Bats and Dams

Conservation Actions in the Region of the Reservoir of Alqueva and Pedrogão
Ficha Técnica

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1. Introduction

Of the 834 species of microchiropteran bats present worldwide, over 21% are threatened with extinction (Fig. 1). Other 23% are considered “near threatened” and are thus of conservation concern (1). Overall, most species have steadily declined throughout Europe during the last century (2).

Bats are intrinsically highly vulnerable to extinction. Not only they reproduce slowly, with most species producing only one offspring each year, but they also gather in large numbers, meaning that many bats can be affected when their roosts are damaged or disturbed. However, extrinsic factors are the main reason for bat decline. The loss of suitable habitat and the destruction or disturbance of existing roosts are pointed out as the most significant factors contributing to this decline (1,3).

As a result of their status across Europe, all species of bats have been listed on Annex BIV of the EU ‘Habitats and Species Directive’ and some on the Annex BII. The Portuguese legislation which enforces this directive, combined with other national legislation, ensures the protection of individual bats, their breeding sites and other areas of dependence.

Most threats to bats are directly related to increasing human demand for land, food and other resources. This demand ultimately results in the degradation or destruction of habitats suitable for bats (4). A wide range of development projects has a growing potential to create negative impacts upon bats and their populations. Among these developments are big dams (Fig. 2).

The Alqueva Multipurpose Project, located in the region of Alentejo, Portugal and partly-funded by the European Union, includes two of these big dams: Alqueva and Pedrógão. Additionally, it also includes eight other smaller dams, over 4800 Km of irrigation canals, 114 pumping stations, as well as nine bridges and 12 new roads.
As a result of its magnitude, this project was due to have large ecological costs on the ecosystems of the region (Fig. 3). Consequently, the proponent of the project - Empresa de Desenvolvimento e Infra-estruturas da Alqueva, EDIA SA - assumed the task of investigating for unknown impacts and monitoring of all existing impacts, as well as minimising and compensating reversible negative impacts and stimulating positive impacts. Within the several projects proposed to address these objectives, there was one focusing on the study of bats. This was a joint project executed by Instituto da Conservação da Natureza (ICN) and funded by EDIA and the European Regional Development Fund.

This brochure summarizes the results of the conservation actions implemented for bats in the region affected by the construction of the two big dams - Alqueva and Pedrógão. With this publication we aim to (a) raise public awareness, (b) share acquired knowledge during the project and (c) provide useful suggestions on procedures and mitigation measures to be used in similar cases. Notice however that various mitigation measures proposed here were the result of personal experience and as such, other may prove to be more adequate.

Above all, we hope that this brochure will promote the collection of better information about the success or failure of mitigation measures in this type of development projects.
2. bats

Flying mammals

Bats are one of the most diverse group of mammals, with more than 1000 species spread through the world (7). These animals have all the characteristics inherent to mammals, such as the body covered with fur, the presence of mammary glands for the production of milk to nourish newborn and the ability to maintain a constant body temperature (9). Nevertheless, the adaptation of bats to flight, especially in total darkness, makes this animal group unique.

The wings of bats are perhaps one of the most characteristic aspects of this group. Yet, the bone structure of the wing of a bat does not differ much from the hands of any other mammal. In fact, this characteristic gives name to the order that groups all species of bats – Chiroptera, word of Greek origin meaning hand-wing (9).

Bat diversity

The order Chiroptera is subdivided in two sub-orders – Megachiroptera and Microchiroptera. The former range from Africa eastwards to the Pacific Islands (Old World bats) while Microchiroptera comprise a very large number of species worldwide, including all species in Portugal. Bats are characterised by a big variety of shapes of the head and facial appearance (Figs. 4 and 5), particularly when compared with other mammal groups (9). This variability is associated with the diet of the species and, to a lesser extent, to their roosting habits. Despite about 70% of world bats species feed on insects, many other are frugivorous, carnivorous, piscivorous and nectarivorous. In Portugal, all species are primarily insectivorous.

Also, the type of roosts used by each species is much diversified (9). Depending on where they roost, bat species can be grouped as cave-dwelling (when living in subterranean roosts like caves and mines; Fig. 6), tree-dwelling (when mainly using cavities in trees) and
crevice-dwelling (when mainly using fissures in rocks and man-made structures). Some species reveal a high plasticity in roost selection, and despite using natural structures as the ones mentioned above, they also use human structures as roosts (e.g. buildings).

