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Running head: Restoration in France

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Abstract

Ecological restoration has developed greatly over recent decades. Promoting harmonious relationships between scientists and practitioners, between restoration ecology and ecological restoration, is essential to improving restoration projects. These relationships are difficult to achieve at a global scale, although international action remains essential. Therefore, regional and national networks are attempting to take up the challenge. With several European countries planning to create their own network in the coming years, insights from current practice are

helpful. Here, we 1) describe the context in which ecological restoration is developing in France and 2) present the French Restoration Network REVER. Most public policies related to restoration in France are derived from EU directives, such as those on Water, Ecological Networks, Biodiversity and Protected species and natural habitat. Restoration can also be undertaken through EIA (Environmental Impact Assessment) or subsequent to damage. Following the model of the International Society for Ecological Restoration, the French network for ecological restoration (REVER) aims at accompanying and promoting restoration by facilitating relationships between the various stakeholders: practitioners, scientists, site managers, etc.. To encourage exchange of knowledge and experience, REVER manages a website, organizes workshops, and provides links with SER-Europe and SERI. This article provides information that will be of interest to other countries trying to meet the Aichi targets of the Convention on Biological Diversity: the restoration of 15% of degraded ecosystems by 2020.

Keywords: applied science, horizontal communication, knowledge sharing, mitigation hierarchy, compensate or offset impacts on biodiversity

Conceptual Implications
- Implementing EU Directives linked with the environment has helped promote ecological restoration in France, and should do so in other EU countries;
- National policies on Environmental Impact Studies and Environmental liability further promote ecological restoration *sensu lato* before and after damage;
- Agro-environmental schemes, and local initiatives carried by public institutions or site managers significantly contribute to the implementation of restoration;
- Annual workshops have been REVER's most valuable tool to improve communication between restoration stakeholders and to initiate collaboration and exchange.

Introduction

It has taken only a few decades for ecological restoration to become an essential part of the response to various environmental issues, such as habitat and biodiversity conservation, ecosystem service rehabilitation or sustainable development of human societies (Roberts et al. 2009; Aronson & Alexander 2013). Improvements to restoration quality and technical feasibility are still needed, however, and substantial efforts will have to be made over the coming years to fund and implement large-scale ecological restoration (Aronson & Alexander 2013; Cortina-Segarra et al. 2016). Better communication between the various restoration stakeholders, and particularly between scientists and practitioners, should help. Cabin et al. (2010) reported that only 26% of stakeholders surveyed at the 2009 SERI conference (Society for Ecological Restoration International) considered their scientist-practitioner relationships "generally mutually beneficial and supportive of each other". One of the issues most commonly cited for the improvement of restoration science and practice was the science–practice gap.

One of the main objectives of SERI, created in 1989, is to promote harmonious relationships between scientists and practitioners, between restoration ecology (i.e. the scientific process of developing theory to guide restoration) and ecological restoration (i.e. the practice of restoring degraded ecological systems) (Clewell 1993). Since it is particularly difficult to reach this objective at a global scale, regional chapters and national networks are developing to take up the challenge. Two networks were recently created, SIACRE - *Sociedad Ibero-Americana y del Caribe para la Restauración Ecológica* - in Latin America in 2013 (Echeverría et al. 2015; Zuleta et al. 2015) and REVER - *Réseau d'Echanges et de Valorisation en Ecologie de la Restauration* - in France in 2008.

This article 1) describes the context in which restoration is developing in France and 2) presents the French Restoration Network REVER and 3) concludes on how national networks are helping to improve restoration.

