

Hay-meadows, pastures, fallows: Experiences of a LIFE project in the Luxembourg Ardennes

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Abstract. The wetlands of the Luxembourg Ardennes are home to a variety of endangered species, amongst others, the three target species of the LIFE Éislek project, *Lycaena helle*, *Saxicola rubetra* and *Lanius collurio*. The disappearance and degradation of their habitat, the wetlands, is the main reason for the decline of the three species. natur&ëmwelt Fondation Hëllef fir d'Natur and its partners restored and managed wetlands within the framework of a LIFE project from 2012 to 2017 within 11 Natura 2000 areas in order to improve the conservation status of associated endangered species. The main actions were the restoration of abandoned sites, rewetting of drained wetlands, removal of spruce in wet stations and reconversion into open habitats and restoration of bistort meadows. The recurrent management through grazing and/or mowing was adapted and a management plan created to secure the sites in the long term. The restoration measures of waterlogged sites were carried out either by manual labour, often by firms related to the economy of solidarity or with adapted equipment from expert companies, according to the circumstances. For the ordinary wetland management of accessible wetlands, the project relied on good collaboration with local farmers. Complex measures, such as the remeandering of a stream relied on careful planning by engineers. Altogether, the state of 150 ha land was ameliorated through the LIFE Éislek project. Monitoring of the three target species and the sites in general allowed to assess the techniques used and to ameliorate them by adapting to the circumstances.

1. Introduction

1.1. The Éislek – landscape history

The Éislek is the northern part of Luxembourg and is geologically differentiated as a foothill of the Ardennes region, an old transboundary rock massif stretching from France through Belgium and Luxembourg to Germany. The relief is a high plateau culminating at 560 m interspersed with valleys (Brichet et al. 2009). The underground is shale and characterised by the low abundance of lime and therefore allows only low

productivity. Agriculture is at a disadvantage compared to the Gutland in terms of soil characteristics and climate with repercussions on culture and cultivation methods (Philippe et al. 2008).

In order to understand the current characteristics of the region and to conserve the typical flora and fauna, it is necessary to look into traditional management methods and the development of the landscape in the past. The plateaus were a mixture of poor heathland and small acres until 1850. Today, they are cultivated as acres. The brook val-

leys of the Éislek, with their wetland communities, are important in terms of nature conservation. In this region, they have a specialised composition of species that are adapted to fresh temperatures (annual mean temperature: 9 °C) and high humidity (800-950 mm annual rainfall) (Pfister et al. 2005). After the last glacial period, the valleys were colonised by alluvial forests with openings, which were home to a flora, which is still typical to most of today's wetlands in the region (Colling & Meyer 1986). Jumping to the 18th century, the same valleys were cleared and being used as hay meadows, as can be observed on the Ferraris maps dating from 1771-1777 (ACT 2019). The grass was cut once in summer and used to feed the cattle in winter (Philippe et al. 2008). Many species profited from the anthropogenic changes in the valleys, for example, the two butterfly species *Lycaena helle* and *Boloria eunomia* (Colling & Meyer 1986).

With an increase of the population, the demand for meat and dairy products increased. A railway was built to connect the coal region of Liège with the iron region in southern Luxembourg. This modern infrastructure allowed the distribution of the products from agriculture. To keep up with the high demand, the cattle and sheep numbers were raised, and the hay meadows had to be cut twice each season to collect enough hay to bring the animals through winter. This was only possible with a prolongation of the vegetative season, the limiting factor for this region. The farmers developed a technique called "Fléitzen", an irrigation technique used at the end of winter to clear the meadows from snow and frost much earlier in spring, while at the same time providing nutriment and greatly increasing the quantity and quality of the second hay cut in August. After the Second World War, the landscape changed further, the settlements increased in size, transportation ways were improved and agricultural practices were modernised. Fertilisation was facilitated through a by-product of the steel industry -Thomas slag- and later through other chemical fertilisers. The impact of fertilisation was especially pronounced on the poor soils of the Ardennes. This brought about significant changes in the composition of

the vegetation and habitats as well as related butterfly communities. Heathlands disappeared and sheep numbers collapsed (Engel 2008, Schneider & Naumann 2013). The hay meadows in the valleys were no longer mown but grazed by bovine animals in separated parcels after the apparition of barbed wire (Philippe et al. 2008).

The development of the agricultural mechanisation required land that was easily accessible and had a maximum size. The valleys that met these requirements were drained but most of them had no or difficult access and were of small size. As a result, many fell into disuse. For socio-economic reasons, the habitats were planted with conifers, primarily spruce (Colling & Meyer 1986).

In more recent times, further changes occurred, the number of farms decreased from 10,250 in 1962 to 3,800 in 1990 to 2,000 in 2015. The remaining ones managed a much larger area, from 13.4 ha/farm in 1962 to 65 in 2015. The agricultural sector had increasingly shifted towards meat and dairy production with a resulting increase in fodder fields, primarily corn and grass silage mown up to 4 times a year (Casali & Hupert 2012, Serv. d'Economie rurale 2016).

1.2. LIFE ÉISLEK: a project for three typical wetland species

The LIFE Éislek project was introduced by natur&ëmwelt Fondation Hëllef fir d'Natur (n&ë) to improve the conservation status and the connectivity of wetlands and the associated endangered species in the Luxembourg Ardennes. The project was carried out between September 2012 and August 2017. Its area of action were 11 Natura 2000 areas with a coverage of about 15,000 ha, of which about 150 ha were managed during the project. It was a collaboration between the afore mentioned coordinator, natur&ëmwelt asbl - Centrale Ornithologique (COL) and the Comité national de défense sociale - Projet Naturaarbechten (CNDS). A methodological support was given by the Chambre d'agriculture, the Musée national d'histoire naturelle (MNHNL) and the Luxembourg Institute of Science and Technology (LIST). This article primarily concentrates on one

part of the project, the concrete conservation measures. Other actions were the purchase of land, monitoring, raising public awareness, analysis of ecosystem services (manuscript in preparation) and networking.

Comité National de Défense sociale (CNDS), is a social structure with the aim of helping to reintegrate socially disadvantaged people. CNDS Natuuraarbechten specifically provides employment opportunities in nature conservation that should help to stabilise, motivate, qualify, inform and orientate people with psychological, social, addiction, incarceration, medical or other problems. The goal is to prevent a further slippage. In this context, CNDS Natuuraarbechten provides services in mowing and shrub removal, building of fences, planting of trees and hedges, etc. Thus, a part of the restoration and management measures were taken over by them. The LIFE project in return financed two foremen who supervised the individuals, as well as new equipment to facilitate management.

LIFE+ is the instrument that was applied to assure the financing of the measures. It is run by the European Commission to support demonstration and best practice projects for the management of the Natura 2000 areas and to preserve biodiversity through networking between European conservation organisations to facilitate implementation of strategies. LIFE covered 50% of the finances, the rest was provided by the Ministère de l'Environnement, du Climat et du Développement durable (before Ministère du développement durable et des infrastructures) as well as through investments of the project partners.

The target species, *Lycaena helle* (Denis & Schiffermüller 1775), *Saxicola rubetra* (Linnaeus, 1758) and *Lanius collurio* (Linnaeus 1758), were selected to represent the three different habitats targeted by the project, extensive managed hay meadows, pastures and fallows in wet areas.

