

ABSTRACTS OF THE YOUNG BOTANISTS DAY 2007  
“PLANT CONSERVATION IN THEORY AND PRACTICE”

A MEETING HELD IN BAILLEUL (FRANCE) ON 23 NOVEMBER 2007

KEYNOTE LECTURES

**A framework for the conservation of rare and endangered plant species applied to *Primula vulgaris* in Northern Belgium**

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Deterministic processes such as habitat loss, habitat fragmentation and habitat degradation are the main drivers for distribution range retraction and population decline of plant species. Random variation in environmental conditions (so-called environmental stochasticity) will further impose serious threats to the viability of individual populations or metapopulations. However, as to the ultimate effect on population persistence there may also be strong interactions with demographic and genetic stochastic processes once population size, and seed and pollen flow descend under a critical threshold, especially for rare species or endangered species naturally occurring in small populations. While it is generally accepted that the latter may result in loss of evolutionary potential and/or inbreeding depression, several studies suggest that these aspects only come into play once populations are so small that they would disappear regardless the restoration measures that are applied.

Given these driving forces on population dynamics, we propose a framework, slightly adapted from SCHEMSKE *et al.* (1994) and CASWELL (2001), outlining four critical steps toward the recovery of rare and endangered plant species:

- (1) Assessment: every conservation programme should start with a thorough evaluation of the current status of the species. Questions such as: “What is the distribution range? Are individual populations declining?” should be answered.
- (2) Diagnosis: the next step is to diagnose the causes of decline, which is inherently a comparative exercise. The primary tool is retrospective perturbation analysis (LTRE) on population transition matrices to quantify the contribution of vital rates to past changes in population growth rate.
- (3) Prescription: here specific management strategies that attempt to change the vital rates so that population growth rate increases are evaluated. The best tool for evaluating management prescriptions are prospective perturbation analyses (or, in terms of population matrix models, calculation of elasticities), because they identify the points in the life cycle where perturbations will have the largest effect on population growth. A combination of both retrospective and prospective analyses is also commonly used to determine management targets, but results should be handled with care.  
Finally, the goal of
- (4) prognosis is to predict the population’s fate (population viability analyses, PVA). Ideally, this should be done for different scenarios (e.g., several initial population sizes, inclusion of environmental stochasticity).

Through application of this framework to the conservation of *Primula vulgaris* in Flanders, we aim to illustrate the relative importance of

deterministic and stochastic processes for population viability and provide some clear guidelines for remediation of the current situation.

### References

- CASWELL H., 2001. — *Matrix population models - construction, analysis, and interpretation*, 2<sup>nd</sup> edn.: 722 p. Sinauer, Sunderland, MA.
- SCHEMSKE D.W., HUSBAND B.C., RUCKELSHAUS M.H., GOODWILLIE C., PARKER I.M. & BISHOP J.G., 1994. — Evaluating approaches to the conservation of rare and endangered plants. *Ecology* **75**: 584-606.

### Global change: to evolve or to run? Potential responses to climate change in sea beet (*Beta vulgaris* subsp. *maritima*).

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The present climate change might result in three possible outcomes for species: (1) extinction; (2) shifting of distribution areas following the shifting of climate zones; (3) adaptation to the local “new” environment. Without migration, *in situ* adaptation would be necessary, e.g., for life-history traits related to phenology, such as the timing of germination, timing of flowering, or for any other trait locally adapted to climate.

We assessed in several studies the abilities for migration and adaptation of sea beet, *Beta vulgaris* subsp. *maritima*, in the context of global climate change. We studied the variability in sea beet of timing of germination and flowering, life span, their dependency on climate (through controlled-conditions and field experiments) as well as their evolutionary potential (through genetic studies). We also studied its migration potential (through controlled-conditions experiments, simulations and population genetics studies). Experiments were conducted on a large number of popu-

lations collected along a latitudinal gradient from Southern to Northern France.

Flowering time (vernalisation requirement and day-length sensitivity) showed a strong dependency on latitude. Heritability within populations was 0.33. The necessary day-length for flowering induction could be reduced by artificial selection from 13h to 11h in less than 10 generations. Germination timing is affected by seed dormancy, which can be released by cold or drought. We found a high variability for dormancy rate under greenhouse conditions, negatively correlated with latitude. Average heritability was 0.5. Mean life span in greenhouse conditions showed a strong dependency on latitude. Comparison of spatial autocorrelograms for life span and cytoplasmic neutral markers showed a strong selection for life span. Possible selective factors on this trait are disturbance or climate. We finally show a high migration potential in this sea-transported species. Our study reveals very high buoyancy in sea water. This trait is variable among populations with latitude. According to drift simulations this allows long-distance dispersal, which was supported by population genetics studies.

Sea beet thus showed a high evolutionary potential for several climate-affected traits, as well as a strong dispersal potential allowing both gene flow between populations and species-area shifting. Although its habitat is plausibly directly affected by global change through seashore erosion, sea beet may therefore be at the most favourable part of a gradient ranging from highly endangered species to plausibly flexible species facing global change.