Background to ecological restoration in France

The first documented "restoration" in France dates back to the 1860s, when the Department of Mountain Land Restoration - *RTM: Restauration des Terrains de Montagne* - carried out large-scale tree planting to combat heavy soil erosion. However, these actions do not meet the current definition of restoration (Society for Ecological Restoration International Science & Policy Working Group 2004), as some exotic species were used, such as Austrian black pine *Pinus nigra* subsp. *nigra*. Follow-ups 120 years later however showed that the pine could serve as a nurse species enabling native species to establish if appropriate silvicultural practices, such as thinning, were used (Vallauri et al. 2002). With related objectives, between the 1940-1980, soil defense and restoration – *DRS: Défense et Restauration des Sols* – were developed by foresters around the Mediterranean Basin to face up to droughts, reservoir silting, soil erosion and degradation (Roose 2004). Much later (1970), the restoration of open ecosystems, such as grasslands, wetlands, marshes, etc. started mainly by reintroducing extensive grazing with rustic breeds and continued on in the 1990's with seeding or other techniques aimed at reducing agricultural intensification (fertilization, early cutting, etc.) (Muller et al. 1998). Starting in the mid-1980s, coastal environments have also been the focus of many restoration projects. Between 1984 and 2007, 35 projects were carried out to restore Atlantic coast cliffs following years of excessive visitation (Bioret & Gallet 2015).

A century after the first mountain land restoration, the French law on Nature Conservation (1976) provided for Environmental Impact Assessment (EIA) prior to land-use planning actions potentially affecting the quality of the human environment (Table 1). The law provided for a 3-step mitigation hierarchy procedure: avoid, reduce and offset (i.e. ecological measures implemented outside the impacted site to compensate for residual losses). However, it did not meet expectations on ecological restoration, partly because the mitigation procedure was not enforced before 2012 (Lucas 2009).

Other incentives also contributed to the development of restoration in France, particularly the promotion of research supported by the French Department of the Environment, the CNRS & Irstea research centers, etc. (Fig. 1; Appendix S1; Gallet et al. 2017). In 2008, a research program funded the creation of the French-language restoration network REVER (*Réseau d'Echanges et de Valorisation en Ecologie de la Restauration,* Appendix S1). REVER became a French non-profit organization in 2011, its objectives inspired by SERI. Its main aim is to organize and promote relationships between land managers, practitioners, students and researchers working in ecological restoration and/or restoration ecology. As recently recommended by Meli et al. (2017), REVER is based on a nonhierarchical knowledge spreading. 2008 also saw the first attempt to create mitigation banking out of a restoration project in France: the restoration of a Mediterranean dry grassland, La Crau area, in southeastern France (Dutoit et al. 2015). Inspired by the U.S. wetland mitigation bank, it aimed at anticipating restoration by creating compensatory mitigation credits ahead and independently of land-use planning actions. Mitigation banking opened new perspectives for restoration in France, as did the release in 2007 of the order related to the Environmental Code protected species section. This updated the EIA 3-step mitigation hierarchy procedure, which until then had scarcely been implemented. On January 1st 2017, a new public institution, *Agence Française pour la Biodiversité* (French Agency for Biodiversity) was created, principally to contribute to the protection, management and restoration of biodiversity in terrestrial, aquatic and marine environments.

The driving forces behind the development of restoration in France
In France, the increase in the number of protected areas over the second half of the 20th century, and the creation of protected species lists in 1979, reduced pressures on certain species and ecosystems. Yet, it is now clear that, in France and in Europe, this must be accompanied by measures to increase habitat areas, to restore ecological functions or to recreate ecological networks (Mose, 2007). Restoration, an essential partner to conservation, has grown substantially since the turn of the 21st century due to the evolution of conservation practices, input from research, social demand and the evolution of the EU and French regulatory framework (Fig. 1; Appendices S1; S2; Gallet et al. 2017).

At the European scale, several EU directives encourage restoration activities (EU directives set out results that all EU Member States must achieve, with national authorities then choosing the forms and methods of intervention). Directives are then translated into national laws that should reflect common policy (Table 1). Some prescribe restoration objectives, some aim at anticipating future impacts and the need for restoration and offsets, while others provide for restoration following structural or accidental damage due to human activities.

