Additional File 2

Key knowledge gaps in relation to each proposed additional infrastructure to be implemented

Lacks of knowledge are identified according to three main questions:
- Do we have a basic understanding of the natural functioning at the species, ecosystem and landscape levels?
- Do we know the impacts of these human disturbances (e.g. aerial obstacles, sensory pollutants) on biodiversity?
- Do we know what solutions and mitigation measures to implement to limit these disturbances?

Level of knowledge deficit:	
	High to very high
	Medium
	Low

	Natural processes	**Impacts of anthropogenic disturbances**	**Solutions and mitigation**
Aerial infrastructure	Some species are well studied (bats, birds), but there are still gaps (e.g. flight height, migration patterns). Other organisms that attend the aerosphere, often with passive flight (e.g. aerial plankton) remain largely unexplored. The airscape, as a functional compartment and a vector for different types of movements, receives little attention	Some impacts have been well studied and quantified, such as mortality caused by wind turbines, but other types of impacts are less well known. There is also no quantified monitoring of certain aerial obstacles such as collisions with building windows or electrocutions on power lines (except for raptors or storks).	Some solutions exist, for instance regarding wind turbines (e.g. acoustic or visual deterrence systems, slowing down speed, painting, etc.) but their efficiency is little assessed. There is still a great deal of research to be carried out into other types of obstacles (e.g. the effectiveness of strips stuck to windows, visual deterrent device on power lines).

	Natural processes	Impacts of anthropogenic disturbances	Solutions and Mitigation
Underground infrastructure	Soil life remains largely unidentified (although estimated to a quarter of terrestrial biodiversity). Mapping of soil species distribution is a deeply lacking piece of knowledge. Ecological traits of soil fauna are mainly unknown (e.g. dispersal distances).	The links between biodiversity and soil quality are scientifically explored, for example in relation to agriculture and forestry. However, knowledge on the impacts of underground anthropogenic structures (pipes, foundations, underground car parks, etc.) on soil fauna communities is a strong gap, particularly in terms of connectivity disruption.	Solutions for improving soil quality are well known (soil management), but soil building from mineral waste and organic matter (technosols) is a very recent field of research, and the effectiveness to restore a brown infrastructure has not been demonstrated yet. In addition, ecological engineering methods for reconnecting soils need to be explored (creation of underground passages under roads).
Dark infrastructure	Even if nocturnal species are by definition cryptic, knowledge is developed for several taxa. For instance, understanding bat ecology has taken a huge leap forward with the development of acoustic survey. Precise parameters are known for various taxa, such as the critical fusion frequency or spectral sensitivity. On the other hand, some groups remain poorly described, such as moths while they represent many more species than butterflies.	The impacts of artificial lighting on living organisms have been the subject of major scientific research since 10-15 ans. Artificial light has been demonstrated to disturb many taxa in many ways (environment, outcomes). However, even though many reviews have been published, quantified data on the links between light pollution and life-history traits (mortality, fertility) remain weak or unsynthesised, which limits the model inputs. Some groups remain underconsidered, such as owls, non-flying mammals, non-turtle reptiles or diurnal organisms (except passerines). Spatial outcomes and impact on life history traits (survival, fecundity) are also less studied than physiological and behavioural ones, even though the effect of	The solutions for reducing the impacts of artificial light at night are quite obvious and well listed. They may concern the spatial or temporal dimension of lighting or technical aspects (e.g. spectral composition, amount of light, orientation). There are still points to be explored in order to define the best scenarios (e.g. switching off lighting vs. lighting on-demand).

		light on habitat loss and fragmentation has been shown for several organisms. Knowledge needs to be translated into more operational terms (e.g. sensitivity thresholds in duration, amount, frequency or color temperature of light).	
	Natural processes	**Impacts of anthropogenic disturbances**	**Solutions and Mitigation**
Noise-free infrastructure	Acoustic communication processes have long been described for various taxa (owls, orthopterans, birds, amphibians). However, the details of hearing ability (e.g. frequency and amplitude ranges) are not synthesized. Soundscape ecology is developing more and more to better understand the richness and function of acoustic landscapes	The impacts of anthropogenic noise on living organisms have been attracting great interest in ecological research in recent years. The effects on species are now well identified in the literature for several outcomes (behaviour, physiology), although space use, habitat fragmentation and ecosystem level remain less well explored. However, studies should also be diversified in terms of taxa, as they currently focus mainly on birds. Metrics used in the studies are very centred on human acoustic perception which is not necessary relevant to non-humans (e.g. Decibel weighting). Evidence base also needs to be translated into more operational terms (sensitivity thresholds).	Solutions to minimize noise pollution are difficult to identify, apart from limiting the emission at source. Solutions have been implemented for a long time to avoid noise pollution for humans through civil engineering, but they do not really address the issues of non-humans (e.g. anti-noise walls which create new landscape barriers for wildlife, building insulation which therefore concerns indoor noise pollution). Research has a major role to play here in experimenting and proposing various solutions.

	Natural processes	Impacts of anthropogenic disturbances	Solutions and Mitigation
Olfactory infrastructure	The sense of smell is well known, described both anatomically and functionally for several taxa. The exchange of volatile compounds is a well-known process; e.g. between plants and insects. However, a strong lack of knowledge concerns the diversity of odours, their classification and in relation to the 'olfactory niche' of species (their relationship to different odoriferous molecules). Mapping of odorscapes in relation to plant communities (vegetation, natural habitats, phytosociology) is also a necessity	First of all, we need to better describe and quantify man-made odour pollution (diversity of molecules, in-situ measurements, monitoring indicators). This task is unexplored and more difficult than for light and noise pollution. Secondly, the impacts of anthropogenic volatil organic compounds (i.e. artificial odours or molecules that degrade/mask natural odours) remain largely unknown. Only a few studies exist on hydrocarbons or nitrogen derivatives, mainly on insects. This is a field of research that needs to be explored almost entirely.	Some solutions for neutralizing anthropogenic odours in the environment are theoretically possible (e.g. landscape buffers, essential oils, odor-neutralizing materials) but there is little or no experience of them, so their effectiveness in relation to odorscape restoration has not been assessed. Consideration must also be given to reducing anthropogenic volatile organic compounds emission at source by rethinking production models and regional planning (industrial processes, agriculture, transport, etc.).