Cerema

Information memo
Environment – Health – Risk

Linear transport infrastructures and Reptiles

Application to three significant protected species

Almost all reptiles are protected on a nationwide scale, apart from some species of lizard that are protected on a European scale (Fauna, Flora and Habitat Directive, Annexes II and IV) and/or an international scale (Bern Convention, Appendix III). This means that these taxons must be taken into consideration in development projects.

Reptiles in the lizards suborder (*Lacertibaenia*) are represented in France by 14 species and those in the snakes suborder (*Serpentes*) by 13 species. The purpose of this information memo is not to introduce all the species in these two taxonomic groups. It is rather to shed light and detail on the biology, the preferred habitat and the behavior of some of them: two species of snake – the Meadow viper and the Southern smooth snake – and one species of lizard – the Ocellated lizard – and to review the risks they are exposed to.

This document, which is illustrated by some examples of measures to mitigate the impacts of roads, also aims to allow contracting authorities, designers or operators to assess the various measures of the AMC (avoidance, mitigation and compensation) doctrine that they should adopt in order to best conserve these species, and reptiles in general, in accordance with the outlines of habitat and species conservation defined in the French SNIT (national land transport infrastructures master plan) published in October 2012 as part of the national strategy for biodiversity [2].

Note n° 03 | May 2015

Collection | Connaissances

1. Introduction

The impacts of human activity on biodiversity have been accentuated in recent decades. Nevertheless, the largest industrialized nations have taken account of this erosion, which has even been qualified as massive extinction, since the Rio de Janeiro conference on the environment and development in 1992. As a consequence, measures to reduce and mitigate the impacts of road infrastructures have become more robust since this date. But they soon reached the limit of their effectiveness due to the poor fundamental scientific knowledge of certain groups of fauna, their behavior and their ecology.

The conservation of biodiversity demands not only the protection of emblematic species, but also of more common species that play an equally important role in the workings of an ecosystem. Relatively little is known about reptiles, mainly due to their unpopularity with the general public. However, just like many other groups of species, reptiles are globally on the decline worldwide [1]. Linear rail and road transport infrastructures play a role in this decline and have a significant impact on reptile populations. Road traffic has been constantly on the increase for decades, but few specific measures have been taken to mitigate the impact of roads on reptiles. The observed frequency of reptiles killed on departmental/national highway networks is dropping significantly [2]. This drop indicates that the density of reptiles is also decreasing, because this phenomenon cannot be explained by anthropic pressure alone [1]. The intensification of agricultural practices is one important factor, but the destruction of adults on the roads during the reproductive season and of young reptiles as they spread out cannot be negligible either [photo1]. It is primordial to take this group of fauna into consideration in linear transport infrastructures.

Photo 1: a green and yellow grass snake killed on the roads (source: Parc Naturel Régional des Landes de Gascogne)

2. Presentation of the species

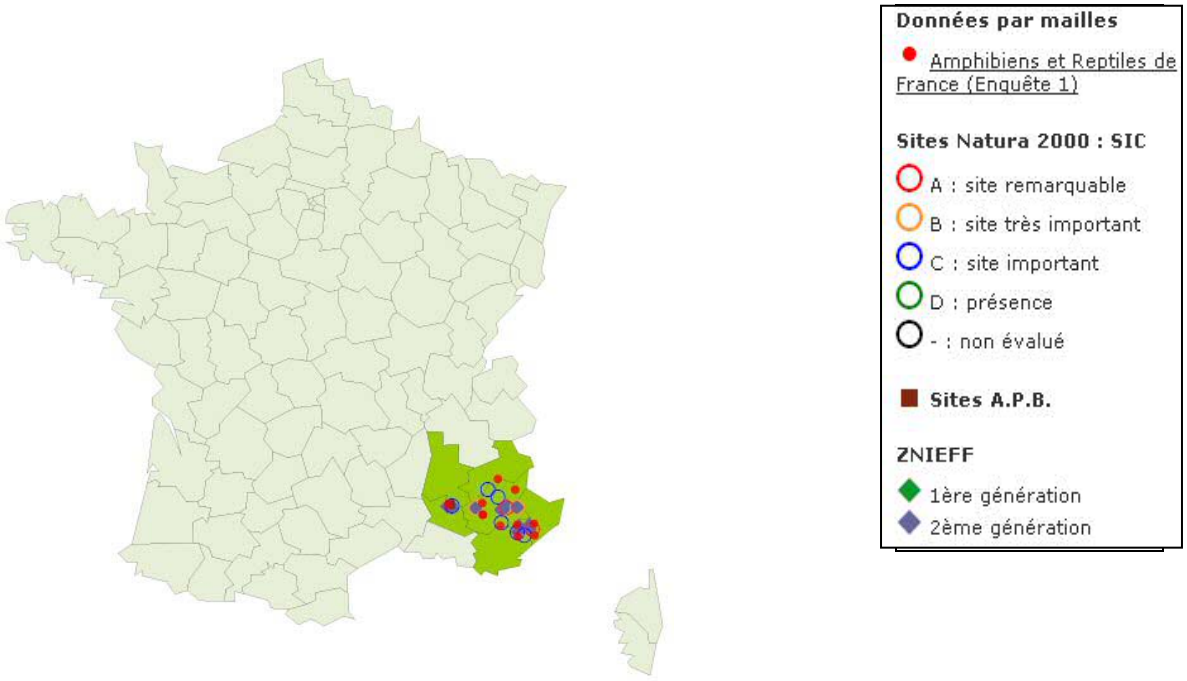
This document does not aim to give details of all the species of reptiles in France. The species presented in this study were mainly chosen for their emblematic character, as species that are under serious threat or are particularly exposed to death on the roads.

English name	**Meadow viper**	**Southern smooth snake**	**Ocellated lizard**
Scientific name	*Vipera ursinii* (Bonaparte, 1835)	*Coronella girondica* (Daudin, 1803)	*Timon lepidus* (Daudin, 1802)
Class	Reptiles	Reptiles	Reptiles
Order	Squamata	Squamata	Squamata
Family	Vipers	Colubrids	Lizards
Code Natura 2000	1298	/	/
	 *© Arnaud Lyet / ONF*	 *© Philippe Geniez / EPHE*	 *© Bruno Descaves (Cévennes National Park)*
Conservation status			
International	Bern Convention: appendices II and III Washington Convention: appendix I	Bern Convention: appendix III	Bern Convention: appendices II and III
European Union	Habitats Directive: appendix II and appendix IV	/	/
France	Protected reptiles: government decree, November 19, 2007	Protected reptiles: government decree, November 19, 2007	Protected reptiles: government decree, November 19, 2007
Red List	IUCN Red List – Global: Vulnerable IUCN Red List – France: Critically Endangered	IUCN Red List – Global: Least Concern IUCN Red List – France: Least Concern	IUCN Red List – Global: Near Threatened IUCN Red List – France: Vulnerable
Morphology			
Description	Squat body, short tail, vertically split pupils. Oval head, only slightly distinct from the body, careened back scales (rough appearance) arranged in 19 rows.	Slim head and body, relatively short tail, round pupils (distinct from vipers). Rounded head. Smooth back scales in 21 rows.	Distinct dimorphism of the adults: the male is bigger, with a massive head, a slender body and a bulge on the tail, while the female has a smaller head and a wide belly.
Size	The smallest viper in Europe Total length: 30 to 50 cm for females, which are generally longer than the males.	Small colubrid. Total length: about 50 cm (the females are generally longer than the males) up to 90 cm.	The biggest lizard found in France. Length from snout to cloaca: 20 cm (female) to 25 cm (male) for a total length of 60 to 70 cm. Weight: 130-180 g up to 345 g.
Color	Light gray or light brown back with pronounced dark brown or gray-black zig-zag. Light gray underbelly with a few scattered, dark colored spots.	Brown or gray back (occasionally pinkish or reddish near the belly in particular) with dark, crossways marks. Black stripe from the snout to the eye on both sides of the head. White, yellowish, pink or dark orange underbelly, with a characteristic checkered pattern or two parallel lines of dark marks (the main difference from the *Coronella austriaca*, which is very close).	Variable with age. Coat specific to the species: the back is covered with yellow and black ocellated scales on the female and young lizards. Two or three rows of cerulean blue marks on the sides. The belly and throat are usually yellowish. The back of the year's offspring has a brown-green coat with white marks, surrounded by black. Over time, the white marks on the sides turn blue.