European and national policies anticipating impacts
The first policy connected with restoration is the Environmental Impact Assessment (EIA) (Table 1). EIA requires entities implementing land-use planning actions subject to administrative permits to avoid environmental impacts, and when impossible, to reduce, restore and offset the residual impacts through compensatory measures; these three steps (avoid, reduce, offset) are called the hierarchical mitigation procedure. As mentioned previously, this procedure was included in the French 1976 Nature Conservation law, and later within European directive 85/337 in 1985. Despite the fact that the "No Net Loss" notion was introduced in US laws in 1987, and applied in other European countries in the 1990s (Rundcrantz & Skärbäck 2003), guidelines, as well as the implementing decree, were released in France only in 2012 (MEDDE 2012). EIA also concerns projects which are likely to have a significant impact on any kind of habitats within a Natura 2000 site or on a protected species or habitat inside or outside a Natura 2000 site (Table 1). The 1992 Habitats directive also provides a means of derogating from the prohibition on destruction of protected species habitats, through effective compensatory measures (Table 1; Regnery et al. 2013). The July 2016 law on Biodiversity, Nature and Landscape Recovery (*loi pour la reconquête de la biodiversité, de la nature et des paysages*) could also encourage ecological restoration, notably by setting performance obligations and by creating the French Agency for Biodiversity.

European and national policies with restoration objectives
In addition to EIA policies, many legislative texts set ecological goals (Table 1), a key example being the above-mentioned Habitats directive. This European directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species, inciting EU Member States to "maintain or restore, at favorable conservation status, natural habitats and species of wild fauna and flora of Community interest" (article 2). This means resorting to ecological restoration when the conservation status of a species or a habitat is not favorable, particularly within Natura 2000 sites (Table 1).
Adopted in 2000, the Water Framework directive 2000/60/EC also underpins European regulations favoring restoration. This directive does not directly concern natural habitats, but sets mandatory targets in terms of water quality that cannot be achieved without restoring watersheds and wetlands and their associated ecosystem services. French legislation adopts the principles of this directive in the 2006 law on Water and Aquatic Ecosystems, which stipulates

that ecological restoration is to be used, funded by the six Water Agencies located throughout France, to meet EU targets (Table 1; Appendix S2). Recently, the French environmental summit (*Grenelle de l'environnement*) incited the development of ecological networks in land-use planning (Table 1). Thus, whether by establishing networks or by recreating damaged corridors, ecological restoration is used to increase or improve ecological continuities.

More recently, in May 2011, the E.U. adopted the 2020 Biodiversity Strategy which aims to halt the loss of biodiversity and improve the state of Europe's species, habitats, ecosystems and the services they provide, by 2020. Among other goals, it implements the i) 1992 Habitats directive 92/43/EEC; and ii) Oct. 2010 Aichi Biodiversity Targets, whereby Europe committed to restoring at least 15% of degraded ecosystems by 2020. All member states were to deliver a sound national restoration prioritization framework by the end of 2014, which none did (Cortina-Segarra et al. 2016) contrary to other countries of the world, such as Colombia, Ecuador and Guatemala (Meli et al. 2017).

European and national policies following damage

Finally, some policies seek to restore degraded ecosystems following legal activities or accidental damage (Table 1). For example, the 1977 Act on Facilities Classified for Environmental Protection was designed to ensure public safety and aesthetically improve and stabilize the terrain following mining. This increased restoration opportunities, especially for quarries and mines. The 2004 European directive on Environmental Liability (transposed into French law in 2008) introduced the notion of reparation for environmental damage (i.e. damage to protected species and natural habitats, damage to water and damage to soil). It is the first attempt in France to repair accidental ecological damage, and favors concrete restoration measures, under the auspices of the public authorities. While the scope of application appears limited and no restoration has yet taken place in this context, the French Department of the Environment is now working on a national method of biophysical assessment of less severe damage.

While not exhaustive, the above list of legislative texts highlights key EU and French environmental laws promoting the use of restoration.

Other incentives and policies

In addition to legally enforceable regulations, other measures also support the development of restoration. One example is the "no net loss of biodiversity" objective included in the July 2016 law on Biodiversity, Nature and Landscape Recovery & the Environmental Code, which incites public and private stakeholders to implement restoration actions. The French National Strategy for Biodiversity 2011-2020 also prioritizes the restoration of natural habitats and of ecological continuities (FDE 2017, Appendix S1).

Various incentives led by the French Department of the Environment, such as *Opération Grands Sites*, target restoration on Heritage Sites or natural sites of major importance, within a concerted framework (Pára 2013). Agro-environmental schemes, implemented within the framework of EU Common Agricultural Policy, also favor ecological restoration of natural habitats (EC 2013). Both the Coastal Conservancy (which protects coastal areas through land acquisition and adequate site management) and the departmental council (under their sensitive natural areas policy) can also initiate restoration actions on their sites (CL 2015; DdF 2015). Restoration can thus be required by law or promoted by incentives. Moreover, local voluntary actions implemented at more or less large scale (notably in nature reserves) by local or regional authorities or NGOs should not be underestimated.