**The ability to echolocate**

More than half of the known species of bats guide themselves and capture their prey by echolocation. Echolocating bats emit ultrasonic signals and perceive the returning echoes to detect, characterize and locate the reflecting objects. The ability to echolocate is one of the primary characteristics distinguishing the two sub-orders of the order Chiroptera, as it is present in all microchiropterans, but apparently absent in all but one genus of the megachiropterans. Call patterns are often used to identify bat species while foraging at night. However, echolocation calls vary considerably both within and among species, often making it difficult to establish species-specific vocal signatures.

The nocturnal and elusive behaviour of bats, along with the high diversity of species and behaviours makes this group one of the less known among mammals.
3. The Alqueva multipurpose project

The region

The Alentejo region is located in southern Portugal, occupying a third part of the country, though with less than 5% of its population. It is therefore a vast and depopulated region, as well as one of the poorest regions in the EU, with a negative demographic and economic growth. Regarding climate conditions, Alentejo is under the major climatic influence of the Mediterranean. It is therefore characterised by a dry and very hot season, high annual temperature amplitude, and a very irregular distribution of rainfall over the wet season. Additionally, very intense floods or severe drought periods are also frequent. Two main rivers drain this region - Sado and Guadiana rivers (Fig. 7).

History

The Alqueva Multipurpose Project was first conceived in 1957 with the purpose of supplying water to the region (Alentejo Irrigation Plan), in order to promote its agriculture and contribute to its economic development. Despite these early plans, the project was only approved in 1975. The preliminary works started in 1976, with the construction of a water by-pass and a geological survey in the area of the future dam. The project was then interrupted between 1978 and 1993, year when the Portuguese government decided to resume it with a broader set of objectives:
Objectives of the Alqueva Multipurpose Project

- To guarantee a strategic water reservoir for populations and industries in the area;
- To gradually modify the model of agricultural specialisation in Alentejo; to supply the necessary water to the region to accomplish the Alentejo Irrigation Plan;
- To produce hydroelectricity;
- To create opportunities for tourism;
- To refrain physical desertification and climatic changes;
- To intervene in an organised way in the domains of environment and patrimony;
- To stimulate the regional employment market.

The construction of the dam of Alqueva, main infrastructure of Alqueva Multipurpose Project, begun in 1995 (Fig. 8) and lasted for seven years. Meanwhile, during 2001, the deforestation of the area to be flooded was deforested. By January of 2002 the dam was finished and the flooding begun in the following month (Fig. 9). The dam of Pedrogão, a retaining dam which resulted in the second largest reservoir of the Alqueva Multipurpose Project, was constructed downstream the dam of Alqueva between 2004 and 2005.
The dams of Alqueva and Pedrógão

The dam of Alqueva is located on the mainstream of the river Guadiana, near the village of Alqueva (Municipality of Portel). The dam structure is 458 meters wide, 96 meters high and has the capacity to retain a total of 4150 hm³. The reservoir at its maximum storage level creates the largest artificial lake in Europe occupying an area of 250 km², of which 35 km² are located in Spanish territory. The dam of Pedrógão, built 23 km downstream in the river Guadiana, creates a reservoir with a 54 hm³ capacity, that occupies an area of about 12 km² (Fig. 10).

Figure 10 - Location of the reservoirs of the dams of Alqueva and Pedrógão
Habitats of the region

The region where the reservoirs of Alqueva and Pedrógão are located is part of the Mediterranean bioclimatic region which is characterised by semi-natural ecosystems highly rich in terms of fauna and flora. In fact, this region is included in the Mediterranean Basin, one of the 25 biodiversity hotspots of the world (15).

The region contains remnants of ancient Mediterranean woodlands constituted by perennial trees, whose dominant species are the holm oak (*Quercus rotundifolia*), the cork oak (*Quercus suber*) and the kermes oak (*Quercus coccifera*). These ecosystems suffered human-induced changes throughout time, originating the agro-forestry-pastoral ecosystem known as Montado (Fig. 11), which used to dominate the landscape of the region. In addition, the area of the reservoir of Alqueva previously possessed large extensions of well-developed riparian habitat in the edges of the Guadiana River and its main tributaries, of extreme biological importance due to its rich associated fauna and flora (Fig. 12).
4. bats and the alqueva multipurpose project

The Alqueva Multipurpose Project had and will have large ecological costs in the region. All major national environmental non-governmental organizations claimed that the construction of the dam of Alqueva alone, promoted large-scale destruction of prime wildlife and plant habitat in the river banks and adjoining areas, with serious consequences for the populations of several threatened species protected under European Union law, as well as under several conventions signed by Portugal. Bats are among the species strongly affected by the Project as a whole.

The construction of the dam of Alqueva, the very first stage of the Alqueva Multipurpose Project, resulted in the destruction of a major roost of cave-dwelling species. This was followed by the massive destruction of roosts of tree-dwelling species during the deforestation process and the cut-down of over a million trees. Moreover, numerous other roosts were either demolished or submerged during the filling of the reservoirs (Fig. 13), and major foraging areas for bats were destructed (Fig. 14).

