CONSERVATION RECOMMENDATIONS FROM A LARGE SURVEY OF FRENCH ORCHIDS

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ABSTRACT

The French Atlas of Orchids published in autumn 2010 is a large-scale and intensive survey of orchid populations throughout the France territory. The project was directed by the French Orchid Society and involved 3000 specialists in orchids. Overall, more than 110,000 stations were referenced and 160 taxa were reported with their range on 154 maps. This project is original by synthesizing, at large scale, much accurate naturalistic information from local surveys, thanks to a participative approach and on the basis of scientific objectives. Some orchid populations have been recorded for more than 20 years, revealing demographic trends at the scale of the country. Guidelines for application IUCN Red List criteria at regional level have been applied in order to establish The French Red List of orchid species. This represents one of the few examples of IUICN criteria being applied at a regional scale for a plant family. Based on the IUCN categorization about 1 in 5 species is threatened, one as Regionally Extinct (RE), 4 as Endangered (EN) and 23 as Vulnerable (VU). The main extinction risk consists of population size decrease, mostly due to habitat change. Further investigations are needed for the 33 taxa classified as Data Deficient. Most threatened species benefit already from protection regulations. Some recommendations will be drawn in order to conserve orchid species, paying attention to patrimonial and threatened species.

Keywords: conservation biology, mapping, *Orchidaceae*, population management, Red List

Introduction

Global biodiversity is facing one of the most intense extinction period in the history of life, called the sixth great extinction event (Canadell and Noble 2001). In this context many species of the most diverse plant vascular families by their number of taxa are probably also exposed to extinction. The five largest Angiosperm families (*Asteraceae*, *Fabaceae*, *Orchidaceae*, *Poaceae* and *Rubiaceae*) account for about a third of all known species and the *Orchidaceae* could be the largest family with more than 25,000 known species (Cribb and Govaerts 2005). Orchid species appear particularly threatened in their natural range and susceptible to extinction risks as revealed in the 2008 IUCN Red List of threatened species with a high proportion of species classified as Endangered (EN) (Vié et al. 2009).

The main threats recorded for orchids, which are mostly tropical species, came from forest overexploitation and loss and, for some decorative species, also from collection. Orchids provide ideal model species for focusing conservation programs in plants (Swarts and Dixon 2009). A special attention has been already paid to this family consisting of a lot of species, some of them being represented by a limited number of plants. Thus international trade and exchange of all orchid species are regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) because many species are considered endangered in the wild and face a compromised future through overexploitation. Orchid species face various threats like deforestation by logging or burning for agriculture, global warming, solar dimming, genetic erosion, forest fires, ex situ propagation (Kopowitz 2005). Some cultured species are also subjected to collecting for trade or for private orchid collections. In tropical areas are found most threatened Angiosperms species (Vié et al. 2009), including orchids. Various orchid species are protected in their natural environment in many countries, including tropical and temperate areas, with a variable success.

The purpose of the present study is to evaluate the level of risks of extinction on which are exposed temperate orchid species and to provide some management recommendations. France shows a large range of ecological conditions and the dataset allows reliability of presence of orchid species to their ecology (Prat 2010) and extent to Mediterranean region, which is recognized as a hotspot of biodiversity (Myers 2000). Species growing in the studied area have already been well documented (Bournérias 1998; Bournérias and Prat 2005; Delforge 2005). Some populations have already disappeared in the last century (Bournérias and Prat 2005). Main factors responsible of population size decrease would be identified. Several species benefit of an official protection status in France. In this study, the protection status can be then linked to extinction risks. Efficiency of these regulations and proposed recommendations in order to preserve orchids will be discussed.

