a pond system	✓	
Water troughs	Bricks and cement water troughs, with a ramp in order to facilitate amphibian moving in and out	✓	✓
Holes for old catenary supporting	Holes fitting using ramps of phenolic plywood in order to facilitate amphibian moving out	✓	

Connectivity assessment of new scenarios showed that *Watt* corridor fails to effectively connect water bodies in west area **(Table 5**); however, it is a valuable element as linear connexion axis for the landscape. Moreover, putting the old railway to a new use will allow preserving its ethnographic value. *Amundsen* corridor effectively connects the southern water bodies to the habitat core in the gravel pit (**Table 5**).

Table 5*. Corridor effectiveness for improving connectivity. $dECQ_{initial}$=initial connectivity of isolated areas; $dECQ_{final}$=connectivity of isolated areas if corridor is constructed; ∆dECQ=connectivity improvement with the corridor.*

Species	***Watt* / West Area**			***Amundsen* / South Area**		
	$dECQ_{initial}$	$dECQ_{final}$	**∆dECQ**	$dECQ_{initial}$	$dECQ_{final}$	**∆dECQ**
Pelophylax perezi	10,4	10,15	**-0,25**	55,27	62,46	**7,19**
Pelobates cultripes	11,43	11,25	**-0,28**	50,96	71,49	**20,53**
Pelodytes punctatus	12,15	11,94	**-0,21**	51,81	71,93	**20,12**
Triturus marmoratus	10,13	9,91	**-0,22**	47,14	66,54	**19,4**

Estimated project timing and costs for corridor's construction are included in **Table 6**. Success indicators for every single structure and action along the corridor (**Table 4**) are explained in **Table Annex 1**. Detailed budgets are included in **Table Annex 2**.

Table 6*. Estimated project timing and costs for corridor's construction, and success indicators for every structure and action that forms the corridors.*

	Timing	*Costs*	*Success indicators*
Watt	6-8 days	4.000–4.500 €	Species richness, Aquatic vegetation, Water level, Water quality, Presence of dead amphibians
Amundsen	5-7 days	4.500-5.000 €	

5.2. Habitat improvement

Seven out of 27 attributes for the suitability of amphibian habitat (**Figure Annex 3**) were selected according to (1) their importance for the species as a whole, and (2) their key role for at least one species (**Table 7**). Actions were designed to improve mainly these selected attributes in current habitats, in order to optimise the allocation of efforts and resources.

Table 7. *Most important attributes for amphibians and action posibility. ≥0,75/4 spp.=importance for species as a whole higher than 0,75; ≥0,90/1 sp.=importance higher than 0,90 for at least one species.*

Attribute	≥0,75 / 4 spp.	≥0,90 / 1 sp.	Is it possible to act?
Red crayfish	●	●	?
Fishes	●	●	✓
Stream speed	●	●	×
Slope		●	✓
Type		●	×
Regime		●	✓
Sandbanks		●	✓

Four out of seven selected attributes ((1) *abundance of fishes*; (2) *slope*; (3) *regime*; and (4) *sandbanks*) can be easily improved (**Table 8**) by simple measures. These actions are proposed for current water bodies in the gravel pit that were constructed after restoration of some areas. They are human-made and they could be replicated in future restorations. The integration of the proposed measures into the restoration design process will enhance amphibian populations form the beginning.

Table 8. *Measures for habitat suitability improvement in the gravel pit, and the improved attributes. The procedures for measure implementation are described in the* ***Amphibian Monitoring Guide*** *(https://goo.gl/shqu5v)*

	Fishes	Slope	Regime	Sandbanks
Reduce shore's slope *in order to facilitate amphibian moving in and out of the water bodies*		✓		
Create shallow areas *(15-20 cm) near the shores of permanent water bodies. Thus, the water body will have areas (1) with seasonal regime (for specialist amphibians), and (2) with poor access to fishes (which reduces predation over the amphibians)*	✓		✓	
Build 1-2 ***sand heaps*** *in a 10 m width area around the water bodies, in order to create shelters mainly for Pelobates cultripes*				✓

Theoretical improvement of habitat suitability in the gravel pit enhances connectivity for all the amphibian species (**Table 9**). Connectivity enhancement (ECQ) substantially exceeds associated changes in maximum quality (Q). This confirms that small measures would enhance in a synergic manner the connectivity for amphibian populations.

Table 9. *Maximum quality improvement ($\%Q_{imp}$) and connectivity improvement ($\%ECQ_{imp}$) after improving habitat suitability.*

Species	$\%Q_{imp}$	$\%ECQ_{imp}$
Pelophylax perezi	0,19	0,24
Pelobates cultripes	1,25	1,54
Pelodytes punctatus	0,57	0,71
Triturus marmoratus	0,72	0,9

In spite of red crayfish (*Procambarus clarkii*) predation has an important impact on amphibian populations (**Table 7**), there are not documented effective measures to reduce damage when it has expanded throughout the landscape. Because of that, experimental measures are proposed to improve this habitat attribute. *P. clarkii* is a non-native species in Spain that has spread very quickly [**22**], due to its adaptation capacity to the hydrologic regime of ponds in Iberian Peninsula. During summer drought the red crayfish is able to burrow into deep and wet layers of the soil. It is also able to move over dry land long distances in order to reach new water bodies [**23**]. Moreover, *P. clarkii* is an active predator that produces collapse for amphibian populations [**24**]. The red crayfish is in almost every permanent water body in Áridos Sanz gravel pit (**Figure Annex 6**). Thus, any created habitat will be quickly affected by red crayfish arrival.

A set of "non-crayfish" measures are proposed to avoid impacts of *P. clarkii* (**Table 10**). The efficiency of these measures is being tested in Áridos Sanz gravel pit. Two identical pond systems were built, with the hole covered by a plastic liner. One of them is surrounded by a wired mesh. Details of construction steps are included in the **Amphibian Monitoring Guide** (https://goo.gl/shqu5v). Monitoring and results of the field experiment are beyond temporal limits of Quarry Life Award 2016. It is expected that, during the spring of 2017, amphibians will arrive to the new ponds and, after 2-4 years, conclusive results will be achieved. This experiment is an innovative approach against *P. clarkii* invasion in Europe.

*Table 10: "Non-crayfish" measures. Details of construction steps are included in **Amphibian Monitoring Guide** (https://goo.gl/shqu5v)*

Measure	Material	Function
Insolation of pond hole	*0,25 mm thickness plastic liner*	To prevent that the red crayfish digs into deeper soil horizons when the pond gets dry
Fencing	*41 mm size wired mesh*	To allow amphibian transit but to prevent that red crayfish goes into the pond system

Implementation timing and costs for habitat suitability improvement actions depend on the degree of improvement desired. **Table 11** includes a estimation of time and costs for the designed scenario in Áridos Sanz. Success indicators for habitat enhancement actions are explained in **Table Annex 1**. Detailed budgets are included in **Table Annex 3**.

***Table 11**. Estimated timing and costs for habitat suitability improvement actions, and success indicators for structures and actions.*

	Timing	*Costs*	*Success indicators*
Reduced slopes, shallow shores and sand heaps	2-4 days	800–1.200 €	Species richness, Aquatic vegetation, Water level, Presence of red crayfish, Presence of specialist species
"Non-crayfish" measures	1-2 days	400-500 €	

6. A special case: the natterjack toad

The natterjack toad (*Epidalea calamita*) is not included in connectivity analysis with other species because of its different requirements of habitats. This amphibian prefers shallow, ephemeral and sunny water bodies, with gentle slopes and low vegetation cover, for breeding [**25,26**]. This, together with the high impact that competence with other amphibian species causes on natterjack toad populations [**27**], causes this specie to be pioneer in colonization of first stages of ecological succession [**28**].

Natterjack toad tadpoles are very abundant in Áridos Sanz gravel pit. They were located in floodable areas, post-rainfall roads puddles, and above all in water bodies that mining activity creates: the extraction face and the puddles at the foot of gravel stocks (that are formed by filtration of irrigating the materials) (**Figure Annex 5**e). Gravel pit's potential to create new habitats for natterjack toad has already been studied mainly in the United Kingdom and in northern Europe [**13**], due to populations in these regions are more threatened. A set of measures are proposed in order to facilitate *E. calamita* populations development, without disturbing mining activity in gravel pits, but specifically in Áridos Sanz gravel pit (**Table 12**).

Table 12. Measures for enhancing Epidalea calamita populations in gravel pits. The procedures for measure implementation are described in the ***Amphibian Monitoring Guide*** *(https://goo.gl/shqu5v)*

	Extraction face	Stocks
Create 3-4 shallow and small scratchings on the soil (20-25 cm depth and 2-4 m² surface) in order to keep infiltrated irrigating water		✓
Be aware for tadpoles' presence, delimit as far as possible the occupied puddles and prevent the movement of machinery in these water bodies	✓	✓
Remove vegetation around water bodies where Epidalea calamita is, because vegetation attracts other amphibian species		✓
Be aware that water points with tadpoles do not dry during the hottest days		✓

Measures have a very low cost or no cost **(Table 13)**, because is not necessary to make any monetary investment in materials or other items. Detailed budget is included in **Table Annex 4**. The timing is indeterminate, because there are little actions, but it is necessary being constantly aware of them and taking care during breeding period, from February to June [**29**]. Success indicators are explained in **Table Annex 1**

Table 13*. Estimated timing and costs for enhancing Epidalea calamita populations, and success indicators.*

	Timing	*Costs*	*Success indicators*
Measures for enhancing *E. calamita* populations	Short and intermittent actions during breeding period	< 10 €	Aquatic vegetation, Water level, Presence of natterjack toad

8. Benefits

This QLA project and the designed proposals bring direct benefits not only for the conservation of the biodiversity, but also for corporate responsibility of mining company and for society in general (**Table 14**).

Table 14*. Benefits resulting from the project and the proposals*

BIODIVERSITY	1. Proposals increase connectivity for amphibian species and strengthen the gravel pit as a source and suitable habitat for amphibians and as a key habitat connecting element.
	2. Proposals may encourage the emergence of other amphibian species, cited in the past in the same area by Spanish Herpetological Association but not detected during samplings, as Alytes obstetricans, Hyla molleri, Discoglossus galganoi and Pleurodeles waltl.
	3. Small and low-cost measures would result in increasing the presence and breeding of the natterjack toad in gravel pits.
	4. The reproductive success of amphibians and the consequent population growth, as well as the general habitat improvement, would attract other animals such as snakes, turtles, birds and little mammals and would contribute to increase biodiversity.
SOCIETY	1. The generated knowledge on old railway reutilization, on dealing with invasive species as the red crayfish, and amphibian management in gravel pits, could be used in future similar situations.
	2. Abandoned railways are in process of progressive dismantling. This means the loss of historical and ethnographic elements deeply rooted in society, especially at local level. Reutilization proposals as biological corridors would provide a new application to these connecting structures.
	3. Transformation of degraded mining sites in species-rich environments involves a change in local people's perception of these degraded sites, because past environmental values would be partly restored.
	4. Proposed success indicators are tools for society in order to assess and verify environmental obligations of mining companies.
	5. The development of the proposed measures involves a contribution to the fight as a society for the preservation of planet's biodiversity and the maintenance of ecosystem services that biodiversity provides (e.g. plague control)

	6. Monitoring the evolution of amphibian populations and their ethology could serve as an early regional indicator for global change, due to sensitivity of these animals to climate variations.
COMPANY	1. The protocol for the construction of suitable water bodies for amphibians, adapted to gravel pit's tools and resources, would be very useful for restoration, maintenance tasks and assessment of gravel pit impacts and benefits on biodiversity.
	2. Analysis and procedures performed in this project are easily replicated to other gravel pits, both in Spain and other countries. The connectivity analysis could serve as the basis for future restoration actions.
	3. Proposals can be incorporated both during operation and restoration, which would generate actions that favour amphibians throughout the whole life cycle of the gravel pit.
	4. The creation of a network of gravel pit that follow the same protocols on biodiversity assessment, as field labs, could provide information about conservation status and population trends of amphibians, at national and international scale.
	5. Ability to incorporate to "Rector Plan on Biodiversity" goodness of gravel pit for amphibians, either as a generator of favourable conditions for the conservation of natterjack toad habitat, or as a connecting element in the landscape for the other analysed species.
	6. The success indicators based on amphibian populations could be extrapolated as quality indicators of mining itself.
	7. The development of this project and the proposals which are carried out, provide a better corporate imagen.
	8. Interactions with public administration are created, through involving them in projects such as the rehabilitation of the abandoned railway. In addition, proposals could be the base for environmental education activities involving local government with the company, to show what is being done in the gravel pit.