Mitigation measures and conservation actions were taken for some of these impacts.

Nonetheless the forthcoming stages of the Alqueva Multipurpose Project pose a new challenge on the conservation of this group in Alentejo. The implementation of the irrigation scheme may result in a vast landscape change, further bat foraging habitat destruction and in a massive increase of pesticide use. All these are known threats to bats.
5. mitigation measures and other actions

5.1. Bat Inventory

Due to the limited information available on bat species in the area of the reservoirs of Alqueva and Pedrógão, the first measure taken was to perform a bat survey before any major change in the landscape occurred. The survey aimed to:

- Identify bat species present in the region.
- Locate their roosts.
- Determine their most important foraging habitats.

Methods

In order to identify the highest number of bat species several methods were used simultaneously. Roosts were located through enquiries to populations and were visited throughout the year; whenever bats were found inside, these were identified and counted. Other bat species were identified through the use of bat-detectors, while surveying bat’s foraging habitats (see section “Loss of Foraging Habitat” for further details). Even with this combined methodology, some of the species present were probably not identified. This is, for instance, the case of tree-dwelling species which roosts are not easily located nor the species easily identified through their vocalizations (e.g. Myotis bechsteini).

Results

In continental Portugal there are 24 species of bats\(^\text{[130]}\). From these at least 14 species exist in the area (Table 1). The roosts found, mainly buildings and old mines, where not numerous but some were occu-
plied by important breeding and hibernating colonies. While foraging, most species preferred riverine habitats intermixed with wooded areas in detriment of agricultural fields.

**Table 1** - Schematic overview of the species identified in the region of the reservoirs of Alqueva and Pedrógão, their roosts and their foraging habitats: roost preference (tree-, house-, cave- and crevice-dwelling species) and foraging habitats (complex habitat, pond or urban). Common name and threat status is presented (CR (critically endangered), Vu (vulnerable), DD (data deficient), NT (not threatened). Graphic outline adapted from Limpens et al. (17).

<table>
<thead>
<tr>
<th>Name</th>
<th>Species</th>
<th>Status</th>
<th>Summer</th>
<th>Hibernation</th>
<th>Feeding areas</th>
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<tr>
<td>Greater horseshoe bat</td>
<td><em>Rhinolophus ferrumequinum</em></td>
<td>Vu</td>
<td><img src="image1" alt="bat1" /></td>
<td><img src="image2" alt="bat2" /></td>
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<td>Mehely's horseshoe bat</td>
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<td>CR</td>
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<tr>
<td>Daubenton's bat</td>
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<td><img src="image3" alt="bat3" /></td>
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<td><em>M. nattereri</em></td>
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<td><em>M. myotis</em></td>
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<tr>
<td>Soprano pipistrelle</td>
<td><em>Pipistrellus pygmaeus</em></td>
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<td><img src="image3" alt="bat3" /></td>
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<tr>
<td>Kuhl's bat</td>
<td><em>P. kuhli</em></td>
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<td><img src="image3" alt="bat3" /></td>
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<tr>
<td>Leisler's bat</td>
<td><em>Nyctalus leisleri</em></td>
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<tr>
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<td><img src="image3" alt="bat3" /></td>
</tr>
<tr>
<td>Grey long-eared bat</td>
<td><em>Plecotus austriacus</em></td>
<td>NT</td>
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<td><img src="image2" alt="bat2" /></td>
<td><img src="image3" alt="bat3" /></td>
</tr>
<tr>
<td>Schreiber's bat</td>
<td><em>Miniopterus schreibersii</em></td>
<td>Vu</td>
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<td><img src="image2" alt="bat2" /></td>
<td><img src="image3" alt="bat3" /></td>
</tr>
<tr>
<td>European free-tailed bat</td>
<td><em>Tadarida teniotis</em></td>
<td>DD</td>
<td><img src="image1" alt="bat1" /></td>
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5.2. Loss of roosts

Bats of temperate regions show a great dependence on their roosts, spending all daytime period in them. Roosts offer protection from adverse climate conditions \(^{(15)}\) and from predators \(^{(19)}\). They also provide hibernation, breeding and mating sites and are the focus of most social interactions with conspecifics \(^{(20)}\). Roosts are therefore, one of the most important features of the bat life cycle and the choices made with respect to these sites are likely to have an effect on their survival and fitness \(^{(21)}\). Consequently, the loss of roosting sites is an important threat to bats.