A large dataset suitable for extinction risk assessment in orchids according to the regional IUCN guidelines

(IUCN 2003) was provided from an intensive inventory and mapping of orchids recently carried out in France (Dusak and Prat 2010) followed by a dedicated survey to estimate trends of evolution of the populations with the local co-ordinators. French orchid Red List (UICN et al. 2010) was established from these data since possible population decline could be stated

Materials and Methods

French orchid mapping and inventory

The French Orchid Society (SFO) formed in 1969 has in its goals development of knowledge on orchids and to promote their protection. As the distribution of orchid species was not really established at that time, SFO launched the inventory of orchid distribution in France involving more than 3000 collaborators (SFO members, partner institutions and botanists). Presence of orchid species was recorded and places where they grow were localized with their geographical coordinates. The importance of this work was recognized by the French Ministry in charge of ecology which ordered officially in 1987 SFO to carry out inventory of orchids in France. In each local administrative territory, a cartographer responsible for local data collection and territory exploration has been designed. Data collected over 28 years accounted for 421,325 records of species presence distributed in 116,189 stands in October 2008 (Dusak et al. 2010). As taxonomy of orchids has changed during this period with the description of new taxa and phylogeny considerations (Bateman et al. 1997, 2003, 2005), the final number of taxa considered was 175, distributed in genera *Anacamptis* L. C. M. Richard, *Cephalanthera* L. C. M. Richard, *Chamorchis* L. C. M. Richard, *Coeloglossum* Hartman, *Corallorhiza* Gagnepin, *Cypripedium* L., *Dactylorhiza* Necker ex Nevski, *Epipactis* Zinn, *Epipogium* Gmelin ex Borckhausen, *Gennaria* Parlatore, *Goodyera* R. Brown, *Gymnadenia* R. Brown, *Hammarbya* O. Kuntze, *Herminium* L., *Himantoglossum* Sprengel, *Limodorum* Boehmer, *Liparis* L. C. M. Richard, *Neotinea* Reichenbach fil., *Neottia* Guettard, *Ophrys* L., *Orchis* L., *Plantanthera* L. C. M. Richard, *Pseudorchis* Seguier, *Serapias* L., *Spiranthes* L. C. M. Richard and *Traunsteinera* Reichenbach. As a consequence of taxonomic changes during the time of data collection and difficulties to separate some taxa, the atlas of French orchids consisted of 154 maps (Dusak and Prat 2010). In order to respect the IUCN guidelines for publication of a national Red List (IUCN 2003), a rough estimation of the percentage of the world population observed in France has been made and it was assessed according to the whole range of the species in foreign countries and to our knowledge of population density and size.

Extinction risk assessment according to regional IUCN guidelines application

The survey of French orchids species involved populations estimates but not their evolution that is an important criterion for IUCN Red Listing. Therefore a specific evaluation of the trends for the last 30 years was made, thanks to a request sent to each of the more than 90 local car-