8. Conclusions

1. Connectivity for Amphibians in Áridos Sanz gravel pit and its surroundings for generalist species (e.g. *Pelophylax perezi*) is higher than connectivity for species with further habitat requirements (e.g. *Triturus marmoratus*)
2. *Amundsen* corridor is more effective in connectivity improvement than *Watt* corridor. However, Watt corridor has other important benefits, as the reutilization of railway old infrastructure and its lineal character.
3. A small effort in suitability improvement of current habitats in the gravel pit would lead to great improvements in amphibian connectivity.
4. Predators (red crayfish and different fishes) are key elements that limit amphibian development. Due to a lack of strategies to avoid predation and expansion of the exotic red crayfish, we propose innovative management approaches to limit the impact over amphibian populations: fencing free-crayfish ponds with a double mesh and the insulation of ponds' bottom
5. Gravel pits promote *Epidalea calamita* breeding, due to the ephemeral water bodies and disturbed areas that are created during normal functioning in gravel pits. Low-cost measures (i.e. shallow scratchings, minimize machinery transit, remove pioneer vegetation) could enhance even more the abundance of this specie.

9. Acknowledgements

Thanks to HeidelbergCement Spain for organizing the contest, particularly to José Ignacio Cañas for the willingness to help. We also thank Áridos Sanz S.A., particularly José Manuel Rodríguez, for their collaboration, the courtesies and mainly for putting up with us. We want to thank Tormes Foundation, Raúl, Victor and Ángel for helping with the construction of the pond systems and for their pieces of advice. Thanks to Gonzalo Alarcos for joining to a group of strangers to find tadpoles and toads, like everyone else. Finally, we thank to others who helped us to complete this project: Flashito, Teresa, Juan Antonio, Sergio, Óscar, Alcores 404 Scout Group, Antonio, Olaia and Enrique. Thanks to all of you!

To be kept and filled in at the end of your report

Project tags (select all appropriate): This will be use to classify your project in the project archive (that is also available online)	
Project focus: ☒Biodiversity management ☐Cooperation programmes ☐Education and Raising awareness ☒Endangered and protected species ☐Invasive species ☐Landscape management - rehabilitation ☐Rehabilitation ☐Scientific research ☐Soil management ☐Urban ecology ☐Water management Flora: ☐Conifers and cycads ☐Ferns ☐Flowering plants ☐Fungi ☐Mosses and liverworts Fauna: ☒Amphibians ☐Birds ☐Dragonflies & Butterflies ☐Fish ☐Mammals ☐Reptiles ☐Spiders ☐Other insects ☐Other species	Habitat: ☐Cave ☐Cliffs ☐Fields - crops/culture ☐Forest ☐Grassland ☐Human settlement ☐Open areas of rocky grounds ☐Recreational areas ☐Screes ☐Shrubs & groves ☐Soil ☐Wander biotopes ☒Water bodies (flowing, standing) ☐Wetland Stakeholders: ☒Authorities ☒Local community ☐NGOs ☐Schools ☐Universities

ANNEX: Literature, list of figures and tables

Literature

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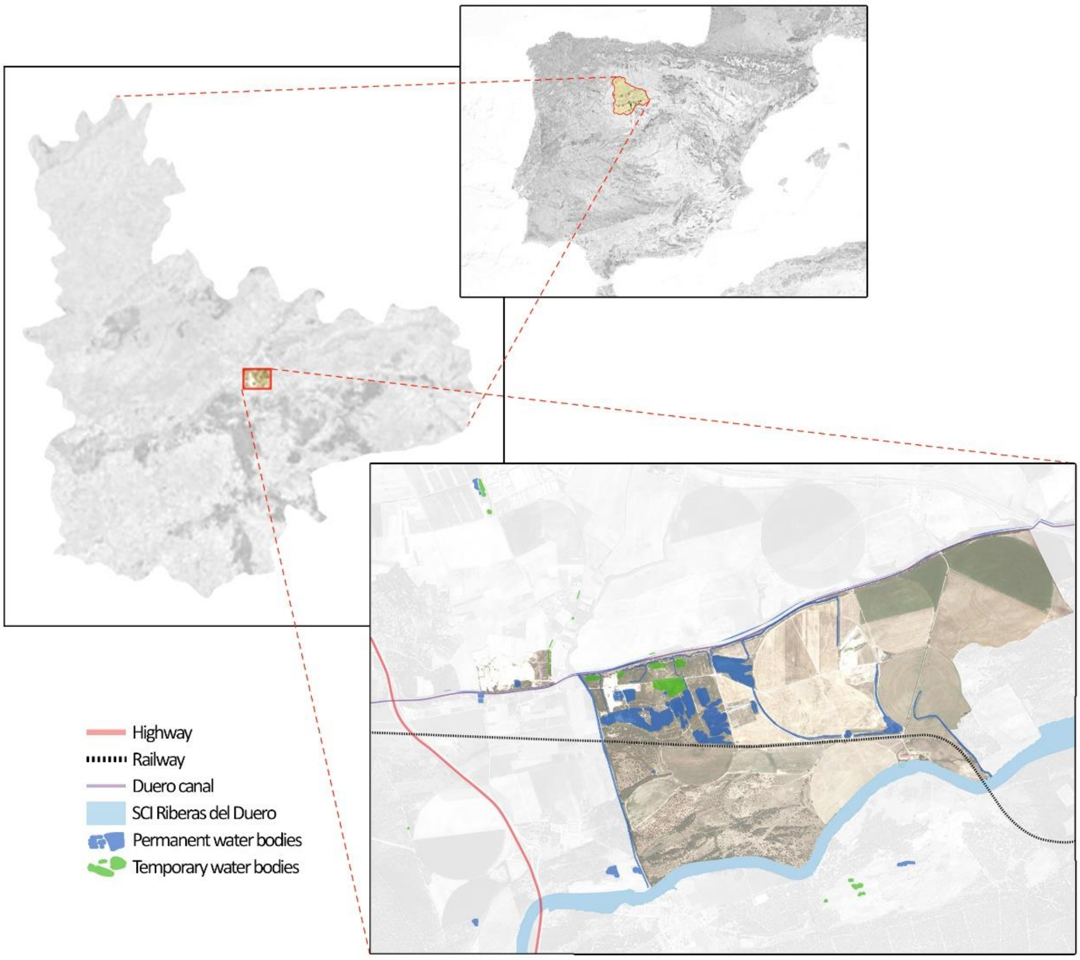


Figure Annex 1. *Geographical location of Áridos Sanz gravel pit and water bodies in the landscape.*

Figure Annex 2. *Tolerance functions for 27 habitat attributes according to the preferences of Pelophylax perezi, Pelobates cultripes, Pelodytes puntactus and Triturus marmoratus*

Figure Annex 2. *(Cont.) Tolerance functions for 27 habitat attributes according to the preferences of Pelophylax perezi, Pelobates cultripes, Pelodytes puntactus and Triturus marmoratus*

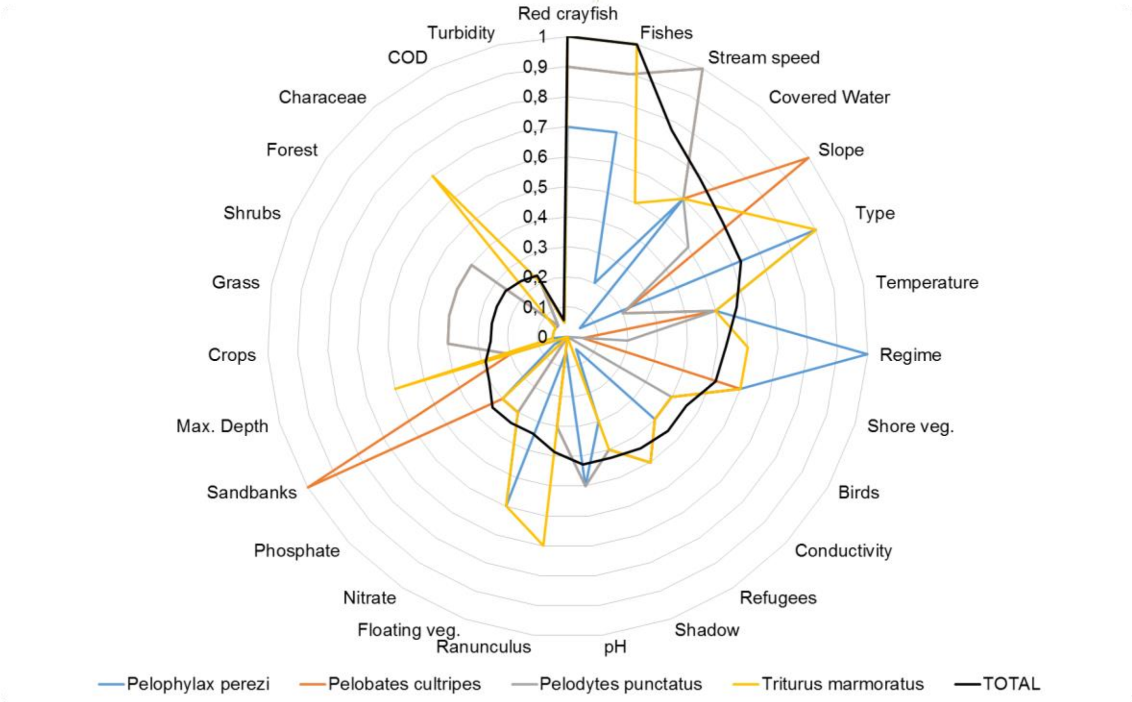


Figure Annex 3. *Importance of each habitat attribute for Pelophylax perezi, Pelobates cultripes, Pelodytes punctatus and Triturus marmoratus*

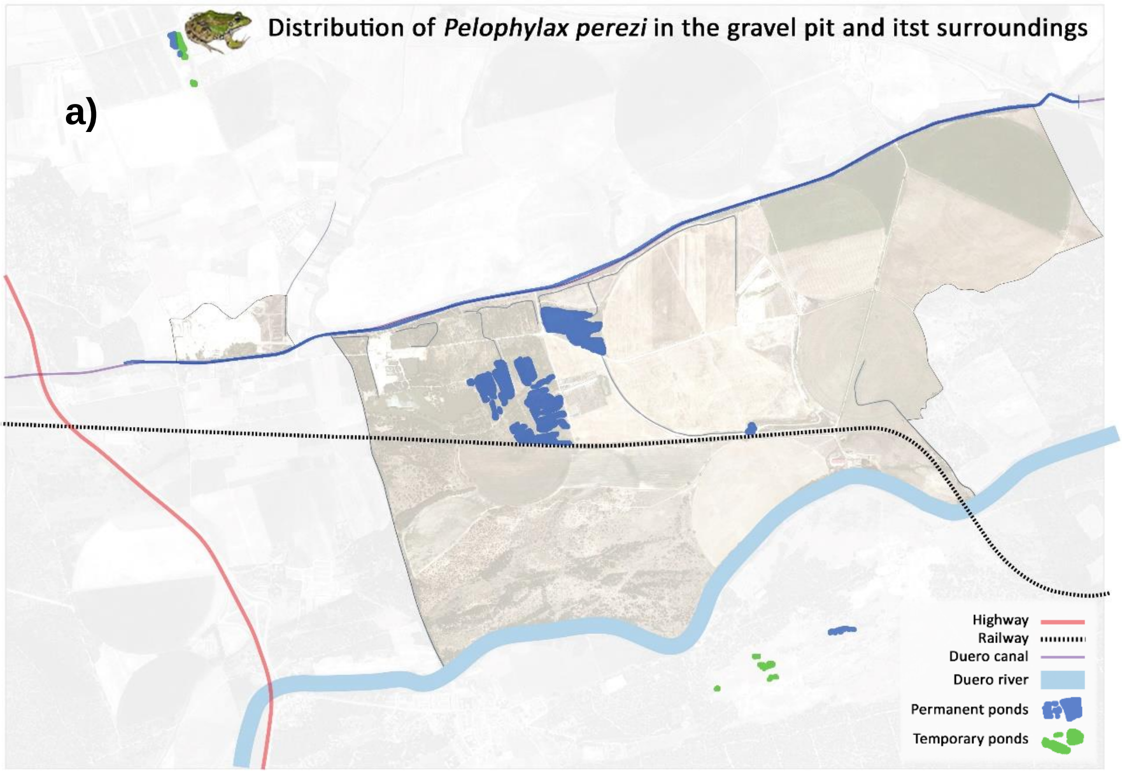
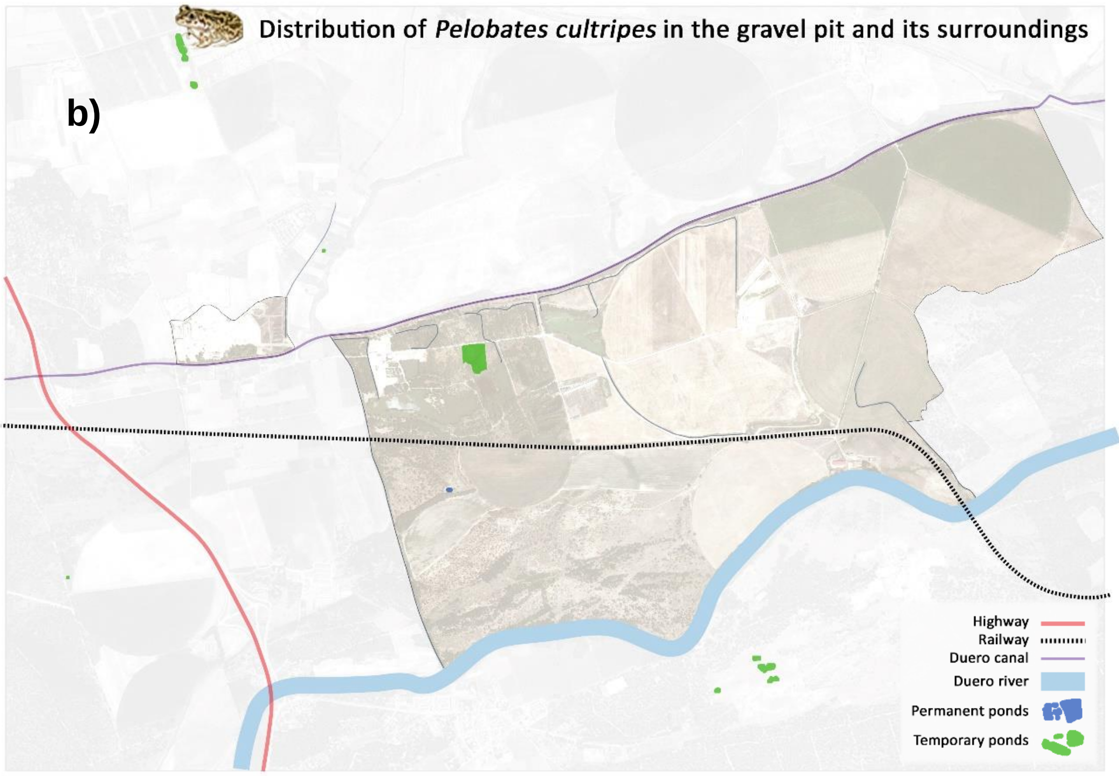