Within Luxembourg, the violet copper (*L. helle*), a glacial relict species, is limited to the wet fallows of the Ardennes. The populations in Luxembourg are often small and isolated. The fact that the species has specific habitat requirements and responds quickly

to changes in management, make *L. helle* a useful indicator species (Wipking et al. 2007, Caspari 2010, Delsinne et al. 2012). *Jewels in the Mist* (Goffart et al. 2014) provides a good overview on the studies surrounding this species. Its distribution range was analysed during the first three years of the project, in the last years, a standardised monitoring method was introduced to follow the development of the species' status, especially in areas of action.

The whinchat (*S. rubetra*), a ground-nesting bird in the open landscape, is currently classified as extinct as breeding bird in Luxembourg and can only be observed during migration through the former wet hay meadows of the Éislek region, that are now classified as wet fallows (in the biotope cadastre: BK11). The former breeding sites are important during migration and have potential for recolonisation (Biver 2008, Biver & Collas 2012).

The red-backed shrike (*L. collurio*) is declining in numbers throughout Europe (BirdLife International 2017). In the project area, it managed to maintain relatively stable numbers of breeding pairs. It requires a mosaic of different managements, especially pastures with hedges as viewpoints from where it can hunt. However, it can also evade to clear-cuttings (Biver & Collas 2012).

In the frame of the LIFE Éislek projects, the concrete conservation measures were planned in order to satisfy the demands of these three target species for their habitat. Previous publications specifically relating to the conservation of the target species of the LIFE Éislek project are available (Molitor & Schiltz 2013, Kayser 2014, Clemens 2015, Bastian 2016).

2. Experiences on conservation measures

The main mission of natur&ëmwelt Fondation Hëllef fir d'Natur is the purchase of land and its management for nature conservation. The foundation owns a considerable assemblage of wetland habitats in the Éislek region. Recommendations to biotope management specific to *Lycaena helle* on a parcel of n&ë go back to 1994. It states: Biotope

management should always be accompanied by scientific investigation of population dynamics of the target species (Meyer & Helminger 1994). The LIFE project provided an opportunity to focus on wetland habitats and the related species.

The abandoned wet valleys of the Éislek can be restored in several ways as has already been proposed by Colling and Meyer in 1986. Areas that were profoundly changed from the semi-natural wetland habitats, such as progressive successional stages, drained sites or sites planted with spruces, had to be restored before being put into a recurrent management. The restoration measures were regrouped into four main actions, fallow restoration, hydrological restoration, reconversion of spruce plantations and restoration of bistort meadows. The recurrent management was an extensive land use that was often compensated through contractual nature conservation under so called biodiversity contracts (Mémorial 2017). Mowing requires a high investment in time and is limited by the available capacity of specialised providers. It is therefore limited

to ecological and botanical areas of special interest. Extensive grazing (in most cases by itinerant sheep) can be applied on a larger scale to preserve typical flora and fauna. This will be further discussed below. In the end, a mosaic of habitats allows to conserve a maximum of species. An overview of all the actions and the area affected are provided in Fig. 1.

2.1. Restoration measures

Most restoration measures were carried out on land that belonged to n&ë or on land that was purchased especially for this project by the same organisation. Long-term protection of measures that were carried out on privately owned land was assured through conventions (building of fences with a duration of 10 years). The managed sites are located in the Éislek region, the Luxembourg Ardennes, more specifically the northern high Éislek. Management was on wet meadows and their fallow stages. These plant communities are described in Ferrantia 66 (Schneider, 2011):

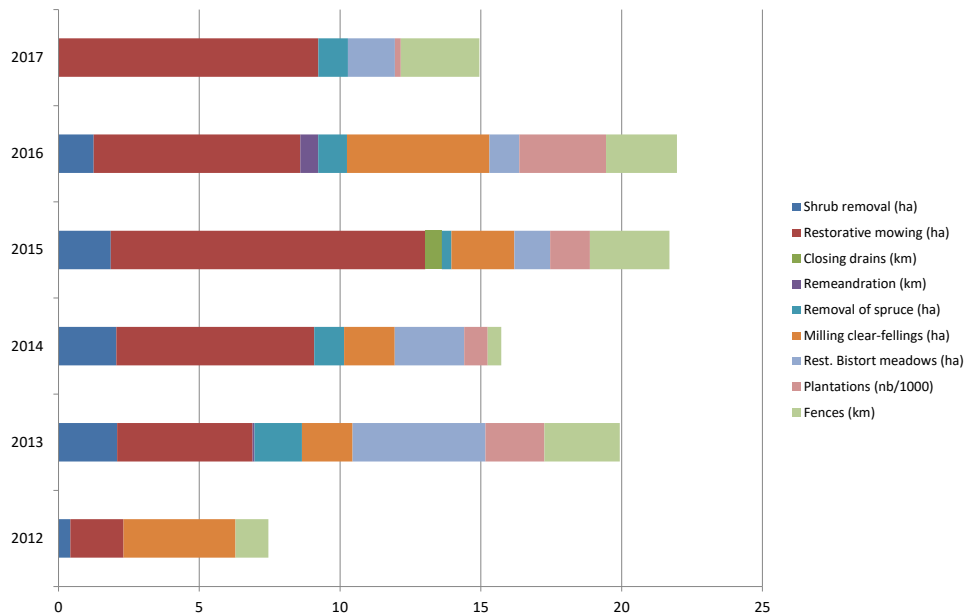


Fig. 1. Summary of the restoration measures carried out in the framework of the LIFE Éislek project from 2012 to 2017.

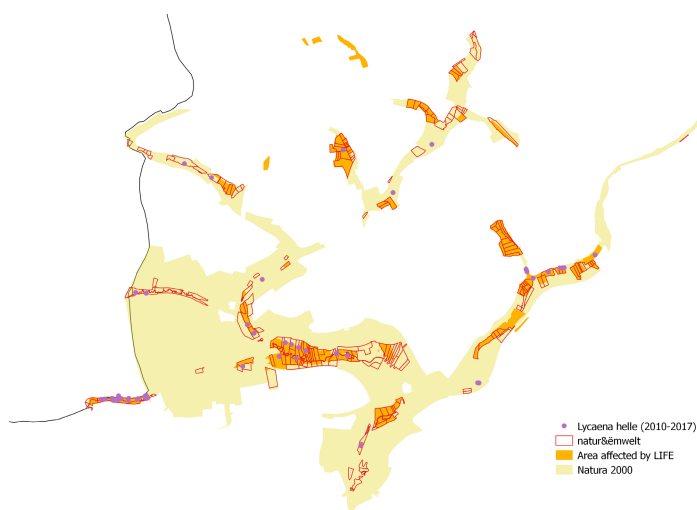


Fig. 2. n&ë purchases land targeted on the protection of biodiversity. *L. helle* is a good indicator for the state of wetlands in the Éislek region. The map of the Troisvierges area, as an example, shows that the species occurs primarily on land managed by n&ë. Therefore it was important to adapt site management to this highly endangered species. Another aim of the project was to ensure connectivity between populations as highlighted by the orange areas on the map.