2.1. Meadow viper [3][4]

a) Distribution

The Meadow viper is found from the Alps to China. Its distribution is very fragmented. In France, its distribution is very localized. The Meadow viper is only found in Alpes-de-Haute-Provence and Alpes-Maritimes, which are the two most favorable departments for this species, and in Var and Vaucluse. This distribution zone is fragmented into about 15 populations, each usually comprising a limited number of individuals.



Map of the distribution of the Meadow viper in France (source: INPN)

b) Biology and ecology of the species

Behavior

The Meadow viper is a diurnal species that is calm by nature, but that actively defends itself when under threat. During its summer period of activity, it tolerates temperatures of between 11 °C to 38 °C, with an optimal temperature of 28 °C. The male hibernates from October until the end of April, and the female until mid-May. The adult males and immature vipers molt three times a year, while the females only molt twice. This is a solitary species, except during the mating season. Vipers are very sedentary. Individual adults live within an area of 0.1 to 0.2 hectares. Movements within this area are irregular and depend on sources of food and potential shelter. No particular concentrations or seasonal movements to search for shelter to hibernate have been observed.

Reproduction

The mating season is in May, just after hibernation. Like most vipers, this species is viviparous and gives birth between mid-August and mid-September. The baby vipers, usually born in fours, have a total length of about 15 cm at birth and quickly go into hibernation until June of the following year. The males reach sexual maturity at the age of 3 to 4 years, and the females at the age of 4 to 5 years. The annual survival rate of young vipers is high. The females mainly reproduce every two years. On average, female adults reproduce twice in their lifetime. This species can live for more than 15 years.

Diet

Their diet is made up almost exclusively of orthopterans (grasshoppers and crickets). Only those measuring a total of at least 16 mm in length are consumed, irrespective of the size of the viper. The feeding period of the species lasts from the end of June, when its prey reaches the minimum required size, until the end of September. On average, the species feeds every three days. If no suitably sized orthopterans are available in the spring, the adults can ingest micromammals (only in certain European countries, and not in France) and especially lizards.

Habitat

In France, this species is only found on the mountainous and sub-alpine levels of the Southern Alps, between 900 m and 2,200 m. Its habitat is made up of dry grassland, often scattered with dwarf juniper (the plant that best characterizes the habitat of the species), lavender or broom, and always of rocky outcrops that provide effective shelter. These environments are rich in grasses and are home to dense populations of orthopterans, which are the species' exclusive prey. These environments are characterized by high exposure to the sun, significant thermal contrasts, Mediterranean rainfall and a few months of snow.

c) Threats to the species

The distribution in small isolated populations (fragmentation of the territory, in particular by infrastructures) makes this species extremely fragile.

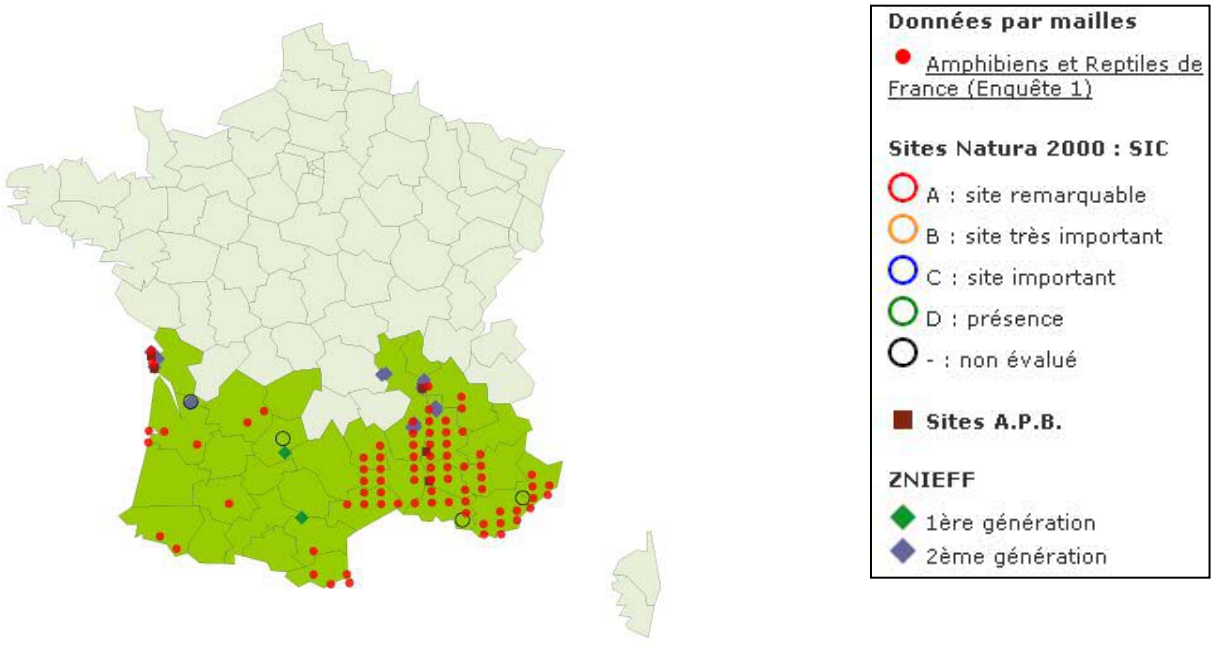
The gradual decline of pastoralism has resulted in reforestation. Consequently, there is a serious risk in the medium term that this habitat, and therefore the Meadow viper, will disappear. Human activity has created other short-term risks for the species: urban development, roads, ski slopes, burning, illegal removals, excessive presence of humans, etc.

A national restoration plan (2006-2011), followed by an action plan (2012-2016) and a LIFE-NATURE program (2006-2011) have been implemented to protect the Meadow viper.

2.2. Southern smooth snake [3][4]

a) Distribution

The Southern smooth snake is found in north-west Africa and south-west Europe. In France, it is found in the Mediterranean basin, the Rhône valley, south-west France (Aquitaine, Limousin, Midi-Pyrénées and Poitou-Charentes), the central Pyrenees and on the southern flank of the Massif Central.



Map of the distribution of the Southern smooth snake in France (source: INPN)

b) Biology and ecology of the species

Behavior

While the Southern smooth snake is active in the daytime, it seeks refuge from the heat by hiding under stones. Consequently, it is active mainly at dusk and at night. This species is very agile and is capable of scaling rocks and walls. It prefers fleeing and hiding to attacking. In the presence of a predator, it behaves like a viper by pressing its head against the ground, rolling itself into a flat triangle, exhaling and pretending to bite by quickly thrusting its head forwards.