### Ecological impacts of invasive plant species

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Global change is a major threat to biodiversity. The way organisms will cope with, react or adapt to such changes is of fundamental impor-

tance to the conservation of biodiversity. Biological invasions represent a major component of global change and the recognition of the problems associated to this phenomenon has meaningfully grown over the past decade. Understanding underlying mechanisms of impacts is crucial to develop prevention strategies and management solutions. However, the deficiency of knowledge on ecological effects of invasive species has frequently been underlined by the scientific community. Moreover, besides the existence of some general patterns, the amplitude and direction of impact depend on local abiotic conditions and on the composition of the native community.

In this presentation, the range of ecological impacts that non-native species have on native

species was reviewed by highlighting the variety of mechanisms involved. Impacts were illustrated according to biological level of organisation, from gene level to individuals, populations, communities and ecosystems. What affects one level, of course often affects the others. Generalising about the impacts of non-native species needs tools for assessing and comparing impacts across ecological communities and biological levels. Different attempts were examined. Moreover, as a practical example of information needed, *Harmonia*, an interoperable database dedicated to alien species introduced by man on the Belgian territory, was described as well as the *ISEIA protocol* (Invasive Species Environmental Impact Assessment protocol).

## CONTRIBUTED LECTURES

### Steppe restoration by hay transfers

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The steppe of La Crau has been defined as a priority habitat by the EU. This habitat rich in animal and plant species has incurred a lot of damages and today has been reduced to 11,500 hectares, of which 23 were destroyed in 2006 during the construction of an underground pipeline. As reported from previous studies, the steppe vegetation resilience is extremely low. Ecological restoration was used as a tool of conservation biology in order to mitigate the damage caused by pipeline construction. Ecological restoration experiments were carried out in order to find ways of accelerating steppe vegetation colonization on the buried pipelines. The aim of the study was to adapt and to test techniques of hay transfer to reintroduce stress-tolerant steppe species in a Mediterranean

ecosystem. A factorial experiment was set up at three sites to test the effects of grazing and habitat characteristics (ploughed or unploughed) on hay transfer.

Expected results include (1) low efficiency of the measures taken to reduce negative impacts of pipeline construction (e.g., remove topsoil with seed bank, stockpile it during construction, spread it back on top at the end of construction) due to construction delays; (2) success of hay transfer with reintroduction of steppe species. Among these species, we found a lot of Poaceae. Some of them are rare, such as *Taeniatherum caput-medusae*. We hope to analyze our vegetation results in terms of Grime adaptive strategies to export our techniques for conserving other dry herbaceous ecosystems.

### Ungulates as seed dispersers in plant conservation: what do dung beetles do?

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In nature conservation, the use of large herbivorous mammals is -among others- often motivated by their capacities to disperse plant seeds, mainly through consumption and subsequent excretion of seeds (i.e., endozoochory). In Western Europe, for instance, up to 300 plant species associated with secondary grasslands are known to have viable seeds present in dung of free-ranging herbivores (cattle, horses, deer, sheep...). Considering this great potential, recent literature regards the importance of endozoochory to be highly underrated. However, if we want to compare the efficacy of endozoochory with other means of dispersal, all stages of this multistage process have to be taken into account. Secondary dispersal, for instance, is often known to have a disproportionate effect on regeneration success.

In the case of endozoochory, secondary dispersal could occur by mice or dung beetles removing or burying dung-borne seeds. In tropical rainforests, seed burial by dung beetles is known to have a positive effect through decreased seed predation by rodents. However, as the plant species and predator guilds are considerably different for temperate systems, this result might not hold true for the latter.

In two temperate grassland sites, we performed a field experiment in which cages excluded dung beetles from horse and cattle dung samples with mixed-in grass seeds (*Poa pratensis* and *Agrostis capillaris*). Seedling emergence from these samples was significantly higher than from samples that were accessible to dung beetles. This indicates that their effect on short-term seed germination is negative, which contrasts with the patterns found in studies on large-seeded tropical plant species. The effect is most likely attributed to the larger depth at which tunneling *Geotrupes* species bury seeds and to the lack of roller species.

### **What causes the decrease in reproductive success in *Biscutella neustriaca* (Brassicaceae), an endangered and self-incompatible plant species?**

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Homomorphic self-incompatibility (SI) systems are present in many Angiosperms. SI allows selfing avoidance and reproduction between relatives through the recognition of pollen by stigmas and rejection of incompatible pollen. SI is determined by two main genes strongly linked and forming the S-locus. SI limits inbreeding depression, but it also reduces the number of potential mates in a population, which can limit reproductive success, especially in small populations. Indeed, the number of potential mates mainly depends on the diversity at the S-locus. This phenomenon has been called the "S-Allee effect" (WAGENIUS *et al.* 2007). Recent works based on both theoretical and empirical approaches seem to confirm this effect. However, those works have mainly showed an effect of allogamy due to SI and little is known about the impact of diversity at the S-locus, because no genetic markers were available. It is yet necessary to estimate this diversity to understand the impact of SI on reproductive success and predict demographic fate of a population.

*Biscutella neustriaca* is endemic to the Seine Valley (Haute-Normandie, France). In 2007, this declining species was represented by about 1200 individuals structured in strongly fragmented populations. These showed important lags in phenology, highly variable patch size and different ecological situations. A preliminary work based on crosses allowed us to confirm that *B. neustriaca* was strongly allogamous, and we highlighted at least seven alleles at the S-locus. Genotyping tools for this locus and molecular markers for microsatellite loci are currently under development. Also, first investigations in natural populations showed a dramatic effect of local density on seed set, suggesting a strong S-Allee effect.