Figure Annex 4. *Amphibian distribution in the gravel pit and its surroundings: (a) Pelophylax perezi; (b) Pelobates cultripes; (c) Pelodytes punctatus; (d) Triturus marmoratus; (e) Epidalea calamita*



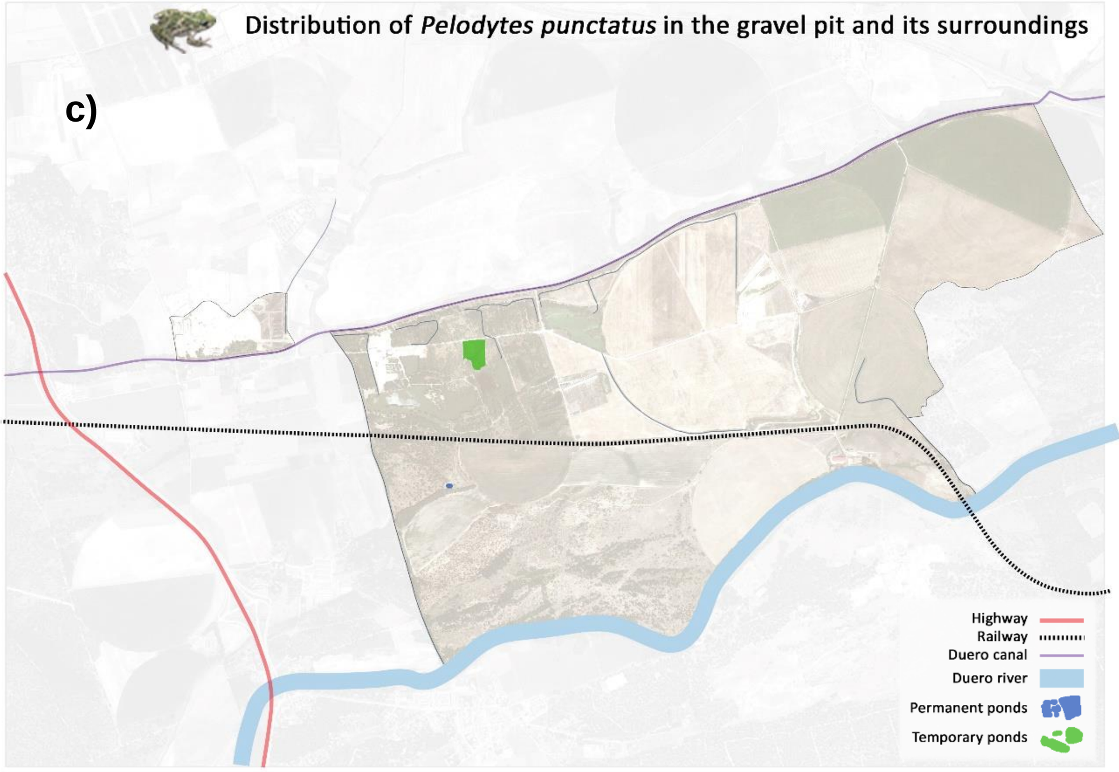
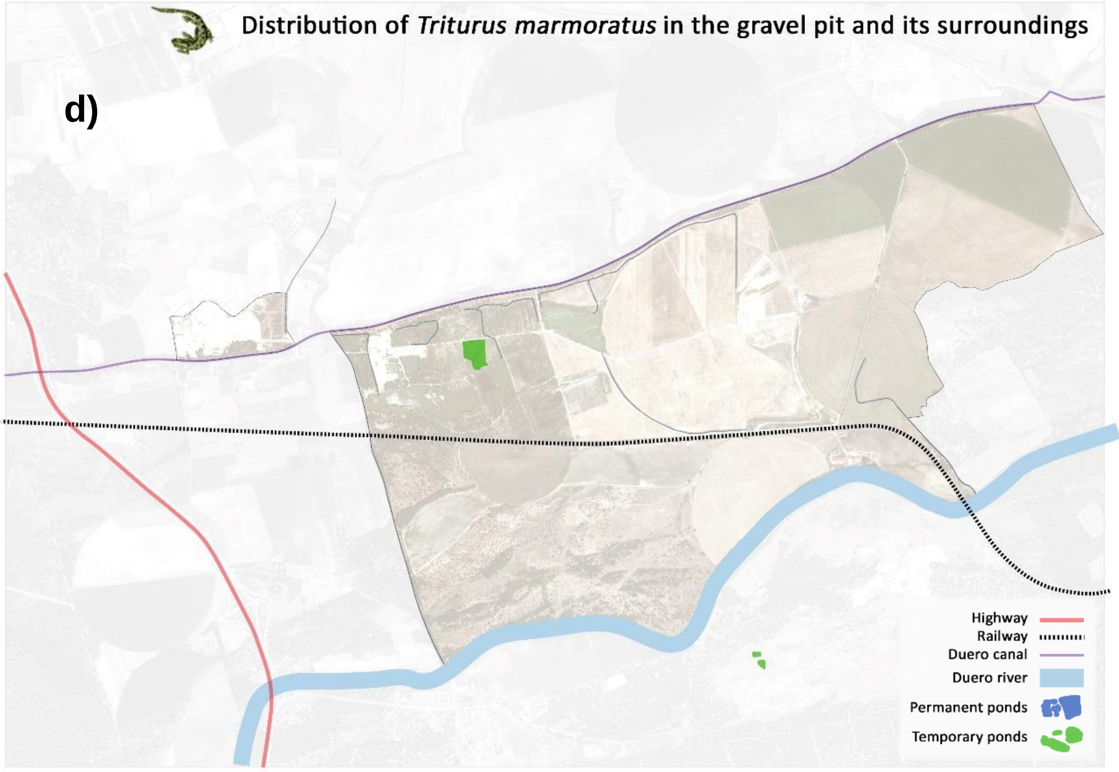


Figure Annex 4. *(Cont.) Amphibian distribution in the gravel pit and its surroundings: (a) Pelophylax perezi; (b) Pelobates cultripes; (c) Pelodytes punctatus; (d) Triturus marmoratus; (e) Epidalea calamita*



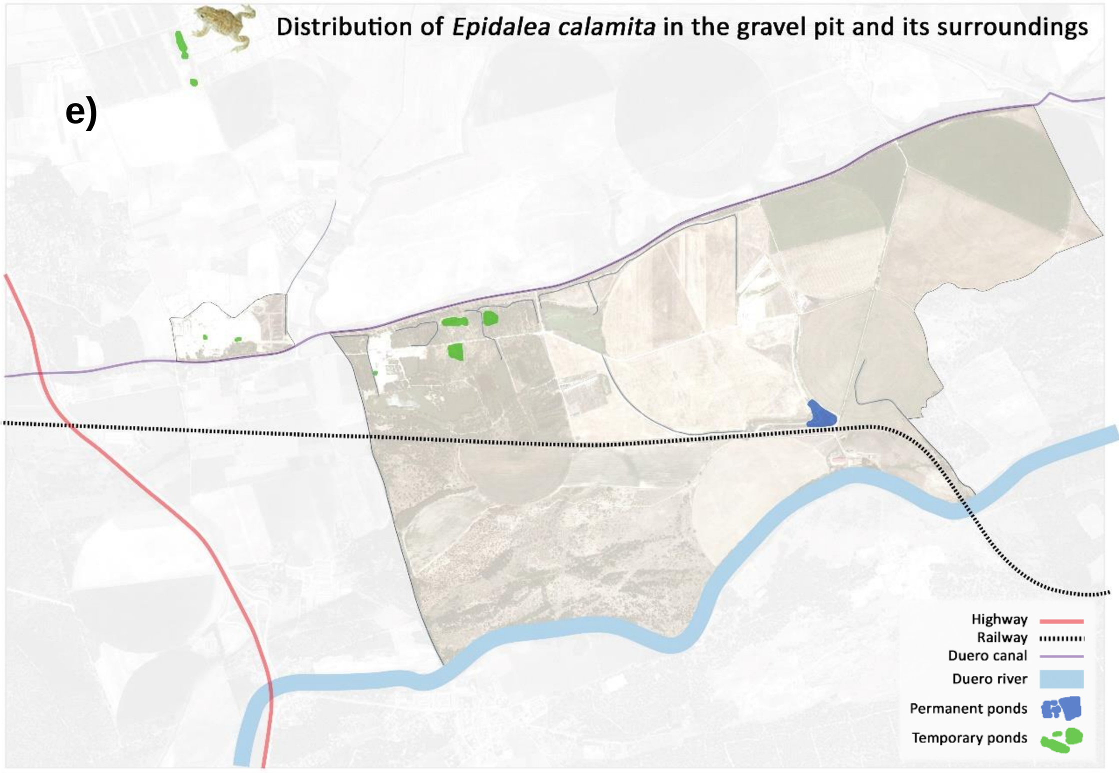
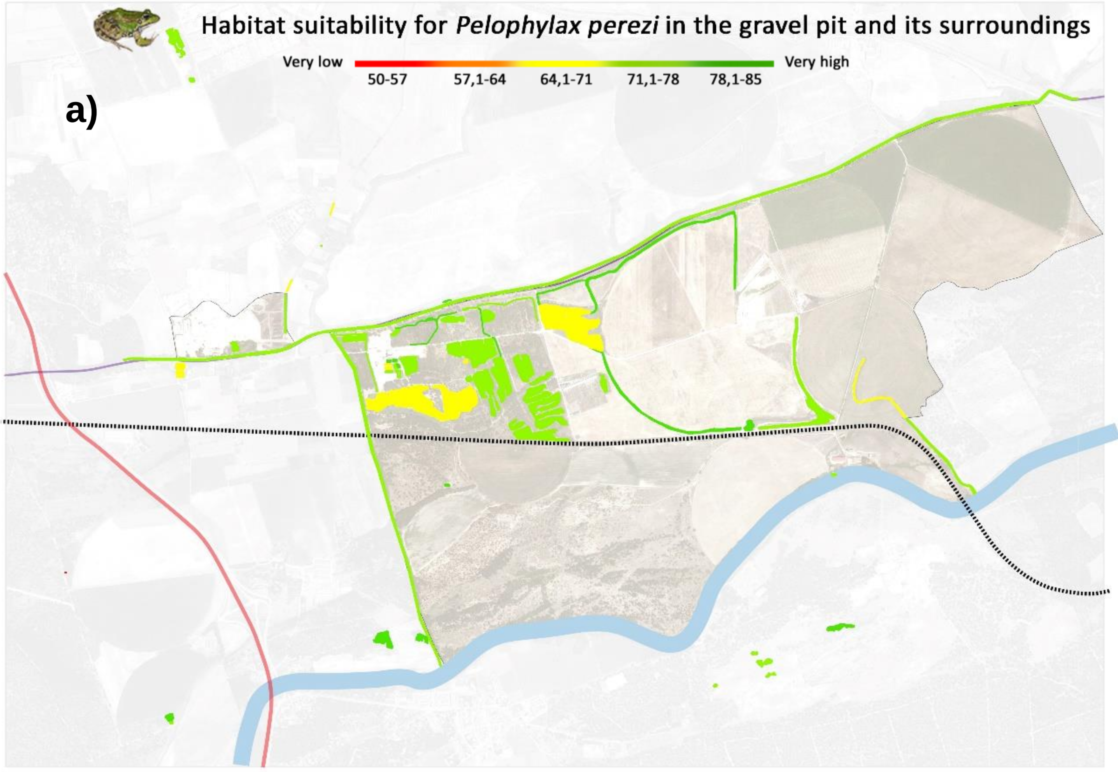