The species hibernates from November to April, and is totally inactive in the coldest months, between December and February.

Reproduction

This is an oviparous species. The mating season is in May and June, after hibernation, and the eggs are laid between the end of May and the end of June. An average of six to nine eggs are laid, and they hatch in September. Newborns measure between 17 cm and 19 cm in total length at birth. They reach sexual maturity at the age of about 4 years. Females reproduce once a year. This species lives for about 15 years.

Diet

Their diet is made up almost exclusively of lizards. The Southern smooth snake occasionally eats arthropods, lizard eggs, small birds and micromammals. It locates and follows its prey by smell.

Habitat

In France, this species lives at altitudes of up to 1,000 m to 1,200 m. Its habitat is made up of areas with low to medium tree cover (sparse forest, woodland edges, scrubland, moors and grasslands). In the north of its zone of distribution, it is usually found in dry and very open areas. Farmed land with low walls and piles of stones is another favorite habitat of the Southern smooth snake. In the south of France, this is the snake that is best acclimatized to the urban habitat.

c) Threats to the species

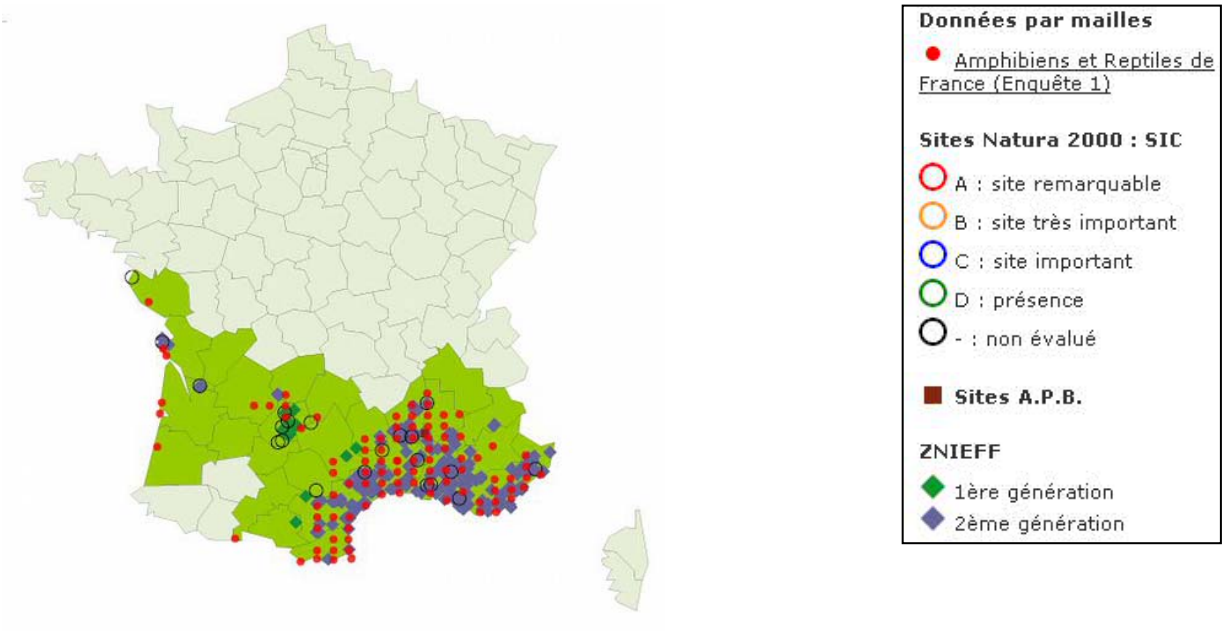
This snake has a very specific diet and is present in numbers that are generally low. Consequently, it is particularly vulnerable to the deterioration and destruction of its habitat. The species is also threatened by the proliferation of boars, which eat the Southern smooth snake and its eggs, and by fires that destroy its natural habitat. It is regularly killed by humans, who mistake it for a viper.

Moreover, this species is sensitive to the fragmentation of its territory by road infrastructures. Many of this slow-moving species die on the roads. The snakes are often killed on the roads when the males search for a sexual partner in order to reproduce in the spring, when the females look for a place to lay their eggs, and when the newborns leave their nests. The negative effects of roads on reproducing snakes can have a dramatic impact on the populations, because they can reduce, or completely wipe out, the appearance of young snakes. The death of numerous individuals killed by road traffic is very harmful to species with a long lifespan, as is the case for snakes.

2.3. Ocellated lizard [3][4]

a) Distribution

The Ocellated lizard is found in a large part of the Iberian peninsula and certain regions in the south and west of France. The species is found in three main regions in France: the Mediterranean, the Lot and the south-west of the Massif Central and on the coast of the Aquitaine basin. There are also around 20 isolated populations of varying sizes.



Map of the distribution of the Ocellated lizard in France (source: INPN)

b) Biology and ecology of the species

Behavior

The Ocellated lizard is a mainly diurnal species. It likes the sun, but looks for shade or shelter in the heat of summer. Its period of activity stretches from the start of March until mid-November, with a distinct peak of activity in May and June, which decreases from July onwards, due to the high temperatures. It hibernates from October to March under roots or in holes. It is a relatively sedentary species.

Reproduction

The spring mating season, which is preceded by fights between the males, stretches from April to June. The females lay between five and 25 eggs per year, in holes that they dig themselves, at the start of the summer. The eggs hatch at the start of the autumn, in September and October. When they hatch, the newborns measure a total length of about 8 cm. They reach sexual maturity at the age of about 3 years. Their life expectancy is quite short: 5 to 6 years on average, for a maximum longevity of 10 to 11 years.

Diet

The Ocellated lizard mainly eats insects. Beetles account for most of its diet (35 % to 85 %). It also captures arachnids and mollusks (snails). Occasionally, and even regularly in certain populations, it also eats berries, fruits and grains. Exceptionally, it may eat small vertebrates.

Habitat

The Ocellated lizard inhabits sunny habitats. It is accustomed to most dry and bushy landscapes, away from dense forests, marshes and farmland that does not offer any shelter at all. In the south of France, it is found in rocky steppes, scrubland and maquis with few trees, rocky coastal escarpments, dry olive and almond orchards and on windy mountain peaks. In central France, it is found on hillsides and plateaus with cropped vegetation. On the west coast, this species can be found on dry siliceous grasslands, in heather and on coastal dunes. The presence of shelter is always necessary. Populations of Ocellated lizards are often found in places where they can find shelter in rabbit burrows and warrens [5].

c) Threats to the species

The situation of this species in France is worrying. Numerous populations have disappeared in the course of the last century. Populations are declining sharply in the Mediterranean. They are under serious threat in the short term. The relictual character, low numbers and fragmentation of the populations make them extremely vulnerable. Their decline is due mainly to the damage to their habitat (clearing of grasslands, fragmentation of populations and urban development that causes this particularly shy species to flee, etc.).

Moreover, the almost universal decline of the cottontail rabbit appears to be playing an important role in the disappearance of this species, which benefits from their burrows and their action on the vegetation.

This lizard is often a victim of road traffic. It can live on the roadside and use the road surface as a means of thermo-regulation. When it remains immobile on the edge of quiet roads, it can be run over.

In 2012, the Ministry of the Ecology launched a 5-year national action plan to help to conserve this species.

3. Measures to avoid, mitigate or compensate the impacts of linear transport infrastructures

Any development or infrastructure project that can have a significant negative impact on the environment must include measures that avoid, mitigate or compensate for these impacts [6]. This obligation also applies to the proper preservation of protected species and their habitats.