Barriers to ecological restoration

Although the French and European contexts appear to favor ecological restoration, various barriers need to be recognized. The implementation of restoration may encounter barriers linked to local factors, such as 1) laws and administrative procedure or 2) the socio-economic context, particularly local practices and local stakeholders' perception of the site's state of conservation.

Legal and administrative barriers

Environmental laws can paradoxically complicate or even prevent the implementation of ecological restoration. Some restoration projects may even be considered as potentially damaging to the environment and to protected (although degraded) habitats and areas. In such cases, complex administrative procedures have to be initiated before any action can be taken. Wetland restoration is a particular problem, as any intervention on river beds, modification of hydrological regimes or creation of ponds requires administrative authorization under the Water and Aquatic Ecosystems law. Similarly, any action planned on Heritage Sites (*sites classés, sites inscrits au titre de la loi de 1930 sur les paysages*) has to be declared by the project planner and is subject to ministerial authorization.

Moreover, sites considered for restoration may contain populations of protected animal or plant species that could be impacted by restoration, thus requiring EIA or special procedures for the manipulation, transfer or destruction of protected species (Table 1). It has to be proved that, despite a potential temporary negative impact, the final state will be more favorable to the species involved. Similarly, before a protected species can be reintroduced, the French Nature Conservation Council needs to be consulted and a derogation obtained for its manipulation and transportation. These procedures are cumulative, and although a favorable outcome is often reached, the process can be discouraging.

Stronger legal barriers can durably impede restoration actions. For example, various ecosystem types, such as sand dunes, heathlands, etc., which underwent tree planting in the 1960s-70s can be considered degraded and in need of restoration. Legally however, they are considered as forested and thus subject to forest governance. Since restoration of open ecosystems and shrublands is regarded as deforestation, another permit is required. This also illustrates how the current designation of land devoted to tree planting as compensatory afforestation (Forest Code article L341-6) has to be considered very carefully. Similar cases are reported in other European countries: e.g. Bottin et al. (2005) showed that, in Belgium, restoration of calcareous grasslands were pine trees were planted is in conflict i) with restoration to beech woodlands as natural beech regeneration can be observed in the pine understory, and Natural Beech Forests are an EU protected habitat (Natura 2000 code: 9150), and ii) with a bird species of EU interest, the Black Woodpecker (*Dryocopus martius*) which forages in these pine woods. Manning et al. (2006) also show that Human memory fades in time and provide a "shifting baseline" for restoration.

Soils also present complications. French and European regulations do not consider soils as an ecosystem component, which reduces the scope for restoration (Bispo et al. 2016; Desrousseaux et al. 2016). Where polluted soils are being rehabilitated, it is usually only to ensure public health or security (see Table 1 for details). While the French law is in accordance with the European legislation, and most Member States set equivalent obligations, new approaches should be developed to better take into account soils, important element of biodiversity (Desrousseaux et al. 2016; Heckenroth et al. 2016). Germany and Belgium do benefit from a more detailed and "soil-based" legal framework (Desrousseaux et al. 2016).

Social barriers

The success of ecological restoration also depends on social acceptance of the project locally (Meli et al. 2017). There can be local opposition to projects that do not take account of local practices, where ecological gains are not perceived by local stakeholders or where the project is perceived as too radical or difficult to visualize (Manning et al. 2006; Menozzi & Pellegrini 2012). Take the above case of afforested grasslands, of which the artificiality is generally not recognized and which are considered part of the natural landscape. Restoration through deforestation can therefore provoke strong local opposition. Strong opposition generally appears where ecological restoration implies restriction (e.g. foot traffic control) or prohibition of access or a ban on certain local practices, unless dialogue is previously established with stakeholders to reconcile restoration objectives with local practices. Destruction of dams and weirs that entail major landscape changes and destroy connected fishing ponds is another example of a restoration project requiring extensive local dialogue well ahead of realization (Germaine & Lespez 2014).