***Figure Annex 4**. (Cont.) Amphibian distribution in the gravel pit and its surroundings: (a) Pelophylax perezi; (b) Pelobates cultripes; (c) Pelodytes punctatus; (d) Triturus marmoratus; (e) Epidalea calamita*



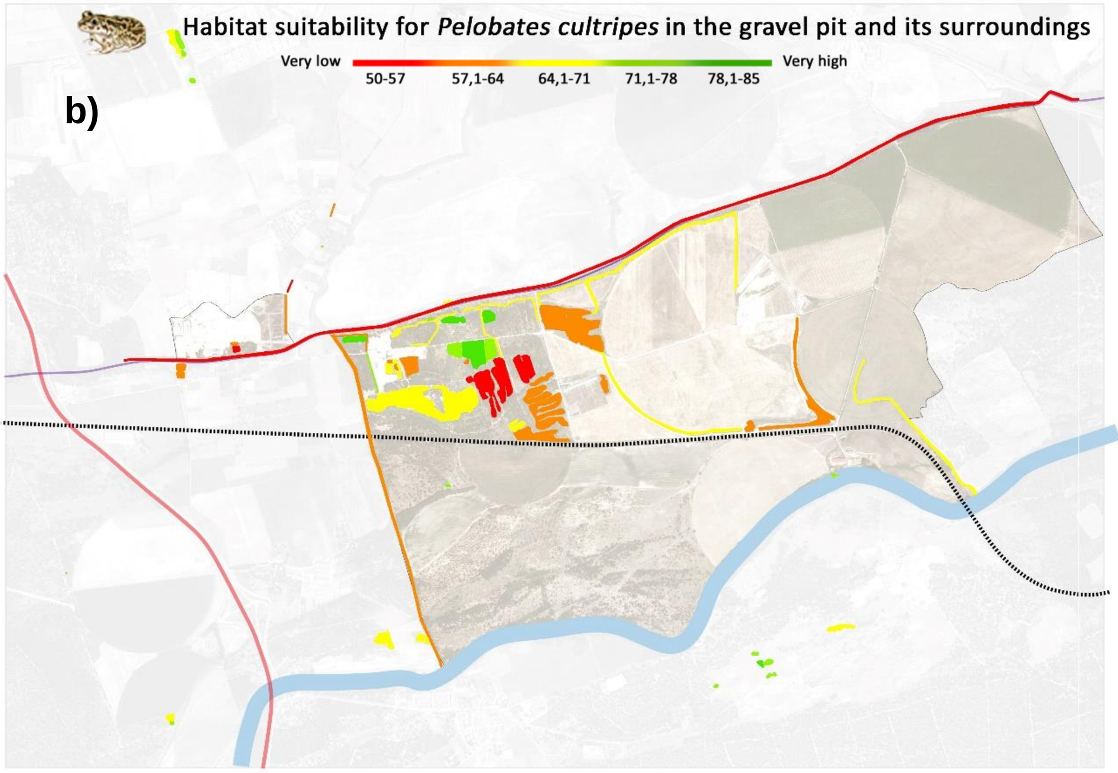
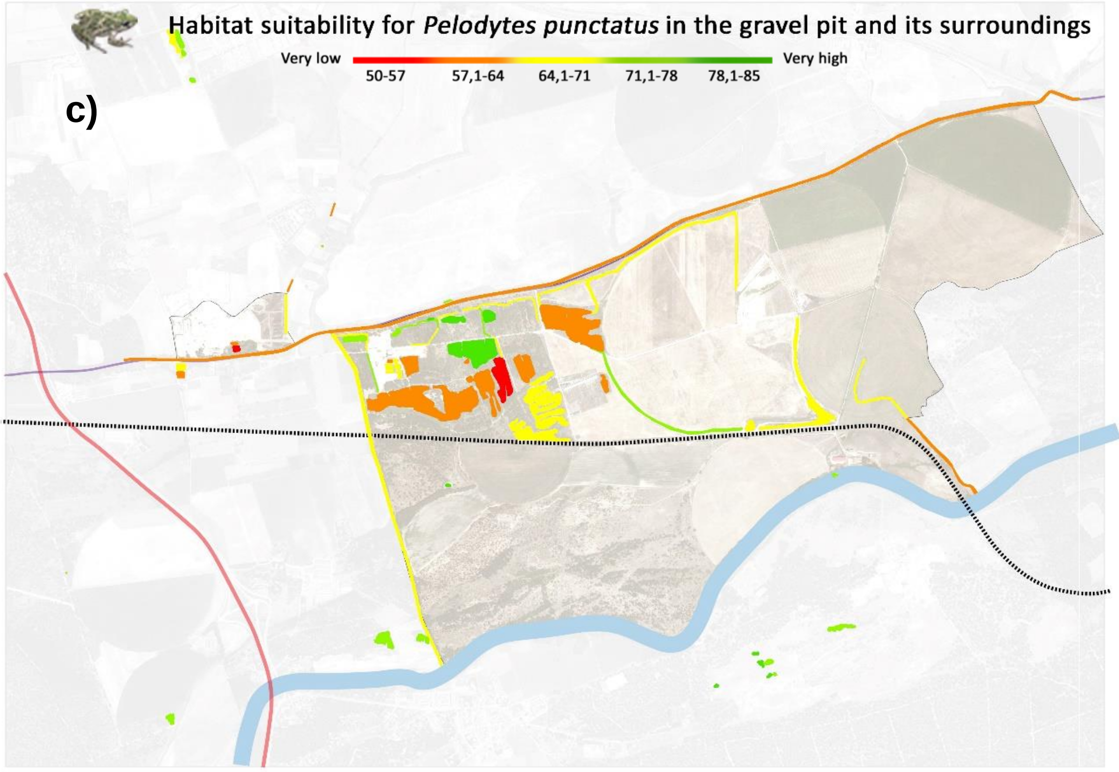


***Figure Annex 5**. Habitat suitability for amphibian species in the gravel pit and its surroundings: (a) Pelophylax perezi; (b) Pelobates cultripes; (c) Pelodytes punctatus; (d) Triturus marmoratus*



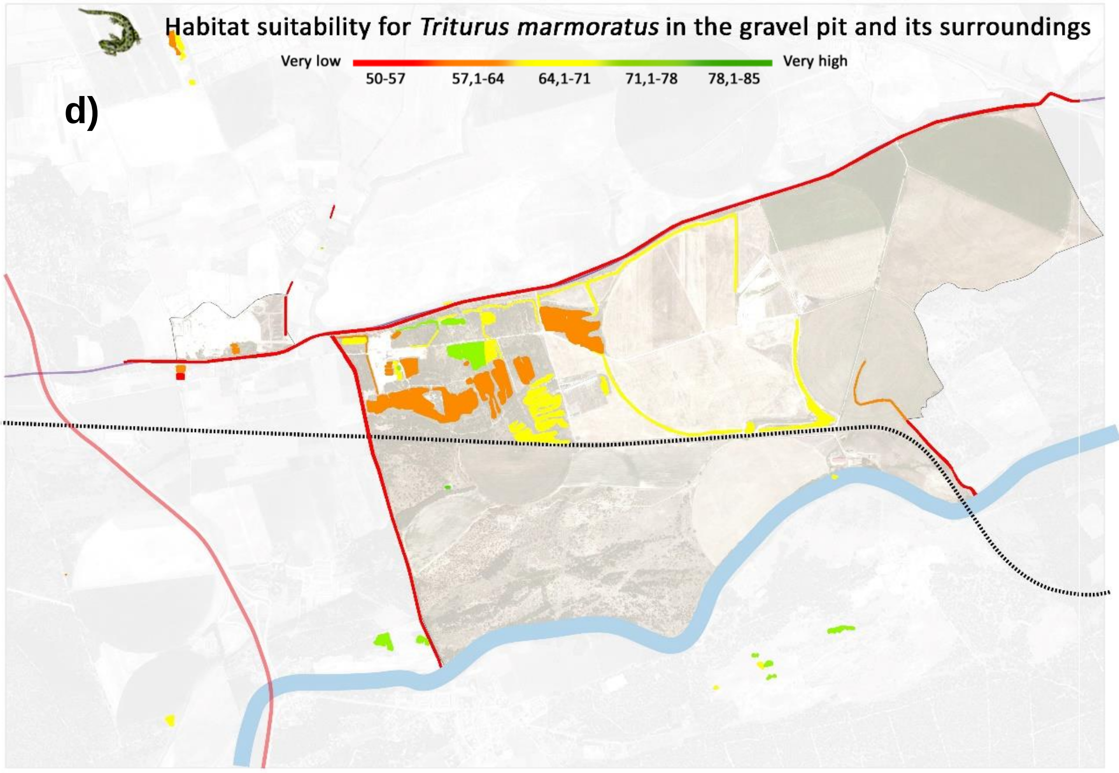


Figure Annex 5. *(Cont.) Habitat suitability for amphibian species in the gravel pit and its surroundings: (a) Pelophylax perezi; (b) Pelobates cultripes; (c) Pelodytes punctatus; (d) Triturus marmoratus*

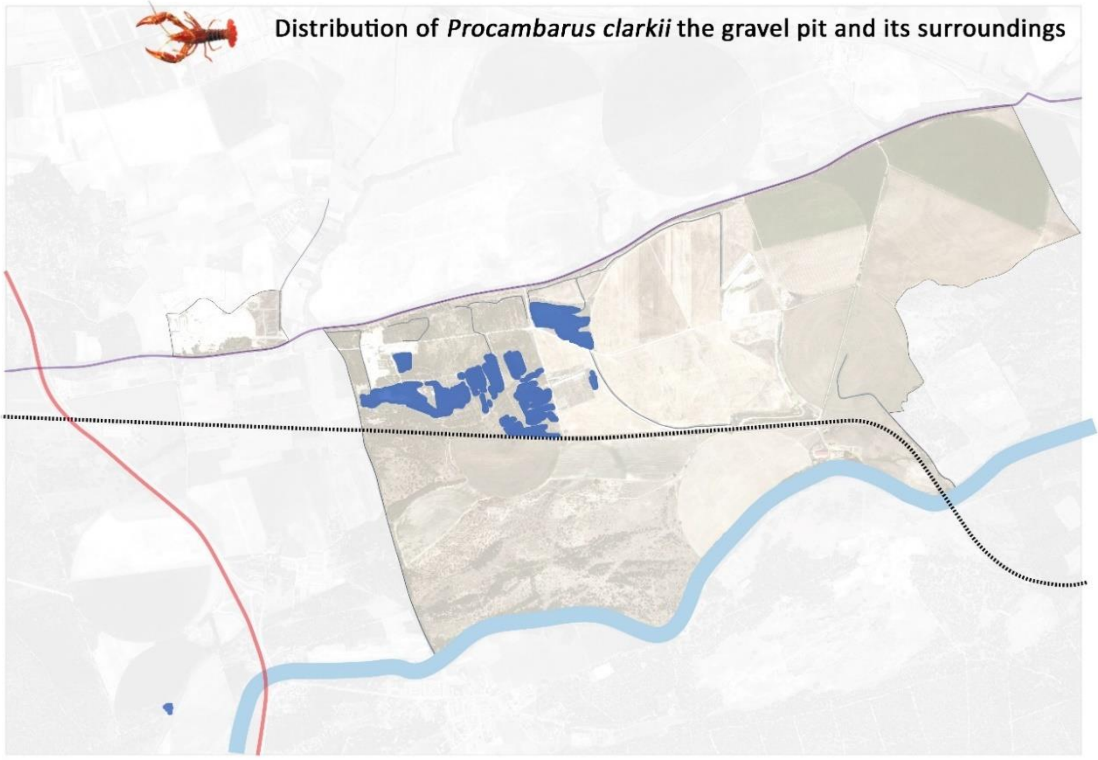


Figure Annex 6. Distribution of Procambarus clarkii in the gravel pit and its surroundings