This initiative, which was introduced by the law passed in France on July 10, 1976, for **avoidance, reduction and compensation [7]**, has gradually been taken on board in various environmental procedures. In particular, if the project is subject to an impact study, these measures will also be accompanied[1] by an estimate of the corresponding costs, a description of the expected effects and of the means of keeping track of the effects.
Therefore, different types of measures must be considered from the design phase. *"This phase is essential and preliminary to any other actions that consist of minimizing the environmental impacts of the projects, in other words, minimizing these impacts and finally, and if necessary, compensating for the residual impacts after avoidance and mitigation. It is in view of this order that we talk of the avoidance-mitigation-compensation sequence",* excerpt from the national guidelines on the avoidance-mitigation-compensation sequence [7].

This approach applies to opportunity studies, but mostly applies to the studies that are made before the public inquiry. For the contracting authority, it results in the issue of one or more authorizations, whose form(s) may vary according to the type of environmental procedure adopted: Declaration of Public Interest (DUP), project declaration (DP), protected species and Natura 2000, for example. These avoidance-mitigation-compensation measures, and the monitoring thereof, now form an integral part of the authorization[2] of the project, since the reform of impact studies that came into effect on June 1st, 2012.

3.1. Avoidance and mitigation measures in the various project design phases

The **avoidance measures** consist of looking for alternative solutions that could avoid the impact. They are intended to lead to the adoption of the solution with the least impact. If the imperatives of the greatest common interest prevent the avoidance of a significant impact on the protected species, then the least unfavorable direct or indirect residual impact on the protected species and/or their habitats must be identified.

The **mitigation measures** apply to both new projects and to the environmental requalification of existing transport networks. They are intended to reduce any negative impacts that cannot be avoided or eliminated. These measures supplement the choice of the solution with the least impact in the project design phase. They are particularized and detailed in order to reduce the direct or indirect impact. They are included in the request for exemption and contribute to its substantiation.

1 Article R. 122-5 of the environmental code
2 Article R. 122-14 of the environmental code

The objective may be to reduce the impact of the project, for example by improving the technical characteristics of the constructions and/or the means of construction.

a) Opportunity studies

In this phase, the geographical zone in which the impact occurs is defined and the scope of study of the future linear transport infrastructure is marked out. It is therefore essential at this stage of the project to be in a position to describe and identify, amongst others, the reptiles and their habitats that are present, or the habitats that they are susceptible to occupy.

After this study, and before the start of the works, the substantiation, the opportuneness, the usefulness and the imperative benefits for the greater good of the project must be established. It is at this stage that the variant of the route that has the least impacts, according to multiple criteria, is selected.

b) Preliminary studies (Natura 2000, impact study)

In the so-called preliminary studies that are conducted to prepare the public inquiry, just before the declaration of public interest, the initial study is scoped in order to select a solution (multi-criteria analysis and negotiations). At this stage, the contracting authority orders the various studies of the impacts of the project on the natural environment, and those affecting Natura 2000 sites [8]. These studies must examine the effects of the project, in particular on the species of snakes and lizards that are present within the scope of the study and, above all, the heritage species. The analysis covers the species and the habitats that substantiated the designation of the site. In this regard, the species and their preferred habitats must be protected both inside and outside Natura 2000 sites. Therefore, the studies must take all the potential and proven habitats affected by the project into consideration, whether they are inside or outside a regulated perimeter, by considering this study zone as "the area of direct influence of the project" on the species.

The natural environment in the initial situation

The initial situation must include an analysis of the habitats of the species of lizards and snakes that are present within the area of the study, in addition to the zones already identified by other studies. This is the reason why it is important to draw up inventories in all the phases of the accomplishment of their biological cycle. The census campaigns, which consist in particular of installing slabs of concrete under which the reptiles can find shelter, may be of use in the studies. The next step consists of mapping the zones of potential and proven presence of the various species inside these habitats (1/10,000 or even 1/5,000). The initial report must also identify any connections between the habitats of the lizards and snakes and prioritize the issues affecting these zones.

Comparison of the variants and optimization of the routes

The layout of the planned infrastructure must take the following parameters [8, 9] into consideration:

- the isolation of the populations, which incurs a major risk of extinction for the most fragile species ;
- the destruction, deterioration and fragmentation of the habitats of these reptiles ;
- the risk of being killed by vehicles.

When the habitats and/or corridors of the reptiles identified in the preliminary studies cannot be avoided, they must be crossed in the sectors that are the least unfavorable for these species. The goal is to build constructions in sectors of the least ecological importance, in order to optimize the global ecological functionality of the network of habitats.

Reminder: the comparison of the variants is based on the residual impacts that can be observed after the mitigation measures have been taken.

c) Pre-project studies

In this phase, the mitigation measures (see the next chapter) are precisely sized and positioned for the species that are present.

Additional analyses of the situation must be made, plus precise topographical readings and studies of the habitats in the zones directly or indirectly impacted by the definitive footprint of the project. These analyses bring up to date the inventories compiled in the impact and/or opportunity study, following any changes in the initial situation, and/or take the conclusions of a possible public inquiry into consideration.

d) Avoidance measures in the construction phase

In the zones where the species are particularly threatened and where they are suspected to be present, works are to be forbidden in winter and summer (hibernation and the period between laying and hatching or birth, Figure 1), unless authorization is given to destroy a protected species (art. L.411-1 to 6 of the environmental code).

This means that any grubbing operations and/or earthworks must only take place in spring and autumn. On the other hand, undergrowth can be cleared in winter, because the machines only remove vegetation and do not work the substrate.

		Ja	Fe	Ma	Av	Ma	Jn	Jt	Ao	Se	Oc	No	De
Vipère d'Orsini	Phénologie												
	Chantiers												
Coronelle girondine	Phénologie												
	Chantiers												
Lézard ocellé	Phénologie												
	Chantiers												

Key:

Periods for opening a site that are favorable and unfavorable to the species	Favorable period for land clearing and earthworks	
	Unfavorable period for land clearing and earthworks	
Biological calendar (phenology)	Laying, hatching or farrowing periods	
	Hibernation (outdoor temperatures below 10°C)	

Figure 1: calendar of works according to the biological cycles of the three reptiles

In the favorable periods (Figure 1), independent individuals can safely move to a more favorable site during the works. Irrespective of the location and the species, the biological calendar is based on the average monthly outdoor temperature. The temperature threshold under which the reptiles go into hibernation is 10°C. This parameter must be taken into consideration in the coldest zones.

General comment: *Irrespective of the projects and their preliminary studies, measures and monitoring operations, the contracting authority or the project manager must call on experts, who may be local or not, to give guidance, assess the impacts and adapt the schedules and the measures to the local situation and the species living in the impacted zone.*

3.2. Application of mitigation measures to reptiles

a) Description of specific measures: specific reptile crossing

The construction of corridors for small fauna, designed to maintain/restore the ecological transparency of the infrastructure, is one of the measures to mitigate the impact on small fauna, by reducing the fragmentation caused by infrastructure projects. These corridors are usually oval-shaped or rectangular culverts. But these measures are not very favorable to reptiles. A study in the Czech Republic [10] demonstrated that Aesculapian snakes (*Zamenis longissimus)* cross roads through rainwater pipes (with side cavities) built under the pavement. Adults that use these pipes are significantly less impacted than young snakes.