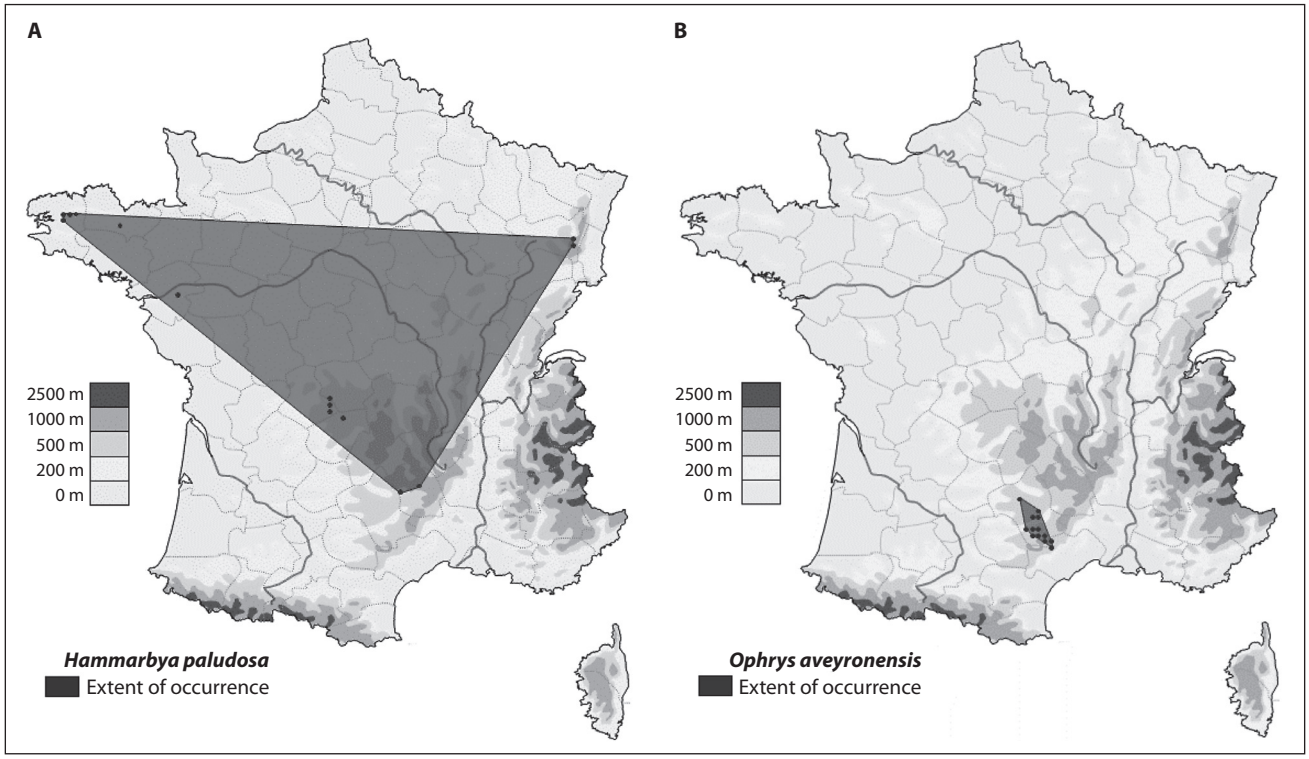

Fig. 1 Extent of occurrence of *Hammarbya paludosa* (a) and *Ophrys aveyronensis* (b) in France.

tographers. These data were analyzed and, if not suitable for processing of the Red Listing Quantitative Analysis criteria (E) proposed by IUCN, were largely suitable to apply the other proposed criteria, namely Population reduction criteria (A), Geographic range evolution criteria (B), Small population decline criteria (C) and very small or restricted population criteria (D). Therefore IUCN criteria could be used without major difficulties to evaluate the risks of extinction and eventually classify most of the species in one of the Red List categories at regional level, in this case French territory, as it has already been done for orchids in Guadeloupe (Feldmann et al. 2005). Indeed, IUCN rules do request only one criterion to be filled to propose a category of Red List (IUCN 2001, 2003; Vié et al. 2009). Criterion A was used in the present study because the compilation of observations over more than 20 years allowed us to evaluate whether or not populations were declining. Criterion B was used because the data covered the entire country and it was thus possible to determine the geographic extent of occurrence and the area of occupation of each species (Fig. 1). Criteria C and D could also be tested from data on population size and their possible observation of reduction. When taxonomical changes led to separation of a single taxon in new taxa, IUCN criteria have been tested both for the original and individual derived taxa. In the present study, only results for individual derived taxa are shown.

The French orchid Red List has been established under an agreement between UICN France, Museum National d'Histoire Naturelle, Fédération des Conservatoires Botaniques Nationaux as required for plant species in France, and Société Française d'Orchidophilie and then validated by a specific committee (Feldmann and Prat 2009; UICN et al. 2010).

Based on the IUCN criteria used in this study, threatened orchid species were classified as Regionally Extinct (RE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU). Near Threatened (NT) is a specific category when criteria for threatened category were not fulfilled but close to be it. A species is Least Concern (LC) when it has been evaluated against the criteria and does not qualify for CR, EN, VU or NT. Some taxa were listed as Data Deficient (DD), which is not a category of threat, when there is inadequate information to make a direct, or indirect, assessment of its extinction risk based on its distribution and/or population status. In most instances, DD species were orchids that had been recently described or taxonomically placed into separate taxa and for which the existing population data were not sufficient for classification. Taxa that were outside their usual range and were represented by few individuals or were of questionable status were evaluated as Non Applicable (NA).

Protection and IUCN orchid status

Twenty-one species are protected at the national level. For these species, any collection of any part of plants, including seeds, is prohibited. Several additional species (79 taxa) are protected at the local level by administrative authorities and this protection is official and recognized by ministry in charge of ecology. Any collection of any part of plants is also prohibited but only in a delimited administrative area. In the present study, we looked for relationships between protection and risks of extinction to have a first analysis of the quality of coverage of threatened species by current regulations.