The case of tree-dwelling species:

Placement of bat boxes

From the 14 species of bats listed for the studied area (Table 1), eight are dependent on trees for roost at least during part of their life cycle (Fig. 15). These bats usually select roosts in tree holes and crevices with an opening to the exterior or under the loose bark of trees (Fig. 16). As a consequence of the deforestation process, many trees were cut-down, and there was a massive loss of roosts for tree-dwelling bat species (Fig. 17).

Prior to the deforestation of the region, several recommendations were made to minimize the mortality of bats, namely:

- Cutting of trees out of the periods considered most critical to bats: breeding and hibernation,
- Instruct workers on the procedures to follow when finding a tree with bats,
- Instruct workers to pile the logs in a way that allowed bats to escape.
After the deforestation, measures taken aimed to temporarily increase the availability of roosts to tree-dwelling bats whose roosts have been destroyed. For that we:

- Erected bat-boxes of distinct models and colours near deforested areas.
- Surveyed the occupation of bat boxes.
- Evaluated the influence of the variables model and colour in the occupancy success of bat boxes.

**Methods**

Two distinct bat box models were used to better reproduce the diversity and characteristics of natural roosts (Fig. 18). One of the models (Model 1) was adapted from Bat Conservation International \(^{(22)}\) and intends to mimic a breeding roost (Fig. 19). The second model (Model 2) \(^{(23)}\) intends to reproduce the conditions of the holes in the interior of trunks, possessing an ample central space with an access through narrow crevices (Fig. 20).

Moreover, two colours - black and grey - were used in bat boxes, since colour (and its respective absorbance) has a strong influence in the temperatures reached in the interior of the boxes \(^{(23, 24)}\).
The use of two distinctive colours allows broadening the range of internal temperatures, so that these can comprise roost preferences of different species.

The bat boxes were constructed in maritime plywood, which offers high durability and is indicated for adverse climate conditions. All the wood junctions were sealed with silicone sealant and the bat boxes painted with non-toxic paint.

The priority areas for the placement of bat boxes were oak woodlands (Fig. 21 and 22). Within these, the preferred trees were the highest and oldest, offering higher security against predators and more trunk cavities, normally used as roosts by tree-dwelling bats.

Figure 22 - Location of sets of bat boxes (black dots) placed in the areas of the reservoirs of Alqueva and Pedrogão. The shaded green represents the forested areas that existed in the area before the Alqueva Multipurpose Project.
Two sets of 100 bat boxes were placed, the first during October 2001 and the second during February 2004. These were mostly placed in groups that combined boxes of different models and colours. All boxes were south orientated to increase sun exposure. This allowed higher internal temperatures that favor breeding for some bat species. Bat boxes were always placed as high as possible, to avoid a potential human disturbance and the attack by predators.

The survey of bat boxes was done mainly during breeding and hibernation periods, when roost selection is considered critical to most bat species. Generally, bats were counted inside the boxes. However, during the breeding season, when bats were too numerous to allow a reliable count inside the box, individuals were counted at dusk, while emerging to forage.

Results

Species colonizing bat boxes

For the first three years, bat boxes were only used regularly by two species: *P. pygmaeus* and *P. kuhlii*.

Occupancy rate

The bat boxes were quickly colonized; the first bat (*P. pygmaeus*) was identified just five months after the placement of bat boxes, and the first breeding colony (*P. kuhlii*) identified three months after that. This first colony observed increased during the following years, spreading to nearby boxes.

Overall, the occupancy pattern of bat boxes showed a progressive increase both in number of bat boxes occupied and number of individuals occupying them (Fig. 23).
The occupancy of bat boxes was higher during spring. This is expected, since both designs of bat boxes favour breeding colonies, due to the warm temperatures they provide. Although the designs of bat boxes do not favor thermal conditions for hibernation, results show a progressive occupancy by bats during this period.

**Model 1 versus Model 2**

Overall, bats preferred bat boxes of model 1. In fact, model 1 was more frequently used during breeding season. However, bats used boxes of model 2 during hibernation (Fig. 24). The first colonisers of bat boxes of model 2 were birds; by the end of the first year these occupied 80% of bat boxes of this model. It is highly probable that this occupation by birds constrained the use of boxes of model 2 by bats.
Figure 24 - Variation in the number of individuals (bars) and the number of occupied bat boxes (lines) of models 1 (M1) e 2 (M2) colonised.

Black boxes versus grey boxes

Regarding colour, bats seemed to prefer black boxes (Fig. 25). This preference seemed to be clearer during the breeding period, probably due to the benefits of higher temperatures present inside black boxes.