The purpose of our upcoming work is to estimate the impact of population size reduction in connection with the SI system on reproduction success and demography, knowing SI genetic bases. Through the biological model of *B. neustriaca*, we

aim at: (1) evaluating the relative impact of S-Allee effect on reproduction success compared to other factors (e.g., ecological conditions, local density, phenologic variations, pattern of seed and pollen dispersal); (2) modelling the demography of a SI species taking the diversity at the S-locus into account, to predict viability of the populations and to test different conservation plans in the wild.

### Reference

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### Plant species extinction debt in a biodiversity hotspot: community and species approaches

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Destruction and fragmentation of natural and semi-natural habitats are considered as major threats for plant species richness. However, the response of plant species richness to habitat alteration is sometimes delayed. This delay induces an extinction debt in plant communities that are thus prone to undergo species extinctions in the following years. Several methodologies were proposed to detect this extinction debt and estimate the mean number of species yet to disappear. In this study, we developed a new methodology for the estimation of the extinction debt extent. Moreover, we proposed a species approach aimed at determining which species are more sensitive to extinction as a consequence of habitat destruction and fragmentation. Finally, we explored the colonization ability of habitat specialist species. This aspect is of first importance to counteract local species extinctions. Our model habitat is calcareous grasslands of Southeast Belgium that have

suffered an important fragmentation process since the beginning of the twentieth century. We estimated that the mean extinction debt of the calcareous grassland patches was ca. 24 species, including ca. six specialist species. We showed that 16 of the 46 specialist species did not meet their area requirement anymore and were therefore considered as sensitive to extinction. However, the species composition of the more recent grasslands indicates a non-negligible recolonization potential of specialist species. There is thus a real possibility to reduce extinction risk by restoring suitable habitats.

### Long-term floristic change in the Thiérache (Picardie, France): strong floral loss in a non-urbanized rural landscape

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Human activities, next to natural disturbances and succession, are the major factors driving changes in environment. These changes, in addition to natural environmental changes, directly or indirectly influence how vegetation changes. Long-term historical plant lists dating from the 18<sup>th</sup> up to early 20<sup>th</sup> century present a valuable way of assessing species extinction rates due to changed environments. The availability of a complete and accurate historical flora with information on historical species abundance, as well as recent distributional floristic data from 4 by 4 km grid squares, allowed us to assess floristic change and relate it to environmental and ecological indicators. For the Thiérache region, the historical flora was compiled at the end of the 19<sup>th</sup> century by the botanist Bienaimé Riomet. The recent data were

available from the DIGITALE database maintained by the Conservatoire botanique national de Bailleul (France). Floristic change per habitat type was characterized both in absolute numbers of extinct and extant species, and by means of a measure for relative change in range size for the major habitat types. We also assessed land-use change at the level of nine cantons for arable fields, grasslands and forests, which together comprise almost 90% of the region.

Forests were stable landscape features in the Thiérache, whereas arable fields and grasslands changed dynamically. The region is predominantly rural and has not experienced urbanization; population levels even declined since the 19<sup>th</sup> century. Out of a total of 978 species in the historical list, 199 went extinct. Most extinct species were already historically rare species. Extinction

percentages were the highest for arable fields (22%) and the lowest for forests (13%). Regional red list categories (at Picardie level) corresponded well with relative changes in range size. Correlations with species traits indicated that especially traits relating to the established phase predicted relative changes in range size, and less so for traits from the regeneration phase. For instance, species with decreased range size generally were less competitive and of small stature. These results are discussed in the light of extrinsic threats, such as eutrophication and land-use change, and are placed in comparison with similar studies assessing long-term floristic change. It is concluded that, despite being a rural area, floristic losses have been very high and that nature conservation measures are badly needed.

## POSTERS

### **Chemical characterization of essential oils extracted from two ylang-ylang floral morphotypes (*Cananga odorata* (Lam.) Hook. & Thoms. var. *genuina*) from Comoros Islands**

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The Union of the Comoros is the world's biggest producer of ylang-ylang essential oils. This product represents a high percentage of Comoros' annual currency. Ylang-ylang essential oil is obtained by fractioned hydrodistillation or steam distillation of the flowers of *Cananga odorata*. The oil is commercialized in five different grades (extra S; extra; I; II; III).

Direct observations in Comoros reveal that there are several different floral morphologies within ylang-ylang Comorian plantations. These morphotypes can coexist at short distances from each other. Two of these morphotypes were studied: the first one (Broad petals) shows giant

flowers and the second one (Normal) has the most common flower type found in plantations. They show morphological differences at several levels: leaves, flowers and trunk.

Essential oils from these two morphotypes were extracted and characterized by their physico-chemical properties (specific gravity, ester number, optical rotation and refractive index) and chemical profiles. This characterization reveals that there is a very clear difference between the two essential oils. Chemical analysis by GC/MS reveals that the two oils are chemically and statistically different, with the 'normal' morphotype richer in esters whereas the 'broad petals' morphotype is richer in sesquiterpenes. However, the most marked difference between the two chromatograms is the presence of eugenol in the essential oil obtained from the normal morphotype whereas it is only present at very low concentration in the other morphotype.

