A Review of Purpose-built Roosts for European Bats

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Section One- Introduction

In early human history all European bat species would have roosted in natural structures, mainly caves and trees (Dietz, von Helversen & Nill, 2009), adjusting their roosting sites to compensate for the variation in their energetic and reproductive cycles on an annual basis (Altringham, 2011) as they do today. As human populations spread and their cultures developed after the last age ice, human activities started to profoundly change the landscape in which they lived. The first noticeable signs of this were the Neolithic Forest clearances and the development of early agricultural systems. The Bronze and Iron Ages saw a continuation of these developments with the progress of urbanisation and early mining activities. The rate of landscape change was fairly gradual until the start of the Industrial Revolution but since has accelerated until the Anthropocene, in which we have seen widespread and detrimental impacts on once natural landscapes. Throughout the process of human development, bat species have adapted to the changing world around them, some more successfully than others.

The changing availability of roosting opportunities by these human developments has led to changes in relative abundance and the range of different bat species. Old growth forest species such as Bechstein's bat, *Myotis bechsteinii*, appear less adaptable than other woodland bats. The fossil record shows it to have been a numerous species before the forest clearances (Yalden, 1999), whereas today, it is one of Europe's rarest bats. In contrast, the Rhinolophids, originally a year-round cave dweller, have adapted to roosting in buildings that mimic aspects of their original cave roosts. The attic spaces under stone slates or heated cellars both resemble caves. Primarily, these are used in the summer as maternity roosts, although in the winter months, they, can be occupied by colonies all year in favourable climatic conditions. At higher latitudes and in Continental climate zones, where winters can be more severe, caves continue to be used as hibernacula. These are now augmented by artificial caves in the form of mines, ice houses and other underground structures, often in areas where previously there would have been few opportunities to roost underground. This has allowed these species to extend their range into areas without natural caves (Dietz, von Helversen & Nill, 2009).

The more adaptable woodland bat species have also moved into human buildings. They use the gaps behind wooden facia boards or cavities between timber joints that mimic hollows in trees, helping to offset the loss of natural tree roosts. Over time buildings have become an important resource for roosting bats. Traditional building techniques and materials combine to provide bats with numerous roosting opportunities oftenaided by the aging process. Over time timbers warp opening cavities and weathering moves roofing materials allowing bats entry to buildings. The longevity of buildings in the landscape often means they may have been occupied by colonies for many generations and their presence is critical to the continued survival of bat species in the area.

Unless the historical value of older buildings is high, they will not be maintained forever and eventually they fall under the threat of demolition. The removal of older buildings to make way for new developments frequently degrades the area for bats. Contemporary building materials and techniques from plastic fascia boards to breathable roofing membranes are reducing the suitability of modern buildings as bat roosts. Some of these older buildings may survive by being adapted for modern purposes, such as converting old farm buildings into characterful modern dwellings or offices. The extensive renovation and adaptation of older buildings often involves the use of contemporary material, as well as sealing buildings to make them more energy efficient, resulting in the exclusion of bat colonies. In both circumstances the continual survival of the areas resident colonies is reliant on the provision of new roosts.

This document explores a series of case studies where new purpose-built bat roosts were constructed or where existing structures, not previously used by bats, have been adapted to provide new roosts across the Eurobats treaty range.

Section Two- Purpose Built Summer Roosts

New build replacement roosts have been constructed in a range of countries, but the majority have been built in Western Europe and predominantly for *Rhinolophus* species and *Plecotus auritus*. In contrast to the many species of crevice dwelling bats, these species require larger open roof voids, features that are more difficult to incorporate into the redevelopment of older buildings where space may be at a premium. Although there are exceptions, few have been radical in their design, tending to reproduce similar structures to the ones already used by threatened colonies. Roosts that look like conventional buildings have the advantage that they are not so conspicuous and will not attract unwanted attention from curious passers-by or vandals.

