Cerema

Factsheet
Environment - Health - Risk

Linear Transport Infrastructure and Odonata

Odonata, more commonly known as dragon and damselflies, are represented by species dependent on aquatic environments and wet areas. There are 96 species in mainland France. Ten of these are protected nationwide. The International Union for Conservation of Nature (IUCN) says that mainland France has the largest number of species in Europe and one of the highest endemism rates on the continent, with eight species being present only in mainland France. France's position as regards the protection of Odonates is therefore of paramount importance.

Depending on the species, dragon and damselflies live near numerous wet environment and aquatic habitats. However, since 1960, over 50% of these types of environment have disappeared in mainland France [1].

The impact of linear transport infrastructure (ILT) on Odonate populations is, above all, related to the destruction and/or fragmentation of their habitats. The measures to be implemented, in the context of linear transport infrastructure project impact studies, must be appropriate and proportionate to the types of impact identified. They must also take into account the ecological requirements specific to each species, as well as their conservation status and that of their habitats on the region concerned.

After presenting the life cycle of Odonates and the environments they occupy, this factsheet presents some regulations to follow and tools to assist with prioritisation of the issues related to Odonates. Details of some sections of the impact study required for linear transport infrastructure projects are given through consideration of this taxonomic group. Examples of avoidance, mitigation and compensatory measures, as well as monitoring methodologies are also proposed.

This factsheet is intended for contracting authorities, infrastructure managers and environmental entities (associations, public institutions, academies, etc.).

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Connaissances | Series

Odonate Ecology

Unless stated otherwise, most of the information on Odonate ecology given in this factsheet comes from reference publications on Odonates: Les libellules de France, Belgique et Luxembourg, Collection Parthénope Daniel Grand and Jean-Pierre Boudot, biotope Édition (2006) [2].

Odonate Classification:

The order Odonata is represented in mainland France by:

- The suborder Zygoptera or "Damselflies"
- The suborder Anisoptera or "real" Dragonflies.

The main differences between these two "groups", in the case of mainland species, are:

- Zygoptera: smaller damselflies with identical anterior and posterior wings, generally folded along the body when at rest.

Example of Zygoptera:
Ceriagrion tenellum (De villier, 1789) Small Red Damselfly

- Anisoptera: heftier, medium to large-sized dragonflies, with narrower fore-wings than hind-wings which are held out perpendicular to their bodies when resting.

Example of Anistoptera:
Libellula depressa (Linné, 1758) Male broad-bodied chaser

Life cycle

Like many insects, the life cycle of Odonates is distinguished by several stages of development punctuated by moulting processes that profoundly transform their morphology.

There are five main developmental phases in the life of dragon and damselflies. The duration of these may vary, depending on the species and the latitude, from a number of years (larval phase) to a few hours (emergence phase). Depending on the species, each phase corresponds to a specific habitat or micro-habitat. Some species are dependent during part or all of their life cycle on very specific habitats, whereas others are more generalist (pioneer/ubiquitous) species. The last or imaginal moult produces the adult insect, also called the imago, it is at this stage that the insect reaches sexual maturity.

Odonates are predatory insects both during the larval and adult stage. Accordingly, they are fewer in numbers than their prey populations (mosquitoes, flies, butterflies, etc.), their fertility rate is lower and the length of their reproductive life is longer than other groups of insects dependent on wetland areas [3].

Hence, all ecological actions carried out in natural environments such as restoration, rehabilitation, creation or management must be adapted to take into account the specific ecological requirements of the various species in question and enable them to complete their entire life cycle. These actions concern three primary interdependent components of wet environments: land, water and vegetation [4].

The diagram on the following page illustrates the dragon and damselfly life cycle and shows some of the environments on which they depend for each phase of their development.

Imago (Adult)

When they have reached sexual maturity, the adults return to the wet environments (their birthplace or to an area with similar characteristics) to mate. Adult life is punctuated by the (active or passive) search for a partner to mate with, the search for food and resting phases for roosting or due to bad weather.

Habitats required by the adults depending on the species

The habitats must combine:

- Micro-habitats required for egg-laying (see adjacent text: media required for egg-laying).
- The aquatic environments required for larval development (see adjacent text: habitats necessary for larvae).
- Areas for rest and shelter (trees, bushes, plants, etc.).
- Sufficient food sources

Duration of the adult stage

Less than one year

Particularity

For males, the search for a female and food may, depending on the species, lead to territorial behaviour. Individuals of the same or other species are systematically ousted.

Mating and egg-laying

Eggs

The eggs are laid in a wet environment on different types of media.

Media necessary for egg-laying

- Riparian or floating herbaceous vegetation
- Soft wood bark
- Floating plant debris
- Sediment in stream beds
- Release on contact or above water or wet meadows

Particularity

Stage at which some species have an adverse season: winter in cold regions, summer in warm regions.

Hatching

Larvae

In our regions, larvae are exclusively aquatic. They do not have wings, and hunt by chasing their prey or lying in wait.

Habitats required by larvae depending on the species

Types of habitats:

- Ponds, lakes and pools,
- Rivers, streams and ditches,
- Marshes, peat bogs.

Duration of the larval stage

From a few months to several years depending on the species.

Particularity

At this stage, these insects are particularly sensitive to the quality of the water, as well as mechanical activity by humans that damages aquatic environments (dredging, development of the banks, etc.).

Leaving the aquatic environment

Emergence

Transitional phase between larval and adult. When the larva reaches maturity, it leaves the aquatic environment and climbs onto a rigid media near the wet area. The larva extricates itself from its exuvia and stretches out its wings.