Finally, economic considerations, like budget cuts, are sometimes insurmountable barriers for restoration projects, often requiring adaptations or reductions in scope (Manning et al. 2006). Public acceptance is contingent on recognizing differences between stakeholders, in language and in restoration goals. Both local dialogue during restoration planning and solid technical and scientific arguments appear essential to project success. Two of the aims of the REVER network are to i) promote nonhierarchical knowledge sharing and ii) make allowance for the specific expectations and needs of all stakeholders.

REVER: the French restoration network

REVER was created in 2008, after several years of brainstorming among French-speaking researchers and practitioners at SER-Europe conferences highlighted a need to strengthen relationships. As a rising and evolving discipline, restoration requires efficient channels of communication between stakeholders, to share fundamental knowledge, experience and concrete field issues. However, most French practitioners, land managers and policy makers do not have access to scientific literature, do not participate in SER conferences or do not speak English, all of which limits their access to information (Amano et al. 2016).

REVER's main aim is to organize and promote relationships between the various French-speaking restoration stakeholders. Meli et al. (2017) highlight that to face up to the stakes of ecological restoration in a context of global change, there is a need to improve communication between stakeholders who should be gathered in a community. REVER mainly achieve this aim by organizing annual workshops. Using shared definitions, stakeholders can discuss the evolution of the field and conduct joint actions (Prola et al. 2015). Researchers have somewhere to test ecological theories against on-the-ground reality, to find sources of information and new field work opportunities, to develop new investigations addressing land managers' and practitioners' issues, and to present the results of their research. Land managers and practitioners can exploit their empirical knowledge, talk about and compare restoration methods, promote best practices, meet researchers interested in further exploring aspects of their methods (Prola et al. 2015). Communications within the REVER network are intended to be horizontal (as opposed to *top/down* or *bottom/up*) (Meli et al. 2017), to avoid exclusively promoting certain types of knowledge. This is partly guaranteed by the board's composition and is reflected in both membership and participation in REVER workshops (Appendix S3). The average number of members is 60 members with 25% researchers, 29% practioners and 46% students (Table 2), which is quite different from the average number and proportions of participants at REVER workshops (144 participants / year with 25% researchers, 47% practitioners and 28% students; Appendix S3).

REVER uses several tools to provide access to basic information at any time and to increase the visibility of the network and of restoration: a website (REVER 2011), social media accounts, a biannual newsletter, partnerships, an emailing list (408 subscribers), and annual workshops (Appendix S3). While all these tools are complementary, annual workshops have been REVER's most valuable tool to improve communication, and to initiate collaboration and exchange (voluntary entries in the database are rare; Appendix S2). While maintaining all these activities in the future, REVER will also develop closer links with SER-Europe and its affiliated structure and subchapters.

Conclusion

Recently, different regional networks linked to ecological restoration were created. Each of them was designed to meet its local context and is the outcome of different construction processes. For example, in Latin American and the Caribbean (LAC), national networks were created first. Thus, when SIACRE was created in 2013 (Echeverría et al. 2015; Isernhagen et al. 2017), one of its aims was to increase capacity building, education, and outreach that will strengthen pre-existing networks. Because many LAC countries share a common language (Spanish), SIACRE allows easy exchange of experiences from countries with various restoration policies. In Europe, the situation is quite different. Indeed, SER-Europe was created before the national networks (Table 3). Exchanging experiences at the European level completely makes sense as European countries share a common legal framework. However, it is clear that national networks are also needed notably because of the language barrier, especially in the world of practitioners (EU has 24 official languages). Five already created national networks have signed a memorandum of understanding with SER-Europe: France's REVER in 2014, and since then Italy, Finland, Spain and the Netherlands (Table 3). In the coming years, several European countries (Germany, Hungary, the Czech Republic, Portugal) plan to create their own network (or SER-Europe subchapter) in order to communicate better at national level, in their own language, and to network on national advances with SER-Europe and other European countries.

France and REVER are just one example of how restoration can be developed and such networks implemented. More restoration networks should communicate on how they were set up and operate, providing useful input for other countries. Although each country has its own restoration history, EU directives mean that all European countries are likely to see their restoration practices converge. Sharing approaches will help everyone meet common targets.