The first of these bat houses to be built in Britain was in 1998, a new road development in southern England ran close to a small, deserted cottage, which was found to contain a colony of less than 20 *Rhinolophus hipposideros*. The roofing slates had been partially removed and the building was in danger of collapsing and had to be demolished. The new roost was constructed some 100m away, similar in size to the original roost, the new building was constructed in an L-shape to improve the solar gain to the roof, which was steeply pitched to create a wide range of temperature gradients inside for the bats.

Figure 1. Bellaire Bat House. The false shutters were added to this building after construction to make it look less conspicuous.

The destruction of the original roost before the new bat house was constructed led to the colony deserting the area. It was two years before *R. hipposideros* started to use the building in small numbers and 11 years before a relatively substantial colony of over 60 bats were using the roost. The total cost of this building was £70,000.

A more ambitious bat house for *R. hipposideros* was constructed near Ennis in the west of Ireland in 2005 as mitigation for a housing development. The building was 14m long and 8m high and made provision for a maternity roosting area in the roof as well as a hibernation area in the basement. It was built some 400m from the original roost, which contained a small colony of only 5 bats. Take up of the building by the local population of *R. hipposideros* has been very limited. After seven years only two bats were recorded hibernating in the site, and one was observed in the roof void in the summer.

Figure 2. The Ennis bat house shortly after construction.

The reasons cited for the lack of uptake have been the potentially small population of *R. hipposideros* in the area and the availability of other suitable roosts. However, problems in the original design may have also contributed with the building lacking the humidity required by hibernating bats due to the floors having an efficient damp-proof layer. Some subsequent modifications have been made to the building and it continues to be monitored.

In 1999 the Breton Mammal Group acquired land around a slate working in Finistère. This underground site was used by some 200 hibernating *R. ferrumequinum,* however, the maternity roost used by these bats had not been identified. In order to safeguard the future of the colony the group decided to undertake a purely conservation project to create a new maternity roost on the site. As with the Ennis bat house, this incorporated a hibernation area as well as spaces in the roof for a maternity roost. The project was funded by a consortium of organisations from local authorities, NGOs and foundations.

The building was relatively small with a height of 5m, width of 4m and the buildings was 6m long.

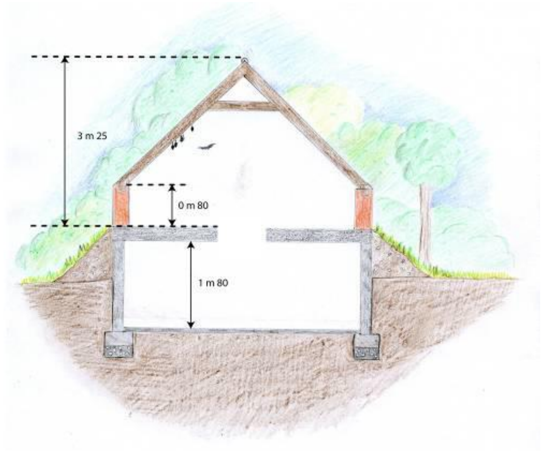

Figure 6. The new bat house for R.ferrumequinum in Finistère had a cellar for hibernation and a slate covered roof for a maternity roost.

Figure 7. The Breton Mammal Group also cleared rubbish and planted vegetation around the site.

The site was adopted by hibernating bats within a few months, but it took five years before a maternity colony was using the building. The overwintering bats number some 120 individuals with a maternity colony of 100 bats.

Moving away from the more traditional approach to building roosts for Rhinolophids, a project in Navarre, north-east Spain has focused on providing roosts for both *R. ferrumequinum* and *R. hipposideros*. The original roosts for these colonies were buildings associated with a derelict fish farm, in addition to the two Rhinolophid colonies the buildings were also used by *Pipistrellus pipistrellus* and *Myotis emarginatus*. Safety concerns around the condition of the buildings led the local authorities to require their demolition and pressure for suitable mitigation from Spanish Bat Society led to the provision of two new roosts.