Media necessary for emergence depending on the species

- Riparian vegetation
- Banks
- Rocks
- Trees

Duration and distance covered for emergence

Depending on the species:

- Duration: from 1 to 3 hours on average.
- Distance covered: the immediate vicinity of the river bank and up to several meters away.

Particularity

This phase is the one in which dragon and damselflies are at their most vulnerable to predators on account of their immobility and fragility.

Migration towards open environments some distance away from the wet areas.

Sexual maturation

Once they are able to fly, dragon and damselflies move some distance away from the wet areas to develop their sexual organs and strengthen their physical constitution.

Habitats required for sexual maturation

The exact typologies of the habitats for each species are still not well understood. However, they have specific characteristics, these are open, sunny environments, with areas for resting and sheltering from predators and the vagaries of climatic conditions (wind, rain, etc.).

Examples of habitats:

- Clearings
- Hedges, bushes
- Sunken paths
- Woodland boundaries

Duration and distance covered for sexual maturation

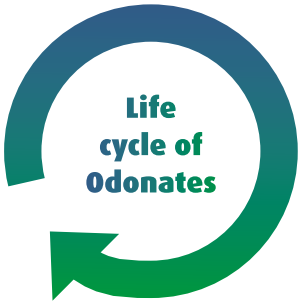
Depending on the species:

- Duration: between two and fifty days.
- Distance covered: varies from ten metres to several tens of kilometres (even hundreds and in exceptional cases, thousands of kilometres).

Particularity

Dragon and damselflies' capacity for dispersal is related to their capacity to fly, as well as air currents that may carry them large distances.

Return to wet environments



Life cycle of Odonates - Laurent Dramais/Cerema

Odonate regulatory status

Odonates are protected by a number of regulations relating to individuals and the different environments in which they are found. This concerns the species listed in the various appendices of the EU Habitats Directive within the framework of the Natura 2000 network [5] and [6], as well as species protected at national [5] (and regional in the case of Île-de-France) level. Damage to the wet and aquatic habitats in which they are found is subject to the provisions of the Water Act [5]. Damage to these species and/or the wet environments where they are found requires administrative procedures to be undertaken by contracting authorities [5]. Besides these "specific" requirements, Odonates also need to be taken into consideration when completing any impact study.

Administrative tools for taking Odonates into consideration

The regulatory framework referred to above requires contracting authorities to take Odonates into consideration on various levels. The various considerations and types of impact identified are based on documents and lists of references that substantiate the concerns and ecological actions proposed. These include: the regional and national red lists [7], the National Plan of Action for Odonates (Plan National d'Actions en faveur des Odonates, PNAO) [8] and its regional formats, as well as the species of interest for the national coherence of the Green and Blue Belt (TVB) [9].

Methodology for the consideration of Odonates in linear transport infrastructure projects

Linear transport infrastructure projects can have an impact on Odonate populations either:

- Through destruction of individual insects (larvae or imagos);
- The deterioration/destruction of the different environments that they inhabit in particular and all wet environments.

Accordingly, certain sections of the impact study require specific attention to be given to Odonates' ecological characteristics. It should be noted that exemption application dossiers are improving overall. The points detailed below are essential for the completeness and relevance of impact studies [10].

Initial state of the environment (EIE) assessment

The quality of this initial state is an essential prerequisite to "ensure the fairness and relevance of the following stages of the impact study" [11] (avoidance, mitigation and compensatory measures, monitoring, etc.). In the case of Odonates, the exhaustiveness of the initial state of the environment (EIE) assessment entails bibliographic research of the data available for the area in which the project is to take place, as well as field inventories based on protocols adapted for different species (number of passageways, period, sampling arrangements, etc.). Specific skills are essential.

Bibliographical research

This must be based on existing inventories produced for the area (natural areas of special interest for flora and fauna (ZNIEFFs), Landscape Information System (SINP), Regional Information System, Open and Collaborative Naturalist Information Management (GINCO) platforms, National Inventory of Natural Heritage (INPN), Nature association data, etc.), regulatory zoning (National Nature Reserves (RNN), decrees for the protection of biotopes (APB), etc.) and national tools (National Action Plan (PNA) and the national Red List (LR)). This research must also be based on the regional versions of the National Action Plan (PNA) through the Regional Action Plan, as well as regional red lists, where available, and local references for this subject must be requested where applicable. This work makes it possible to detail the local concerns for the project area as regards Odonates and to orient field inventories.

Field inventories

The ecological characteristics particular to Odonates (larval phase, maturation, hunting and rest areas, etc.) require the use of specific inventory techniques and methods. In the absence of specific protocols for country planning studies, the French Society of Odonatology (Société Française d'Odonatologie) provides techniques and methods on its website. Recommendations can also be found, depending on the type of study (inventory, monitoring, study), types of habitats and frequency of surveys, as well as numerous recommendations [12]. Note that the dates and meteorological conditions for which the inventories have been drawn up are important parameters to mention as the presence or absence of certain species and therefore the quality of these inventories are dependent on these conditions.

Analysis of the effects of a linear transport infrastructure project on Odonates

The impact on Odonates and their environments is derived from the specific nature of the linear transport infrastructure projects: technical characteristics, area, phase of works, etc. This is due to the different types of work required for the creation of new structures: earthworks, levelling, excavation, cut and fill, passing machinery, etc. or, a posteriori, during the operating phase, deterioration of environments in the vicinity of the infrastructure (modification of discharge, contamination, maintenance of verges, etc.) All habitats necessary for the entire life cycle of Odonates are potentially affected (larval habitats, resting areas, sexual maturation, etc.). Accordingly, the analysis of the effects of the project on Odonates requires certain considerations [10] given the different of types of impact possible:

- Particular care must be exercised regarding the destruction/disturbance of Odonates' natural habitats as a result of the project (area covered, run-off/infiltration, etc.);
- Awareness of the evolution of feeding, reproduction and sexual maturation areas from the construction to the operation phase;
- Identification of the risk of changing the ecological conditions (hydraulic regime, composition of vegetation, etc.);

In this regard, linear transport infrastructure projects can have a fairly major impact on individual insects and the habitats necessary for Odonates' entire life cycle.