Extinction risk factors

Field survey of populations and knowledge on species ecology was used to identify the most probable threats compiled following the IUCN guidelines using their SIS-DEM 1.0 software.

Results

French orchid Red List

Only one of the 161 taxa, *Anacamptis collina,* is evaluated as Regionally Extinct in France (Table 1) as the only known single population of this species located has disappeared. There is no species listed as CR but 4 are EN (*Hammarbya paludosa*, *Ophrys aveyronensis, Ophrys eleonorae, Ophrys philippi) and* 23 taxa are VU which represents 21% of classified taxa (DD and NA categories being excluded). Considering together with NT species, 49% of the orchid taxa in France face threats. Species from 14 out of the 26 genera representing the three subfamilies growing in France have been classified into EN or VU categories (Table 2).The DD category represented 20% of taxa, most of them belonging to the genera *Dactylorhiza* (6 taxa) and *Ophrys* (20 taxa).

Table 1 Distribution of analyzed taxa in the IUCN categories of threat.

IUCN threat category	Taxa #
Regionally Extinct	1
Critically Endangered CR	0
Endangered EN	4
Vulnerable VU	23
Near Threatened NT	35
Least Concern LC	63
Data Deficient DD	33
Non Applicable NA	2
Total	161

Threatened species versus protected species

Anacamptis collina was protected at the national level but the species still became extinct. Only *Hammarbya paludosa* and *Ophrys aveyronensis* of the 4 species clas-

Table 2 Extinction risks and protection status of French orchid species classified at national level as Endangered, Vulnerable or Near Threatened according to the IUCN criteria.

Species	Protection status in France	Percentage of world population	Number of stands in France[1]	IUCN category	IUCN criteria	Major extinction risks
Anacamptis champagneuxii		< 5	115	NT		Small occurrence area and fragmented populations
Anacamptis collina	National	0	0	RE	Regionally Extinct	Northern limit of range, already extinct in France
Anacamptis coriophora	National	< 10	1035	VU	A2ac+3c	Drainage and destruction of wet areas
Anacamptis laxiflora	Local	> 10	4375	VU	A2ac	Drainage and destruction of wet meadows
Anacamptis longicornu	National	< 5	29	VU	B1ab(i, ii, iv)+2ab (i, ii, iv); C2a(i); D2	Disappeared from continental France by collection
Anacamptis palustris	Local	< 5	413	VU	A2ac	Regression of wet meadows
Anacamptis papilionacea	Local	< 1	545	NT		Limited population size
Chamorchis alpina	Local (whole national range)	< 1	466	VU	A3c	Range decrease projected from global climate change
Coeloglossum viride	Local	< 1	3613	NT		Agriculture intensification
Corallorrhiza trifida	Local	< 1	690	NT		Population size decrease, unknown cause
Cypripedium calceolus	National	< 1	397	VU	A4acd	Small fragmented populations, agriculture extension, collection
Dactylorhiza elata	Local	< 10	409	VU	A2ac+4ac	Regression observed in large areas in relation to use of wet meadows
Dactylorhiza incarnata	Local	< 10		VU	A2abc+4c	Population regression related to use of wet areas
Dactylorhiza insularis		< 10	3917	NT		Few populations of limited size
Dactylorhiza majalis	Local	< 10	5337	NT		Regression observed in large areas in relation to use of wet meadows
Dactylorhiza occitanica	Local	**100**	75	VU	A2c; C2a(i)	Regression observed in large areas in relation to use of wet meadows
Dactylorhiza ochroleuca		< 1	12	VU	D1+2	Only a small population known in France
Dactylorhiza praetermissa	Local	< 5	867	NT		Regression observed in large areas in relation to use of wet meadows
Dactylorhiza traunsteineri	Local	< 5	545	NT		Regression observed in large areas in relation to use of wet meadows
Epipactis fageticola		< 30	44	NT		Few populations of limited size
Epipactis fibri		**100**	27	NT		Few populations of limited size
Epipactis kleinii		< 2	28	NT		Few populations of limited size
Epipactis neerlandica		< 1	76	NT		Few populations of limited size
Epipactis palustris	Local	< 5	2999	NT		Drainage of wet areas, regression of wet meadows
Epipactis phyllanthes	Local	< 10	117	NT		Few populations of limited size
Epipactis placentina		< 5	7	NT		Few populations of limited size, population fragmentation