Figure 25 - Variation in the number of individuals (bars) and the number of occupied bat boxes (lines) of black (Black) and grey (Grey) colour.
Discussion

Overall, the placement of bat boxes proved to be successful and valuable in minimizing roost loss due to deforestation. It is probable that the fast colonization of bat boxes is related with the magnitude of destruction of nearby natural roosts, as the availability of alternative natural hollows is an important determinant of the extent to which boxes are occupied\(^\text{(28)}\).

An important issue while planning bat-boxes placement is the height at which bat boxes are placed. Some tree-dwelling bat species are known to occupy tree roosts at great height\(^\text{(26,27,28,29)}\). However, the entrance height in natural roosts is, dependent on factors such as tree height and canopy levels\(^\text{(20)}\), which differ with the forest type in different regions\(^\text{(30)}\). The natural forest in this region does not frequently allow high natural roosts, as the canopy level of trees is generally below five meters. In cases such as this, when natural forests present low canopy levels, poles or even exotic tree species (e.g. eucalyptus trees) can be used to increase the heights available to place bat boxes.

In conclusion, despite the number of bat species using boxes was low, these structures proved to be successful to the species that occupy them. The use of sets of bat boxes with two models and two colours seems a good strategy, allowing bats to change boxes according to their thermal needs.
The case of cave-dwelling species: exclusion of bats and replacement roosts

Eleven of the 24 bat species present in Portugal depend on underground roosts. In fact, caves and mines are very important sites for bats to rear their young in the summer, hibernate in the winter, and use as temporary refuge. Underground roosts are also used by bats as crucial migratory rest stops during spring or autumn, as temporary night roosts, and as places for courtship and mating. Bats usually remain loyal to their roosts, mainly due to the low availability of these structures. In addition, the existing underground roosts are increasingly subjected to human disturbance.

Several roosts of cave-dwelling species were identified during the inventory of the study area. These were mostly underground roosts, although some of these species were found occupying buildings. The majority of these roosts were destroyed during the flooding of the area of the reservoirs of Alqueva and Pedrógão. Among these, five were considered essential for bat conservation, due to their importance as breeding or hibernating sites for threatened species (Fig. 26 and Table 2).

| Table 2 - Species present in the five most important roosts affected by the Alqueva scheme (breed – breeding; hibern – hibernation). |
|---|---|---|---|---|---|---|---|---|
| Type | R. fer | R. hip | R. meh | M. myo | M. dau | M. sch | Impact |
| Alandroal I | mine | hibern | hibern | breed | * | breed? | partially submerged |
| Alandroal II | watermil | * | breed | | | | destroyed |
| Moura II | gallery | | | | | | destroyed |
| Serpa I | mine | * | * | * | | | destroyed |
| Serpa II | watermil | breed | | | | | submerged |
Overall, this action aimed to guarantee the conservation of bat colonies that used these roosts. For that we:

- Surveyed seasonal bat occupancy of original roosts by bats, both in terms of abundance and diversity;
- Defined strategies of exclusion of bats that occupied roosts to be destroyed;
- Defined strategies to allow a proper replacement or protection of these roosts;
- Surveyed the colonization process of bats in the replacement roosts.

Figure 26 - Location of identified roosts of cave-dwelling species. The name of the five more important roosts is indicated.
Methods

Roost survey

The underground roosts that were identified during the inventory, and which were occupied by important bat colonies were surveyed yearly during hibernation and breeding periods, prior to their destruction. Bats were identified and counted, and some were captured and ringed. Data-loggers were used to monitor continuously the temperature and humidity of these roosts. The same procedure was followed in the replacing or altered roosts.

Bat exclusion

Bats were excluded from underground roosts and buildings before their destruction or flooding (Fig. 27). Exclusions were made shortly before destruction of roosts. Bats were excluded in summer during the day, and relocated to other nearby roosts. The original roosts were then temporarily closed, visited at night, to confirm the absence of bats, and then definitively sealed.

Some particular cases of bat exclusion occurred in the mine Alandroal I and in the watermills located throughout the Guadiana River. The roost Alandroal I was a mine complex which sheltered several bat species and important hibernation and breeding colonies. This was composed of three levels, from which only the lowest was flooded. In this particular situation, bats were removed from the lower level and released in the remaining area of the mine. Additionally, both the adit and winze connecting the lower levels were sealed (Fig. 30) to avoid bats to return to the flooded area when the water level of the reservoir was low (e.g. during summer).
Regarding watermills, these were not demolished as most buildings in the area, and some could not be safely sealed before flooding. Whenever sealing was not an option, new openings were open in the uppermost structures of the watermills, assuring this way that bats would not be trapped inside during the flooding.