- *Caltha* alliances (wet meadow plant communities)
- *Bistorta officinalis* communities
- *Filipendula ulmaria* communities
- *Crepido-Juncetum acutiflor*
- *Deschampsia cespitosa* communities
- *Juncus effusus* communities

The sites were chosen according to the distribution of the target species. Besides hot-spots within the distribution range, smaller habitats acting as stepping stones and corridors have been recognised as important factors in species conservation by providing connectivity for dispersal, genetic exchange between populations and colonisation. Especially for butterflies, a habitat network is essential for long-term (meta)population survival (Delsinne et al. 2012, Parkinson et al. 2012, Goffart et al. 2014). The two bird target species rely on small structures as perches for hunting or during migration. Many projects have already contributed to restore and create such a network of habitats: Interreg II Ourtalprojekt (1998-2001), Interreg III-A Nat'Our (2003-2007), Interreg III-A Réseau Eco (2004-2007) (Spithoven 2012), Interreg IV-A Restau Eco (2008-2012) (Delsinne et al. 2012, Granda Alonso & Moes 2012, Biver & Collas 2012, Parkinson et al. 2012, Molitor et al. 2012), LIFE moule perlière (2005-2011), LIFE Loutre (2005-2011), LIFE Arnikawiesen (2007-2010) (Caspari 2010). The LIFE Éislek project contributed to the efforts previously undertaken and tried to further

complete the habitat network throughout the Luxembourg Ardennes (Fig. 2).

For each action, preparatory work included:

- literature review
- analysis of conflicts (target biotope), decisions on long-term management
- preliminary investigation to protect rare species that may be present on the site
- consultation of experts in various domains (e. g. on target species, botanical experts, other LIFE projects, management methods, ecosystem services etc.)
- applying for the relevant authorisations
- meetings with concerned stakeholders (communities, administrations, hunters, farmers etc.)
- identifying and hiring firms specialised in the domain, giving preference to those with previous experiences with working in wetlands
- field visits with potential candidates to make sure they understand the special requirements of the project
- choice of the best value for money, taking into account expertise
- marking of the site
- meeting on-site at the beginning of the execution
- supervision and/or assistance of the firms, visit at least once each day
- construction site inspection and acceptance at the end of the works.

2.1.1. Fallow restoration

Wetlands with difficult accessibility or those that are of small size had often been abandoned due to low profitability. In the early stages of abandonment, the biodiversity of grasslands increased. The appearance of shrubs (willows) diversified the plots of land and created microhabitats. With consecutive successional stages, however, the surface homogenised and sunlight was blocked as the shrubs grew in size until it finally becomes woodland. One action of the project foresaw the clearing of land parcels that had been encroached by shrubs and to subsequently reinstate a very extensive management. Several methods were used to reach this goal.

The manual removal of shrubs was part of the actions carried out by the project partner CNDS Naturaarbechten. Willows were cut back manually, using chainsaws. At the beginning of the project, the ensuing wood cuttings were burned on the willow rootstocks to prevent regrowth. With implementation of the law forbidding the burning of waste wood (Règlement grand-ducal du 18 décembre 2015, Art. 42), it was removed from site to be used as wood energy or simply left as a woodpile outside sensitive biotopes. Manual labour was the preferred method on small sites where only individual willows needed to be cut back. Manual removal of shrubs allowed a very precise and targeted work with low impact on the fauna. The method was the preferred option in well-established ecosystems. The use of chainsaws did not prevent regrowth; up to 3 years after the initial implementation, the site needed to be mown by brushcutter. The frequency of maintenance varied between sites. As a consequence, the evolution of restored sites and especially the development of succession needed to be closely monitored. This method was only reasonable on a small scale and was not very efficient in completely overgrown wetlands.

For larger sites, another method was the preferred option: milling of shrubs with machines with low ground pressure. A converted Pistenbully on chains was used to mill sites in a more advanced successional stage. Most of the fallows were not completely

cleared, shrubs on the edges of the parcel prevent or at least limit run-off from adjacent parcels and provide wind cover for *L. helle*. Individual shrubs, especially *Crataegus spec.*, can be used by *L. collurio* as hunting perches. Solely wetlands that are used each year by *S. rubetra* during migration were opened almost completely to correspond to the requirements of this open habitat species. Immediately after treatment, the site looked devastated. However, already in the consecutive season, the habitats recovered well. Larger sites were never treated in their entirety, but a part was always left as a refuge. Nevertheless, monitoring needed to be kept up in the following years and regrowth suppressed.

A method that did not require any after-care was the removal of the roots with a cable winch (Goffart et al. 2014). The willows were first cut-back with chainsaws up to 1 m above ground. The remaining trunk with the root was then pulled out by cable winch. This method was applied on a small scale, it was therefore very precise and applied in well-established ecosystems. The depressions that were thus created in the ground filled with water and provided a temporary interesting habitat for waders and amphibians.

2.1.2. Hydrological restoration measures

The second measure targeted wetlands that had been drained to increase the surface available for farming. In many areas, the streams had been straightened to quickly evacuate the water from the area or relocated towards the edge of the parcel to facilitate management. In other areas, ditches or drainage systems were used to dry out wetlands. The goal of this measure was to re-establish wetlands for the target species but also to mitigate flooding events.

The remeandration of a straightened river section on the Trëtterbaach near Asselborn was one of the more spectacular measures carried out within the frame of the LIFE Éislek project with additional finances from the Fonds pour la Gestion de l'Eau and the Royal Bank of Canada. In order to highlight the restoration efforts along this section of the Trëtterbaach, the project instigated the

Life Éislek trail, which starts at the Moulin d'Asselborn and loops around the site, while providing additional information on the LIFE project along the way. The site of implementation was a section of the Trëtterbaach on which the stream had been heavily modified to supply a mill and flood the meadows further downstream (Fléitzen). The aim was to redirect the stream back into the old river bed and restore a functioning flood plain ecosystem. For this purpose, the stream was pre-defined, using old cadastre plans. Natural meanders further upstream also served as a template to define the future course of the stream. The LIFE Éislek Team was helped for planning by a bio-engineering consulting firm specialised in aquatic habitats (Stream and River Consult). The method of choice was a pre-profiling of the new river bed with the use of an excavator. The old riverbed was filled with the soil from the excavation, with the exception of a section with a steep shore that was conserved as stagnant water. A diversified habitat was created through a change in depth (including pools and rapids) and width, resulting in a change of water velocity. Tree trunks and roots, as well as stones of various sizes were introduced as fish caches. To get the depth-width ratio and size of the loops right, the natural conditions of the river needed to be studied. The execution relied upon the craftsmanship of the operator of the excavator, who needed a thorough guidance. The detailed execution gave evidence of a good execution: the topsoil with the root system was laid apart to later cover the slip-off slope to stabilise the ground faster and the banks were not pre-shaped but dug-out in a box form, allowing the river to shape its course in a natural way. The dug-out channel was not a final course but will help to accelerate the restoration process. From this point, the river was left to act in a natural way of erosion and deposition. Even though this method was costly and required elaborate planning, it allowed a straightened river with high depth erosion to leave its artificial bed (Fig. 3).