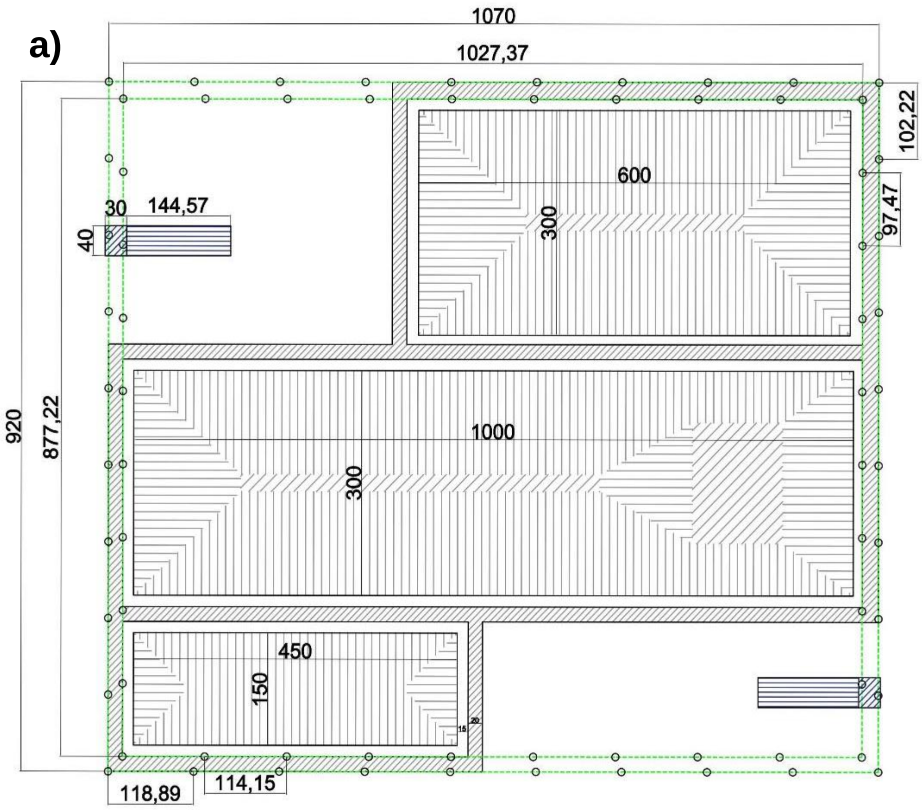


Figure Annex 7. Construction drawing of the ponds. (a) Top view of the spatial distribution of the pond system, the double wired mesh and the exit structures; (b) Top view and profiles of the three types of ponds. Units are in cm

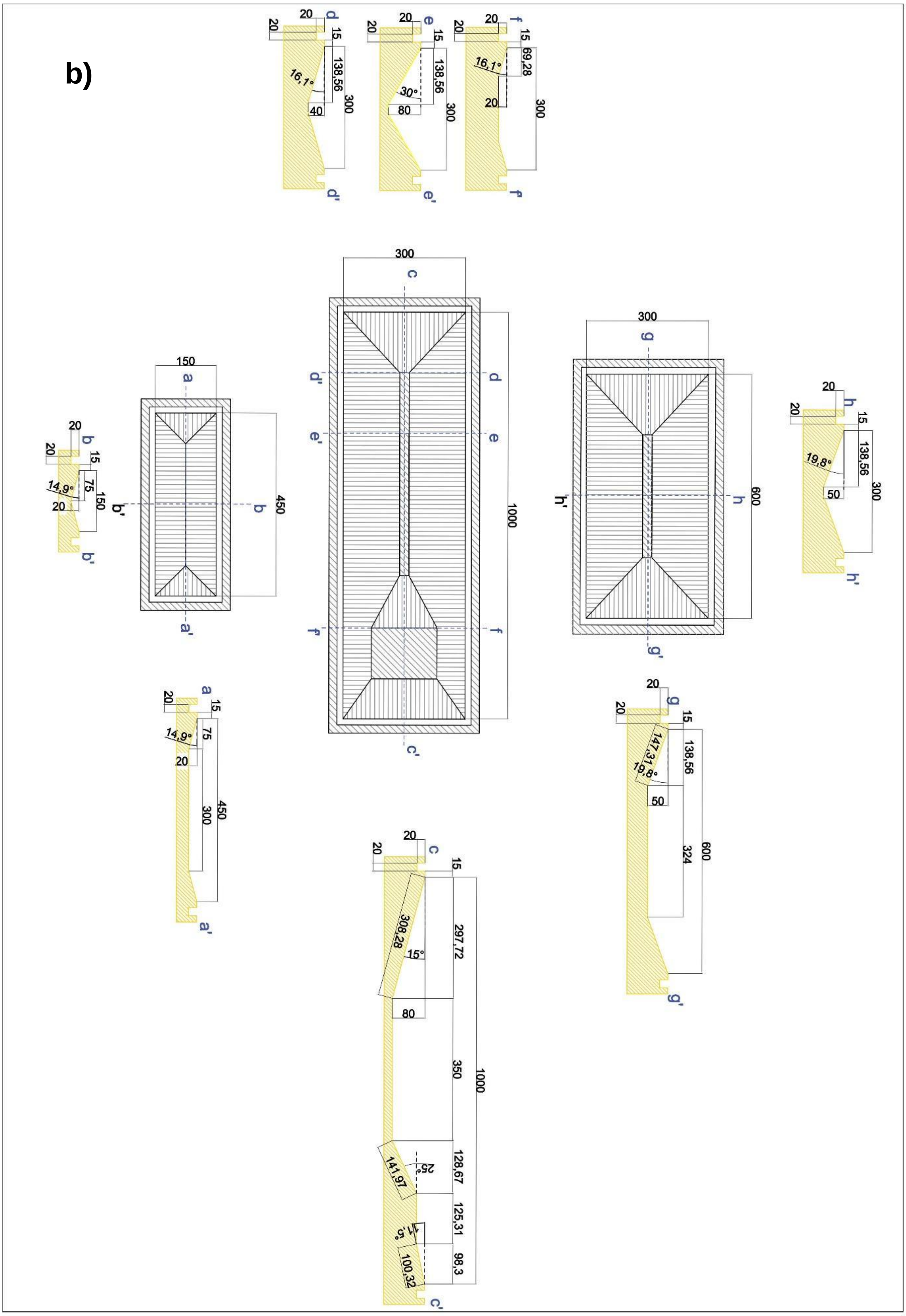


Figure Annex 7. *(Cont.) Construction drawing of the ponds. (a) Top view of the spatial distribution of the pond system, the double wired mesh and the exit structures; (b) Top view and profiles of the three types of ponds. Units are in cm*

Table Annex 1. *Success indicators. The monitoring plan for this indicators are described in the* ***Amphibian Monitoring Guide*** *(https://goo.gl/shqu5v)*

Description	Method	Periodicity
SPECIES RICHNESS		
Number of species in new or restored habitats	Amphibian sampling (tadpoles and adults) and naked eye observation in ponds	Once a year (from March to April, to ensure that all species are in breeding period)
AQUATIC VEGETATION		
Existence of plant (submerged, floating or in the shore of water bodies) and the covered surface	Checking of the existence of vegetation and estimation of the percentage of area occupied. Species identification if needed	Once a year for new or restored ponds. Once a week for natterjack toad scratches
WATER LEVEL		
Existence of water and its depth	Check at a glance the presence of water and depth measurement with a ruler when needed	Twice a year, preferably at spring and late summer, in order to measure maximum and minimum levels. In case of natterjack toad scratches, presence of water must be frequently checked
WATER QUALITY		
Physicochemical water parameters: pH, conductivity, nitrates and phosphates	Water sampling and immediate analysis using a pHmetre-conductimetre, and nitrate and phosphate measurement kits	Once a year
PRESENCE OF NATTERJACK TOAD		
Existence of natterjack toad tadpoles	Naked eye observation of tadpoles (they are very easy to see and recognize)	Once a week
PRESENCE OF RED CRAYFISH		
Presence or absence of red crayfish, particularly in ponds where control measures have been implemented	Installation of red crayfish traps, sampling in water and naked eye observation along the pond's shore	Three times a year
PRESENCE OF DEAD AMPHIBIANS		
Presence of dead individuals because they were not able to get out of the hole for catenary supporting	Naked eye observation	Three times a year
PRESENCE OF SPECIALIST SPECIES		
Presence of species that require short depth for spawn or for larval development (*Discoglossus galganoi*, *Hyla molleri*, etc.)	Tadpole sampling in the water and naked eye observation of lays	Once a year (between March and April to ensure that all species are in breeding period)

***Table Annex 2**. Detailed budget of designed structures and actions for the corridors: pond systems, ponds, water troughs and ramps*

Pond system				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
MACHINERY				
Backhoe loader/ excavator shovel	h	4	30	120
LABOUR				
Worker	h	16	10	160
MATERIAL				
Geotextile	m^2	200	0,39	78
Plastic liner	m^2	100	0,73	73
			Tax Base	431
			Taxes (21%)	90,51
			TOTAL	**521,51**

Pond				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
MACHINERY				
Backhoe loader/ excavator shovel	h	1,5	30	45
LABOUR				
Worker	h	6	10	60
MATERIAL				
Geotextile	m^2	70	0,39	27,3
Plastic liner	m^2	35	0,73	25,55
			Tax Base	157,85
			Taxes (21%)	33,1485
			TOTAL	**190,9985**

Water trough				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
MACHINERY				
Backhoe loader/ excavator shovel	h	0,5	30	15
LABOUR				
Worker	h	1,5	10	15
MATERIAL				
Stones	Tn	0,005	20	0,1
Cement	m^2	2	50	100
			Tax Base	130,1
			Taxes (21%)	27,321
			TOTAL	**157,421**

Ramps				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
LABOUR				
Worker	h	0,25	10	2,5
MATERIAL				
Phenolic plywood	m^2	0,75	15	11,25
			Tax Base	13,75
			Taxes (21%)	2,8875
			TOTAL	**16,6375**

Table Annex 3. *Detailed budget of designed measures for habitat suitability improvement: reduced slopes, shallow shores, new sand heaps, and "non-crayfish" mesh*

Reduced slopes, shallow shores, new sand heaps				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
MACHINERY				
Backhoe loader/ excavator shovel	h	0,75	30	22,5
LABOUR				
Worker	h	1,5	10	15
			Tax Base	37,5
			Taxes (21%)	7,875
			TOTAL	**45,375**

"Non-crayfish" mesh				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
LABOUR				
Worker	h	1,5	10	15
MATERIAL				
Stakes (75 cm high)	ud.	15	1,25	18,75
Wired mesh (41 mm mesh size)	m^2	15	0,6	9
Exit structure	ud.	1	5,8	5,8
			Tax Base	48,55
			Taxes (21%)	10,1955
			TOTAL	**58,7455**

Table Annex 4. *Detailed budget of measures for enhancing Epidalea calamita populations*

Measures to enhance *E. calamita*				
Description	Units	Amount (A)	Cost (€)	Total cost (Ax€)
MACHINERY				
Backhoe loader/ excavator shovel	h	0,1	30	3
LABOUR				
Worker	h	0,2	10	2
			Tax Base	5
			Taxes (21%)	1,05
			TOTAL	**6,05**

SYNTHESIZED PRESENTATION OF THE PROJECT

(PRESENTACIÓN SINTETIZADA DEL PROYECTO)