The new sites were constructed of pre-formed concrete sections manufactured off site. The larger of the structures was 2.6m square and 4m high, the smaller was 2m square and 3.2m high. Both had smooth exteriors and rough interiors, wooden boarding was attached to the ceiling in areas to provide extra purchase for the bats.

Figure 8. The larger R. ferrumequinum roost made out of two sections.

Figure 9. The smaller R. hipposideros roost.

Both new roosts have been successful with the larger site have a colony of 48 *R. ferrumequinum* and the smaller one 33 *R. hipposideros*. The *M. emarginatus* colony has also taken up residence in the larger of the two structures, although the numbers here have dropped from 200 down to 91 bats. Modifications were made to the buildings following the first year of monitoring, as evidence suggested the sites were overheating and causing the bats to abandon them in hot weather. The exterior surfaces were treated with heat-reflective paint and the roofs were modified to provide an air gap between the outer metal lining and the concrete ceiling. Both of these actions have reduced the extreme temperatures and no further abandonment of the roosts.

Following these successes in Spain, the idea of bat towers for Rhinolophids has been trialed successfully in France. These structures have also been built in Ireland and the UK, with the sites being adopted by *R. hipposideros* within months of being completed.

Figure 10 Bat towers constructed for Rhinolophus hipposideros in France (left), Ireland (centre) and the UK (right)

Away from Rhinolophids, many of the purpose-built roosts have been created for *Plecotus* species, bats that also require an open and spacious roof void, although provision for crevice dwelling bats has often also been incorporated into these buildings. In common with the roosts built for Rhinolophid species, these have also followed a similar pattern of relatively conventional buildings that fit in with their often suburban environment.

A typical example of one of these structures is a new bat house at Brackley in the English midlands. The demolition of existing older buildings was undertaken to make way for a new housing development. The new bat house was constructed before the main development in order to allow the bats to become accustomed to the new roost. The new building was a square design and incorporated an open loft space slot entrances and crevices for local Pipistrellus populations.

Figure 11. New built roost for Plecotus auritus with slot entrances for crevice dwelling bats (©ecologybydesign).

There were signs that bats were using the new roost within a matter of weeks of its construction.

A similar site was built in the north of England following the demolition of an ordnance factory. The roost followed a similar design to the Brackley bat house with block work walls and a tiled roof. Access points for the bats were via slot entrances in the gable walls and one of the ridge tiles.

Figure 12. This roost was occupied by bats within five months of construction (©Bowland Ecology)

The funding of new build roosts is sometimes made more palatable for householders by incorporating areas of human use such as garaging for vehicles. This dual use building in southern England was also constructed for *P. auritus* bats. Figure 12 shows the open roof space under construction.

Figure 13. A dual use building with a garage below and bat roost above.

Conservation projects in the Netherlands led by the Dutch Mammal Society have constructed bat towers. Whereas the UK buildings previously described have been designed to provide new roosting opportunities for bats but have not attempted to mimic the roosts lost during a development, the Dutch designs aim to reproduce a whole suite of features found in the original roosts. The great advantage of these designs is the height. At 4 metres these bat houses maintain the elevation of the original roosts and their entrances. By building them so they have an aspect similar to the original roost and close to vegetation they try to reproduce similar microclimatic conditions to the roosts that have been lost.

Figure 14. Dutch bat tower.

These buildings are designed to be used by a range of species but particularly *Plecotus, Myotis* and *Pipistrellus* species.

Concerted attempts to replicate roosting conditions have been attempted in Portugal, where the destruction of a 15-storey building used by a colony of some 100 *Tadarida teniotis* and smaller numbers of *Eptesicus serotinus* and *Pipistrellus pygmaeus*, was compensated for with a purpose-built roost. The bats were found roosting in crevices behind the concrete skin of the building and to replicate this, the new building was constructed using the concrete plates from the original structure.