A less invasive measure was tried on another section of the Trëtterbaach. Here the initial situation was different from the first site. The river was not completely removed from its

natural bed but only some loops were cut to straighten the river and evacuate the water more efficiently. The old meanders were still visible in forms of depressions and sometimes even used during winter floods. When the parcel was purchased during the project, it was still covered by spruce. The first step was the removal of these non-native trees. At this occasion, several stems were used to redirect the river into its old riverbed (Gebler 2005, Bunusevac 2007). The stems were anchored in the banks, nevertheless 2 out of three deflectors were washed away during the first high waters in winter. The remaining logs were stabilised with additional stakes and remained another 4 winters before being washed away as well. In the after LIFE, a large remeandration project at this site was carried out in 2018. River restoration with small means (deflectors) was only possible where the riverbed was not too low as a result of depth erosion and where old meanders were still present. Appropriate anchorage of the deflectors was the main problem in the LIFE Éislek project. However, the deflectors were a very cost-effective measure. In contrast, the large-scale measure with pre-defining of the river's course allowed to work on a river section with pronounced depth erosion but was therefore more expensive and required expert knowledge.

Apart from the restoration of straightened rivers, this action also focussed on closing drainage systems to rewet plots of land. Drainage was used by farmers to render the parcels workable. The biotope was profoundly changed through this measure as the plant communities adapted to wetlands were replaced by those adapted to drier soils. Management through the farmers further changed the plant composition. Parcels with active drainage systems are usually in agricultural use and therefore rarely up for sale. Thus, this action was carried out only once in the framework of this project. The target parcel was clear-felled land that was drained 50 years ago to accommodate a spruce plantation. These trees had been felled as part of another project (Parkinson et al. 2012). The drainage, however, had remained on site and consisted of a trench system, which in many places was man-deep. Since the removal of



Fig. 3. The remeandering of the Trèterbaach as seen from above.

Upper photo. The site was mown before the remeandering to facilitate the work.

Lower photo. The river section has multiplied in length, reducing the velocity of the water and allowing it to overflow the shores and reconnect with the floodplain. This way, remeandering projects can mitigate flood events.

the spruce plantation, a new habitat had already established. The aim was to rewet the site while keeping interference with the existing habitat to a minimum. To further complicate the situation, the rootstocks had been left intact. After consultation with several firms, an excavator operator with good experience in nature conservation projects was willing to work in these difficult conditions. The solution consisted in the digging of two ponds on the site, which provided the soil for the filling of selected sections of the trenches. The closing of the channels allowed the water to remain in the field and recreate wetlands. The blocking of drainage systems is a measure that has been carried out to larger extents in countries with larger areas of bogs. In the LIFE Éislek project this was only a relatively small component where a simple solution was applied.

2.1.3. Reconversion of spruce plantations into wetlands

“Si l'évolution actuelle se poursuit, le monde vivant des fonds de vallons aura bientôt disparu sous le manteau vert sombre de l'épicéa.” (Colling & Meyer 1986). This phrase sums up one of the main threats to wetland species. Land that was not available for agricultural use had been planted with conifers, a sombre land cover unsuitable to the typical wetland species.

Removing spruces on wetlands was an action, which had been executed by n&e and others throughout a number of projects (see point 2.1.). Therefore, the method had been well established and experiences were made before the start of the LIFE project. To prevent soil compaction, light machines (harvester and forwarder / skidder) with chains or low tyre pressure were imposed. In addition, the operators were asked to drive over a bed of branches to further spread

their weight and to use the same route for the returns. The target habitats are not a climax community, therefore management was needed after clear-felling. Semi-natural habitats created through management are more interesting for biodiversity and were targeted by the LIFE Éislek project. To restore open habitats, the branches and stumps can be milled after exportation of the tree trunks. However, milling both branches and stumps creates a thick layer of mulch on the ground. The seedlings require space and light in order to sprout, otherwise seeds that arrive from outside the sites' seedbank are favoured (*Epilobium* spec., *Senecio* spec., *Rubus* spec., ...). In addition, the quick mineralisation of the mulch liberates a nitrogen peak that favours banal nitrophile species. To restore open habitats, three restauration techniques were used after harvesting the spruce. (1) Milling both branches and stumps and then pushing the mulch to the edge of the site (or exporting it). (2) Clearing the sites by piling the branches on swaths. Swaths provide a further ecological service by creating habitats for fungi and xylobiotic species. They were also colonised by micro-

mammals and ants highly appreciated by the European green woodpecker (*Picus viridis*). In theory, stumps can remain on sites that are grazed. However, experience showed that the extensive and late grazing applied lead to a high fodder refusal and upcoming natural succession. Therefore, the second option was systematically followed by milling of the stumps in between swaths. This way, the sites can be managed in a grazing/mowing rotation concerted with all the ecological requirements of the target species (see chapter on recurrent management). (3) On small sites where a lack of space did not allow to keep swaths, the branches were exported from the sites to be used as wood energy, the stumps were milled. In all 3 options, the period between clear-cut and clearing was minimised to accelerate and facilitate the recreation of the target habitat (Dassonville 2001, Granda Alonso & Moes 2012, Goffart et al. 2014).

In the LIFE Éislek project the aim was to restore open wetlands, therefore, the clear-felling was followed by a site-specific management. Extensive grazing (see point 2.2.1) was chosen to be the most appropriate form

Experimental set-up

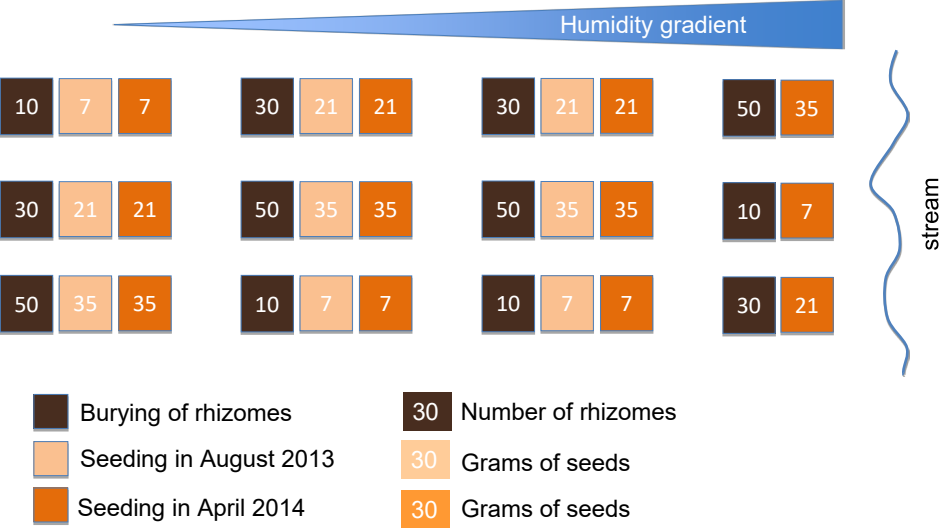


Fig. 4. The experimental set-up was used to determine the best densities and soil humidity for burying rhizomes of the bistort. The same set-up was used for seeding experiments.

of use for most of the restored sites. In the year after the intervention, the sites were usually mown before being put into a grazing scheme. Monitoring of the sites in the years after clearing was essential to follow the development and intervene if necessary.