Different types of impact by projects on Odonates

- Destruction of individual insects during the works phase

The destruction of individuals particularly affects the larval stage through the blocking and/or modification of water flows, leading to the drying and/or silting of aquatic and wet environments, which results in the destruction of larvae. As regards the adult phase, certain species of zygoptera with limited flying capacity can be destroyed during the construction phase when there are earthworks, if these are carried out at an inappropriate time (flight time in particular). This also affects specimens during the emergence phase.

- Destruction of the environment

This type of impact is associated with the destruction of aquatic habitats in which larvae develop: ponds, pools, ditches, rivers, through the works mentioned above. On top of that there are other types of work carried out on certain construction projects: dredging, canalization, recalibration, bypassing waterways. The environments necessary for other stages of development may also be destroyed during construction work: destruction of hedgerows, tall herbs, riverine habitats, etc.

- Deterioration of the environment

A particular facet of these types of deterioration is the modification of the environment's ecological characteristics: changes to riverbank or aquatic vegetation, or physical and chemical changes to the aquatic environment including modification of the flow, turbidity, pH level, siltation, etc., which can cause the destruction of insects at the larval or emergence phase even well after the construction phase. The waterways intercepted and/or situated within the vicinity of the project may suffer contamination of the surface waters if run-off is not collected and processed before being discharged into the natural environment. In the case of imagos, these types of deterioration affect all or part of the habitats required for hunting and rest: deterioration of hedgerows, grasslands, copses, verges, pathways, etc.

- Fragmentation of habitats

Work related to linear transport infrastructure projects may cause the fragmentation of habitats required for the life cycle of dragon and damselflies as a result of the barrier effect produced. This effect can take the form of a physical barrier or a break in thermal and light conditions, and can be illustrated by the fact that some species of zygoptera that fly along the sunny banks interrupt their flight when they reach the shade created by a viaduct over the banks of a waterway.

This particularly affects species that are dependent on very specific habitats and are sometimes rare and/or that have poor dispersal capacity. The Southern Damselfly, for example, is very sensitive to fragmentation due to its poor dispersal capacity and its specific ecological requirements, and although its habitat can be found over the entire mainland of France, one of the main threats faced by this species is the lack of connectivity between different populations [8].

Impact assessment

The types of impact identified must be assessed and graded. This assessment is performed in view of the regulations and national and local concern to protect species of Odonates. Among other things, it is based on the presence or absence, on the sites affected, of species:

- With a (national or regional) regulatory protection status;
- Of community value;
- On the national and/or regional red list;
- That are the subject of specific PNAO and/or PRAO action;
- Of interest for the coherence of the Green and Blue Belt (TVB).

The simple presence of these species in the area covered by the project is not sufficient for satisfactorily grading the impact. Their conservation status must be assessed on different levels, particularly local and regional, from the initial state onwards. For example, *Cordulegaster bidentata*, a non-regulated species, is classified as being of low concern (LC) on the national red list yet as endangered (EN) on the Provence-Alpes-Côte d'Azur (PACA) regional red list and must therefore be fully taken into consideration in any project affecting this species in PACA.

It should be noted that the assessment of the state of conservation is often overlooked in exemption application dossiers in the case of adverse impact on protected species [10], whereas it is a necessary condition of said exemption being granted (ali. Article 4. L.411-2 of the French Environmental Code).

The National Action Plan (PNA) provides a protocol for assessing the state of conservation of certain species of Odonates on a given site with four main indicators: estimation of numbers, habitat quality, deterioration and prospects [8]. The Regional Action Plans for Odonates (PRAO) also provide an assessment of the state of conservation of certain species on their territory.

Measures: avoidance, mitigation, compensation, support (ERCA)

When the overall impact of the project has been identified and graded, in the case of adverse impact on species of Odonates that are protected or endangered, and/or the wetland areas on which they depend, reflection must be undertaken with a view to *Avoiding* or *Mitigating* it. If it cannot be avoided or sufficiently mitigated and the residual impact remains, it must be *Compensated* for. *Supporting* measures may also supplement this approach (these are not dealt with here).

Examples of avoidance, mitigation and compensatory measures from existing projects or, failing that, recommendations from the French Commission on Sustainable Development (CGDD) are presented below: Guide d'aide à la définition des mesures ERC, 2018 [13] (Guide to assist with definition of avoidance, mitigation and compensatory measures 2018).

The following examples may concern populations of Odonates at different stages of development and/or the habitats on which they depend.

Avoidance

Definition: "A measure that modifies a project or an action from a planning document designed to remove an identified negative impact that this project or action would cause" [14].

Measures that totally eliminate an impact are therefore considered avoidance. In other words, no adverse impact affects the environment and/or species identified over the entire duration of the project (works and operation).

Two types of avoidance can be implemented during different phases associated with the project (preparation, works, operation):

Geographical avoidance

Examples:

- Redefinition of the characteristics of the project: choice of an alternative layout for the infrastructure and/or different access routes to the worksite and/or site facilities,
- Access restrictions (by means of signposting, for example) during works or permanently during the operating phase.

Technical avoidance

Example: total absence of discharge into the natural environment (rainwater and from the site), source of contamination causing potential destruction of larvae through collection and closed circuit processing of run-off water from the site.

