

Rehabilitation of habitat connectivity between two important marsh areas divided by a major road with heavy traffic.

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'Vignarca' is a major road between Piombino and Follonica along the coast in Southern Tuscany, in the Province of Livorno. Until the 1940s, the area crossed by Vignarca was a large marsh, which in turn was the remains of an ancient coastal lake (Lake Piombino). Over the years the area was reclaimed, and now only two wetlands remain: one is a typical brackish water marsh ('Orti') and the other a freshwater marsh ('Bottagone') with large areas of reedbeds. These marshes are bisected by the Vignarca road. Since 1991, the marshes have been protected by the WWF by the establishment of the Orti-Bottagone Nature Reserve.

In 1994, the author began to analyze the impact of the Vignarca road traffic on the species that attempted to cross. Between 1995 and 1996 this stretch of road was included in a group of roads of Tuscany (a total of 55 km) where once a week for one year a census of the remains of vertebrates was taken (Scoccianti et al., 2001). In subsequent years many other observations were made in different seasons (data not published). All data collected confirmed the high risk of this road for many species. The impact was particularly high for amphibians: *Triturus carnifex*; *Triturus vulgaris*; *Bufo bufo*; *Bufo viridis*; *Hyla intermedia* and *Rana synklepton hispanica*; and for reptiles: *Emys orbicularis*, *Lacerta bilineata*, *Podarcis muralis*, *Podarcis sicula*, *Hierophis viridiflavus* and *Natrix natrix*. Observing where most of the remains of the reptiles were found (generally very close to the edges and much less frequent towards the middle of the road) as well as individuals in activity, clearly indicated that the road edges were preferred areas for thermoregulation activity. In some periods, in particular weather conditions, thousands of individuals were killed. For instance at the end of July 1997, after a night rainstorm, we counted over 6,500 remains of newly-emerged *Rana synklepton hispanica* juveniles on a mere 100 metre stretch of road. Similar mass killings of *Bufo viridis* were also noted in subsequent years. Even many species of mammals (in particular micromammals) and birds had been found hit by vehicles.

In 1998 the Administration of the Province of Livorno began to take an interest in this old road because subsidence caused by heavy truck traffic serving the many steel mills along the coast was increasing risk of its collapse. As a result of a further agreement between WWF and the Province of Livorno, and within the large-scale project of the overall road reconstruction, the author was given the task of designing an impact mitigation project for the stretch of road which crosses the Reserve.

Two possible solutions emerged: either to divert the road northwards and build a new road far from the Reserve, or build a new road in the same place with new features in several points to offer safe passage to the species (the 'tunnel' hypothesis). The first idea was impracticable from the outset because it would have required even more money to appropriate new land and much more time for construction as against the urgency caused by the collapse of the old road. Finally, another important fact emerged from the study of the area. Besides impeding movements of individual animals between the two marshes, Vignarca also acted as an ecological barrier, which had the curious effect of preserving the typical ecological features of both marsh areas. In point of fact, this complex of wetlands is extraordinarily varied ecologically because there is both a brackish habitat and a freshwater one (with broad areas of reedbed). Many years ago a major power station was built close to the coast which completely isolated the so-called Bottagone section of the marsh from the sea. The freshwater springs made it into a wetland with large areas of reedbed (*Phragmites australis*). On the other hand, the so-called Orti marsh, despite being further from the sea is linked to it by a canal (the 'Cosimo Canal') and has thus developed features typical of a brackish wetland. The Vignarca road is, effectively, the barrier that prevents the mingling of waters of the two marshes. If the two areas were connected, it would lead to salification of the Bottagone water as well, with consequent loss of biodiversity, especially of reedbed biocenosis.

The results of analysing the various aspects of the problem led to a project for enabling faunal species to cross the road safely while maintaining the two different marsh habitats. To solve this problem, the author, together with the engineering department of the Province of Livorno, conceived a particularly innovative solution for the entire stretch of road crossing the reserve bisecting the two wetlands. Instead of digging several tunnels, as had been done in other mitigation projects (Scoccianti, 2001), the road was raised by building a viaduct 215 metres long with nine spans, each of which was some 24 metres long. The piers of the viaduct rise from a bank the height of which was calculated on the basis of flood statistics of the plain over the previous ten years in order to prevent any possibility of the waters mingling even during a flood. This bank was thus determined as 1 m higher than the average water level of the marshes enabling the preservation of the different original ecological conditions of the freshwater Bottagone and the brackish Orti (Fig. 1). Then, the open space needed for the passage of the faunal species was calculated between the top of the bank and the under level of the spans of the viaduct as 1.6 metres. These large spaces provide year-round microclimatic conditions very similar to the outside, which makes it easier for species to cross. Moreover the broad field of vision beyond the spans was expected to make it easy for the species to pass under the viaduct.

The construction of the viaduct took place in 2003. The work was subsequently completed with 300 metres of drift fence along both sides of the road starting from both ends of the viaduct. The purpose of these drift fences was to prevent amphibians, reptiles and micro-mammals crossing the road before or after the viaduct and to channel them below it.

Monitoring the new stretch of road revealed no remains of species of amphibians and reptiles hit by vehicles. At the same time it was observed that many species were using the open space under the spans to go from one marsh to the other and also to find microhabitat for hibernation and aestivation. Furthermore, the effect on birds improved significantly. In fact some species can easily pass under the viaduct either by walking (e.g. *Gallinula chloropus*) or flying (e.g. *Alcedo atthis*); at the same time the new road, which is higher

than the old one, gives the other species which fly over the reedbed a better chance of seeing moving obstacles (cars or trucks) in advance and consequently act to avoid collision. Furthermore, the 2 metre-high guardrail obliges birds to raise their flight path when they are flying across the road.

Particular attention was focused on maintaining the reserve biodiversity during the construction works; the project demanded that all the work (demolition of the old road and construction of the new one) be made in the bed of the old road to prevent any even temporary occupation of any part of marsh habitat along the road.

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Fig. 1: The viaduct under construction (2002), seen from the 'Orti' brackish marsh. Piombino, Province of Livorno, Tuscany, Italy.