2.1.4. Restoration of bistort meadows

The propagation of the bistort (*Persicaria bistorta*) was an action specifically for the highly endangered butterfly species *L. helle* and *Boloria eunomia*, that depend on it as a host plant. Through collaboration with the LIFE Papillons project in the Belgian Ardennes, it was known that spontaneous colonisation by the bistort is rare and very slow, probably due to low seed persistence in the soil and little seed dispersal as well as the fact that the seeds are hard-shelled. A method that had been implemented with success in their region was the burying of rhizome pieces. Experiments showed that implementation was best applied in spring when soils were waterlogged. However, their experiences on density of planting and on soil characteristics were limited (Goffart et al. 2014).

An experimental set-up was used in the LIFE Éislek project to analyse the best conditions for the planting of bistort rhizomes. On a recently clear-felled area, the restoration measure was tested for different degrees of humidity and different densities of rhizome pieces (Fig. 4). After 3 weeks, the first leaves were observed; the blossoms appeared after 2 months. This is contrary to experiments in Belgium, where bistort blossomed only in the year after burying of the roots (Goffart et al. 2014). The experiments on optimum planting density indicated that plots with 50 roots per 4m² had proportionally fewer stems, compared to those with 10 or 30 rhizomes. The second aspect that was analysed was the humidity of the soil and success of colonisation. The test areas were distributed on a slope starting close to the stream with highly waterlogged soils, moving up to drier uphill areas. The results showed that intermediate patches had more stems than those saturated with water or those highest on the slope (Fig. 5). Waterlogged patches were not

colonised at all as the rhizomes rotted in the wet ground.

The results from the set-up were used to test rhizome propagation primarily on clear-felled areas, with different management after removal of spruce. The results were positive as the bistort sprouted on the restored sites. However, even though one would think that bistort grows anywhere in wetlands, it showed that the sites had to be chosen carefully and the management adapted accordingly. Before the treatment, soil samples were taken from each site and analysed by ASTA (Administration des services techniques de l'agriculture). In his doctoral thesis, Janssens (2001) analysed soil characteristics for different plant compositions. His results showed that sites with more than 5 mg/100 g free phosphorous always had less than 20 species per 100 m². In the LIFE project, the recolonisation strategy was tested primarily on clear-felled areas, the measured phosphorus levels laid between 4 and 27 mg/100 g on the target sites. At a conference (LIFE+ Workshop Renaturation von Graslandhabitaten, SICONA 2014), experts agreed that 20 mg was a threshold that could be used to determine sites suitable for a restoration measure.

Problems occurred after about 2-3 years due to competition from brambles, willowherb etc. when management was too restrained. To establish bistort permanently, the clear-felled sites had to be mown in the first years to prevent natural succession. Only after the typical flora of open wetlands had established, the parcel could be extensively grazed (see recurrent management). Another drawback on this method was its labour intensity. Therefore, an altered method was tested, where rhizomes were not extracted and buried individually but instead a shovel-sized area was removed in a bistort meadow and the whole patch transferred to the receptor parcel. With this method however, a competition to the bistort was introduced at the same time and reduced the number of roots that could establish.

A whole number of experiments were conducted on seed propagation, a method that would significantly reduce labour intensity. It was first tested on the experimental set-up that was used for the rhizome method

(Fig. 4). The number of stems counted in each of the squares was zero. In Belgium, similar results with low rates of germination were found (Goffart et al. 2014). This coincided with the finding that spontaneous colonisation was rare and indicated that bistort spreads primarily through vegetative propagation. As a consequence, more contacts with experts were taken and lead us to design several set-ups to learn about natural propagation through seeds. These included different sources of seeds, different lengths and temperatures of vernalisation, controlled conditions in the laboratory, varying densities of sowing, different receiver parcels. Even though professional seed producers are able to germinate the bistort seeds, within this project, although many efforts, the results of the different germination tests were not encouraging and this method was not further considered as an alternative within our possibilities. Further studies will be necessary in this domain. Furthermore, a genetic analysis was conducted by the Musée nationale d'histoire naturelle (MNHN) (not published) to learn about the genetic similarity between plants within and between sites that were of varying distances to each other and thus learn about propagation strategies. The details of these experiments are beyond the scope of this article.

A third method for restoration of species-rich meadows was the transfer of grass cuttings. This represented a method frequently used for the restoration of lowland hay meadows (6510) and has been elaborated by other actors (LIFE+ Workshop Renaturierung von Grasslandhabitaten, SICONA 2014). In the LIFE project, the transfer of seeds with the cuttings allowed the reestablishment of a meadow on a land plot that was previously managed as acre. The results were encouraging as most of the typical species had established in the years after the transfer of the cuttings. The bistort, however did not establish with this method and had to be introduced additionally through rhizome transfer.

2.2. Recurrent management methods

After the restoration of abandoned wetlands, whether through reameandration or

removal of spruce, the sites had to be maintained to conserve them in the long term and to suppress natural succession. Management had to be chosen in consideration of the target species for each site and in consideration of feasibility. The habitat of *L. helle* for example has a transitional character and therefore needs to be managed (Goffart et al. 2014). However, as *L. helle* is sensitive to the management methods, a compromise between management and abandonment had to be found. Two main management methods were considered: grazing and mowing, often as a combination of the two.

Historically, the valley bottoms were mown almost exclusively for hay production. Several species profited from mowing (e. g. *P. bistorta*). Nowadays, mowing is often not possible due to the wet soil conditions and mechanisation not adapted to this terrain. Grazing is mostly easier to implement and has an economic use, contrary to late mowing which produces strawy fodder with low energy content. Even though it may cause damages from trampling, it keeps the habitat open and creates a microhabitat-mosaic that can be utilised by a variety of flora and fauna, thus increasing biodiversity (efor-ersa 2012). Mowing can be used as a restoration measure to export nutrients (primarily nitrogen). After initial care, it can be followed by recurrent mowing or grazing. A rotational care with a pluriannual regime leaves unmanaged areas each year (at least 1/3 of the parcel) as refuges for the entomofauna. Both target bird species *L. collurio* and *S. rubetra* require small structures such as fallow strips with Apiaceae species e. g. wild angelica (*Angelica sylvestris*), Valeria (*Valeriana officinalis* L.) and thus also profit from a rotational management (Biver & Collas 2012).

In the scope of the project, the management plan of the parcels belonging to n&e had been reconsidered and adapted. Sensitive parcels were grazed later in the season and very extensively and refuges were left for butterflies and other insects. However, extensive sheep grazing was not sufficient to remove the biomass and the parcels started to mat. Therefore, these parcels will be mown every 5-7 years. In general, at the end