Figure 15. The original building at Mordegário Portugal (left) and the new purpose-built roost (right)

Although most of these constructions have been built in Western Europe, there are examples from further afield. An initiative in Saudi Arabia has been creating bat roosts by recreating traditional buildings. In this area buildings were traditionally constructed of mud bricks, used by *Pipistrellus kuhlii* and *Asellia tridens*. As people in the area have started to employ more modern materials in their buildings the mud brick houses have started to deteriorate and collapse, with the resulting loss of bat roosts.

Figure 16. Traditional mud brick buildings in Saudi Arabia

This project worked from scratch to recreate the buildings by manufacturing mud bricks in the traditional way and baking them in the sun. Roosting opportunities have been provided for the bats by creating holes and crevices inside the buildings.

Figure 17. The rough surface on the ceilings provide bats with perching sites

Figure 18. Newly constructed mud brick bat house.

The roosts considered so far have replaced building that are used by bats, however, in southern areas of Europe many species use underground sites as maternity roosts. Although the threats to these roosts usually come from human disturbance, there are occasions where they are destroyed due to development pressures from infrastructure projects. This was the situation in Portugal during the construction of three large dams, two in south-east and one in north-east of the country, where bat roosts were destroyed or submerged during the construction.

A large number of species were affected by these developments including *R. ferrumequinum, R. hipposideros, R. mehelyi, R. mehelyi/euryale, M. myotis, M. daubentonii* and *Miniopterus schreibersii*. The developers were obliged to provide three replacement galleries to serve as alternative roosts. Surveys were conducted to determine the patterns of use of the original roosts along with data on temperature and humidity. The replacement roosts were located as close as possible to the originals and were fenced in order to reduce disturbance (Fig. 17).

Figure 19. Fence entrance to new underground roost

Tunnels were excavated in the rock which led to galleries of different heights. These height differences provided a range of different microclimates for the bats.

Figure 20. Excavated tunnel in the replacement roost

Figure 21. Galleries for the bats to roost in

This type of roost creation work is very innovative and unusual; the designs had to be modified after construction to optimise them for the bats, such as by the addition of panels in the tunnels to reduce light levels inside the roosts. These modifications continue as the conditions in the new roosts do not fully match the ones in the original roosts, however, bats are using the new sites and the numbers resident have been increasing since their construction.

Section Three- Modifying existing structures to provide summer roosts for bats.

Constructing purpose-built bat roosts is expensive, with some of the examples given in Section One costing up to €100,000. Therefore, it is often much more cost effective to attempt to adapt an existing structure and incorporate features that will attract roosting bats. These could be existing dwellings that are no longer inhabited or other types of human constructions that have fallen into disuse. Even a derelict shell avoids the costs of digging out and laying foundations, and for existing buildings in good structural repair the modifications needed to attract bats can be quite cheap.

The privately owned building in Figure 20 was acquired on the 30-year lease by the local authority in Wallonia, Belgium. The project to adapt this disused house for bats intended to solve a number of conservation issues in the area. A roost of *Myotis myotis* was under threat by repeated disturbance and predation of the colony by *Martes foina*. In addition, there was a need to increase and improve roosting opportunities for the local populations of *R. hipposideros.*

Figure 22. Before and after photographs of the old guard house in Virton

The building was re-roofed and shutters were placed over the open windows to make the interior darker for the bats. It was secured by metal doors on the ground floor to prevent unwanted access. Bat shaped entrance holes were cut into some of the shutters to provide access for the bats.

Figure 23. Photographs of the shutters and bat access holes

Bat conservationists in Britain were faced with a similar problem around a roost of some 200 *R. hipposideros*. The colony was continually threatened with disturbance and access for monitoring was forbidden by the building's owners. The hibernation site used by the threatened colony had been identified in a mine about 2Km from the roost. Close by was a small derelict building that had been used as a wages office when the mine was active. There were no signs that any bats were using the office building, and this was acquired to create an alternative maternity roost.

Figure 24. The derelict mine wages office

The roof of the wages office was lifted to provide a large void for the bats. As it was surrounded by trees and partially shaded, the ends of the roof were hipped to increase the solar gain to the building. The ground floor windows were blocked up and a new grilled entrance was added. Within three months *R. hipposideros* droppings were found inside the site and over the following two years day roosting bats were found in residence. After ten years the building is now occupied by a maternity colony of over 100 animals.