Example of avoidance: Redefinition of the area covered by a purification basin

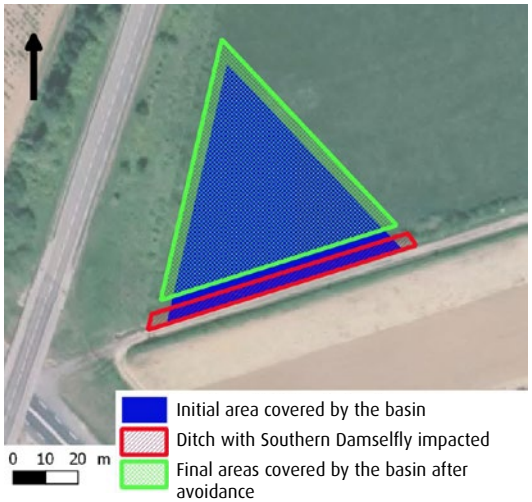
According to: Application for exemption relating to the conversion of roadway RN79 to a two-lane dual carriageway (DREAL BFC 2017)

- Description of the measure

The location of the future purification basin, below in blue, was redefined to avoid a ditch populated by the Southern Damselfly.

- Costs

This avoidance measure is integrated into the project design costs and makes it possible to avoid any impact related to the destruction of individual Southern Damselflies and their habitat. Accordingly, there is no specific cost associated with this measure. Any additional costs generated in relation to the initial project must be balanced against the savings made by the absence of any need for mitigation or compensatory measures. However, it is necessary to check that the presence of the basin has no indirect impact on the ditch: drainage, discharge or infiltration of waters from the basin.



Mitigation

Definition: "Measure defined after avoidance and designed to reduce a project's permanent or temporary negative impact on the environment during the construction or operating phase." [14]

This entails similar measures to those considered for avoidance when the measures implemented have not succeeded in entirely preventing impact.

Geographical mitigation

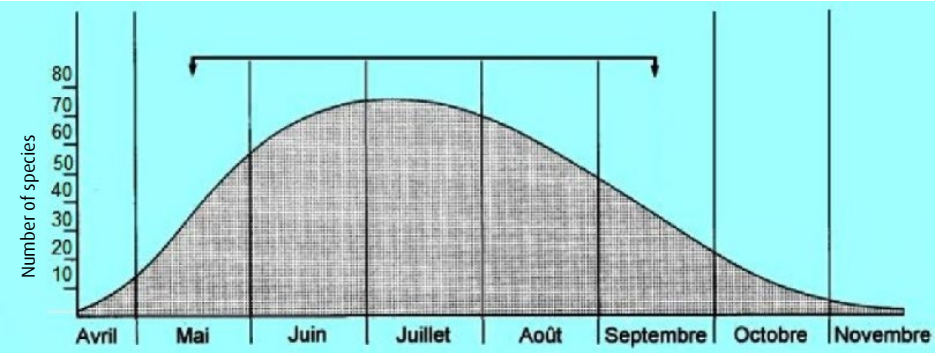
Example: provision of signposting and/or restricted access for part of an environment inhabited by a population of Odonates.

Technical mitigation

Examples: implementation of provisional purification systems to manage rainwater and for the construction site, ecological management of habitats supporting Odonates in the area covered by the project, maintenance of a minimum "biological" waterway flow, installation of a net on bridge railings to prevent collisions [15].

Temporary mitigation

Example: carrying out work or maintenance at an appropriate time of year for the context and/or the species concerned. Excluding emergence periods (all species), the best observation period (see graph below) or, if the entire wetland area is impacted, avoiding the execution of work during winter (which could destroy all of the larvae and therefore the entire population).



Average curve of activity of adults of all species growing on lowland areas over the course of the year (according to SFO) [16]. The favourable observation period falls between mid May and mid September.

Examples of mitigation measures

1. Provision of a means to cross waterways

- Description of the impact and associated measure

The passing of construction equipment may damage small waterways and ditches, which are the habitats of some species of Odonates. The installation of temporary means of crossing the waterway is one possible mitigation measure.

- Costs

Log or metal bridges, these types of crossing systems come at a cost of between €1,000 and €1,500.

2. Management of suspended matter during the construction phase

- Description of the impact and associated measure

All phases of infrastructure construction work are affected by the problem of suspended matter released into the wet and aquatic environments. In the larval stage of their lives, Odonates are very sensitive to water quality, particularly turbidity, which depends on the concentration of suspended matter. The use of straw filters upstream of the settling basins makes it possible to manage part of this suspended matter and also, to some extent, other types of contamination (chemicals, hydrocarbons, etc.) [17].

- Costs

Installation and maintenance: settling basin + straw filter for two years = €5,000.

3. Adapting work periods to species' biological cycles

- Description of the impact and associated measure

Within or in the vicinity of areas of concern for Odonates, the aim is to avoid works during the most sensitive periods: mainly during the emergence phase for all species and during the flight period for zygoptera with limited flying capacity. These periods vary depending on the species, the regions and the climatic conditions. Bibliographical research is therefore necessary to determine these sensitive periods in accordance with the biology of the species affected and the location of the project. These elements must be weighted by meteorological conditions at the time (variation of emergence periods).

- Cost

This type of measure is generally incorporated into the costs of the work with a study on the most appropriate phasing of the varied jobs to be carried out in the areas of concern.

Compensation

Definition: Each compensatory measure is designed in response to residual impact, i.e., impact that occurs after the implementation of avoidance then mitigation measures. Articles L.163-1 and subsequent of the French Environmental Code stipulate the statutory compensatory measures which are "(...) made mandatory by legislation or regulations to compensate, in keeping with their ecological equivalence, for foreseen or foreseeable adverse impact on biodiversity caused by the performance of a project (...)".