Species	Protection status in France	Percentage of world population	Number of stands in France[1]	IUCN category	IUCN criteria	Major extinction risks
Epipactis provincialis		**100**	86	NT		Few populations of limited size
Epipactis rhodanensis		> 10	168	NT		Few populations of limited size
Epipogium aphyllum	National	< 1	205	NT		Scarse and fragmented populations
Gennaria diphylla	Local (whole national range)	< 1	22	NT		Few populations of limited size
Gymnadenia odoratissima	Local	< 10	906	VU	A4ac	Regression observed in large areas in relation to use of wet meadows
Hammarbya paludosa	National	< 1	20	EN	C2a(i)	Regression observed in large areas in relation to destruction of peat-bogs
Herminium monorchis	Local	< 1	190	VU	A2ac	Habitat destruction by stand closing and deforestation
Liparis loeselii	National	< 1	587	VU	A2ac+3c; C2a(i)	Regression observed in large areas in relation to utilization of wet areas
Neotinea conica		< 10	19	VU	C2a(i)	Few populations of limited size
Neotinea lactea	Local	< 2	195	VU	A2ac	Habitat destruction, stand closing
Neotinea tridentata	Local	< 1	434	NT		Population size decrease, unknown cause
Ophrys aurelia	National	50	214	NT		Few populations of limited size, habitat destruction
Ophrys aveyronensis	National	**> 50**	74	EN	B1ab(ii, iii, iv, v) +2ab(ii, iii, iv, v)	Habitat destruction by stand closing and deforestation, climate change
Ophrys aymoninii	Local	**100**	90	VU	A4c; C1	Few populations of limited size, habitat destruction by agriculture changes and deforestation, climate change
Ophrys bombyliflora	National	< 1	88	NT (VU in continental France)	(A2a in continental France)	Few populations of limited size and habitat destruction
Ophrys catalaunica	National	50	14	NT		Few populations of limited size, habitat destruction
Ophrys drumana	National	**100**	250	NT		Few populations of limited size, habitat destruction
Ophrys elatior	Local	< 20	39	NT		Few populations of limited size
Ophrys eleonorae		< 1	3	EN	D	Few populations of limited size
Ophrys magniflora	National	**100**	44	NT		Few populations of limited size, habitat destruction
Ophrys morisii		< 20	50	NT		Scarse populations of limited size
Ophrys philippi		**100**	26	EN	D	Few populations of limited size
Ophrys speculum	National	< 1	61	VU	D1+2	Few populations of limited size
Ophrys splendida	Local	**100**	183	NT		Scarse populations of limited size
Ophrys tenthredinifera	National	< 1	65	VU	C2a(i)	Few populations of limited size

Species	Protection status in France	Percentage of world population	Number of stands in France[1]	IUCN category	IUCN criteria	Major extinction risks
Orchis langei	Local (whole national range)	< 5	23	NT		Few populations of limited size
Orchis olbiensis		< 2	230	NT		Few populations of limited size
Orchis pauciflora	National	< 1	18	VU	D1	Very scarse populations of limited size
Platanthera algeriensis		< 1	10	VU	D1	Scarse populations of limited size
Serapias cordigera	Local	< 2	403	VU	A2ac	Population regression related to land use changes
Serapias lingua	Local	< 5	3190	NT		Population regression
Serapias neglecta	National	< 5	325	NT		Few populations of limited size
Serapias nurrica	National	> 20	19	VU	D1	Few populations of limited size
Serapias olbia	Local	< 5	123	NT		Few populations of limited size
Serapias parviflora	National	< 5	260	NT		Scarse and localized taxon
Spiranthes aestivalis	National	< 1	364	VU	A2ac+4ac	Strong population regression related to habitat destruction (drainage of wet areas)
Spiranthes spiralis	Local	< 1	3058	NT		Population regression related to land use changes

[1] Some stands may consist of a single plant.

Table 3 Relationships between protection status in France and IUCN classes of threats.