**Roost replacement**

Two underground galleries were built as replacement roosts. These were built near two of the major destroyed roosts: Moura II (in 1995) and Serpa I (during 2005). Both galleries were dug in the rock (Fig. 28 and 29) and possess a curved adit of about 40 meters to help maintain stable environmental conditions in the interior of the roost. Additionally, both galleries end in two rooms connected, which allow bats to escape in case of disturbance (Fig. 31). Finally, galleries possess drillings in the ceiling and walls to make it suitable for crevice-dwelling species.

From the experience and results obtained with the gallery built in 1995 (Fig. 32), some adaptations were implemented in the design of
the second gallery: 1) the two rooms were built at different heights to increase thermal range (Fig. 31 Section C-C), 2) a hole was drilled to connect the coldest lower room to exterior, and to allow warm air accumulated near its ceiling to escape (Fig. 33) and 3) a wedge-shaped ditch of 2.5 meters deep was excavated near the entrance to avoid human disturbance (Fig. 34).

Figure 32 - Entrance of the replacement roost of Alqueva.

Figure 33 - Metal structure covering the outer end of the hole drilled on the lower room of the roost.

Figure 34 - Entrance of the replacement roost of Pedrógão.

Figure 31 - Top view and sections of the replacement roosts. All the measures in meters. (Adapted from the technical plans of EDIA S.A.).

Results

The case of the replacement roost of Moura II

The replacement roost of Moura II was constructed during 1995, just downstream of the wall of the dam of Alqueva. The first step after its
construction consisted on relocating forty-two bats to this roost. The original roost was then sealed and destroyed. The survey of the replacement roost started in the first months of 1996 and has continued ever since.

The first bat (a male *M. myotis*) was observed in July of the first year of survey. In February 1997 individuals of *R. mehely*, *M. schreiberi* and *R. ferrumequinum* were also observed. *R. hipposideros* was the last species known from the original roost to occupy the replacement roost.

The seasonal occupation of this roost by bats varied significantly during the ten-year survey (Fig. 35). In fact, *R. hipposideros* and *R. ferrumequinum* used the roost occasionally, while *R. mehely* and *M. schreiberi* used it regularly, but in irregular numbers. In contrast, *M. myotis* had a clear pattern of seasonal use since 2001, with higher and increasing numbers during the breeding season (Fig. 35); the first newborn *M. myotis* were observed during spring of 2005.

*Figure 35* - Patterns of occupancy of the replacing Moura II roost.
Thermal data revealed that annual temperature of the roost varied between 16.7°C and 19.4°C. It is likely that these temperatures are high enough to prevent it from becoming an effective hibernation roost.

**Discussion**

The results suggest that replacement roosts can be a viable solution for mitigating the loss of underground sites occupied by cave-dwelling species, as already observed in other countries.\(^{30}\)

There are, however, many pitfalls that can limit the success of these measures. One of these limitations is the scarce knowledge about the thermal requirements of many bat species. In addition, there is always some uncertainty regarding the thermal behavior of the roost itself. As a result, the construction of replacing underground roosts should be only considered when it is impossible to maintain the original ones.

The occupancy of a new roost by bats can take years or even not occur at all. The quick colonisation observed in the roost Moura II is surely a consequence of the destruction of the original roost, and of its thermal characteristics, particularly during the breeding season.

In this project, replacement roosts tried to mimic the characteristics of the original roosts. Nevertheless, several other successful replacement roosts were built using diversified plans and materials\(^ {33,34}\).

One of the main requirements for the success of a replacement roost is its location. It is known that bat roosting preferences are strongly influenced by the quality of the surrounding landscape as foraging habitats\(^ {32,35}\). The replacement roost should, thus, be located as close as possible to the original one, and in an area where the landscape favors bat foraging activity.
5.3. Loss of foraging habitat

Landscape change and the destruction of foraging habitats are among the major threats to bats (1). In fact, bats depend on a complex network of habitats to feed. The landscape in Portugal is becoming more homogenous, mainly due to agriculture and forestry intensification (Figs. 36 and 37). This homogenization reduces the structural variety of the landscape, and consequently its ability to sustain a diverse bat community.

The landscape homogenization trend is quite obvious in the Alentejo region. The Alqueva Multipurpose Project further contributed to this process, with the conversion of 250 Km² of diversified habitat into a single lentic habitat (Fig. 38). To evaluate how these changes influenced bat foraging behaviour in the region, we:

- Studied habitat use by bats in 2000 (previous to flooding) and 2003 (after flooding), focusing on the comparison between newly created habitats and the original habitats replaced by these,

- Compared bat activity in different habitats during 2003, focusing in the newly created habitats and their characteristics.