Acknowledgements

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Table 1. Summary of legal tools promoting ecological restoration in France. [1] Many texts in the table have been amended since publication. [2] EIA is a decision-making tool that describes the environmental effects of the land-use planning actions. [3] the hierarchical mitigation procedure is a 3-step procedure (avoid, reduce, offset) which when it is impossible to avoid environmental impacts, permits to reduce, and restore and offset the residual impacts through compensatory measures

	Regulation fields	Regulation text (year[1])		Competent Authority	Links with restoration	Details
		European or international	French law			
Restoration implemented when a project is expected to have environmental impacts [2]	Environmental Impact Assessment (EIA)	directive 1985/337	1976, 2016	Administrative authorities	EIA decrees the hierarchical mitigation procedure [3]	
	Facilities Classified for Environmental Protection (EIA)		1976	Administrative authorities		
	Aquatic impacts (EIA)		1992	Administrative authorities		
	Protected habitat (EIA)	directive 1992/43	2001, 2007	Administrative authorities	EIA exception for protected habitats: the offset of residual impacts is one of the three conditions to obtain derogation from the prohibition on destruction of protected species habitats (other conditions: absence of alternative solutions, imperative reasons of overriding public interest)	French ministerial decree of February 19th 2007

Public Policy on restoration	Protected species and natural habitats	directive 1992/43	2001	Management committees of Natura 2000 sites	Natura 2000 sites must be maintained or restored to favorable conservation status (management plans)
	Water	directive 2000/60	2006	Water agencies, national authority	Good water quality cannot be achieved without restoring watersheds and wetlands
	Ecological network	Paneuropean Ecological Network, 2010	2009	Local authority	The 2009 Grenelle 1 law, article 23 sets out the following government goals, to halt the loss of wild and domestic biodiversity and to restore and maintain their evolutionary capacities: i) setting up, by 2012, a green and blue infrastructure network (action plan for ecological continuities - *plan d'actions pour la restauration de la continuité écologique* -) funded by Water Agencies; ii) implementing measures for protection, for natural habitat and species restoration and for offsets due to environmental damage.
	Biodiversity	Aichi objectives 2010	2016	National authority	Restoring at least 15% of degraded ecosystems by 2020 (thereby contributing to climate change mitigation and adaptation and to combating desertification, as well as including green infrastructures in land-use planning)

Restoration following environmental damage	Facilities Classified for Environmental Protection (damage expected at the end of the exploitation)	directive 96/61	1976	Administrative authorities	Increased restoration opportunities, especially for quarries and mines
	Biodiversity, water, soil (accident, severe damage)	directive 2004/35	2008	Administrative authorities	Where polluted soils are being rehabilitated, rehabilitation measures are designed to meet quality requirements needed for the future use of the site; most of the time a very low level of environmental quality is set (public health or security) - polluted water or biodiversity degradation : restoration in kind as a priority (no application in France since 2008 because no case of severe damage, but application methodology already set in the law)
	Environmental liability (ecological damage, accident)		2016	Judge	Compensate ecological damage with restoration (instead of financial compensation)

Table 2. Membership of the French restoration network REVER (*Réseau d'échanges en écologie de la restauration*). Created in 2008, it only became a French non-profit organization (*association loi 1901*) in 2011.

Year	2011	2012	2013	2014	2015	2016	2017	Average
Number of members	62	27	69	69	55	53	84	60
% researchers	38.7	25.9	23.2	23.2	25.5	26.4	26.2	25
% practioners	43.5	59.3	27.5	27.5	21.8	15.1	20.2	29
% students	17.7	14.8	49.3	49.3	52.7	58.5	53.6	46

Table 3. Creation date of SER-European chapter and European national restoration networks. When two dates are written, the first date is the date of informal creation and the second is that of official registration as an NGO or Association.

| Name of organization	Country	Year of creation
SER-Europe	NA	1998 / 2012
Asociación Española de Ecología Terrestre	Spain	2004
Ennallistamisen ja Luonnonhoidon Ohjausryhmä	Finland	2007
Ontwikkeling+beheer natuurkwaliteit	Netherlands	2006
Società Italiana di Restauro Forestale	Italy	2012
Réseau d'échanges et de valorisation en écologie de la restauration	France	2009 / 2011