IUCN status	National protection	Local protection (partial range)	Local protection (but covering whole national range)	No official protection
Regionally Extinct	1	–	–	–
Endangered (EN)	2	–	–	2
Vulnerable (VU)	9	10	1	3
Near Threatened (NT)	8	14	2	11
Least Concern (LC)	1	46	–	16
Data Deficient (DD)	–	5	1	29

sified as Endangered are protected at the national level (Table 3). One of the species protected at the national level, *Orchis spitzelii,* is not subjected to threats and 8 species (in genera *Epipogium*, *Ophrys* and *Serapias*) out of them are classified as NT (Table 3). Threatened species (EN and VU) are more well protected than other species (NT and LC) at the national level ($\chi^2 = 13.19^{***}$). NT and LC species are protected in similar proportion at the national level ($\chi^2 = 0.41$). Four other species *Chamorchis alpina*, *Dactylorhiza sphagnicola*, *Gennaria diphylla* and *Orchis langei*, have their whole national population protected despite no national protection but due to their restricted regional location, by regional regulations. Species are mostly protected at the local level and the majority of them are classified as LC. At the local level, the proportion of protected species is similar whatever threat importance (EN and VU vs. NT and LC: $\chi^2 = 2.54$). Even the most frequent species by the number of stands like *Orchis mascula*, *Orchis purpurea*, *Anacamptis pyramidalis*, *Himantoglossum hircinum*, *Gymnadenia conopsea* are protected somewhere at the local level. Sixteen out of the twenty more frequent species by the number of stands (more than 7000 stands recorded per species) are protected in a part of their national range by local regulations. Two out of the four species classified EN (*Ophrys eleonorae*, *Ophrys philippi*) and 3 out of the 23 species classified VU (*Dactylorhiza ochorleuca*, *Neotinea conica*, *Plantanthera algeriensis*) benefit of no protection.

Identification of threats

Most species classified as EN or VU are threatened because of population decline while others were it because they occur over a very limited geographic range or the

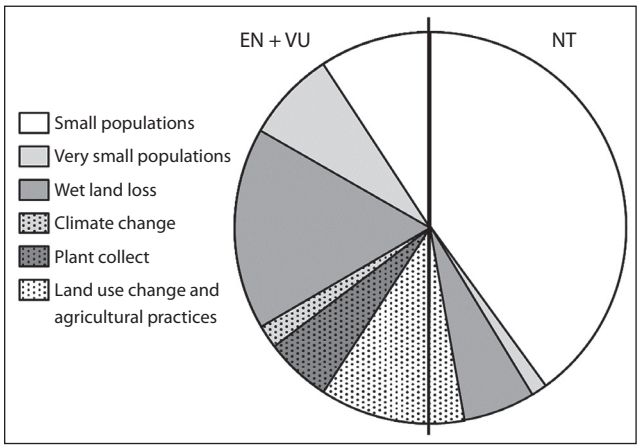

Fig. 2 Distribution species according to the main extinction risks for threatened (EN and VU) and Near Threatened species.

number of known plants is very low and, in some case, the known populations have been declining (Table 2). The criterion A (population reduction) is fulfilled for 15 species, the criterion B (geographic range) for 2 species, the criterion C (small population size and decline) for 7 species and the criterion D (very small or restricted population) for 8 species. Four species combined different criteria (A and C for three species; B, C and D for one). More than a third of threatened species grow on wet meadows or peat-bogs (Fig. 2). Regression of these species is related to habitat loss. Six different sources of threats were recorded in the present study: very small population, small population with regression, plant collected for private collection or industrial use, climate change (*Chamorchis alpina*), wetland loss and land use changes. Small population size is the main threat for species classified as NT. They would become in threatened categories if their populations will show further regression.

Discussion

National versus local protection

The regulations aim to protect species from destruction, collection, possession and trade so well at regional and national levels. Nevertheless, regional protection is less efficient to protect against collection, because it cannot be applied out of the area of application as soon as the collected plant material had passed the administrative border.