These measures must comply with the following principles:

- ecological equivalence with the need to "compensate in keeping with their ecological equivalence";
- "goal of no net loss and even gains in biodiversity";
- Geographical proximity with the priority given to compensation "on the damaged site or (...), in the vicinity of the latter in order to guarantee its functionalities on a permanent basis";
- Effectiveness with "performance obligations" for each compensatory measure;
- Sustainability with effectiveness of compensatory measures "over the entire duration of adverse impact".

Some examples of compensatory measures favourable to Odonates are given below. For further clarification on the technical aspects of different types of actions or environmental engineering measures to be implemented, see the French Office for Insects and Their Environment (OPIE) technical guide on the protective management of Odonates, Aborder la gestion conservatoire en faveur des Odonates, 2016 [4].

Creation/renaturation of environments

This involves the creation or renaturing of an environment with identical ecological characteristics to the environment destroyed and/or conducive to the species affected. These types of compensatory measures must comprise:

- Control of the site through ownership or by contract;
- Technical measures aimed at creating the environment;
- The management measures necessary for the effectiveness and sustainability of the action.

Concerning Odonates, the implementation of this type of measures involves the creation or renaturation of the habitats required for the life cycle of the target species:

- Larva habitat (hydraulic regime, substrate, etc.);
- Existence of the conditions necessary for emergence (riparian vegetation, forest, etc.) ;
- Environment necessary for the maturation of immature insects (wooded boundaries, hedges, etc.);
- Resting and hunting areas, and existence of the necessary conditions at egg-laying for imagos.

Example of the creation of a ditch favourable to the Southern Damselfly

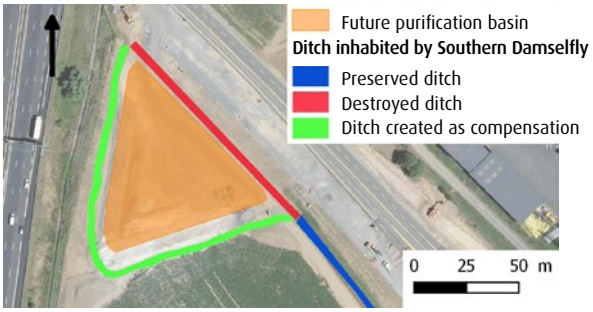
According to: Single authorisation application dossier A406/RN79 Noeud de Macon Sud (APRR , April 2017)

- Description of the measure

Within the context of the conversion of a section of the RN79 roadway into a two-lane dual carriageway accompanied by a multifunction basin, the unavoidable destruction of 110 linear meters of ditch populated by Southern Damselfly (in red) was compensated for by the creation of 220 linear meters of ditch suitable for the species (in green).

The exemption application file also states the technical and ecological characteristics of the ditch and the means of managing this measure to meet the needs of the damselfly's life cycle:

Stage(s) concerned	Development/maintenance
Larvae	• Creating the ditch facilitating the meandering and softening of the banks. • Maintaining the hydrological regime • Protecting the larval habitat during dredging • Maintaining and improving the physical and chemical quality of the ditch
Egg-laying and emergence	• Preventing the complete closing off of the ditch
Immature and adult	• Maintaining and protecting (fencing off) nearby herbaceous areas, • Favouring the species' capacity for dispersal.
costs	Estimated at €70,000.



Points requiring particular care

Choosing a compensation site

The complexity of the functioning of wet environments suitable for Odonates means the site on which the compensatory measure will be implemented must be chosen with care in order to ensure its effectiveness over time. Indeed, selection of a site that does not present the abiotic characteristics of the habitat envisioned (water supply, soil type, etc.) entails a very high risk of failure [15]. It may be pertinent, for example, to choose a site on which a population of the affected species is already present but in decline and/or was present in the past, accompanied by an assessment of the capacity of the compensatory measure to turn this decline around and/or recreate the habitat destroyed.

Ecological engineering measures/actions

In order to be effective, the measures and actions must recreate all of the biotic and abiotic characteristics of the habitats (which vary considerably from one species to another) needed for the life cycle of the species affected:

- Recreation of the habitats necessary for the different stages of evolution (vegetation, substrate), sexual maturation and imagos (hunting, resting, egg-laying areas),
- Recreation of the physical and chemical characteristics of the aquatic larval habitats (hydraulic regime, pH, turbidity, etc.).

Restoration/rehabilitation

This is defined in the guidelines [14] as an "Action on a damaged environment by man or by natural evolution (e.g.: an environment closed of due to development of woody species following cessation of management), designed to develop the environment towards conditions that are more conducive to its proper functioning or biodiversity. Interventions requiring works (earthworks, hydraulic works, environmental engineering, etc.)".

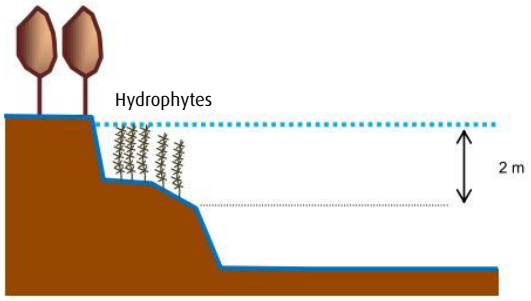
Accordingly, in the case of Odonates, restoration/rehabilitation may concern waterways with actions on the banks, (re)connection with hydraulic extends, restoration of the hydromorphological conditions of the flow channel of the waterway (remeandering, diversification of flows, provision of materials, reprofiling to change profile cross-wise or length-wise, bridge), all actions liable to create different micro-habitats favourable to Odonates at different stages of their development.