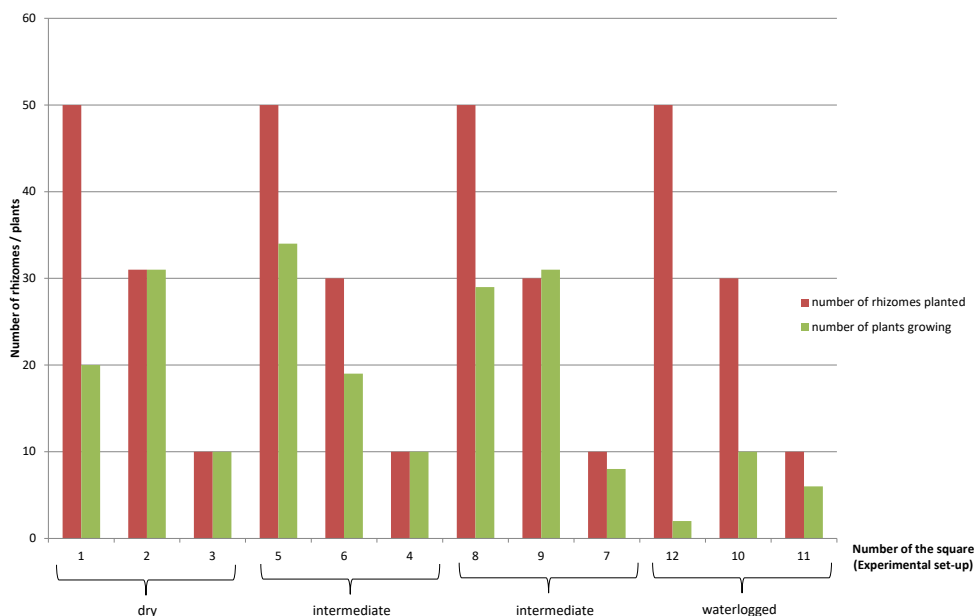


Fig. 5. The results of the set-up for the burying of bistort roots show that the most efficient results can be obtained with 30 roots/4m². The number of plants was highest for intermediate humidity levels.

of the project, the recurrent management of n&ë parcels had been adapted to better suit the requirements of *L. helle* and other butterfly species as well as the bird target species. Furthermore, the management of these wetland habitats is now based on a multianual management plan that was established using findings from the project.

2.2.1. Grazing

In the scope of previous projects of n&ë, a butterfly monitoring was already implemented to control the effects of management on the populations (Caspari 2010, Delsinne et al. 2012, Parkinson et al. 2012). The results showed that the grazing timing, duration and density was often not adapted to the rare butterfly species. The before mentioned authors recommended a restricted number of livestock, no grazing during sensitive times (no winter grazing and no grazing during reproduction) and the creation of refuge zones. Specific to *L. helle*, Gofart et al. (2014) recommend low stocking rates and the avoidance of grazing during the flight period, between April and July.

Lanius collurio also profits from late grazing with low stocking rates (Biver & Collas 2012). The management of the sites targeted by LIFE Éislek was reanalysed and adapted to the specific conditions. Grazing was carried out through lease agreements with an itinerant shepherd, CNDS Natuuraarbechten and local farmers.

The itinerant shepherd managed most of the important habitats of *L. helle*. A herd of 300 mother sheep and their female progeny grazed the sites for 1 to 20 days depending on the size of the sites. The strategy is a short disturbance with a high number of cattle. To improve and adapt management, the collaboration with the itinerant shepherd was intensified during the project. Meetings were held every two weeks to plan the movement of the herd and to discuss difficulties that may have occurred on the previous grazing period. The grazing plan had to be flexible during the season to accommodate unpredictable problems, new sites or adverse weather conditions. It was adapted to accommodate sensitive areas with presence of *L. helle* to be grazed later in summer. "Parking spots" were less sensitive areas where the sheep were kept

for prolonged periods when sensitive areas had to be left unmanaged, e. g. during crucial times of the life cycle of *L. helle*. Besides keeping the sites open, the sheep provided an important service for site restoration as they transported seeds and small animals in their fur, on their claws and in their dung from one site to another (personnel observation). The sites were monitored after grazing to analyse the effects of grazing pressure and duration on the vegetative composition. Monitoring showed that some areas were systematically under grazed. Two sites were intersected by a river that could not easily be crossed by the sheep. In these areas, cattle bridges were installed to optimise sheep mobility on the sites. The same observation was made for sites with high shrub cover. Where a zone was colonised by shrubs, the sheep, as they are flight animals, did not sufficiently graze behind this area, which was consequently also threatened for shrub colonisation. The sheep prefer to stay together in their herd. Shrubs were therefore removed at strategic points to widen up narrow passages between willows and facilitate and increase the mobility of the herd.

CNDS has a herd of Galloway cattle, a species adapted to the humid character of the target habitats. To facilitate the work with the herd and to protect sensitive parcels from trampling, a large land plot was provided for winter on which a shelter was built. The project furthermore financed a transporter to move the cattle from one area to another. Fences were installed on abandoned parcels to allow grazing. On each of the grazed parcels, biodiversity contracts were signed, defining time, duration and density of exploitation. The timing of the grazing is adapted to the various sites with a start date of sensitive sites after the 15th of July or even the 1st of August. The sites are grazed below the 2 livestock units per hectare defined in the contracts.

Monitoring of the grazed areas revealed that extensive grazing in late summer was not sufficient to suppress dominant plant species. Many sites will have to be mown every 5 years to prevent natural succession. Furthermore, livestock selectively grazed on *Polygonum bistorta*. To reduce the pressure

on the host plant of *L. helle* and *B. eunomia*, areas with dominance of *P. bistorta* within the parcel were fenced to bar the access to the livestock. The fenced-out areas were mown or grazed in a multiannual rotation when the dominance of *P. bistorta* was weakened from overgrowing plant species.

The aim of collaborations on private land was mostly not to graze abandoned areas but to reduce the pressure from intensive farming on the land. It was based on the conclusion of biodiversity contracts or through the provision of fences to establish migration corridors along streams. The opportunity for a larger project in collaboration with a farmer came up during the project. Here, LIFE Éislek financed a part of the removal of shrubs and the construction of fences. In return, the farmer adapted grazing to the requirements of *L. helle*: the meadows were divided into 5 lots, allowing to move the Highland cattle in between individual sections with the most sensitive areas being accessed later. Grazing was allowed only after the 1st of August and only on half of the area. In another area, the LIFE project financed the construction of a fence along the *Trëtterbaach* to create a riparian fallow strip as migration corridor. To provide water for the cattle, a solar powered water pump was installed next to the stream.

2.2.2. Mowing

Mowing was used as a restoration measure on nutrient-rich soils with a dominance of plants (e. g. *Filipendula ulmaria*) that suppress the desired wetland vegetation or on clear cuttings with encroachment from thistles, nettles or willowherb (*Epilobium angustifolium*). The removal of nutrients is most successful when the nitrogen content in the above ground part of the plant is highest. This is the case in the beginning of blossom. Therefore, such areas were mown in early summer. Depending on the state of the parcel, it was necessary to repeat this process in consecutive years (see also Goffart et al. 2014).

As a recurrent management, the frequency and timing of mowing depended on the species that were present on the site. Most wetland plants prefer mowing in late June/ July,

which was the traditional time for the first cut (Dassonville 2001, Goffart et al. 2014). For the entomofauna, the ideal timing for mowing was after pupation (late August for *L. helle* when the pupae had fallen into the upper litter layer). A particular attention had to be given to zones with high cover of *Deschampsia cespitosa* surrounded by *P. bistorta*. The tufts formed by the Tufted Hairgrass play a major role in thermoregulation of larval stages of *Boloria eunomia*. Mowing destroys these microstructures and thus is highly lethal for populations of this species. Mowing can also act as ecological trap as *P. bistorta* benefits from mowing. After the cut *P. bistorta* provides a thick cover and is very attractive for egg laying. If mowing is repeated the following year, however, the larval stages of *L. helle* and *B. eunomia* are lost. The ground breeding *S. rubetra* cannot raise its brood successfully if mowing is too early. Even though it has vanished as a breeding bird in Luxembourg, it passes through for migration. With all the management efforts that have been implemented for the species to promote a favourable condition of its stop-overs, it may stay for breeding.