Threatened species are mostly protected at the national level whilst local protections affect species no matter their status or national risk of extinction. A good example is *Orchis simia*, which is not threatened at the national level. Because of its broad distribution, populations are small over some parts of its range and in those areas it benefits from local regulations, especially in the western part of its range where it is declining. Several species abundant and showing a large distribution at the national level are thus locally protected in the part of their range with low population density and size. But some other species with a limited range and evidence of threats like *Ophrys eleonorae* and *O. philippi* are not which shows some level of lack of coherence. While taking into account the relationships between local populations and other conspecific populations, regulations priorities should be reassessed in regard of data provided by evaluation of extinction risks according to UICN criteria. Moreover, *O. philippi* can be considered as several other species as a patrimonial species for which most if not all populations grow in France. Protection of patrimonial species should be a priority for wild area managers in order to keep biodiversity and their evolution potential.

Species protected at the national level showed population reduction. Some of them like *Anacamptis longicornu*, *Cypripedium calceolus* are still exposed to plant collectors in spite of regulations even these collections were rare. *Anacamptis collina* disappeared from national territory because of by plant collection and habitat destruction whilst it was protected. Regulation should be reinforced especially to avoid habitat change or destruction.

Systematics of orchids and protection consequences

The impressive evolution of systematic and taxonomy of some European genera due to the increase of knowledge on the biology, ecology and distribution and the use of molecular tools for phylogeny studies has conducted to major nomenclatural changes but also intense debates on the reliability of these changes. Without going into these discussions that are far to be achieved, there is an increased concern on the impact on conservation. The number of orchid species described in floras has considerably increased during one single century and particularly in the last decades: 68 species (10 *Ophrys* species) in Flora of France and Switzerland of Bonnier (still in the edition of Bonnier and De Layens 1975) up to 160 species (51 in genus *Ophrys*) in 2005 compiling species described or recognized in France (Bournérias and Prat 2005). This increase of species number, particularly in genus *Ophrys* induces a biased evaluation of biodiversity which seemed to grow up while in fact many species disappeared or become threatened. Taxonomic inflation may have therefore negative consequence on plant conservation (Pillon and Chase 2007).

Thus, *Ophrys* genus is considered, depending on the authors, to consist of much more than 200 species (Delforge 2005) or less than 20 (Pedersen and Faurholdt 2007). In the first case, more than 200 *Ophrys* species, this gives a cloudy picture of many micro-species and/or microlocations, which is not easily understandable and helpful to protect species by law, mainly by overestimating the rarity. The evolution potential of these micro-species remains unclear. In the second case, less than 20 species,

this already conducted to include in a general concept, partly stabilized hybrid complex, highly threatened taxa. These threatened taxa can not be protected since their names did not appear. So, the proposal of global Red Listing one the most threatened species, *Ophrys aveyronensis*, has never been processed based on this extreme posture, despite this is a misinterpretation of the Red List guidelines. In fact, Red List guidelines even allow evaluating different levels of taxa (i.e. subspecies or even a specific population). Thus taxa splitters as well as taxa lumpers could have bad consequences in orchid protection.

Systematics changes in orchids can promote confusion on the protected taxa as official species name written in the regulation texts could be different to the new species name find in orchid books without clear synonymy.

Population size variation

Population size evaluation concerns mostly flowering plants which are easy to number. Population survey has revealed a large variation from year to year of the number of flowering plants: an extreme variation (425 vs. 12 flowering plants) has been recorded in a stand of *Liparis loeselii* within four years (P Richard, pers. comm.). A more stable number of flowering plants is recorded in some species like *Ophrys apifera*, *Orchis simia*, *Coeloglossum viride* etc. (Willems and Melser 1998). Most terrestrial orchids have tubers and do not flower each year. For instance, in *Neotinea ustulata*, one year after flowering, most plants can stay dormant with or even without leaves (Tali and Kull 2001). Plant can stay alive but completely dormant for several years. Population reduction can only be noticed if the period of observation is long enough to assess the population size variation and not plant development variation. Data used for the present study have been recorded over 20 years and are less subjected to such impacts of plant dormancy or climatic conditions.