Figure 25. The completed conversion to a bat house

Conflicts with resident bats can often arise when colonies occupy spaces in buildings that are required for human use. An example of this in Portugal led to the successful creation of a new maternity roost some 30m away from the original site.

A colony of around 150 *R. hipposideros* was occupying a room in the historical Monserrate Palace and the requirement to renovate the area required the bats had to be moved to another area of the building. The bats were attracted into a temporary roost in an adjacent building by the use of heaters. Although this appeared to be successful and the bats bred, that room also needed to be renovated. The final solution to this problem was to establish a new permanent roost that could be used by the colony all year around.

Morcegário da Regaleira, a building located 30m from the temporary roost was chosen. The room was approximately 7m long, 3m wide and 5m high. Following modifications to the building guano was placed in the roost and a small number of bats were translocated there. Over the following two years only individual bats were recorded using the new roost. Following the installation of a heater into the space the colony finally moved and started to breed in the site, allowing the temporary roost to be closed to the bats. In addition to the maternity use of the site by c200 bats, smaller numbers of *R. hipposideros can* be found in the building throughout the year. The site is also now used by small numbers of *R. ferrumequinum, R. euryale* and *Plecotus sp.*

Figure 26. A photograph of the new roost building, along with a cutaway graphic showing the location of the roost, the entrances, and the location of the heaters.

The modification of human underground buildings such as military bunkers, have been widely exploited to provide bats with hibernation roosts. At more southerly latitudes they can also be used to offer maternity roosting opportunities. A project in Israel, the "Jordan River Bunker Bats" is a collaborative initiative supported by several organizations, including The Mammal Centre of the Society for Protection of Nature in Israel. The Nature and Parks authority, The Jordan Valley IDF Brigade, The Hoopoe Foundation, Bat Conservation International (BCI) and The Israeli Defence Force District Coordination and Liaison.

Following the 1994 peace treaty between Israel and Jordan, Israeli military bunkers were abandoned, and it was observed that numbers of bats had started to occupy the sites, including *Asellia tridens, Rhinopoma hardwickii* and *R. clivosus.* Although the underground bunkers provided a suitable microclimate for the bats, there use as roosts was restricted by the smooth concrete ceilings of the bunkers resulting in a lack of suitable surfaces for the bats to hang from. The project addressed this issue by roughing up the smooth ceilings of the bunkers by using polyurethane foam and cement. Plastic netting and wires were also attached to these surfaces.

Figure 27. Entrance into the modified bunkers

Figure 28. Roughing up the smooth ceilings

Section Four- Purpose Built Hibernation Sites

The provision of purpose-built hibernation sites for bats is challenging. Ensuring the correct airflow through the new system, maintaining an optimal temperature range buffered against external conditions and retaining high humidity can be difficult to achieve. This is reflected in the number of failed projects reported in this review. Evaluating the failures is a useful tool in trying to ensure success in future projects, and most failures are usually due to the increased movement of air through the structure and it subsequently having a low humidity. However, there have also been many examples of successful projects. The easiest species to provide sites for has been *R. hipposideros,* which readily adopts new underground sites.

Although natural hibernation sites can have colonies numbering into the thousands of bats, for many the numbers are in the low tens or hundreds. Consequently, the financial outlay for building underground or semi-underground structures can be considerable for relatively little return in bat numbers. However, the provision of a new underground site close to a key maternity roost that is some distance from a cave or mine can be insurance against extreme weather events; thus allowing the colony access to a refuge buffered against sudden and unexpected drops in temperature. They can also make maternity roosts themselves more attractive for colonies as a newly provided hibernation site adds value by providing all of their roosting needs in the same locality.