A perspective of further study is to separate ylang-ylang oils into different grades in order to characterize each fraction individually. The study of ylang-ylang variability could also be extended at morphological, genetical and chemical levels in order to explain the origin of this variability

and establish the existence of links between the different levels of polymorphism.

### Determining factors for the dispersal capacity of *Aster tripolium* in northern French and Flemish salt marshes

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The seeds of *Aster tripolium* are wind-dispersed. The number and the morphology of the diaspores are an indication for dispersal capacity. In this study, we investigated six isolated populations of *A. tripolium*, which differed in population size and age, along the northern French and Flemish coast. The objective was to assess the effect of population size, population density and environmental stress (herbivory, infection by *Paroxyna plantaginis* and flooding frequency) on seed dispersal capacity. Therefore, we established 40 plots in each of the six populations. We measured vegetative (plant size and biomass) and generative plant (number of flowers, number of seeds per flower head) characteristics of the central individual in each plot, and collected three random flower heads. For each flower head, 10 randomly collected seeds were weighted, and seed size and pappus length were measured. Based on this, plume loading, a direct measure for seed dispersal capacity, was calculated.

The results indicated that population age and size, the number of flower heads infected by *P. plantaginis* and flooding frequency significantly affected seed dispersal capacity. Population density and herbivory had only an effect on vegetative plant characteristics. The oldest and largest populations contained individuals with the lowest dispersal capacity, while in the youngest and smallest population occurred individuals that produced seeds with a high dispersal capacity. The seed characteristics of the oldest population are in equilibrium with population size and environmental conditions, while a founder effect may explain

the high dispersal capacity of the seeds in the youngest population. In this small population, biomass was also smaller, which may be due to genetic erosion as a result of the founder effect. Infection by *P. plantaginis* resulted in an increased dispersal capacity of the remaining seeds. Individuals growing on frequently flooded locations were smaller and produced a high amount of seeds with a high dispersal capacity, which can be related to the stress escape hypothesis. High population density or herbivory negatively affected vegetative growth, resulting in smaller individuals with a lower biomass.

### Diversity patterns in north-western Gabon and implications for conservation

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In order to identify key places for conservation in North-Western Gabon, an assessment of tree diversity between and within evergreen forests of the littoral region (Pongara National Park and Mondah forest) and of the Cristal Mountains was carried on. Diversity patterns were investigated by looking to the correlations of environmental parameters with alpha diversity and with species turn-over between and within regions.

Tree diversity was assessed by a short transect method (200 m × 5 m) where all individuals with DBH (Diameter at Breast Height) > 5 cm were recorded. Two localities were surveyed in Pongara NP, two in Mondah forests and four in

the Cristal Moutains. Diversity was assessed at the community level (one transect), locality level and region level (Littoral vs. Cristal Moutains). Rarefaction procedures were used to provide unbiased alpha diversity estimates. Dissimilarity matrices based on an unbiased beta diversity index were computed to estimate tree turnover. Finally, canonical ordination detected the correlations of environmental parameters with species composition.

The Cristal Mountains are one of the postulated Pleistocene rainforest refugia in central Africa. High alpha and regional diversity are therefore expected in this region. Indeed, alpha diversity and species, genus and family numbers were higher there than in the littoral. But as alpha diversity is positively correlated to topographic variability, it is difficult to distinguish between the role of historical factors and environmental factors in the present diversity pattern. In the littoral region, the western part of the Mondah forest shows an unexpected high alpha diversity, similar to some transects in the Cristal Mountains. As this forest is threatened due to the expansion of Libreville, we firmly recommend a strict conservation status for this area. In the coming years, we will further study the diversity patterns of the rainforests in Gabon both at the genetic population level and at the community level. This parallel approach will allow us to estimate the relative importance of historical effects and environmental effects in the current distribution of diversity.

#### **Influence of fish community structure on submerged macrophytes in shallow eutrophic ponds (Woluwe river catchment, Brussels)**

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Many shallow ponds have become more and more turbid during the past decennia because of eutrophication. Shallow eutrophic ponds consist of a complex system where biotic and abiotic factors interact with each other. Macrophytes play a

crucial role in the stabilization of a clear water status. In this study the relationship between submerged macrophytes and a series of factors that influence their abundance, such as fish populations, nutrients, turbidity, propagule bank and grazing were studied. Biomass and coverage of macrophytes were studied monthly during a period of four months together with environmental variables. Fykes were used to study the fish populations. Ordination and correlation techniques were performed on all sampled data to investigate the mutual relationships between fish community structure, environmental variables and macrophyte coverage and biomass. Additionally, soil samples were taken to study the germination of macrophytes from the propagule bank. Exclusion experiments were set up to study the effects of disturbance by fish and birds in four ponds classified based upon the concentration of chlorophyll a in the water: turbid (two), intermediate (one) and clear water (one). Macrophyte biomass and coverage percentages showed a transition in dominance from *Chara* spp. to *Potamogeton* spp. along a gradient of increasing turbidity. Macrophytes were completely absent in turbid water. The fishing campaign allowed us to compare the fish populations between vegetated and non-vegetated ponds. Pike, tench and rudd preferred clear ponds with a large amount of vegetation. Perch was mainly found in intermediate ponds whereas roach and carp were mainly found in turbid water. With an increasing turbidity the amount of benthivores, planktivores and piscivores also increased. These functional groups of fish species were negatively correlated with the total coverage percentage of submerged macrophytes. There was no correlation with piscivores, probably because they are situated at the top of the trophic pyramid and most likely influence macrophytes and phytoplankton through indirect interactions. Germination experiments showed that soils from clear water ponds with abundant vegetation all contained viable propagules. Macrophytes germinated in 43% of the sediment samples from non-vegetated ponds, including intermediate and turbid ponds where turbidity of the water column probably was one of the major limiting factors for macrophyte growth. In addition,