The project partner CNDS Naturaarbechten has a very long experience in mowing of wetlands. They manage the land with a lot of knowledge and a specially adapted tractor with double wheels or with brushcutters where necessary. However, the manpower and material of CNDS were charged to maximum capacity. Their requirements were considered in the application of the LIFE Eïslek project. Broken material was repaired and two new mowing machines and brushcutters were purchased. To disburden the CNDS and increase the number of hectares mown, a converted Pistenbully with low ground pressure was hired to mow fallows on a multiannual rotation to suppress the vegetation cover that accumulated because of very extensive and late grazing and upcoming shrubs. The cuttings were immediately transferred into a tipper on the back of the vehicle, allowing the complete removal of the biomass from the site. This in turn reduced nutrient input. Thus, only one vehicle was needed for cutting, lifting and transportation of the material, which greatly reduced disturbance of these sensi-

tive habitats. The adapted Pistenbully with its low ground pressure was ideal to work in wetlands but was only effective on large sites and was an expensive management tool.

Mowing on some parcels was hindered as a result of difficult accessibility. Some parcels could only be mown after prolonged dry spells. Therefore, the LIFE project decided to finance the restoration of access routes to several parcels. Adapted management is the key factor to the long-term success of nature conservation. The implementation of the management plans often depended on the accessibility of the sites.

Ideally, sites were managed with a combination of both mowing and grazing. Mowing on its own may lead to uniform sites, with the same height of vegetation and missing structures such as tufts which in turn poses a problem for some specialised species like *B. eunomia*. Butterflies and other insects clearly benefit from a mosaic of different structures, which tend to be a result of extensive grazing as explained in chapter 2.2.1. As a consequence, mowing should be multiannual and limited to maximum a third of the entire surface, always making sure sufficient refuges, such as grass verges or riparian strips, are left aside (Caspari 2010).

The disposal of the resulting biomass was a major difficulty throughout the project. Being cut very late in the season (after 1.08), the standard acceptors from biogas plants refused the material insisting that the material was of very low energy content, and thus, of little interest for them. This could unfortunately not be refuted as we did not dispose of fodder analysis. In the same way traditional composting plants refused the biomass because due to the coarse nature of the material, it tends to clog up their rotational machines they use to turn the compost. The solution was a collaboration with local farmers that wanted to improve the humus content of their soil. They accepted the material without asking any financial compensation. The cuttings were composted together with manure and then incorporated into the fields. This solution avoids long distance transports and is a good way to consider the biomass not as a waste product but as a resource.

3. Monitoring

Monitoring is an important part of each nature conservation project as it allows to recognise and analyse the effects of different methods on different species. Each site is different with a different management history, species composition and abiotic factors such as microclimate and soil composition. Therefore, management needs to be adapted to each site and monitored to assure the development and preservation of a certain biotope or species. Monitoring in the LIFE Éislek project was twofold, monitoring of the sites and management methods and monitoring of the target species as measurement of restoration success.

3.1. Monitoring of restoration measures

The sites of action in the LIFE Éislek project were regularly visited and the restoration methods analysed. The project did not allow a standardised monitoring of all the measures, but a more pragmatic approach with visual analysis and drawing on experiences allowed to evaluate management. The results from the monitoring were used to improve the methods in the following years. The experiences on conservation measures (chapter 2) are the result of monitoring and adaptation, therefore the chapter already contains part of the monitoring efforts.

For the restoration of abandoned grasslands, the regrowth of shrubs was noted for each management method. As the use of chainsaws did not prevent regrowth, the development of succession needed to be closely monitored and the shrubs recut in June at least the 2 following years after the measure according to the results. Regrowth on sites that were milled depended on the depth of milling. Willow roots had to be milled to a depth of 30 cm below ground to prevent regrowth. On these sites, mowing was sufficient as an after-care. The impact of milling with the Pistenbully seemed significant immediately after passing. However, the presence of rare species such as *L. helle*, *L. collurio*, *Vanellus vanellus*, *Comarum palustre*, *Menyanthes trifoliata* in the year immediately following treatment indicated that the supposed negative impact of the restora-

tion measure was negligible, or rather beneficial to biodiversity as some species require disturbance events and/or access to high insolation. The removal of rootstocks with cable winch does not require after-care and the monitoring team observed that the temporary ponds that were created were used as a breeding site by waders.

Stream and River Consult recorded the situation before the remeandering of the Trëtterbaach regarding higher plants (terrestrial on the brooks and water plants of the riverbed), macroinvertebrates (IBGN), fishes (BIP), sediments (Wolman) and ornithology. Additionally, n&ë analysed water quality. Monitoring will be repeated 5 years after restoration (2021). The observations in the two winters after restoration showed that the stream was able to leave its bed at high waters and the water was retained in the floodplain. This was not the case before the intervention. Regarding the deflectors, after 4 flooding events, erosion of the old meander was clearly visible around the one remaining deflector (Fig. 6).

Regarding the development of clear-felled sites, the results from previous projects were available (Spithoven 2012, Granda Alonso & Moes 2012). After 6 years, wetland and mesophile grasslands had largely established and replaced the typical plant communities of clear-cuts. However, some characteristic plant species of permanent grasslands, especially *P. bistorta*, were missing and *Epilobion angustifolii*- and *Calthion palustris*-basal communities formed. Studies showed that the seed banks were depleted after 30-40 years of spruce.

3.2. Monitoring of species

The scientific monitoring of all three target species started in 2013 and had been carried out on a yearly basis throughout the entire project area. The results contributed to the national monitoring schemes and provided valuable information on the population statuses, both nationally and in the north of Luxembourg.

As not much recent data was available on the distribution of *Lycaena helle* in Luxembourg (Fig. 7), the monitoring initially



Fig. 6. The spruce plantation at *Breitwies* (Win-crang) was harvested and the branches exported, some of the harvested stems were installed in the river bank as deflectors, a fence was built on the periphery to allow grazing by Galloways.

(2013-15) focussed on a qualitative study in order to determine the extent of the species' distribution and verify previously known sites within the project area. As a result, numerous new populations of *L. helle* were discovered, which led to the extension of several Natura 2000 zones. With the main distribution established, monitoring efforts switched to a quantitative study with transect walks from 2016 onwards. This will allow to determine the successfulness of the project actions and monitor population trends of *L. helle* in the long term. Due to the relatively short sampling time of the quantitative monitoring effort, it is not possible to provide any meaningful results at this point.

The populations of the Whinchat *Saxicola rubetra* were known to be steeply declining and its population status in the area was uncertain but probably extinct (as a breeding bird) at the start of the project as indicated by extracts from the database of the COL. Despite considerable monitoring efforts in the project area (2013-2017) and nationally (2013), as well as considerable habitat restoration efforts, no breeding pairs were found or had established since then. The results of the monitoring, however, showed that the wetlands in the north of Luxembourg continue to be of considerable importance for the species as a stopover site during migration. Especially the habitats that have been restored as part of the LIFE Éislek project were among the most important and thus frequently used sites during both spring and autumn migration.