STEPPING PONDS

QUARRY LIFE AWARD PROJECT

STEPPING PONDS

Enhancement of connectivity for amphibians in riverside gravel pits

Mejora de la conectividad para anfibios en graveras de ribera

Daniel Gómez de Zamora

Verónica Cruz

César García

Fernando Viñegla

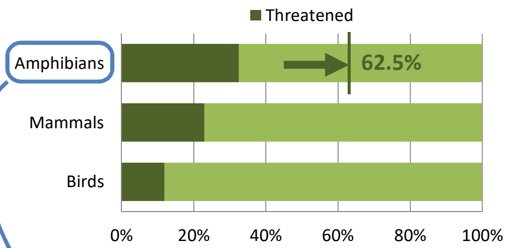
QUARRY LIFE AWARD PROJECT

1. Introduction

STEPPING PONDS

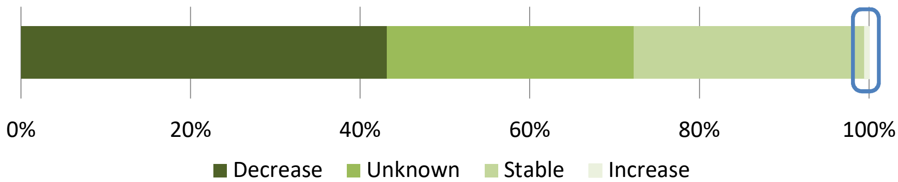
Richness of threatened species

Riqueza de especies amenazadas



Population trends

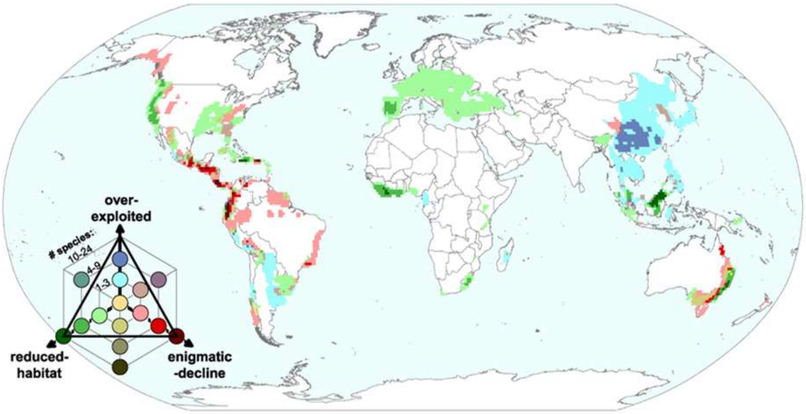
Tendencia de las poblaciones



QUARRY LIFE AWARD PROJECT

1. Introduction

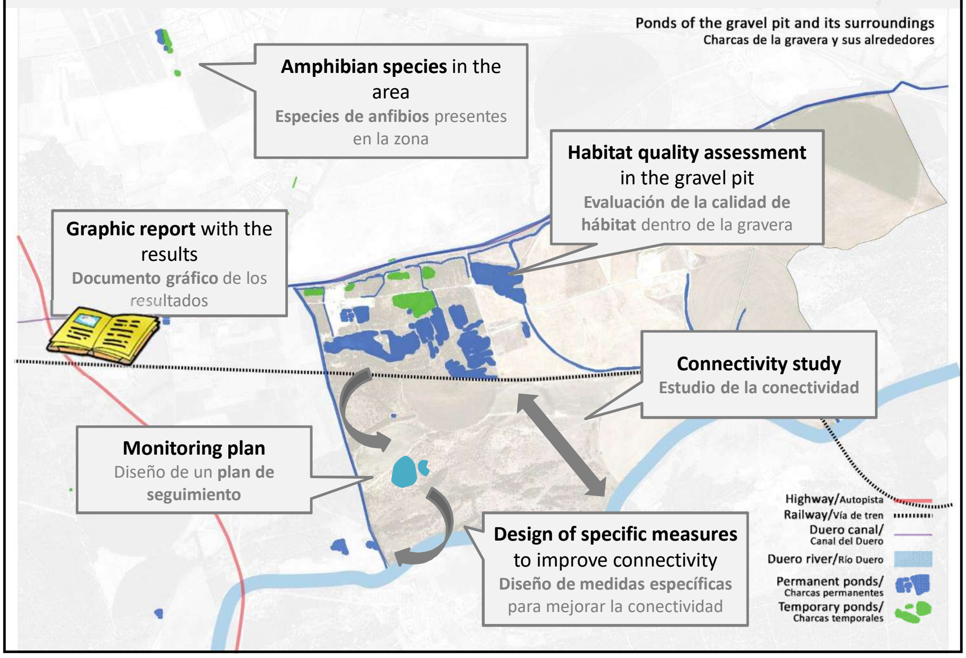
STEPPING PONDS



QUARRY LIFE AWARD PROJECT

2. Objectives

STEPPING PONDS



QUARRY LIFE AWARD PROJECT

3. Target species

STEPPING PONDS

EU Habitats Directive
Directiva Hábitats

Bern Convention
Convenio de Berna

Pelophylax perezi

Iberian waterfrog
Rana común

Extinto · Amenazado · Preocupación menor
EX EW CR EN VU NT **LC**

Trend / Tendenci: →
Anexo V
Anexo III

Pelobates cultripes

Western spadefoot toad
Sapo de espuelas

Extinto · Amenazado · Preocupación menor
EX EW CR EN VU **NT** LC

Trend / Tendenci: ↘
Anexo IV
Anexo II

Pelodytes punctatus

Common parsley frog
Sapillo moteado

Extinto · Amenazado · Preocupación menor
EX EW CR EN VU NT **LC**

Trend / Tendenci: ↘
-
Anexo III

Triturus marmoratus

Marbled newt
Tritón jaspeado

Extinto · Amenazado · Preocupación menor
EX EW CR EN VU NT **LC**

Trend / Tendenci: ↘
Anexo IV
Anexo III

Epidalea calamita

Natterjack toad
Sapo corredor

Extinto · Amenazado · Preocupación menor
EX EW CR EN VU NT **LC**

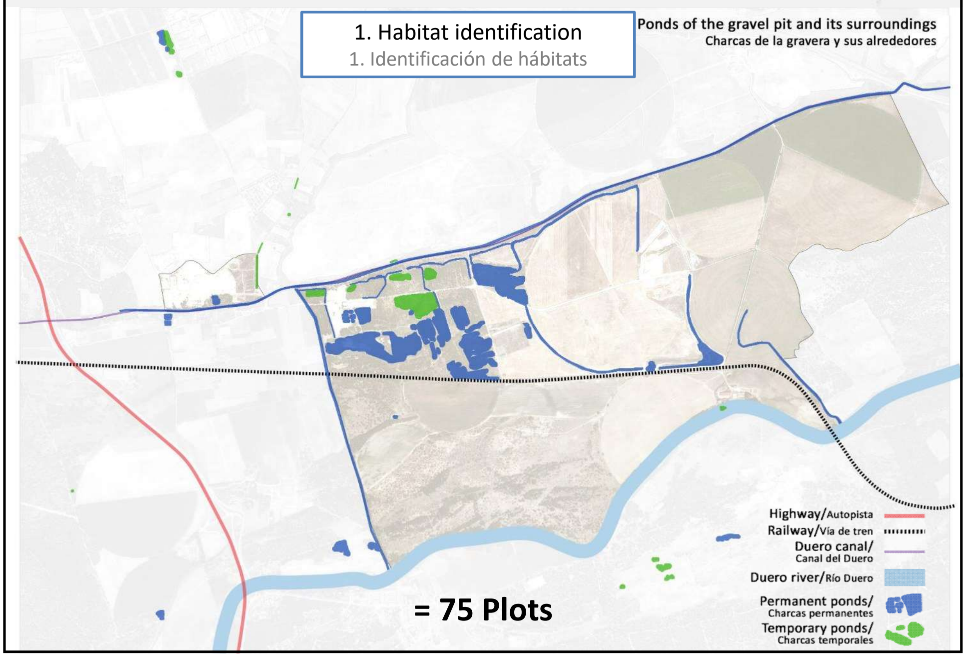
Trend / Tendenci: ↘
Anexo IV
Anexo II

QUARRY LIFE AWARD PROJECT

4. Methods

STEPPING PONDS

1. Habitat identification
1. Identificación de hábitats



QUARRY LIFE AWARD PROJECT

4. Methods

STEPPING PONDS

1. Habitat identification
1. Identificación de hábitats

2. Measurement of habitat features
2. Medida de las características del hábitat

Physical Físicas	Hydrological Hidrológicas	Vegetation Vegetación	Surroundings Alrededores	Relationships Relaciones	Water quality Calidad agua
• Type / *Tipo* • Slope/ *Pendiente* • Max. Depth/ *Profundidad máxima*	• Regime/ *Regimen* • Stream speed/ *Velocidad de la corriente*	• Shadow/ *Sombreado* • Shore with vegetation/ *Orilla con vegetación* • Covered sheet of water / *Lamina cubierta* • Floating veg./ *Flotantes* • *Characeae*/ *Caráceas* • *Ranunculus*/ *Ranúnculos*	• Refuges/ *Refugios* • Sandbanks/ *Arenales* • Crops/ *Cultivo* • Grassland/ *Herbazal* • Shrubs/ *Matorral* • Forest/ *Bosque*	• Red crayfish/ *Cangrejo americano* • Fishes/ *Peces* • Birds/ *Aves*	• Temperature/ *Temperatura* • pH • Conductivity/ *Conductividad* • COD/ *DQO* • Turbidity/ *Turbidez* • Nitrate/ *Nitratos* • Phosphate/ *Fosfatos*