the exclusion experiments showed that in some cases disturbance by fish and birds was the main limiting factor for macrophyte growth and that macrophytes germinated even at high water turbidity. This study showed that macrophyte abundance is linked to fish community structure both through direct and indirect interactions.

### Physiological competitive ability of three species of the *Impatiens* genus: two invasive exotic species and an indigenous species

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This research project is part of the overall problematic of biological invasions. Several studies suggest that invasive exotic plants are more competitive than indigenous species, due to a putatively higher resource uptake and use. This project proposes to test this assumption and to establish some of the characteristics that are specific to invasive species within the *Impatiens* genus (Balsaminaceae). *Impatiens glandulifera* and *Impatiens parviflora* are both invasive species native to Asia, and they will be compared to a species indigenous in Europe, *Impatiens noli-tangere*. In order to measure the physiological aptitudes of each species, these three species will be grown in controlled conditions, under different light intensities and nutrient supplies. The growth of each species in conditions of intraspecific and interspecific competition will also be studied. Measurements will be carried out on a weekly basis in order to characterize growth kinetics of individuals (height of individuals and leaf area), their physiology (performance of photosynthesis, concentration of chlorophyll, concentration of nitrogen and other mineral elements), the allocation of their resources to growth (biomass estimation by measuring fresh and dry weight of aerial parts) and reproduction (by counting the number of flowers).

### Genetic variation of *Thlaspi caerulescens* (Brassicaceae) populations in the Luxembourg Ardennes: implications for conservation

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*Thlaspi caerulescens* J.&C. Presl (Brassicaceae) is an insect-pollinated, short-lived herbaceous plant species occurring both on heavy metal polluted soils (metallicolous ecotype) and on non contaminated soils (non-metallicolous ecotype). The species is a heavy metal hyperaccumulator and considered as a model species for investigating physiological and genetic processes implicated in heavy metal tolerance and accumulation. It is also a promising species for phytoremediation purposes. In the Luxembourg Ardennes, there are only non-metallicolous populations, which are currently threatened by fragmentation and loss of habitat. These populations contain particularly interesting genotypes for phytoremediation because they accumulate more heavy metals than the metallicolous ecotype. To study the possibilities for conserving these populations by *in situ* and *ex situ* methods, we investigated neutral genetic variation and population structure using high-resolution genetic markers (AFLPs). We sampled 20 individuals in 12 populations in the Luxembourg Ardennes in four different valley systems.

Three AFLP primer pairs generated a total of 63 unambiguous polymorphic loci. Nei's genetic diversity within populations expressed as expected heterozygosity was low ( $H_e = 0.066-0.213$ ) and was not correlated to population size ( $r_{\text{PEARSON}} = 0.17$ ,  $P > 0.10$ ). An Analysis of Molecular Variance (AMOVA) revealed an important genetic differentiation between populations (32%), of which only 3% could be attributed to differences among the four valleys. We found a higher correlation between genetic distance and geographic distance along the valleys ( $r = 0.717$ ,  $P < 0.001$ )

than between genetic distance and straight geographic distance between populations ( $r = 0.640$ ,  $P < 0.001$ ), indicating that gene flow occurred mainly within valley systems. In addition, a Principal Coordinate Analysis showed that the populations situated at the extremities of the valleys were genetically differentiated from populations situated in the centre of the study area.

Our results indicate that the distribution of genetic variability in the studied populations of *T. caerulea* is influenced by the landscape morphology (valleys) and that the main routes for gene flow between populations (seeds and pollen) follow the river system. For *ex situ* conservation purposes, as many populations as possible should be sampled throughout the range of the local populations, with a special focus on the populations situated at the edges of the distribution area as they contain private alleles.

### ***Crepidiorhopalon tenuis* in SC Africa: ecological niche and phenotypic variation in Cobalt and Copper shoot concentration**

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*Crepidiorhopalon tenuis* (S. Moore) Eb Fischer (Scrophulariaceae) is an annual metallophyte very abundant in the Eastern part of the “Katangan Copper Arc” (Democratic Republic of Congo) where it is most frequent in metalliferous sites (Cu). It is considered as a hyperaccumulator of cobalt (Co concentration in dried tissue  $> 1000 \mu\text{g/g}$ , i.e.,  $> 0.1\%$ ) and as a copper (Cu) accumulator. We characterised the ecological niche of *C. tenuis* and studied phenotypic variation of Cu and Co accumulation. Five metallicolous and two non-metallicolous populations were localized. Sixteen ecological factors were measured in 30

plots in each site (20 plots with *C. tenuis* and 10 adjacent control plots without *C. tenuis*). Twenty individual plants and soil samples were collected and analysed per site.