One alternative that optimizes the ecological neutrality of highway constructions with regard to these species could be the creation of underpasses made of blocks of stone that replace the existing crossings. The underpasses shown are prototypes that have not yet been built, a suggestion of what could be done, without any feedback to date. There are two possible technical design solutions. In the first technical solution, large-diameter blocks (about 50 cm) are arranged in staggered rows in a 2m by 2m closed culvert construction made of reinforced concrete (Figure 2a). There must be enough space (10-20 cm) between each stone block to allow numerous reptiles to pass through, creating an attractive winding corridor. Moreover, in order to encourage the presence of burrowing animals in the gallery, a mixture of topsoil, or even manure, could be inserted between the stone blocks forming the base of the construction.

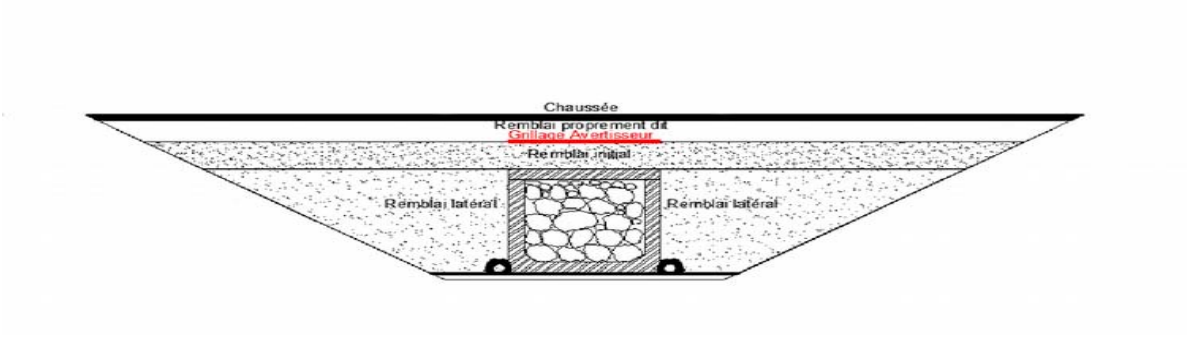


Figure 2a: Diagram and cross-section of a culvert-type crossing specifically for reptiles (F. Vernay, B. Combet, C. Bouquet and A. O'Grady, Joseph Fourier University)

The other technical solution (Figure 2b) consists of an alignment of stacks of molded reinforced concrete slabs forming galleries that allow reptiles and burrowing animals to pass through. The stacks are placed side by side on a concrete base and caged inside a geomembrane sheath. These two constructions measure about 1.2 m to 1.5 m in height and width.

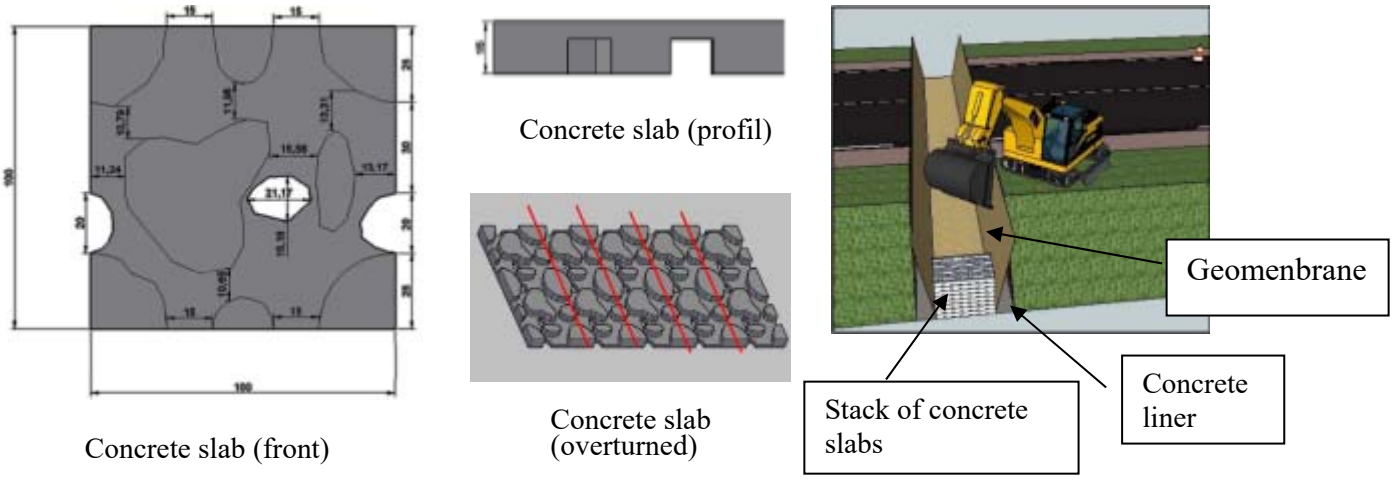


Figure 2b: Diagrams and cross-sections of a crossing specifically for reptiles and the molded reinforced concrete slabs used to build it (E. Doucet, C. Rey, I. Sbai, S. Tari, P. Feraud, A. Le Bihan, T. Thomas and R. Mordome, Joseph Fourier University)

Note: *this type of construction does not require any maintenance.*

Approximate cost of the measures in 2014 (including surrounding works): for requalification projects, the technical solution consisting of a concrete culvert would cost €6,600/lm and the solution made of stacks of molded reinforced concrete slabs would cost €2,200/lm. In both cases, the cost would be lower for **new transport infrastructure projects,** at about €1,400/lm for the second technical solution (source: DIR Atlantique), excluding the surrounding works.

Note: *the design of these technical solutions can be adapted by the contracting authority according to considerations of technical and financial feasibility. Experts should be consulted to finalize the solutions.*

b) Conditions of installation and surrounding works

The choice of the location of the crossing is primordial. Like ducted corridors for small fauna, this crossing must not be placed in the bottom of a thalweg, but above flood water level and clear of zones of temporary run-off in dry thalwegs.
Locations favorable to reptiles and micromammals tend to be humid, enclosed by dense shrubs, with sunny clearings containing piles of stones (ruins) or walls, with continuous hedges and banks that form corridors [10, 11]. The crossings specifically for reptiles should be located near this type of environment (bocage and/or wet woodland or heathland).
The surroundings should have the same characteristics: closed bushes forming thickets up to the crossing on the edge of the major bed of a watercourse or wet area. Low walls or piles of stones can be arranged here and there in the sunny zones; the nearby surroundings must be attractive to reptiles.
The corridor itself establishes a continuous biological flow, but can also act as a habitat by leaving crevices. The corridor and the surroundings provide both a passage and a zone for hibernation and reproduction.
Grass-covered and bare areas should be avoided because reptiles tend to avoid these zones, preferring rocky and bushy zones where they can find cover against predators such as diurnal birds of prey.