Examples of restoration:Reprofiling of banks favourable to *Oxygastra curtisii* and *Gomphus graslinii*

According to: Appendix 3 of Decree No. 2013 220 – 0001 Special exemption for Nîmes-Montpellier high speed line bypass, 2013

- Description of the measure

Proposal to renature the banks of gravel pits to create habitats that are suitable for the larval development and egg-laying of two protected species of Odonates, *Oxygastra curtisii* and *Gomphus graslinii* affected by the project.



Even if these two species are preferentially dependent on waterways with very slow currents, they can also be found in environments with stagnant water. Their presence on sites near the compensation site led the contracting authority to propose this measure. For egg-laying and larval development, these two species need (although in the case of *Gomphus graslinii* the data has yet to be studied in depth [8], [18]), deep, sharp banks and sandy substrate where plant debris can accumulate (leaves, branches, etc.). The presence of riparian woodland with a tree strata is therefore essential on account of the shade that it provides on the surface of the water, as well as the plant debris that it produces, *Oxygastra curtisii* larvae also like submerged root proliferations where they hide. This compensatory measure favours the larval state, egg-laying and the emergence of these species.

- Costs

The costs of this type of measure are very variable and depend on the extent of the shoreline to be renatured. In addition to the reprofiling of the banks, there is the planting of riparian woodland with different layers, wooded in particular, as well as the possible addition of material if the substrate at the bottom of the tank or bed of the waterway is not suitable. However, an idea of some costs can be given for information purposes:

- Earthworks for reprofiling the bank: €800/day mechanical digger,
- reinjection of materials: €10 m^3,
- Reconstitution of the riparian woodland: €20 per linear metre of the bank.

These average costs are mainly taken from [19].

Evolution of management practices

"Evolution of management practices" means two categories of measures including cessation or total change from previous management methods (e.g.: change of cultivation practice through conversion of an intensive cereal crop plot into a permanent hay-making or grazing meadow). This development may be beneficial to the populations of certain species of Odonates by (re)creating, for example, the habitats required for maturation and/or the hunting and resting of imagos in the vicinity of the aquatic environment required by the larva. As a general rule, for the stages of sexual maturation, hunting and roosting activity, Odonates need open areas with an abundance of prey, comprising the key elements of the landscape where they can rest and hide from predators, such as hedges or borders.

The question of the land used for this type of compensatory measure may take different forms, and management practices may be developed either internally or by another operator. All of these issues are addressed extensively in existing literature [20].

Example evolution of management practices

According to: Authorisation application dossier, Development of the A480 and Le Rondeau interchange in the Grenoble crossing, AREA/État, 2018

- Description of the measure

The purpose of this measure is to restore and/or improve the open environments suitable for the species affected by the project and, in particular, avifauna and reptiles, but the future environment will also be suitable for Odonates as a hunting and resting area.

- Details

Objective: to convert the two plots cultivated with crops into grassland environments and in this way diversify the mosaic of environments and floral diversity.

Area: 11.7 ha

Technical description:

- Destruction of the previous crop (stubble ploughing technique),
- Preparation of the seedbed of the land and seeding of treated areas favouring natural regeneration preferentially using local seed ("hay flower" technique) from a source plot whose general qualities (soil type, permeability, etc.) correspond as closely as possible to those of the receiving plot.
- Installation:
  - Outer fencing to be durable and strong
  - Inner fencing, separating the sub plots for grazing, which will preferably be battery powered mobile electrical fencing at the right voltage (sufficient to contain equines to be preferred for grazing).

Maintenance/Management:

- requirement to maintain the surface area in meadows without changing the designated land usage,
- Extensive management preferably by rotational equine grazing with an appropriate charge (value 0.5 to 1 livestock units (LU) per hectare),
- Maintenance of grass strips, particularly in the outer borders of existing afforestation to the south of the site, and planted hedges,
- No fertiliser,
- No use of phytosanitary products.

Cost:

- Stubble ploughing: €100/ha,
- Hay flowers: €300 /ha,
- Fencing: external: €10 /linear metre; mobile: €3-4 / linear metre,
- Extensive management: €250/ha per year.

Points requiring particular care

Management and monitoring

In order to be sustainable, the compensatory measures must be managed in order to achieve and maintain the ecological and physical and chemical characteristics of the habitats over the entire duration of the impact of the project. Monitoring must also be implemented to verify the attainment of the targets initially set and, if necessary, readjust the working practice.

Monitoring associated with the measures

Definition: compensatory measures must involve a "(...) performance obligation and be effective for the entire duration of the adverse impact" (L.163-1 of the French Environmental Code). Accordingly, each compensatory measure must be accompanied by performance objectives that must be assessed through monitoring.

This monitoring makes it possible to:

- Verify the attainment of these objectives or ensure that the ecological trajectory is on the "right tracks";
- Readjust measures if only some or none of the objectives set are/will be achieved.

In the event of adverse impact on Odonate species and measures taken to benefit them, a monitoring programme must be implemented. It must be based on a specific protocol [21].

Initial state of the environment

A precise Initial State of the Environment (EIE) assessment must be conducted on the compensation site to determine the effectiveness of the compensatory measure and define a "0" state on the basis of which the additional environmental value related to the compensatory measure will be estimated. Three possibilities:

- Either the site is within the vicinity of the impact and the project initial state of the environment (EIE) assessment is sufficiently precise and can be used;
- The site is within the vicinity of the impact but the project initial state of the environment (EIE) assessment is not sufficiently detailed and clarification is required;
- Or the compensation site is some distance from the site impacted and needs its own EIE assessment.