The most important variables contributing and correlated to the two first axes of a Principal Component Analysis (PCA) were percentage of soil surface occupied by rocks, proportion of bare soil, soil pH and copper content for axis 1, and organic matter, Fe, Zn, Mg and Ca content for axis 2. Three types of habitats were distinguished by their soil conditions: non-metalliferous (NM), natural metalliferous (NAM) and anthropogenic metalliferous (AM). Metalliferous (NM) differed from non-metalliferous habitats by having higher pH, Cu, Co and nutrient concentrations. For the sites with high Cu concentration in the soil, *C. tenuis* occupies microsites with highest Cu concentration. The results suggest that *C. tenuis* is a genuinely cuprophilous species.

A few plant samples analysed exceeded the hyperaccumulation threshold for Cu. The maximal Co concentration observed is  $600 \mu\text{g/g}$ . Non-metallicolous populations had low Cu/Co concentration ( $< 10 \mu\text{g/g}$ ). The correlation between Co concentration in soil and in plants shows that *C. tenuis*, so far regarded as a Co hyperaccumulator, might turn out to be a Cu/Co indicator.

### **Human impact on biodiversity in Greater West Tlemcen (Algeria)**

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The great Tlemcen, which lies north of the mountains of “Tlemcen”, is rich in plant species. This part of western Algeria is occupied by several species derived from forest degradation, which belongs to the class of *Quercetea ilicis* (DAHMANI 1996). Ecosystems of this set are currently exposed to a dual action: action of man (overgrazing, fire,

clearing, cutting, urbanization) and climatic hazard. Their action in synergy disturbs both the flora and fauna. The plant communities of this area, mainly composed of open land-based chamephytes (*Chamaerops humilis*, *Calycotome intermedia*, *Thymus ciliatus* and *Asparagus stipularis*), are threatened.

The scientific monitoring on the ground based on 150 floristic surveys achieved in 1994-1995 (HASNAOUI 1998) and in 2004-2005 using Braun-Blanquet (abundance-dominance) scale showed a change in physiognomy of the studied sites. Our work mainly focused on the effects of overgrazing and deforestation. The analysis of different eco-floristic surveys showed an increase in toxic and thorny species at the expense of palatable taxa. The species showing overgrazing (*Paronychia argentea*, *Evax argentea*, *Micropus bombicinus*) indicated the aggressiveness of the herd. The species used in traditional medicine (*Ammoides verticillata*) or cooking (*Thymus ciliatus*) have become scarce in the study area. Given this situation, it is necessary to take emergency measures to safeguard the endangered species. The establishment of a seed bank in the region is of great interest.

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### **Inbreeding depression and mating systems in plants: integration of individual, family and population dimensions among three species of *Vaccinium* with contrasting mating systems**

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Even though inbreeding depression (ID) might be detrimental to selfing plant species,

autogamy has evolved over time in the plant kingdom, resulting in a significant proportion (20%) of higher plants that are preferentially autogamous. A better understanding of ID and its effects on fitness remains a challenge, mainly because of its potential importance on the development of reproductive systems and life-history traits and of its implications for plant conservation and reproduction. Although many studies have focused on the negative effects of ID, predictions of its importance in a given population are still rare because this parameter is difficult to predict. This project will seek to determine (1) the expression of ID for individuals and several early stages of the life cycle; (2) the variation of the ID between lineages of descendants in two contrasting environments, and (3) the levels of genetic variation linked to the ID at the population level, by choosing populations with contrasting clonal structure. Our model study consists of three species of Ericaceae: *Vaccinium myrtillus*, *V. uliginosum* and *V. vitis-idaea*. Experimental hand-pollinations will allow us to compare individual reproductive success (selfing vs. crossing). They will be followed by embryo observations, seed germination and seedling survival. On the other hand, the structure of genetic diversity in natural populations will be screened to assess ID at population level (EST-SSR markers).

### **Implementation of the Walloon agri-environmental measures “strip of wildflowers” and “strip of arable plants”: scientific support**

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Taking biodiversity into account in agriculture management has become an important issue for the last decade. Agri-environmental measures are awareness tools available to highlight the role of farmers in nature conservation and management. In return for the efforts made for the environment, farmers receive subsidies. In the present

project, interest has been given in a first step to arable plant species. Arable plants are defined as plant species present in arable fields and having the same life cycle as cereals, therefore linked to crop. They have undergone important agricultural changes in Belgium in the last century and have consequently seriously declined. The agro-environmental measures notably try to preserve the last populations of arable plant species.

The project aims to ensure a scientific and technical follow-up of the installation of two agri-environmental measures: “strip of arable plants” and “wildflower strip”. There are two variants of “strip of arable plants”: sowing of arable plants or conservation of arable plants. The strip of arable plants are stretch of extensive cereal culture (without fertilizers, herbicides...). This project is divided into two parts: a support for technical questions (establishment, maintenance) and a follow-up study of the measures by the assessment of their success and by the installation of experimental tests.