= 27 Atributes

QUARRY LIFE AWARD PROJECT

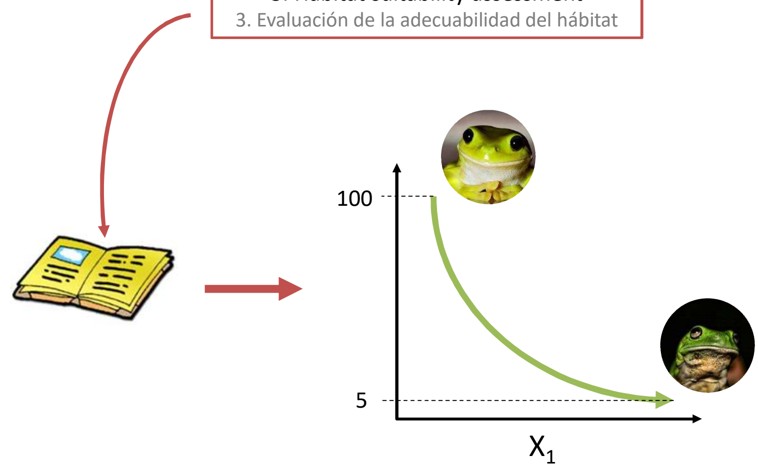
4. Methods

STEPPING PONDS

1. Habitat identification
1. Identificación de hábitats

2. Measurement of habitat features
2. Medida de las características del hábitat

3. Habitat suitability assessment
3. Evaluación de la adecuabilidad del hábitat



4. Methods

1. Habitat identification
1. Identificación de hábitats

2. Measurement of habitat features
2. Medida de las características del hábitat

3. Habitat suitability assessment
3. Evaluación de la adecuabilidad del hábitat

X_1	0,9	0,3	0,3	0,1
X_2	0,3	0,1	0,5	1
…	…	…	…	…
X_{27}	0,1	0,1	0,7	0,3

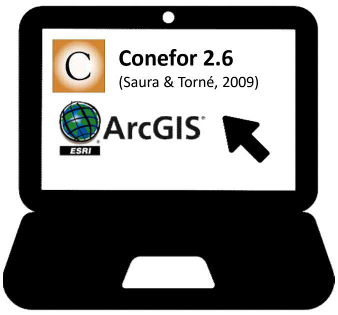
4. Methods

1. Habitat identification
1. Identificación de hábitats

2. Measurement of habitat features
2. Medida de las características del hábitat

3. Habitat suitability assessment
3. Evaluación de la adecuabilidad del hábitat

4. Conectivity assessment
4. Evaluación de la conectividad entre hábitats



QUARRY LIFE AWARD PROJECT

4. Methods

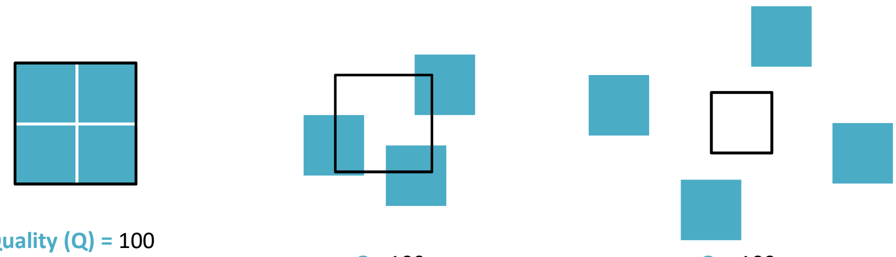
STEPPING PONDS

1. Habitat identification
1. Identificación de hábitats

2. Measurement of habitat features
2. Medida de las características del hábitat

3. Habitat suitability assessment
3. Evaluación de la adecuabilidad del hábitat

4. Conectivity assessment
4. Evaluación de la conectividad entre hábitats



Quality (Q) = 100
ECQ= 100

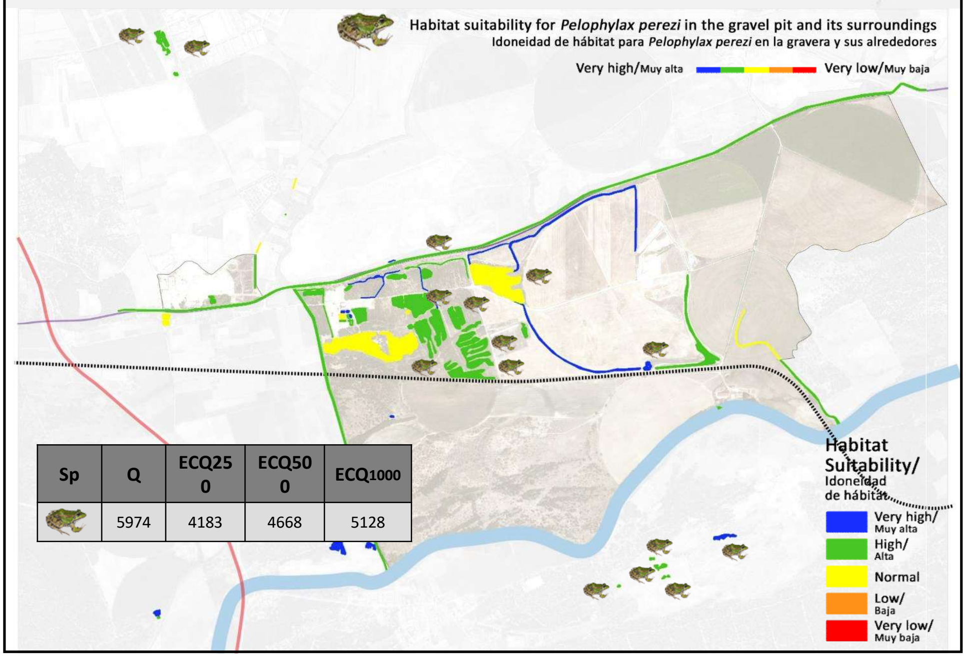
Q= 100
ECQ = 80

Q = 100
ECQ = 50

QUARRY LIFE AWARD PROJECT

5. Results

STEPPING PONDS



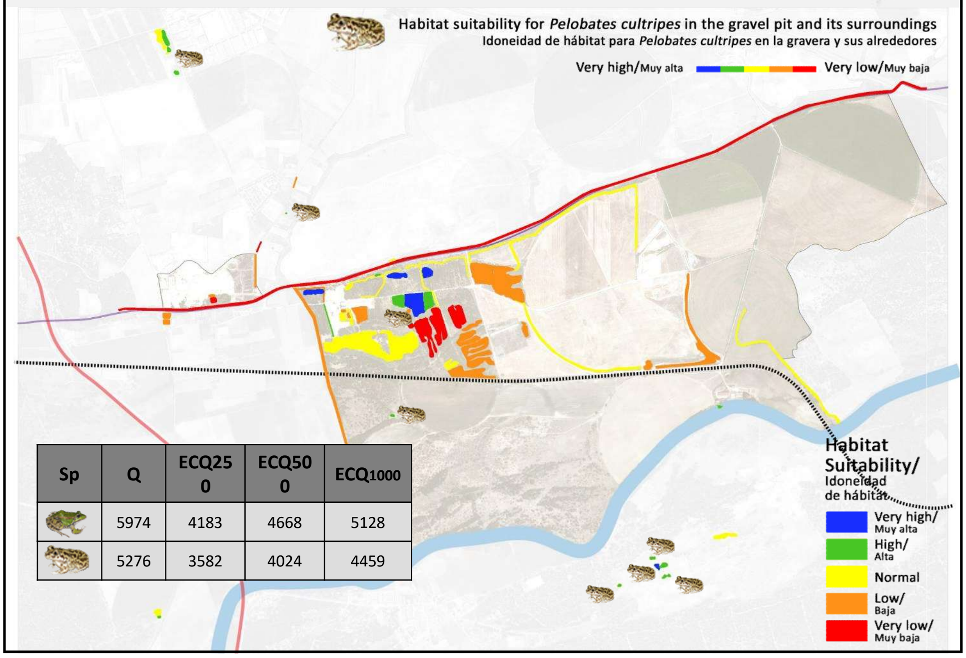
Sp	Q	ECQ250	ECQ500	ECQ1000
(frog)	5974	4183	4668	5128

QUARRY LIFE AWARD PROJECT

5. Results

STEPPING PONDS

Habitat suitability for *Pelobates cultripes* in the gravel pit and its surroundings
Idoneidad de hábitat para *Pelobates cultripes* en la gravera y sus alrededores



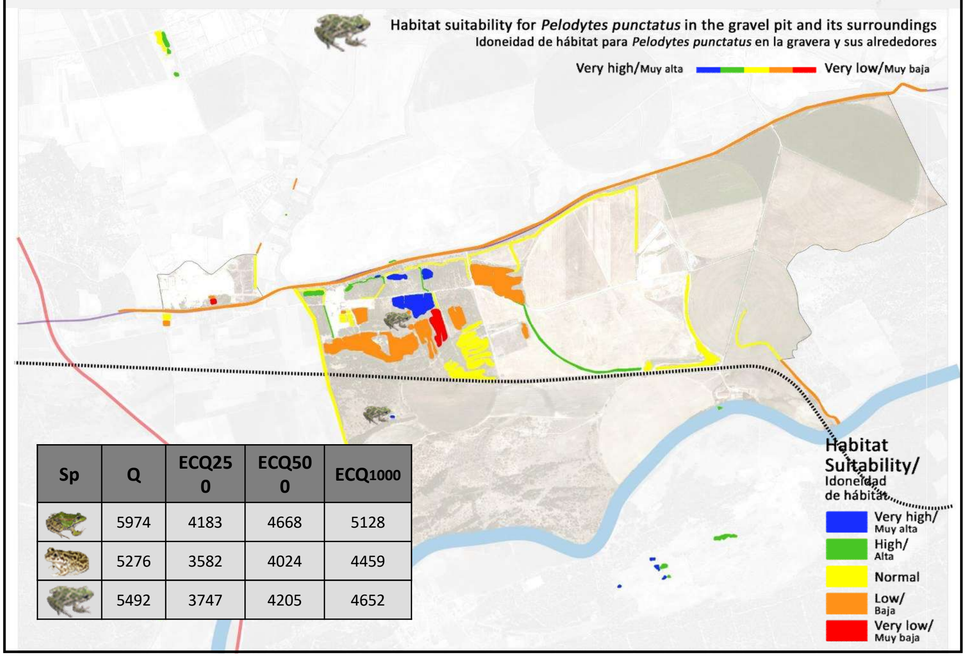
Sp	Q	ECQ250	ECQ500	ECQ1000
	5974	4183	4668	5128
	5276	3582	4024	4459

QUARRY LIFE AWARD PROJECT

5. Results

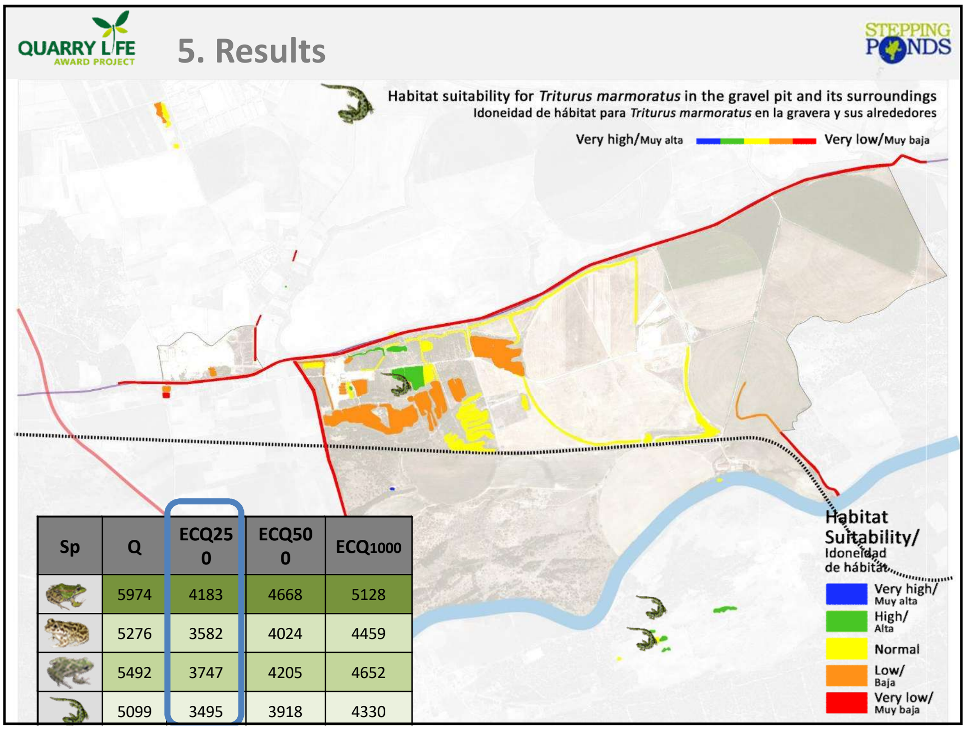
STEPPING PONDS

Habitat suitability for *Pelodytes punctatus* in the gravel pit and its surroundings
Idoneidad de hábitat para *Pelodytes punctatus* en la gravera y sus alrededores

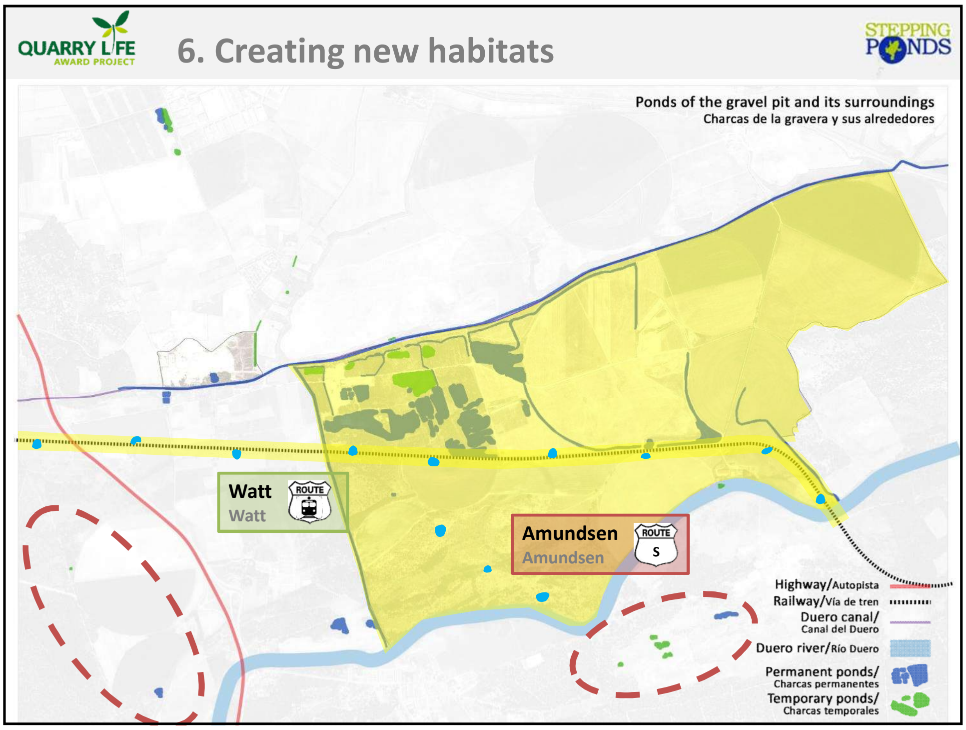


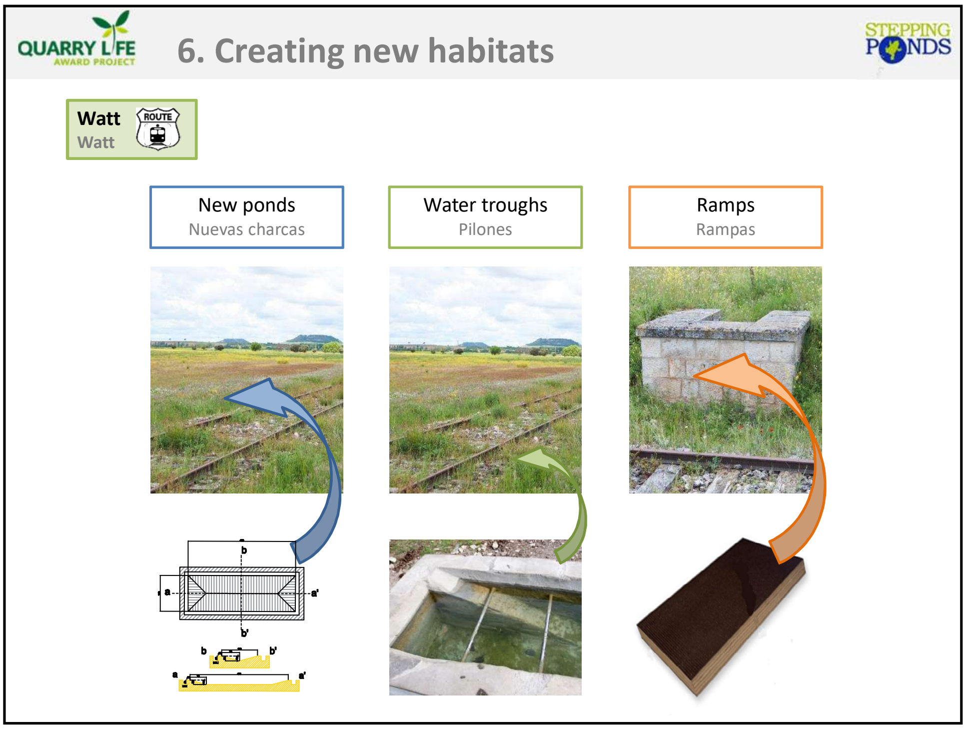
Sp	Q	ECQ250	ECQ500	ECQ1000
	5974	4183	4668	5128
	5276	3582	4024	4459
	5492	3747	4205	4652

5. Results



Sp	Q	ECQ250	ECQ500	ECQ1000
	5974	4183	4668	5128
	5276	3582	4024	4459
	5492	3747	4205	4652
	5099	3495	3918	4330


QUARRY LIFE AWARD PROJECT
6. Creating new habitats
STEPPING PONDS
Ponds of the gravel pit and its surroundings
Charcas de la gravera y sus alrededores
Watt
Watt
ROUTE
Amundsen
Amundsen
ROUTE
S
Highway/Autopista
Railway/Vía de tren
Duero canal/
Canal del Duero
Duero river/Río Duero
Permanent ponds/
Charcas permanentes
Temporary ponds/
Charcas temporales