Objective of monitoring

The performance objectives can be of different types. For example:

- Installation on the compensation site of a stable population of the species affected over a number of years;
- Good state of conservation of the species on the site symbolised by a typology of state (good, poor, etc.).

Indicator to ensure that the objective is met

The indicators needed to assess the performance of objectives must be easily measurable, example:

- Existence of a population of species "x" Quantified objective indicator: inventory of the estimated number of individuals in the species affected and evolution over a number of years.

Monitoring protocol

This protocol must detail the techniques and methods used that are needed to measure the indicators and comprise:

- A sampling plan;
- One or more techniques and/or methods to be applied;
- Supplementary applicable rules: Duration, frequency, weather conditions, etc.

Sustainability of the follow-up

The monitoring must also be the subject of a detailed cartographic restitution to ensure the traceability of the sampling (position of the transects, etc.) accompanied by detail of the monitoring protocol. This is particularly important in the case of any transfer of monitoring to another person or entity (to guarantee sustainability and scientific relevance).

Costs

Example for monitoring to be carried out over 20 years at n+1, n+3, n+5, n+10, n+15 and n+20 (recurrence variable depending on the projects and the type of compensatory measures), with three surveys per year following a detailed protocol with a day with an expert from an environmental consultancy at €600, this comes to a cost of €10,800 for monitoring over 20 years (which is €540/year).

Points requiring particular care

Monitoring inventories

The inventory noting the presence and number of individuals on the compensation site must be supplemented and analysed by behavioural observations: territorial behaviour, heart-shaped mating-wheels, presence of immature individuals, etc. as well as the collection and identification of exuviae to substantiate the actual installation of the species on the site.

On the other hand, if the objective set is to achieve an ecological functioning similar to the impacted site with the return of an Odonate population as indicator, the species richness (= number of species present) of the site is not a relevant indicator of the attainment of this objective. In fact, the creation of a new wet environment will rapidly be colonised by ubiquitous Odonates that may not be those affected by the project and/or are not representative of the ecological functions sought from the environment.

So it is essential to foresee the period of time over which the indicator is necessary in order to confirm the attainment of objectives in terms of the return of a specific species and/or the desired ecological functionalities of the environment.

Examples of measures to support the most affected species

The specific ecological characteristics, threats and examples of compensatory measures for the two protected species most frequently affected by linear transport infrastructure projects on account of their wide distribution (presence in the departments in green on the distribution maps according to the INPN) are presented below.

The Southern Damselfly

Coenagrion mercuriale (Charpentier, 1840)

Status

- Appendix II DHFF (327 Natura2000 sites in mainland France [6])
- National protection: Art.3 of the decree of 23 April 2007

Habitats

The species inhabits small waterways, ditches and sunny seepages with good quality water and a permanent flow. The presence of aquatic (for egg-laying and larvae) and riparian (enabling emergence) vegetation is essential. The areas required for sexual maturation, rest and hunting are found in the immediate vicinity of the waterway (less than 100m) and comprise open areas: tall herbs, grassland, etc.

Flight period

The following table (according to [2]) shows the Southern Damselfly's indicative flight periods. The North/South differentiation shows the variance in the different stages between southern regions and areas with higher latitudes and altitudes, bearing in mind that these periods may vary by approximately two weeks due to the year's weather conditions. Note that the larvae in all species of Odonates are present all year round in aquatic environments.

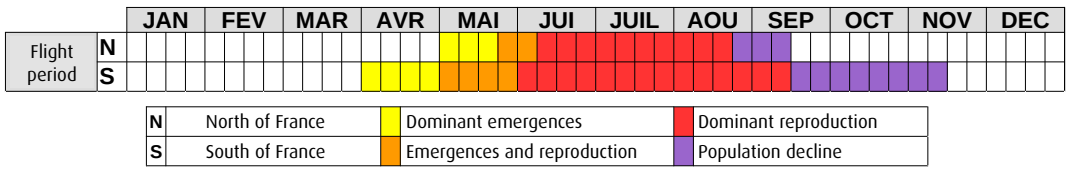
Main threats

- Fragmentation of the population;
- Eutrophication and/or contamination of the water (of agricultural, industrial or urban origin);
- Dredging, straightening and channelling of small waterways;
- Closing off of the environment;
- Cessation of the environment's water supply by lowering the water table.

Example of Southern Damselfly compensatory measures

The creation and/or renaturation of a favourable environment for the Southern Damselfly is a compensatory measure that can be proposed in the case of residual impact caused by linear transport infrastructure projects on this species. The following table shows examples of actions and improvements.

Environmental components		Characteristics of habitats suitable for the Southern Damselfly	Examples of actions and measures to benefit the Southern Damselfly
Land	Banks	• Gently sloping banks	• Reprofiling the banks
Water	Hydraulic regime	• Shallow flowing water with weak to moderate current	• Deepening of the bed of the ditch or remeandering of the stream • Addition of materials if necessary
		• Permanent flow all year round	• (Re)connexion with an existing ditch/stream • Installation of gate
	Water quality	• Oligotrophic to mesotrophic water	• Methods of maintaining the verges of the linear transport infrastructure and/or entering into contracts with local farmers / manufacturers to implement practices limiting the eutrophication/contamination of the waters.
Vegetation	Aquatic and riparian vegetation	• Presence of aquatic vegetation all year round: helophytes and hydrophytes	• Planting helophyte and hydrophyte species • Action on vegetation to avoid the closure of environment (in particular the development of a tree layer).
	Surrounding vegetation	• Presence of semi-natural grassland and/or tall herbs on the edges of waterways	Maintenance procedures appropriate for riparian areas: • Temporarily restricted access during emergence/flight period • Grazing/mowing as of the end of August, September



Monitoring and supporting measures

The effectiveness of these measures requires the monitoring of Southern Damselfly populations with an appropriate protocol throughout the entire duration of the impact, as well as monitoring of the hydrological parameters (level and quality of the water) and vegetation (closing off the environment) essential for the species.