### **Invasive plant species in urban plant communities: example and perspectives**

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Little is known about the effects of invasive plants on plant communities in urban environments. Based on previous observations, we focused on the invasive Japanese knotweed, *Reynoutria japonica* Houtt. (*Fallopia japonica*). In particular, this species invades disturbed urban habitats such as urban wastelands, by establishing dense and homogeneous clonal populations. Given its quick

spreading, we sought to assess the consequences of its success on colonized sites. In four urban wastelands near Paris, we analysed both soil and flora along transects running from the centre of invaded areas towards non-invaded areas. We found a dramatic depletion of floristic richness under the Japanese knotweed. We also showed that the Japanese knotweed increased the incorporation of organic matter and stimulated biological activity. Last we noticed the influence of organic matter content on specific richness, even if edaphic factors seem to be nothing but one of the many factors that shape plant communities. We thus suggest that the Japanese knotweed maintains a positive feedback, but that no other species benefits of this feedback due to the capacity of the Japanese knotweed to exclude them *via* high competitiveness. However, previous results had shown no difference between invaded and non-invaded wastelands. Those results stress the importance of the spatial and temporal dynamics of the Japanese knotweed as well as the one of the plant communities at risk. Longer term monitoring should allow us to check whether those effects remain localized and benign or can in the long threaten the urban flora.

Understanding plant invasions in urban context challenges both fundamental and applied ecology. In order to rethink the attitude to have towards exotics and invasive species, and to provide managers a scientific basis for achieving relevant management actions, we must gather further knowledge on invasive plant species in urban context. This is the aim of a new project in our lab, in particular with a PhD thesis meant to (1) measure the impact of invasive plant species on urban floristic diversity; (2) identify factors in urban areas that can help them to install and expand therein; and (3) understand the mechanisms explaining the success of invaders in urban context.

### **To germinate or not to germinate, that is the question! Germination ecology of the holoparasite *Cuscuta epithymum***

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*Cuscuta epithymum* is a rare and often threatened holoparasitic plant in dry heaths of north-western Europe. Two of the most critical stages in the life cycle of plants are seed germination and seedling establishment, which depend on degree of seed dormancy and presence of suitable conditions permitting germination. Germination timing in relation to local environmental conditions can constitute an important part of a species' adaptation to its habitat. For holoparasitic plants additional factors play an important role, namely host plants must be available at the time of germination for seedling establishment to become possible. Nevertheless, little is known about the seed ecology of holoparasites and hardly any information is available on how germination is timed in relation to its host phenology. To develop appropriate conservation management strategies for this species, more information is needed on its seed ecology. Therefore, some germination experiments were conducted on seeds of *C. epithymum*. Our results indicated that the seeds were water-impermeable (physical dormancy, PY) at maturity, in late summer. An 8-week period at 5°C followed by incubation at 23, 15/6 or 30/20°C resulted in 15-30% germination (MEULEBROUCK *et al.* 2008). Thus, in nature, only part of the seeds exposed to cold winter followed by warm spring temperatures potentially become water-permeable and can germinate in spring. However, when PY was broken by scarification, essentially all the viable seeds (ca. 65%) germinated following cold-stratification for 8 weeks and incubation at 23°C (MEULEBROUCK *et al.* 2008). This mechanism ensures that intact as well as slightly damaged seeds germinate in early spring, but not in autumn or winter or when they are exposed to the high temperature fluctuations occurring in summer. We concluded that these seeds have a combination of physical (PY) and physiological (embryo dormancy, PD) dormancy, which is interpreted as a double safety mechanism preventing germination at unfavourable times or places. After PY and

PD were broken, seeds did not require light or fluctuating temperatures for germination. Some loss of PD (after-ripening) can occur before PY is broken. Our data indicate that a portion of the seed crop remained physically dormant (PY) in spring and potentially formed a persistent seed bank, a strategy that eliminates the risk of a total reproductive failure in a particular bad year. In this way, the parasite may be adapted to the specific conditions that occur in managed heathland situated in a temperate climate. These results are published in MEULEBROUCK *et al.* (2008).

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### Relationship between genetic diversity and reproduction strategy in a sexually-propagated crop in a traditional farming system, *Citrullus lanatus* Matsumura et Nakai var. *citroides*, in view of establishing an adequate conservation strategy

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The general objective of the project is to determinate the relationship between the mode of reproduction and the genetic diversity of a species with sexual reproduction, cultivated and traditionally selected within a farming system: *Citrullus lanatus* var. *citroides*. The specific objectives are: (1) an accurate determination of the reproduction strategies of the species: floral morphology, rate of allogamy, possible occurrence of apomixy and influence of the way of reproduction on the inbreeding depression; (2) to establish the genetic structure of the species according to the geographical origin, the accession, and to estimate intra-population gene flow; (3) to propose a conservation strategy and a rational exploitation of

the species in function of the genetic structure and mode of fecundation.

The accessions will be cultivated in greenhouses and in the field and the different modes of controlled fecundation will be handled during two generations. Morphological and codominant (microsatellites) molecular markers will be applied to determine the genetic structure of the species in relation to its mode of reproduction. Conservation and rational exploitation strategies of the species will be proposed.