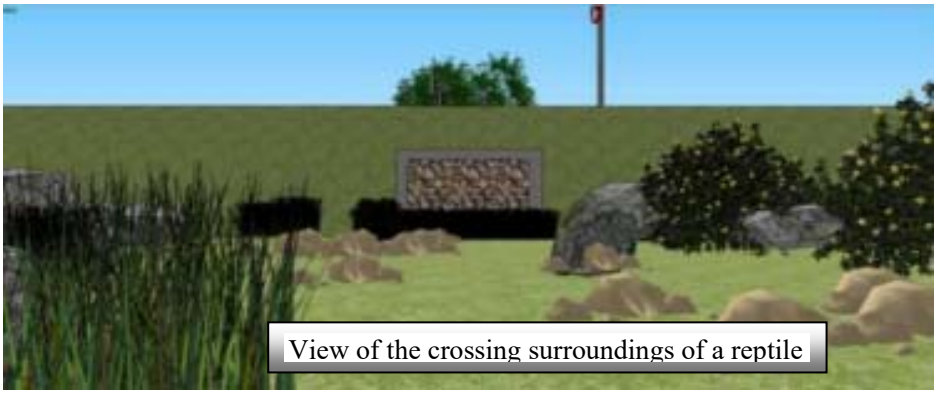


Figure 2c: the surroundings of a culvert-type crossing specifically for reptiles
(F. Vernay, B. Combet, C. Bouquet and A. O'Grady, Joseph Fourier University)

c) Wildlife overpasses and green bridges

Historically, green bridges meet the needs of large ungulates, but they can also be used by many other species, including reptiles, if they are built accordingly [9].

Lizards and snakes tend to keep clear of open spaces in order to avoid the threat from birds of prey. Therefore, refuge areas need to be arranged on these constructions (e.g., along the deck of the bridge) so that the animals can cross easily. A windrow of logs and stones can be installed to make the crossing more attractive and to guide the animals towards the exterior of the construction (photos 2 and 3).

The windrow, made of soil, stones and logs, forms a linear structure that crosses the construction and extends beyond it to the exterior (photo 3). It is built on foundations with a concrete stringer, blocks of rock measuring 40-60 cm sealed on the stringer and wooden logs. It is secured by cables connecting the pieces of wood and sealed at the ends of the stringer.

Photo 2 : windrow on a green bridge (A10 - DTer SO)

Photo 3: detail of the windrow (rocks and logs linked to one another – A10 DTer SO)

It provides contrasting situations in terms of temperature and humidity that are particularly appreciated by reptiles. It also guides the reptiles as they pass through the windrows. It provides potential shelter for these species that can remain on a construction for several hours, before crossing it.

Approximate cost of the measure in 2014: the cost per linear meter is between €120 and €200, including supplies and construction, but only if it is part of a larger development project (source: Vinci ASF).

d) Other measures for ecological transparency in favor of reptiles

In the most favorable contexts for reptiles, like for other species, the passages can be considered as continuous linear areas that form corridors (movement along the crossing and parallel to the road). There must be no physical barriers that could indirectly result in collisions with animals obliged to use the road to get from one side of the overpass to the other (Figure 3).

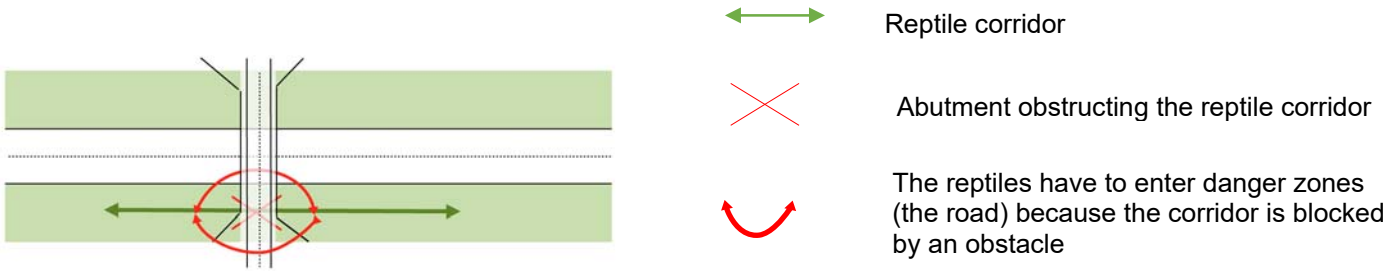


Figure 3: overpass obstructing a reptile corridor

Smooth abutments are not favorable to the passage of reptiles through the construction because they do not offer any refuge, especially if the foot of the wall is very close to the road. The slope in the abutments must be broken once or twice to create a passage through the construction that can be used by small species, such as reptiles (Figure 4).

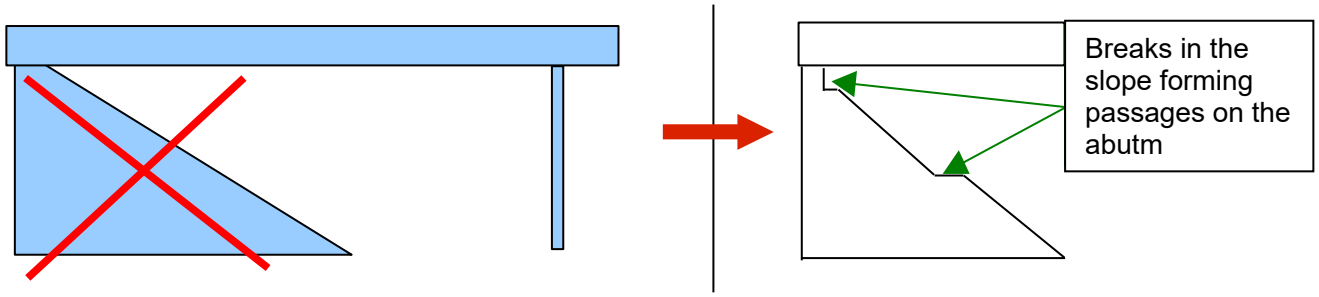


Figure 4: passages on an abutment for small fauna (cross section)

Cost of the measure: Zero, if this measure is planned from the design phase.

3.3. Compensation measures

"The purpose of compensatory measures is to counteract the significant direct or indirect negative effects of the project that could not be avoided or sufficiently reduced. They are taken on, or near to, the impacted site so as to guarantee durable functionality." (Article R. 122-14 of the environmental code).

a) Principles

Compensatory measures generally consist of acquiring plots of land containing the habitats occupied by the impacted species. Compensatory measures can be taken in new projects, but also as part of re-qualification projects.

This type of measure should only be taken as a last resort, when the mitigating measures fail to reduce the impact to a low or negligible level. The residual impacts to be addressed by the compensatory measures must be identified as early as possible in the preliminary study phases of the project, along with the indicators that can be used to assess and measure the effectiveness of the compensatory measures, once they have been taken.

b) Application to reptiles

Layout of verges

Major highways that pass through ecological environments with a rich biodiversity tend to encourage the spread of fauna, because their verges form corridors that are favorable to the most ubiquist species. On the other hand, when highways pass through significantly modified environments with low biodiversity, such as large areas of farmland, their footprint, which is usually managed extensively (apart from the 5m-wide strip of grass by the roadside), constitutes an island of biodiversity, including for reptiles, because their preferred prey, insects and rodents, inhabit them in large numbers [10]. The most favorable verges for reptiles tend to be bushy and rich in mineral cover, with assemblies of blocks of stones. These verges must also take factors linked to visibility and the safety of road users into consideration.

The footprints can only form favorable corridors if they offer a variety of habitats in the degraded surroundings. The regular installation of piles of small blocks in the middle or on the edge of the footprint, in overgrown sectors, is favorable to reptiles, such as snakes and lizards, but also to many other different species. When installed at regular intervals, these piles will make it easier for reptiles to move around. It is also conceivable to arrange slabs of concrete measuring 1 m by 1 m in sunny spots, as they will also attract reptiles. These zones should not be too visible for aesthetic reasons (the ideal position would be on embankments made of backfill), but their positions must be known to the maintenance teams tasked with managing the green areas. These stones or slabs of concrete offer the same degree of heat as when reptiles rest in the sun, except that reptiles are also sheltered.