Source of threats

Orchids have more or less strong interactions with pollinators and with mycorrhizal fungi. Their presence is thus dependent on that of other organisms. This can increase their extinction risks, particularly in rare species specialized in their biotic interactions when no partner substitution could take place (Brundrett 2007). In our study, we have not identified species threatened by the lack of pollinators or mycorrhiza. Most threats result from anthropic activities leading to land use changes and to wetland loss. Many species growing in wet meadows or peat-bogs as in *Anacamptis* and *Dactylorhiza* genera are classified as threatened species. Climate change characterized by temperature increase and erratic rainfall would probably contribute to wetland losses increasing threats on the species growing there. Population reduction due to habitat loss and fragmentation affect gene flows and relatedness among plants and then increase inbreeding depression. Thus, habitat fragmentation can change dramatically population genetic structure even with a limited decrease of total population size. Subsequent reduction of genetic diversity increases extinction risks. In orchids, influence of inbreeding depression could be reported for seed viability and not at seed set (Wallace 2003). Such risks are well documented in orchids (Coates and Dixon 2007; Swarts and Dixon 2009). Several species classified as threatened and most species classified as near threatened exhibited small populations and are thus exposed to these severe risks, especially if biotic interactions are modified by anthropic activities or climate change. Fragmentation of range due to city extension and land use changes was recorded for many species during French orchid survey. This can affect population regeneration and not yet present population structure. For future studies, we can recommend to record the seed set and more interestingly the seed quality in order to predict the regeneration potential.

Climate change has been considered as the main threat for *Chamorchis alpina* which grows at high elevation. A simulation of its potential range carried out according to climate parameters (mainly temperature, rainfall, rainy period) has shown a reduction of its range with temperature increase (Munoz 2010). The migration of the species to a higher elevation due to temperature increase would result in a dramatic limited potential range (Körner 2007).

Recommendations for orchid management

Habitat change or destruction (city extension, agriculture development, field fertilization, herbicide use, competition with shrubs, deforestation . . .) are the main sources of threats against orchids. Protection of orchids is in these conditions only possible by ecosystem management in order to reduce adversities against orchids. No action specific to orchid population would be able to improve its survival. Limitation of weed competition is promoted by late mowing which allows orchids to achieve their developmental cycle up to mature seed production. In the same way, limitation of shrub establishment in meadows is obtained by cutting. Management of wild area to favour orchids is mostly based on these two actions. After removal of shrubs, sometimes new meadow orchids grow and flower.

Wetlands become dried by tree plantation and by draining. The respective areas become thus suitable for agriculture or building. Protection of orchids in these areas enters in concurrence with economic utilization of land. In the lack of support for land owners, no protection could be efficient. For wetland, only political decisions for land uses could save orchids and other plants growing there.

Spiranthes spiralis can become threatened by its utilization for drugs. Species of horticultural application (*Cypripedium calceolus*, *Ophrys* sp., *Orchis* sp., *Dac-*

tylorhiza sp.) can show reduction by plant collection. Production of plants by in vitro culture, and available for private collections in the species of commercial value, can be a way to save wild populations. Cultivation is in fact prohibited or regulated for protected species. Even plants of protected species can be found in orchid market, especially by internet in the lack of official deregulation. Wild orchid trade needs more controls.

Various species already threatened, or close to be, show small populations or even very small populations, moreover eventually subjected to fragmentation. These species will experience inbreeding and a significant loss of genetic diversity and consequently could disappear. Their main biological threat results from a lack of large gene flow. A survey of pollination and seed set allows assessment of the problem. In such situation, we can switch the declining population to a dynamic population by managing gene flows. Pollen from different populations of the same species, adapted to the same environment could be used for artificial and controlled pollination. Crosses produce vigorous plants not affected by inbreeding depression. Viable seed production can increase inducing a new positive dynamics on the population. This kind of population reinforcement should be more efficient than just introduction of few plants from unknown or not adapted stands.

Improving knowledge and communication

Our knowledge on orchid biology is still limited, especially on possible gene flows at short or long distance, the impact and availability of seed bank in soil, impact of climate change, control of plant dormancy . . . many recent studies concerning phylogeny. In order to conserve orchids, a better understanding of population biology is needed but if we wait for this information we could lose species. Conservation should be more practical even we lack some data. A pragmatic approach is recommended. Studies at the population level and at the species level should be promoted. In France a national action plan have been decided for *Liparis loeselii* in order to get data from extensive and intensive survey of populations. Orchid protection is not only based on scientific knowledge but also on social development. Large information towards people is required to explain objectives and to involve them in the protection activities and participative science in order to increase action efficiency.

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