Most of the provision of purpose-built hibernation sites has taken place in Western Europe and away from extensive areas of karst or where mining was historically widespread. The construction of most of these roost follows a similar pattern with the structure being semi-underground and then covered with a layer of insulating soil. The use of pre-cast concrete drainage tubes is common and it is often a cheaper alternative to building block walls and casting concrete floors and ceiling.

Flahive's hibernaculum in the west of Ireland was constructed to improve the resilience of a maternity colony of *R. hipposideros* that roosted in a building close-by. An earthen chamber had been dug into the site some eight years previously and although this had been used by small numbers of bats, it was starting to collapse and a new more robust hibernacula was needed. The front and back walls of the new structure were built using blockwork and the main chamber was formed by pre-cast concrete tubes. A block work baffle reduced air movement and reduced the light entering the chamber.

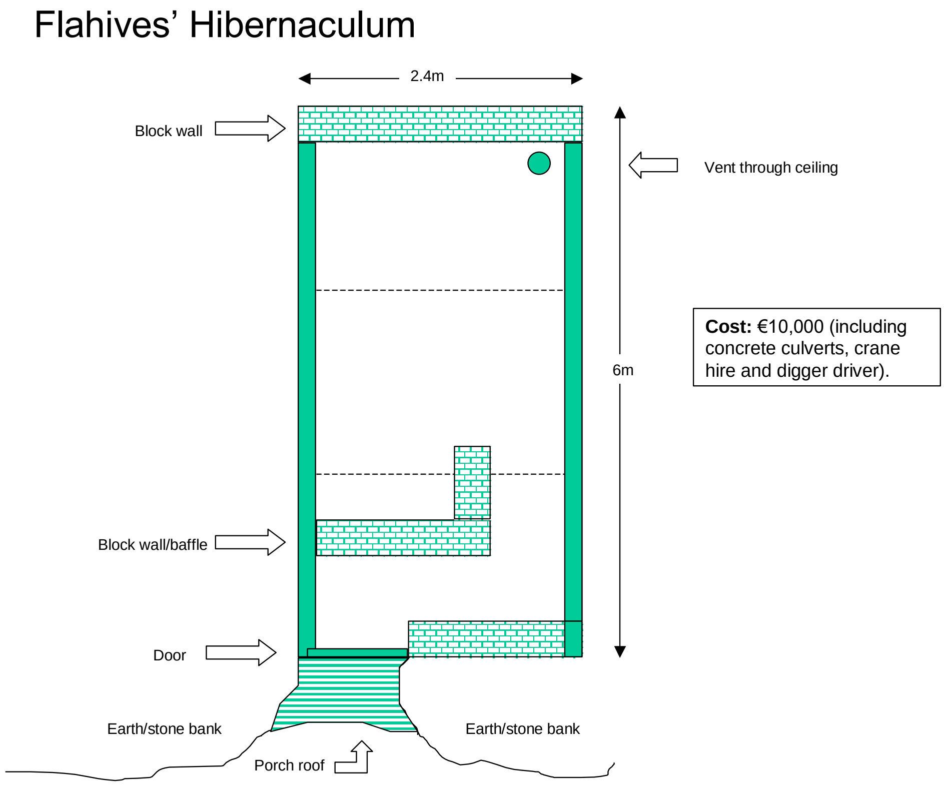

Figure 29. The ground plan of Flahive's hibernaculum

Figure 30. Square profile pre-cast concrete sections being loaded into place.

Figure 31. The new hibernation site before it was covered in earth

The structure had a door with a window to allow the bats access and was covered with earth and vegetation to provide insulation. The new hibernation site was a great success and in the five years following its construction the number of *R. hipposideros* using the site increased to two hundred.

Figure 31. The entrance to the completed structure

Directly linking purpose-built hibernation sites for Rhinolophids to their summer roosts can be very effective and provides the colony with all year around roosting opportunities. At a site in south-west England a simple tunnel was built using a cast concrete floor and ceiling with blockwork walls. The entrance to the L –shaped tunnel was located in a ground floor room of a disused building that was home to 150 *R. hipposideros*.