Methods

To evaluate the foraging habitats of bats, several land use types were selected as representative of the landscape of the region both before and after the flooding took place (Table 3).
Table 3 - Habitat types surveyed during 2000 and 2003.

<table>
<thead>
<tr>
<th>Land use</th>
<th>Abbreviations</th>
<th>Pre-flood 2000</th>
<th>Post-flood 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak woodland</td>
<td>Oak</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Islands</td>
<td>Isl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive groves</td>
<td>Oli</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Eucalyptus plantations</td>
<td>Euc</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Riparian areas</td>
<td>Rip</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Reservoir margins</td>
<td>Mar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ponds</td>
<td>Pon</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Reservoir</td>
<td>Res</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Irrigated farmland</td>
<td>Irr</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Conventional farmland</td>
<td>Con</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Vineyards</td>
<td>Vin</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Deforested areas</td>
<td>Def</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Urban areas</td>
<td>Urb</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

Several replicates of each land use type were surveyed using transects. Each transect consisted of a 15-minute walk with a bat-detector, during which the number of bat-passes and feeding-buzzes were recorded. These data were later analysed using sound analysis software.

To survey the habitats created by the flooding of the area - Reservoir and Islands - the same transects were done on a boat at low speed. Location was confirmed by GPS. The distance travelled on boat transects was similar to the one travelled on foot transects.
Results

Habitat use before and after flooding

The area surveyed in 2000 suffered a major change in its landscape due to the deforestation and flooding that took place. Even though, bats kept the same general preferences about their foraging habitats. Riparian areas was clearly the preferred foraging habitat in the region, with a high number of bats of numerous species using it to feed (Fig. 39). The habitats Urban areas and Ponds also showed some relevance for bats. On the contrary, habitats like Reservoir, Eucalyptus plantations, Irrigated farmland and Deforested areas showed low levels of bat activity and diversity.

![Graph showing habitat importance before and after flooding.](image)

**Figure 39** - Habitat importance considering mean bat-passes number and number of species found in each habitat type. Habitat abbreviations in Table 3.

Original and actual land use

Bat activity was compared between the newly created habitats—Deforested, Reservoir, Islands—and the previously existing ones. Results show a very low foraging activity in the habitats Deforested and Reservoir, suggesting that the Alqueva Multipurpose Project resulted
in massive loss of foraging grounds for bats (Fig. 40). However, the habitat *islands* showed an increase in bat activity when compared with the previously existing habitat.

![Graph showing comparison of bat activity between 2000 and 2003 in habitats located in the current reservoir area. The vertical lines show the 95% confidence limits. The habitat abbreviations are found in Table 1.](image)

**Discussion**

The construction of the dams of Alqueva and Pedrógão destroyed vast areas of important foraging habitats for bats. In contrast, the present homogenised landscape offers poor foraging habitats for bats.

Pre/post flooding surveys proved particularly useful in identifying the impacts of landscape change on bat foraging habitats. At the end of the pre-phase, the obtained results allow to propose some mitigation measures. Afterwards, the post-phase allows evaluating the success of these measures, and monitoring other impacts of the project.
The post-flooding phase of this survey consisted on only one year of field-work, starting during the flooding of the reservoir. As bats were still adjusting to the new landscape the results attained may not completely reflect the long-term effect construction of these dams will have on bats. A longer survey is advisable as it will provide more robust results.

Overall, the appropriate management of the landscape surrounding the reservoir appears to be the key measure to compensate the loss of foraging habitats. Among others, it is recommended to recover the degraded riverine habitat in the region surrounding the dams. In addition, it is advisable to stimulate the forestation with autochthonous species; create corridors with autochthonous vegetation and preserve the existing vegetation on islands (Fig. 41). Although most of these measures were considered before in a wider environmental mitigation plan for the area (56) none was implemented.

In future terms, the situation does not look very promising for bat populations in the region. The conversion of vast areas into intensive farmland will provoke further homogenization of the landscape and an increase in pesticide use (Fig. 42), reducing the abundance and diversity of prey-insects (57, 58) and directly contaminating bats (59). In this context, dams that are built with irrigation purposes should have associated an integrated study, including the survey of the areas to be both flooded and irrigated, in order to correctly evaluate and minimize the cumulative impacts of all landscape change.
5.4. Environmental Education

The lack of knowledge and negative attitudes are some of the greatest, and yet least appreciated, threats to bats. Despite the benefits brought by these animals, in most cultures they are associated with a negative image and are objects of fear. This is mainly due to unfounded myths and superstitions and ignorance about their lifestyles. Adding to the previous conservation actions, an educational project was developed that aimed to:

- Encourage the understanding of these animals and their important role in nature,
- Give a more informed and publicly acceptable image of bats.