Figure 1.
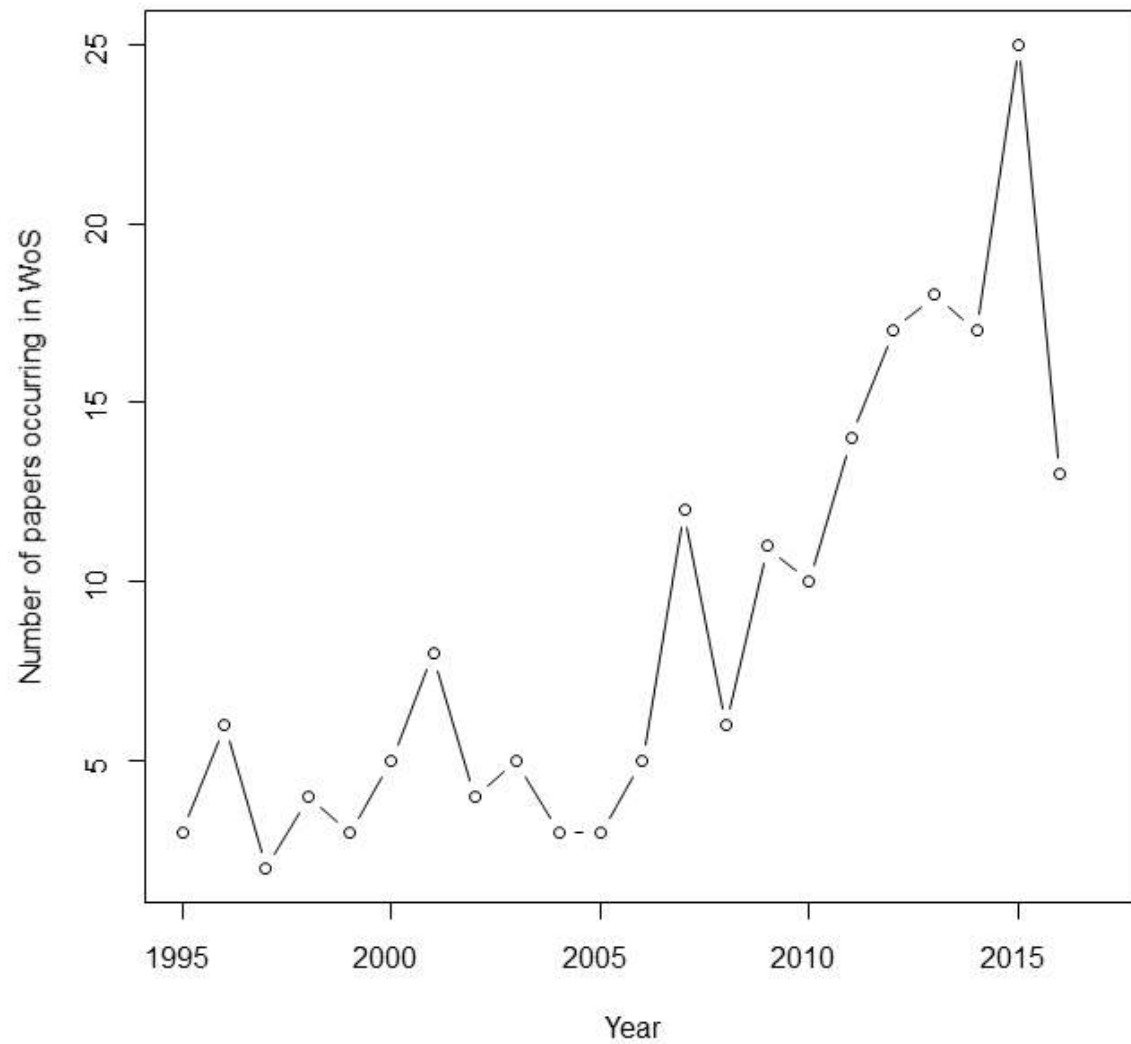
Figure 1. The increase in restoration ecology research in France is shown by the increasing number of papers published between 1995 and 2016 and indexed by the Web of Science (thus excluding most papers written in French). Source: Web of Science, searching for the keywords *"restoration"* AND *"ecology"* AND *"France"* (n= 194).