Figure 33. Part of the blockwork tunnel system connected to the maternity roost before it was covered over with earth

The tunnel ended in a small chamber where most of the bats hibernate. A small chimney at the end of one of the tunnels maintains some airflow through the system and holes in the blockwork walls allow some water ingress and keep the humidity levels high.

These relatively simple open structures work well for *R. hipposideros,* but the provision of numerous crevices and hollows are required when sites are being provided for most Vespertilionid bats. A number of purpose-built hibernation sites have been constructed in Belgium. One of the simpler designs was built at Tilligem and consisted of a central room with a collider running around the outside of it. This is a typical design for icehouses in the area.

The floor of the hibernation site is made of concrete and holes have been drilled into this to allow the water to build up in part of the corridor, this not only increases the humidity but discourages human disturbance. The site is on public land and there were fears around the site being vandalised, the water level in the corridor is such that waders are needed to access the main chamber.

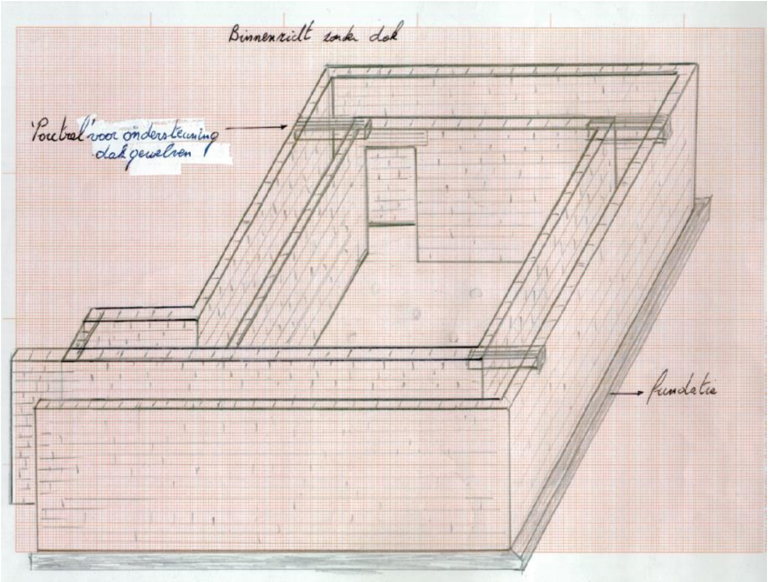

Figure 34. A sketch plan of the Tilligem bat cellar.

The outside walls of the structure are made of concrete blocks, the inner walls of lightweight building blocks.

Figure 35. Showing the solid concrete walls and the lighter internal one.

The construction was covered with a dome of earth and planted with vegetation. A metal door was fitted to the entrance with a hole cut into it to allow the bats access. The site has subsequently been used by small numbers of *P. auritus, M. nattereri, M. daubentonii* and *M. mystacinus/brandtii.* Although the total number of bats using this site is less than 10, this is a significant hibernation roost in the area.

Taking the idea of constructing ice houses a stage further a project at Bulskampbeld in Belgium recreated a traditional dome shaped example. A 4m long service tunnel, with a series of internal doors, led to a round chamber with a radius of 3.6m