Monitoring of the Red-backed Shrike *Lanius collurio* clearly showed, that the project area continued to be one of the major strongholds of the species on a national level. Despite considerable environmental changes (weather, food availability, etc.), the local population remained relatively stable throughout the entire project period, especially when compared with other areas in Luxembourg. The results of the monitoring, however also very clearly showed, that most territories of *L. collurio* were restricted to the river valleys, wetlands, and other extensively used areas, often on land which is owned by n&ë. Surrounding areas, where intensive agriculture is predominant, tended to be devoid of *L. collurio* and are much poorer in terms of species and habitat diversity, overall. On several occasions, habitat restoration efforts carried out as part of LIFE Éislek, were rewarded almost immediately with the colonisation by a new breeding pair of *L. collurio* (e. g. *Rittefenn*, *Cornelysmillen*, etc).

4. Conclusion and outlook

The results of the LIFE Éislek project were presented and discussed at the final colloquium in June 2017. Here the different subjects of the project were presented by the project coordinators and put into context by international experts. The importance of connectivity between biotopes was highlighted as well as bird species protection and butterfly monitoring. The inclusion of farmers and solidarity economy in nature protection were other important factors in the pro-

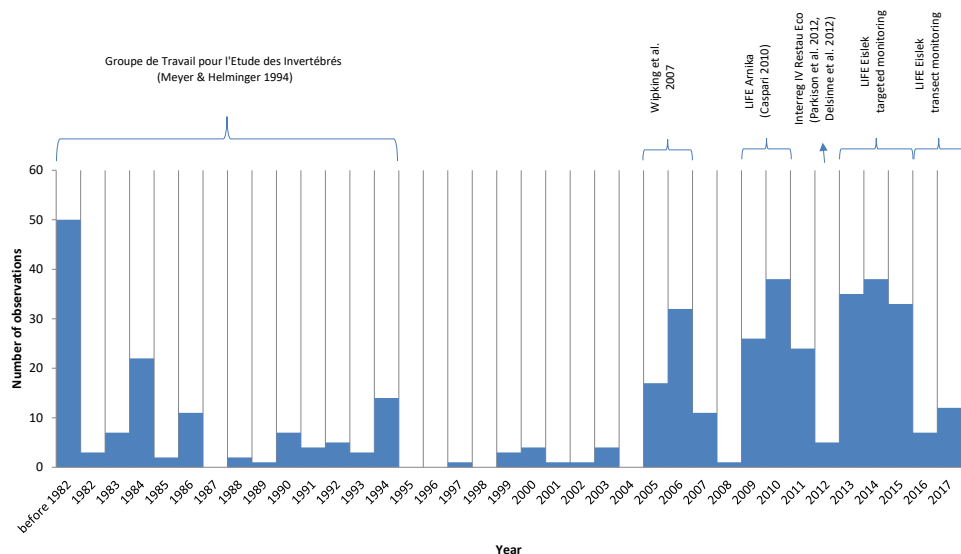


Fig. 7. Number of observations of *Lycaena helle* over time as recorded in the databank of the MNHNL and the contribution of different projects on the knowledge of distribution.

ject and at the colloquium. Ecosystem service analysis and remeandration of the Trëtterbaach were presented by the respective implementing organisations (Luxembourg Institute of Science and Technology (LIST) & Stream and River Consult). The presentations are online at www.life-Eiselek.eu.

The first phase of the LIFE project was the literature research on the species but also on experiences of management techniques. Contacts were made and a networking community set up. That way, it was possible to use information from other similar projects across the border (esp. Germany (Eifel) and Belgium (Ardennes)), to apply best practice management and adapt it to the particular situation of the targeted sites. The project was based on available scientific knowledge and tried to fill gaps where possible. However, LIFE does not finance scientific research, so often filling the gaps was not possible in the scope of this project. Through the help from other institutions (MNHN: bistort, LIST: ecosystem services) however, the work undertaken in the LIFE Éiselek project was strongly supported and ameliorated. The success of each of the described restoration measures depended on a thorough preparation. Contractors with good knowledge of

the required tasks at hand as well as a daily supervision go a long way in preventing bad surprises. Some contractors are not used to nature conservation projects and might not understand the specifics of the task. The presence on-site each day is therefore mandatory.

One of the distinctive features of the LIFE Éiselek project was the synchrony between nature conservation and social engagement. The inclusion of CNDS Naturaarbechten as a project partner highlighted a mutual need between natur&ëmwelt and CNDS to achieve the desired results. During the LIFE Éiselek project 17 people were occupied and 2 foremen financed. natur&ëmwelt relies on CNDS for manual work on sites where very specific measures are required to achieve the management goals of nature conservation. For CNDS Naturaarbechten, the management of nature reserves provides an opportunity for disadvantaged people to learn skills and provide stability in their lives.

Nature conservation costs money. The advantages of a good collaboration between different stakeholders, such as social structures, itinerant shepherds, local farmers and nature conservation organisations are obvious and allow all sides to benefit. Similarly,

in order to keep local farmers involved in the project, good communication skills and mutual respect are required.

Given the small scale and isolated nature of many nature reserves or sites of high conservation value in Luxembourg, conflicts between different species and conservation goals (*L. helle* vs. *Betula pubescens* and *L. helle* vs. *B. eunomia*, recently *L. helle* vs. *Castor fiber*) will always be a problem. Often these species have directly conflicting needs that are complicated to get compatible and most sites are small making accommodation for all of the species difficult. In these situations, conservationists will continue to have the ungrateful task of making difficult decisions in favour of one or another species or habitat. While these choices may seem straightforward at first glance, they should not be taken light-heartedly. While a species, such as the whinchat may be lost permanently as a breeding bird in Luxembourg, the restoration of suitable stop-over sites during migration may help boosting their breeding populations in nearby Belgium or reduce migration-related mortality overall. While focussing on the tiny specks of land that most of the Luxembourgish nature reserves are, it is vital not to forget the bigger picture and put habitats into the larger context by acknowledging their importance for the overall biotope network. Only once we achieve this, our efforts are truly contributing to nature conservation in the long term.

The full development of the restored sites takes time and depends on the initial situation and the type of restoration. Especially the impact of the different measures on the target species cannot be measured in such a short time span. Monitoring of the two bird species is in a 6 year rotation and will continue to be carried out through the COL. The quantitative monitoring through standardised transects of butterfly species on the Éislek wetlands only started in the last two years of the project after the distribution of *L. helle* had been analysed. At least 5 more years will be necessary before any conclusions can be drawn on the trend of the species (Clemens 2015). The monitoring and continuation of the efforts is assured for the next five years through an After-LIFE pro-

ject, financed by the Fonds pour la Protection de l'Environnement. In this follow-up project, the information gathered in the LIFE project will be further implemented and the development of the LIFE Éislek sites monitored. With prolonged efforts in monitoring of the effects of the restoration measures on the species, they can further be ameliorated and adapted according to the results. The project also tests new techniques, for example the optimisation of alder plantations in wet stations for *L. helle* and *B. eunomia* through the removal of trees and creation of clearings where *P. bistorta* can establish (see also LIFE Patches and Corridors).

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