Another advantage of these measures is that they also provide shelter for micromammals. Reptiles, which are ectothermic, look for warm spots at night to prevent their body temperature from dropping below a critical threshold. These measures also allow them to hide from predators, such as birds of prey [12, 13].

Finally, they save significant numbers of snakes and lizards from being killed at night as they rest on the surface of the road, which accumulates heat during the day.

Cost of the measure: Zero, if recovered materials that can be transported manually are used.

Note: *A preliminary study of the impacts of the traffic (high risk of mortality due to collisions on the road) should be made in order to verify that the impact of the traffic on the targeted species is not such that the survival of the populations on the site are endangered and it creates a "well" type effect. Arranging the verges tends to attract reptiles and allows species to develop quickly in the short term, but is not viable in the long term, because the ecosystem it creates is not durable (predators, risk of death on the road, etc.). A massive quantity of individuals then rushes into the "well" or "trap".*

Arranging egg-laying sites

This type of site is generally intended for oviparous species. They consist of piles of topsoil and organic matter (manure, waste, plants, etc.) that are mixed together and laid on a thick bed of stones of various sizes (5kg to 30kg). The pile is covered with a geomembrane that keeps the humidity inside the egg-laying site. The geomembrane can be covered with a layer of grassy earth for aesthetic reasons and to protect it from UV rays. The larger the pile, the more constant the temperature inside it. It must be surrounded by a low stone wall (Figure 5, photo 5) and can be half-buried. the dimensions are from about 4m × 4m and 1.2m in height, up to about 50m^3, with dimensions in the same proportions. The humidity of the site remains constant and the temperature is sufficiently neutral to attract ophidian reptiles. It can also be used as a site to rest in the winter (a *hibernaculum*) for reproducing adults, generally grass snakes.

This system was first tried out in the Deux-Sèvres department, near the A10 highway [13]. Other techniques exist to create *hibernaculum,* as shown in the example by the A63 in Aquitaine (photo 6).

Equivalent sites also exist where lizards lay their eggs [14, 15].

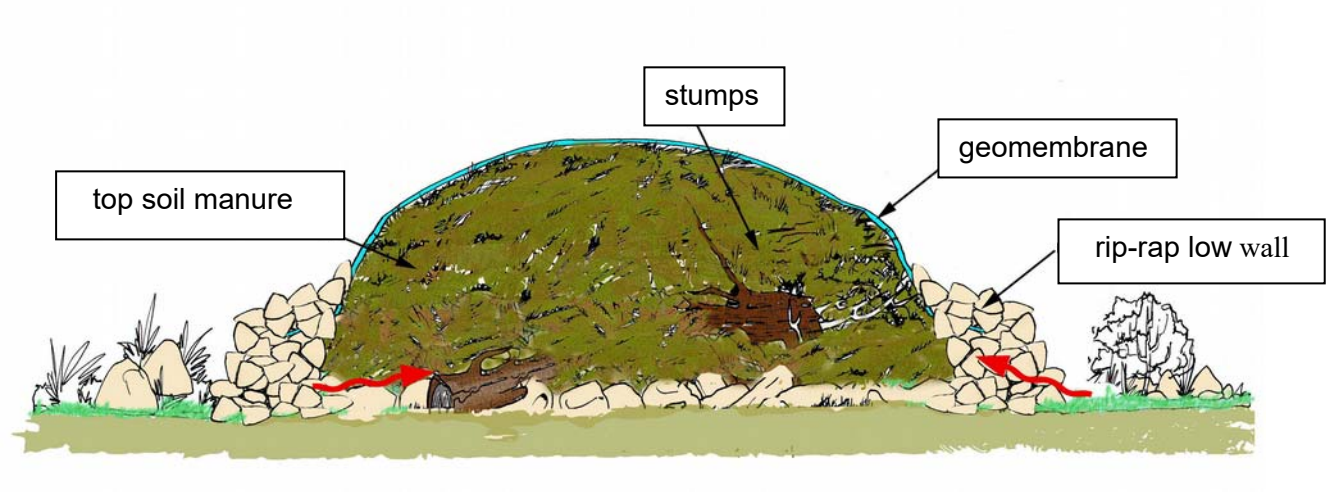


*Figure **5**: diagram of an artificial egg-laying site for reptiles (Cerema DTer SO)*

Photo 5: artificial egg-laying site / hibernaculum under construction (X. Bonnet: A10)

Photo 6: another type of hiberaculum being dug into the ground (DTer SO: A63)

Approximate cost of the measure in 2014: At least €200 to €400 for a long-lasting hibernaculum, using as many recovered materials as possible (source Vinci ASF).

Capturing and relocating species

If, after all the potential solutions have been investigated, no avoidance measures are possible, one alternative measure consists of incubating the reptiles' eggs or capturing individuals during the winter, and then releasing them in the spring on a favorable site, preferably close to the place where they were captured. In this case, an application must be made for permission to capture and transport a protected species, and the authorization to destroy the habitat of a protected species. The eggs or the individuals that are found in the winter must be captured and transferred, with the due authorization, to an ad hoc site. These reduction measures can be taken after consulting the official departments and naturalist organizations or any other competent organization (shooting and hunting authorities, ecological research labs, etc.).

4. Monitoring the effectiveness of the measures

In impact studies, article R. 122-15 of the French environmental code specifies that monitoring the measures *"consists of presenting the state of progress of the measures through one or more assessments that verify the degree of effectiveness of the measures over a given period".* On the strength of the assessments of the effects of the project on the environment, the authority that authorized or approved the project can decide to continue the measures[1].

As part of the official State commitments: For certain projects that are covered by the French law on inland transport (LOTI)[2], *"the economic and social results are reviewed no later than five years after the measures were taken"*. The Bianco circular on major infrastructure projects, published on 12/15/1992 (article L. 1511-6 of the French transport code), extended these reviews to include environmental aspects. Monitoring instances may be set up by the various players in this case (L. 125-8 of the French environmental code).

General indicators must be defined at an early stage, during the study phase of the transport infrastructure project, in order to measure their performance. The two main goals are high numbers of reptiles using the crossings and the conservation of the targeted species on both sides of the infrastructure.

1 Article R. 122-14 of the environmental code

2 Law on the organization of inland transport

These goals can be measured by using precise assessments of the populations before the construction of the project, with descriptors defined early in the design stage: the numbers and density of the populations (both of these figures are essential for the review of the initial situation in the zones that will be strongly impacted), the surface area and integrity of the habitat, the features of the landscape that make up the habitat, such as zones of bushes, or lines or hedges and banks, etc. They must be specified just before the works start in order to make the final adjustments or to acquire another plot of land as a compensatory measure.

The monitoring of crossings and other measures that will favor ecological transparency for reptiles must be taken using repeatable and standardized protocols that do not vary in the course of the measurement campaigns. For the contracting authority, it is essential to call on design offices and a competent project management support provider for this particular taxonomic group that is still relatively unknown. In this case, research laboratories that specialize in reptiles are the most useful source of expertise.

5. Glossary

Corridors: ecologically speaking, connecting passages for fauna and flora. These crossings are intended to connect areas where the species can find favorable conditions for all or part of their biological cycle. Their importance has resulted in the concept of “green and blue infrastructure”, which uses these corridors to maintain exchanges between isolated groups of populations of the species and/or to allow them to complete their various stages or phases or development.

DUP: an official French decree that authorizes expropriation for projects declared to be in the public interest.