Orange-Spotted Emerald

Oxygastra curtisii (Dale, 1834)

Status

- Appendix II and IV of the DHFF (188 Natura 2000 sites in mainland France [6])
- National protection: Art.2 of the decree of 23 April 2007

Habitats

The larvae inhabit the calm parts of flowing water, slow-running rivers, canals and some water bodies: lakes, abandoned gravel pits, etc. The common denominator of these habitats is the presence of developed riparian woodland. The females lay their eggs in areas shaded by the riparian woodland, often at the water-tree root interface. The larvae prefer to live in plant debris and the submerged root proliferation. Emergence takes place on the emerged branches, trunks and roots of the riparian woodland. The areas where sexual maturation takes place are often found some distance from the emergence sites in bushy wild land or forest paths, for example.

Flight period

In the case of this species, particular attention must be paid to the emergence period, which mostly occurs over a short period of time (10 to 15 days). The topography of environments conducive to emergence: roots, branches, trunks in the immediate vicinity of a steep bank (which makes them very sensitive to fluctuation of the water level). Like other species of Odonates, *Oxygastra curtisii* larvae are present the whole year round in aquatic environments.

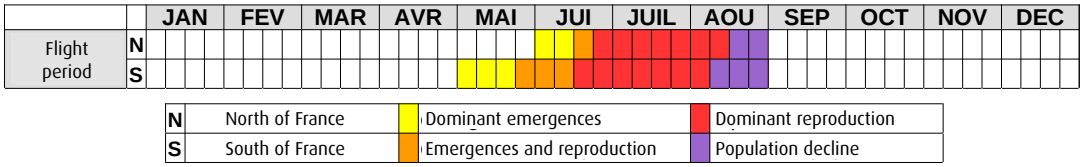
Main threats

- Eutrophication and/or contamination of the water (of agricultural, industrial or urban origin);
- The development of large rivers;
- Aggregate extraction;
- Clearing of the banks;
- Activities affecting the water level during the emergence periods (nautical activities, river traffic).

Example of compensatory measures for the Orange-Spotted Emerald

The creation and/or renaturation of a favourable environment for the Orange-Spotted Emerald is a compensatory measure that may be proposed in the case of residual impact caused by linear transport infrastructure projects on this species. The following table shows examples of actions and improvements.

Environmental components		Characteristics of habitats suitable for the Orange-Spotted Emerald	Examples of actions and adaptations suitable for the Orange-Spotted Emerald
Land	Banks	• Sharply sloping banks	• Reprofiling the banks
	Substrate	• Loamy sand substrate on the river bed	• Addition of materials if necessary
Water	Hydraulic regime	• Calm part of the flowing waters • Sometimes stagnant waters	• Remeandering of waterways to create calm areas of water • Diversification of waterway features (pools, riffles) • Destruction of bank protection structure if the context permits it.
		• Oligotrophic to mesotrophic water	• Methods of maintaining the verges of the linear transport infrastructure and/or entering into contracts with local farmers / manufacturers to implement practices limiting the eutrophication/contamination of the waters.
Vegetation	Aquatic and riparian vegetation	• Presence of developed riparian woodland.	• Planting of species of shrub in direct contact with the aquatic environment and capable of developing a submerged root proliferation: willows and alders in particular • Cutting back every 8 to 10 years by rotation
	Surrounding vegetation	• Presence of a mosaic of diversified plant formations on the banks: grasses, shrubs and trees.	• Management procedures appropriate for plant formations at the edges of waterways to preserve their diversity (grazing/ mowing/maintenance of the riparian woodland)



Monitoring and supporting measures

The effectiveness of these measures requires the monitoring of Orange-Spotted Emerald populations with an appropriate protocol over the entire duration of the impact, as well as monitoring of the hydrological parameters, riparian woodland and adjacent plant formations. An agreement on activities responsible for the potential fluctuation of the water level during the emergence period may also be foreseen as a supporting measure.

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Acronyms Used

APB	Decree for the Protection of Biotopes
BFC	Bourgogne-Franche-Comté
CGDD	French Commission on Sustainable Development
DHFF	Habitats Directive
DREAL	Regional Directorate for Environment, Development and Housing
EIE	Initial State of the Environment
ERC(A)	("Sequence") Avoidance, Mitigation, Compensation (Support)
GINCO	Collaborative Naturalist Information Management
ILT	Linear Transport Infrastructure
INPN	National Inventory of Natural Heritage
LR	Red List
MNHN	French National Natural History Museum
MO	Contracting Authority
OPIE	Office for Insects and Their Environment
PACA	Provence-Alpes-Côte d'Azur region
PNAO	National Action Plan for Odonates
PRAO	Regional Action Plan for Odonates
RNN	National Nature Reserve
SFO	Société Française d'Odonatologie
SINP	French Nature and Landscape Information System
TVB	Blue and Green Belt
IUCN	International Union for Conservation of Nature
ZNIEFF	Natural Area of Ecological Interest for Flora and Fauna

Find out more

Useful Links

- **DHFF**: https://eur-lex.europa.eu/legal-content/FR/TXT/?uri=LEGISSUM%3Al28076
- **Protection nationale**: www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000465500
- **Liste rouge nationale**: https://uicn.fr/liste-rouge-libellules
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- **INPN**: https://inpn.mnhn.fr/accueil/index
- **SINP**: www.naturefrance.fr
- **GINCO**: https://ginco.naturefrance.fr

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