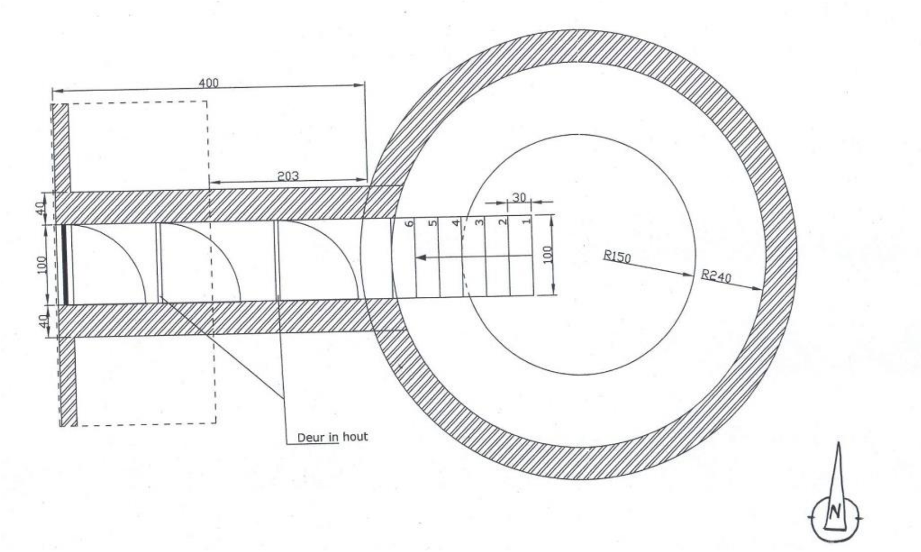

*Figure 36. The ground plan of the Bulskampbeld hibernation site*Numerous gaps and crevices were provided for hibernating bats in the wall of the structure. The contractors built a dome of straw and sand on top of the chamber and used this as a forma for

Figure 37. The Bulskampbeld hibernation site part way through construction

building a brick dome on the chamber.

Figure 38. The brick dome being built over the straw and sand forma.

When the dome was complete the straw and sand was removed from the inside of the chamber. The structure was then covered with earth and planted up.

In the two years following its construction only one or two bats were recorded using the site, since then the numbers have climbed substantially. Over 11 years since it was built this site is now used by over 70 hibernating bats with *P. auritus, M. nattereri, M. daubentonii* and *M. mystacinus/brandtii* all present.

Section Five- Conclusions

This review has shown that purpose-built bat houses and hibernacula can provide species with a valuable roosting resource in the landscape, although one of the recurring themes in the review has been that the uptake of these structures can be slow, in some cases it may be many years before bats fully adopt them. This points to the fact that designs for new roosts in many cases may be perfectly adequate in terms of the roosting ecology of the target species, but a range of other factors around things such as the social structure of colonies or communities may influence their uptake.

They are still relatively unusual structures across Europe generally being restricted to the west of the continent, however where there are individuals or groups with the resources to build them, they are found further afield. The range of species that have been encouraged to use these structures is promising, although most effort has been placed on securing roosts for Rhinolophids where action has been taken to provide new roosts for Vespertilionid and Mollosid species, they have been met with a degree of success. One of the key factors holding back the wider deployment of purpose-built roosts is their cost. For summer sites, the early designs often replicated small human dwellings with a comparable price tag, so the challenge is to develop the concept of purpose-built roosts into cheaper more cost-effective structures, which will mean moving away from a traditional human dwelling type building design or simply trying to replicate a lost building close to the original site.

The multi-species bat towers deployed in the Netherlands bear a striking resemblance in general shape to the roosts built in Spain, France, Britain, and Ireland for Rhinolophids, although clearly there are internal and roost entrance variations. This approach appears to be a step in the right direction, with costs frequently a fifth of those for more conventional style buildings. The Dutch approach of carefully measuring roost parameters and microclimates and then trying to duplicate them in their towers is admirable and clearly the only logical current approach. However, with a fuller understanding of the roosting ecology of species we appear to know little about, would eventually lead to the development of a suite of roost designs that could be deployed in these bat towers- providing an easier and cost-effective solution for mitigating roost loss for a wide range of species.

Building hibernation sites are inherently expensive due to the engineering works often needed to construct structures below ground level. These appear to work well for Rhinolophids where the locating of artificial hibernacula close to existing summer roosts can practically guarantee uptake by a significant proportion of the colony. Although there are exceptions, with the Dutch icehouse design being a prime example, uptake of artificial hibernacula by Vespertilionid species can be in very low numbers. However, they may be a valuable resource in landscapes with few naturally occurring underground sites.

We would recommend further experimentation with the designs for purpose-built roosts, particularly for bat towers, aimed at a wider range of species.

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