Methods

The educational project

The project was carried out in almost all primary schools of the Municipalities affected by the Alqueva Multipurpose Project: Moura, Mourão, Reguengos de Monsaraz, Barrancos and Portel.

It consisted of several sessions that took place in the classrooms of the schools. Each session was composed of two phases: the first phase was theoretical, in which ecological and conservationist concepts about bats were introduced (Fig. 43). The second phase consisted of a workshop in which schoolchildren had the possibility to construct bat masks, hats, drawings, and participate on other activities associated with these animals (Figs. 44 and 45).
The enquiry

An enquiry (Fig. 46) was developed with the main objective of evaluating the success of the educational project. More specifically, it intended to:

- Evaluate children's initial level of knowledge of bats,
- Evaluate children's initial attitudes towards bats,
- Analyse children's fear of bats,
- Compare children's knowledge, attitudes and fears before and after the educational experience and
- Identify which factors could be related with these differences.

![Image with a table and question prompts]

Figure 46 - Sample of the enquiry that was distributed to schoolchildren.
Schoolchildren received the same enquiry at a pre and post session stage. This was composed of 18 questions, which fell into one of the following categories: (1) Knowledge (2) Attitude and (3) Fear.

**Results**

The educational project had the participation of 32 schools of the region and in total included 111 classes and about 1890 children. During the sessions, educational material specifically developed for this project was distributed to all the schoolchildren (Figs. 47, 48 and 49).

**The enquiry**

A sample of 400 schoolchildren was selected from the 1890 that participated in the educational sessions. This sample was considered sufficiently large to allow for generalisations about the children population attending schools in the area (16 %). Some examples of the results for each of the three categories considered in the enquiry will be presented here.

**Knowledge Category:** Do bats suck blood? Do bats come out at night? Are bats poisonous? Are bats helpful for agriculture? Do bats get tangled in the hair? Do bats fly?

Initial answers showed that most children knew that bats are nocturnal animals (95 %), which are able to fly (88 %). However, only 23 % of the children knew that bats do not get tangled in the hair, and almost half (40 %) thought bats were poisonous. The majority of children answered that bats suck blood (84 %) and are useless to agriculture (91 %). The educational session resulted in a significant increase of correct answers (Fig. 50).
Figure 50 - Percentage of correct answers: Do bats suck blood? Do bats come out at night? Are bats poisonous? Are bats helpful for agriculture? Do bats get tangled in the hair? Do bats fly?

Attitude category: Which of these animals do you like the least?

Before the session, 24% of schoolchildren chose bats as the animal they liked the least. The session contributed to a decrease in this percentage (to 10%; Fig. 51).

Figure 51 - Percentage of schoolchildren that choose bat as the animal they liked the least. A) before educational session, B) after educational session.
**Fear Category:** Are you afraid of bats?

Prior to the sessions, the majority of schoolchildren (56%) stated they were not afraid of bats (Fig. 52). The educational session has contributed for an increase in this percentage from 56% to 75%, a decrease in the percentage of children who stated being afraid of bats (from 18% to 4%), and an decrease in the number of indecisive children (from 26% to 19%).

![Figure 52 - Percentage of schoolchildren with different reaction towards bats.](image-url)
Discussion

The educational project had a positive impact on schoolchildren, contributing to deepen their knowledge of bats and to an apparent change of their attitude towards this animal group (Figs. 53 and 54).

Despite the project being directed towards schoolchildren, the initiative also seemed to influence the opinion of schoolteachers. This result is important, as teachers play a major role in the children attitudes, especially at these ages, when they are still modulating their knowledge and attitudes. Likewise, some relatives demonstrated interest and mentioned they have heard about bats, showing that this message was also spreading at the homes of some children.

The project was a pioneer initiative, letting us understand what are the children’s attitudes and beliefs in relation to this animal group. These beliefs affect their attitudes and can be targeted in future educational efforts, when developing public awareness and education programs. It would be interesting to involve schoolchildren in more practical activities, such as the construction of bat boxes. If one wants to change attitudes, education without a practical component might not be very effective. By directly contributing, children would give a different value to bats and would feel more motivated to protect this animal group.

Figure 53 - Schoolchild drawing before the educational Project.

Figure 54 - Schoolchild drawing after the educational project.
6. References


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Este trabalho resume diversas acções realizadas no âmbito de um protocolo celebrado entre a EDIA e o ICN, com o objectivo de conservar as populações de morcegos na área afectada pelo Empreendimento de Fins Múltiplos do Alqueva.

This brochure summarizes the actions performed in the context of a protocol settled between EDIA and ICN, with the purpose of preserving bat populations in the area affected by the Alqueva Multipurpose Project.

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