Ectotherm: a term used to qualify animals with a variable body temperature that is determined by the environment (reptiles, amphibians, fish). Another term, which is not a synonym, qualifies animals as “cold-blooded”. These animals, which do not control their internal temperature, are known as poikilotherms, unlike homeotherms, such as mammals and birds.

Heritage species: by definition, heritage species are all the species that constitute the indigenous fauna and/or flora, thereby forming a local, regional or national heritage that may or may not be protected. Misuse has led this term to being used to designate protected, threatened (red list) and rare species, or, sometimes, species with a particular scientific or symbolic interest. This is not a legal status. Therefore, in the name of accuracy, it is advisable to talk of species exposed to (high, moderate or low) threats relative to their conservation status in a given territory, and to avoid this improper term.

Initial state: [12] an inventory (species and habitats) before any operations related to a project. This inventory must be made during the analysis of the zones and the ecosystems susceptible to being impacted by a project, and is a compulsory precondition of the application for any exemptions. The notion of the environment must be interpreted in its broadest sense, which includes the dimensions relating to the physical, biological and human ecosystems, and the relations between these different environments. This analysis can be based on bibliographical input, but essentially on in situ field investigations and surveys and contacts with the local people. This inventory describes the context and is completed by a global and theme-based analytical approach. It constitutes the baseline.

Taxonomic group: a group of living organisms that generally are the descendants of a common ancestor and share certain common characteristics. The branches, classes, orders, families, genera or species are called taxons. Certain taxons can have several close and known ancestors. They are known as paraphyletics, which is precisely the case of the reptiles class (Reptilia).

Hibernaculum: a refuge, shelter or part of a burrow where animals hibernate. By extension, it also refers to artificial shelters for reptiles or amphibians.

INPN: the French national review of natural heritage

Stringer: a horizontal concrete beam.

Ongulate: an animal with hooves.

Ophidian: this term is frequently used to designate anything to do with snakes.

Oviparous: animal species that reproduces by laying eggs.

Pastoralism: raising livestock using only extensive pasturing practices to exploit the spontaneous feed resources of natural spaces in order to produce all, or part of, the food for animals.

Relictual: a relictual species lives in an isolated ecosystem. It is a survivor of a population that was previously much larger, when the favorable conditions for its survival covered a larger area.

Thalweg: the line that joins the lowest points of a valley.

Ecological transparency of a transport infrastructure: land transport infrastructures fragment the environment. Improving the ecological transparency of the infrastructure amounts to restoring the continuity or the corridors between habitats when this is biologically justified so that they remain functional and allow species to move freely.

Ubiquist: living species that are capable of colonizing very varied habitats and therefore are not bound to any given type of biotope.

IUCN: International Union for Conservation of Nature

Viviparous: animal species that reproduces in utero and gives birth to live young or formed larvae. This reproduction strategy is different from oviparity.

6. Bibliography

[1] Are snake populations in widespread decline: Reading C.J., Luiselli L.M., Akani G.C., Bonnet X., Amori G., Ballouard J.M., Filippi E., Naulleau G., Pearson D., Rugiero L. Biology Letters, rsbl.-royalsocietypublishing.org, 2010, 4 pages.

[2] Schéma national des infrastructures de transport (SNIT) : projet. Draft – October 2012. MEDDE/DGITM.

[3] The dangers of leaving home: dispersal and mortality in snakes: Bonnet X., Nauleau G., Shine R., Biological Conservation **89,** 1999, pp. 39–50.

[4] Les reptiles de France, de Belgique, Luxembourg et Suisse. Collection Parthénope, Vacher J.P. and Geniez M., Biotope (Eds) 2010. 544 pages.

[5] Inventaire de la faune menacée en France. Maurin H., MNHN (Eds) 1994, 176 pages.

[6] L'étude d'impact : principes et contenu : Référence Aquitaine June 2012, DREAL Aquitaine (Mission Connaissance et Évaluation).

[7] Doctrine relative à la séquence éviter, réduire et compenser les impacts sur le milieu naturel, MEDDLT, 2012, 9 pages.

[8] "Évaluation des incidences des programmes et projets de travaux, d'ouvrages ou d'aménagements susceptibles d'affecter de façon notable les sites Natura 2000." Circular dated October 5, 2004. DNP/SDEN n° 2004

[9] Aménagements et mesures pour la petite faune SETRA – MINENV/MEDD, 2005, technical guide, SETRA (Eds), 264 pages.

[10] Living in the road vicinity – unique habitat of Zamenis longissimus in the Ohře River Valley, the Czech Republic. Communication (Poster) Musilová R., Janoušek K., Zavadil V. IENE 2010

[11] Infrastructures de transport biodiversité et territoire, l'apport de l'écologie du paysage, Briefing paper N°95 – 2011, 29 pages.

[12] Reptiles et environnement routier : risques et bénéfices. Proceedings of the 4th colloquium "Routes et faune sauvage", Verheyden C., Bonnet X., Lelièvre H., 2008, September 21-22, 2005, Chambéry, Sétra, 154 pages.

[13] Thermal benefits of artificial shelters in snakes: A radiotelemetric study of two sympatric colubrids. Journal of Thermal Biology Lelièvre H., Blouin-Demers G., Bonnet X., Lourdais O. A radiotelemetric study of two sympatric colubrids. Journal of Thermal Biology 2010, 35 (7), pp. 324-331.

[14] Rabbit burrows or artificial refuges are a critical habitat component for the threatened lizard, Grillet P., Cheylan M., Thirion J.M., Doré F., Bonnet X., Dauge C., Chollet S., Marchand M.A., *Timon lepidus* (Sauria, Lacertidae), Biodiversity Conservation 19, 2010, pp. 2039–2051.

[15] Artificial egg-laying sites for lizards: a conservation strategy: Castilla A.M. and Swallow J. G. Biological Conservation 72, 1995, pp. 387–391.

This "Environment – Health – Risk" information memo is published in the

Cerema " Connaissances " collection

This collection presents the state of the art at a given point in time and provides information on a subject, without claiming to be complete. It brings knowledge and professional practices up to date and includes new technical and methodological approaches. It is intended for professionals who want to maintain and extend their knowledge in technical fields that are constantly changing. The
content may be considered as recommendations, rather than approved references.

The information memos are intended to provide a quick update on a given subject. They review the latest knowledge, studies, reflections, experiments or techniques at the time of writing, but their status and content must be considered according to the most recent regulatory or technical developments.

Connaissances Collection
ISSN: 2417-9701
ISBN: 978-2-37180-072-6

Authors
Jérome Cavailhes –ex-Cerema- Infrastructures de transport et matériaux
Éric Guinard – Cerema – Sud-Ouest
Perrine Vermeersch – Cerema- Infrastructures de transport et matériaux

Illustration
Bruno Tauzin – Cerema – Sud-Ouest

Thank you to the students mentioned in Figures 2a, 2b and 2c who are studying for the GCI Master 2 at the Joseph Fournier University in Grenoble, and to their lecturer Pierre-André Pissard, who supervised their work on an underpass specifically for reptiles.

Proofreaders
Géraldine Audié-Liébert (Cerema – Sud-Ouest)
Xavier Bonnet (CEBC-CNRS)
Jean-Christophe de Massary (MNHN)
Philippe Geniez (EPHE)

Technical input
Perrine Vermeersch – Cerema- Infrastructures de transport et matériaux
phone: +33 (0)1 60 52 30 25 – fax: +33 (0)1 60 52 81 25
e-mail: perrine.vermeersch@cerema.fr