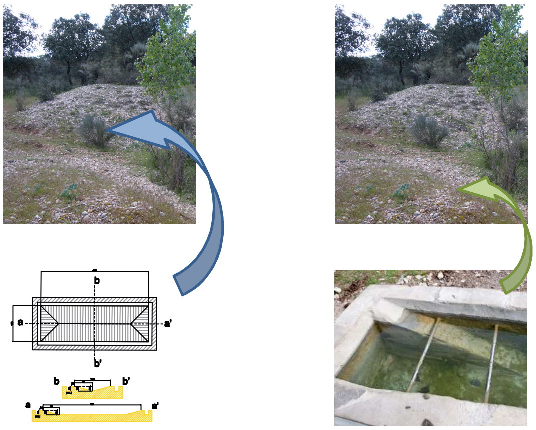

QUARRY LIFE AWARD PROJECT
6. Creating new habitats
STEPPING PONDS
Watt
Watt
ROUTE
New ponds
Nuevas charcas
Water troughs
Pilones
Ramps
Rampas

6. Creating new habitats

Amundsen
Amundsen
ROUTE S

System ponds
Sistemas de charcas

Water troughs
Pilones



6. Creating new habitats

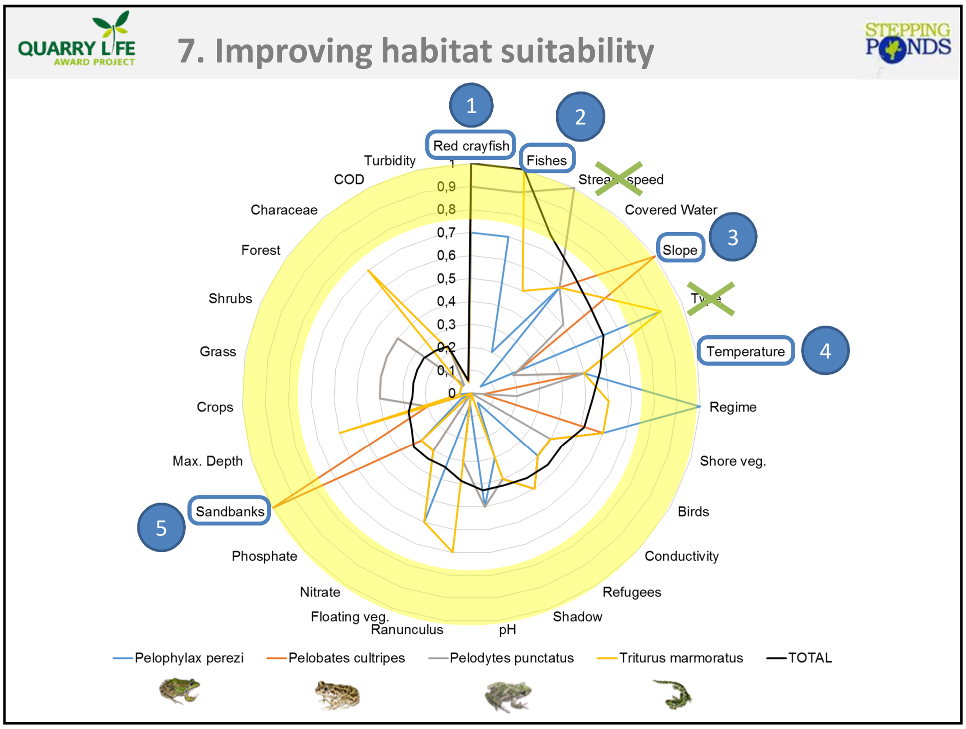
Watt
Watt

Specie	Initial dECQ	Train rail dECQ	ΔdECQ
Pelophylax perezi	10,4	10,15	-0,25
Pelobates cultripes	11,43	11,25	-0,18
Pelodytes punctatus	12,15	11,94	-0,21
Triturus marmoratus	10,13	9,91	-0,22

Amundsen
Amundsen
ROUTE S

Specie	Initial dECQ	South route dECQ	ΔdECQ
Pelophylax perezi	55,27	62,46	7,19
Pelobates cultripes	50,96	71,49	20,53
Pelodytes punctatus	51,81	71,93	20,12
Triturus marmoratus	47,14	66,54	19,4

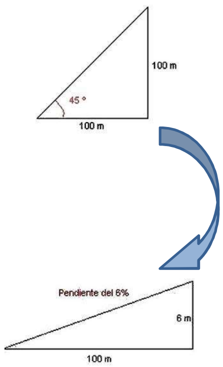

1. Aumentar la conectividad creando nuevos hábitats
To increase connectivity…
…creating new habitats
To increase connectivity…
…improving habitat suitability
2. Aumentar la conectividad aumentando la idoneidad de los hábitats existentes

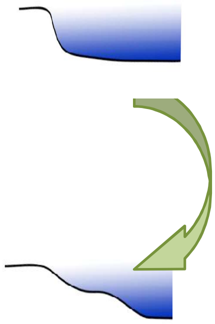

QUARRY LIFE AWARD PROJECT
7. Improving habitat suitability
STEPPING PONDS
1
2
Red crayfish
Fishes
Turbidity
COD
Characeae
Forest
Shrubs
Grass
Crops
Max. Depth
Sandbanks
5
Phosphate
Nitrate
Floating veg.
Ranunculus
pH
Shadow
Refugees
Conductivity
Birds
Shore veg.
Regime
Temperature
4
Slope
3
Covered Water
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
Pelophylax perezi
Pelobates cultripes
Pelodytes punctatus
Triturus marmoratus
TOTAL

7. Improving habitat suitability

Improvement of water bodies suitability
Adecuación de cuerpos de agua

Reduce slopes Reducir pendientes	Shallow shores Orillas poco profundas	Create sandbanks Crear arenales





3 Slope/Pendiente

2 Fishes/Peces

4 Regime/Régimen

5 Sandbanks/ Arenales

7. Improving habitat suitability

Connectivity improvement
Mejora en la conectividad

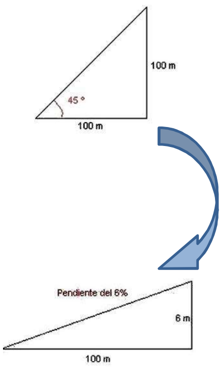
	$\%Q_{improved}$	$\%ECQ_{improved}$
Pelophylax perezi	4182,8	4192,8
Pelobates cultripes	3582,2	3637,4
Pelodytes punctatus	3746,8	3773,4
Triturus marmoratus	3494,7	3526,1

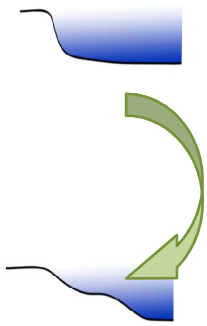
75 habitats → 12 habitats → 27 features → 4 features → x 20 % of maximum improvement

7. Improving habitat suitability

Improvement of water bodies suitability
Adecuación de cuerpos de agua

Reduce slopes Reducir pendientes	Shallow shores Orillas poco profundas	Create sandbanks Crear arenales	Crayfish filter Filtro de cangrejo





3 Slope/Pendiente

2 Fishes/Peces

4 Regime/Régimen

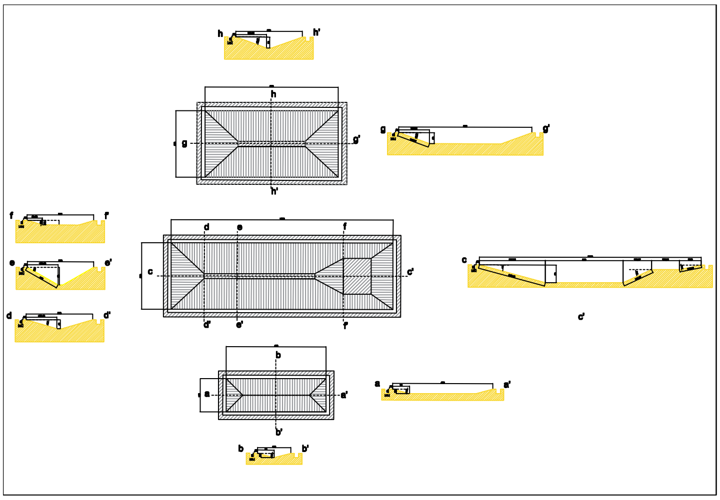
5 Sandbanks/ Arenales

1 Red crayfish/ Cangrejo americano

7. Improving habitat suitability

Pilot ponds to evaluate crayfish and amphibians evolution
Charcas piloto para evaluar la evolución del cangrejo americano y los anfibios

Design
Diseño



7. Improving habitat suitability

Pilot ponds to evaluate crayfish and amphibians evolution
Charcas piloto para evaluar la evolución del cangrejo americano y los anfibios

Design
Diseño

Construction
Construcción

7. Improving habitat suitability

Creation of new ponds
Creación de nuevas charcas

Design
Diseño

Construction
Construcción

8. Natterjack toad

The netterjack toad (*Epidalea calamita*) and the mining activity
El sapo corredor (*Epidalea calamita*) y la explotación minera

Little vegetated, shallow and temporary water bodies
Cuerpos de agua poco vegetados, temporales y someros

Epidalea calamita
Natterjack toad
Sapo corredor

Extinto | Amenazado | Preocupación menor
EX EW CR EN VU NT LC

Trend
Tendenci

Anexo IV

Anexo II

8. Natterjack toad

The netterjack toad (*Epidalea calamita*) and the mining activity
El sapo corredor (*Epidalea calamita*) y la explotación minera

Little vegetated, shallow and temporary water bodies
Cuerpos de agua poco vegetados, temporales y someros

At the foot of material stock
A los pies de los acúmulos

Epidalea calamita
Natterjack toad
Sapo corredor

Extinto | Amenazado | Preocupación menor
EX EW CR EN VU NT LC

Trend
Tendenci

Anexo IV

Anexo II

9. Estimated costs, timing and success indicators

Measures	Cost	Timing	Success indicators
Ponds/ *Charcas*	200 €	3 h	Species richness, Aquatic vegetation, Water level, Water Quality/ *Riqueza de especies, vegetación, nivel de llenado, calidad de agua*
System Ponds/ *Sistemas de charcas*	550 €	5 h	Species richness, Aquatic vegetation, Water level, Water Quality/ *Riqueza de especies, vegetación, nivel de llenado, calidad de agua*
Water troughs/ *Pilones*	170 €	2	Species richness, Water level, Water Quality/ *Riqueza de especies, nivel de llenado, calidad de agua*
Ramps/ *Rampas*	17 €	<1 h	Species richness, Dead amphibians/ *Riqueza de especies, cadáveres de anfibios*
Reduced slopes, swallow shores/ *Pendientes reducidas, orillas poco profundas*	50 €	<1 h	Aquatic vegetation, Water level, Specialist species/ *Vegetación, nivel de llenado, especies especialistas*
Sandheaps and refugees/ *Arenales y refugios*	*	<1 h	Species richness/ *Riqueza de especies*
"Non-crayfish" mesh/ *Valla "anti-cangrejo"*	60 €	1,5 h	Red crayfish/ *Cangrejo americano*
Habitat management for *E. calamita*/ *Gestión del hábitat de E. calamita*	<10 €	<1 h	Aquatic vegetation, Water level, natterjack toad/ *Vegetación, nivel de llenado, sapo corredor*

* According to material availability/ *Dependiente de la disponibilidad de material*

10. Key messages

1. Connectivity for amphibians in Áridos Sanz gravel pit and its surroundings for generalist species (e.g. *Pelophylax perezi*) is higher than connectivity for species with further habitat requirements (e.g. *Triturus marmoratus*)

1. **La conectividad en la gravera Áridos Sanz** y sus alrededores, es mayor para especies generalistas (*P. perezi*) y menor para especies con mayores requerimientos ecológicos (como *T. marmoratus*)

2. ***Amundsen* corridor is effective** in connectivity improvement, but not so *Watt* corridor. The latter has other benefits, as the reutilization of railway old infrastructure and its lineal character

2. **El corredor *Amundsen* es eficaz** para aumentarla conectividad, pero el corredor *Watt* no, aunque tiene otros beneficios asociados, como la reutilización de una estructura ferroviaria abandonada y su carácter lineal.

3. A small effort in **suitability improvement of current habitats** in the gravel pit will lead to great improvements in amphibian connectivity

3. Esfuerzos modestos en la **mejora de la idoneidad de los hábitats ya existentes** en la gravera conllevan mejoras aún mayores en la conectividad para los anfibios



10. Key messages

4. **Predators** (red crayfish and different fishes) are a **key factor for amphibian development**. Due to a lack of strategies to avoid predation and expansion of the crayfish, we propose **innovative management approaches** to limit the impact over amphibian population

4. Los **depredadores** (*Procambarus clarkii* y los peces) **son el principal factor limitante** para el desarrollo de los anfibios. Se proponen innovadoras medidas experimentales para limitar su impacto sobre las poblaciones de anfibios.

5. **Gravel pits promote *Epidalea calamita* breeding** reproduction, due to the ephemeral water bodies and disturbed areas that are created during normal functioning in gravel pits. Low-cost measures could enhance even more the abundance of this specie

5. La **actividad de las graveras favorece la reproducción de *Epidalea calamita***. Mediante medidas de muy bajo coste se puede potenciar aún más la presencia de esta especie.

Thank you for your kind attention

www.quarrylifeaward.es/node/30111

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STEPPING PONDS