**Projet Interuniversitaire Ciblé «Appui à la création d'un diplôme d'études approfondies en biologie végétale et environnement à l'Université de Lubumbashi et remédiation multiscalaire des sols contaminés»**

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Projet financé par la Coopération Universitaire au Développement (CUD)

Le Katanga, aussi appelé «scandale géologique», possède plusieurs centaines de collines riches en cuivre, entre Kolwezi et Lubumbashi. Elles portent une végétation naturelle adaptée aux métaux lourds, riche de plus de 500 espèces, dont 40 espèces endémiques. La région de Lubumbashi a développé, depuis longtemps, une activité d'extraction et de transformation de métaux lourds, spécialement le cuivre et le cobalt. En de nombreux endroits, cette activité a contaminé le sol en métaux lourds, ce qui représente une source de préoccupation pour la santé et la qualité de vie des populations.

L'objectif général du projet est d'étudier la possibilité d'utiliser la flore des collines de cuivre

du Katanga pour restaurer les sites altérés par les activités minières, par le procédé de la phytostabilisation. Les objectifs particuliers sont de renforcer la capacité d'enseignement de recherche à l'Université de Lubumbashi dans le domaine de la biologie végétale et de l'environnement, en relation avec la contamination des sols par les métaux lourds, et la conservation de la flore naturelle des collines de cuivre. Les activités de recherche de ce projet de coopération au développement se structurent en quatre axes: (1) Sélection d'espèces tolérantes aux métaux lourds et mise au point des techniques de culture pour la phytostabilisation des sols contaminés. La graminée *Rendlia altera* est, actuellement, l'espèce privilégiée; (2) Communautés végétales métallocoles et biologie de la conservation des métallobytes menacées de disparition (en particulier l'endémique *Crepidiorhopalon perennis*); (3) Cartographie pédopaysagère des zones à phytoremédier; (4) Physiologie de métallobytes réputés hyperaccumulateurs de métaux lourds (en particulier *Haumaniastrum katangense*).

**Does inbreeding have an effect on leaf fluctuating asymmetry in the rare *Saxifraga rosacea* subsp. *sponhemica*?**

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*Saxifraga rosacea* subsp. *sponhemica* is a rare plant growing on scree slopes and rock faces of Central and Eastern Europe. Currently, the great majority of populations are small and isolated, but the plant was probably more widespread during the last glaciations. Small and isolated populations are known to be especially susceptible to inbreeding and genetic drift. To study how seriously inbreeding affected developmental stability in this plant, we measured fluctuating asymmetry (FA), an indi-

cator of developmental instability, for several leaf characters of plants inbred to various degrees and grown in a common garden. The plants were offspring from plants of a natural Luxembourg population for which flowers had been subjected to different pollination treatments: (1) bagged and left to spontaneously self pollinate; (2) open-pollinated; (3) hand-pollinated with pollen from the same plant (hand-selfing), with pollen from a different plant of the same population or with pollen from a different population. First, no correlation was found between FA and leaf size. Second, a mixed model ANOVA testing the effect of leaf side, measurement error and of directional asymmetry and antisymmetry indicated that two of the studied leaf traits showed real FA. Finally, orthogonal contrasts testing for the effect of the different pollination treatments on these two FA indices revealed that both spontaneous and hand-selfing significantly increased the FA of leaves, measured as the absolute value of the mean difference between the distances from the left and right leaf margins to the midrib, in the F1 generation ( $F = 5.32$ ,  $P < 0.05$ ). These results suggest that the developmental stability of plants of *S. rosacea* subsp. *sponhemica* is negatively affected by inbreeding. Conservation strategies should therefore take both the size and level of isolation of populations into account to avoid enhanced inbreeding.

**Plant Conservation: What about bryophytes? – The example of *Dicranum viride* (Sull. & Lesq.) Lindb.**

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Despite their high diversity and abundance in threatened ecosystems (e.g., tropical forests, peat-

bog, boreal forests), bryophytes are often disregarded in conservation programmes. However, their biological characteristics such as dominant haploid stage and short life cycle make them good biological models. *Dicranum viride* is a threatened European bryophyte protected by the Annex II of EU Habitat Directive, the Annex I of Bern Convention and is a Natura 2000 priority species. This moss, which mainly grows on bark of old deciduous forests, is distributed in Europe from Fontainebleau forest (France) to the west of Russia, but one population is known in the Pyrenees (Spain). Sexual reproduction of *D. viride* is unknown in France but it propagates asexually by breaking leaves. This strategy is thought to influence genetic diversity patterns, with possible consequences for species viability. We studied the genetic diversity of *D. viride* at different spatial scales (colony, tree, stand, forest, country) by sampling French, Spanish and German populations and by sequencing ITS1 (nrDNA), trnL-trnF (cpDNA) and rpl32-trnL (cpDNA) genes. The genetic diversity of *D. viride* was then compared with that of a closely related species (*Dicranum scoparium* Hedw.), known to perform frequent sexual reproduction. Overall, we found a very low genetic diversity for both species, most of which was due to singletons. These genetic patterns might be attributable to a recent demographic expansion of both species; this hypothesis will be studied in future work.

**Conservation des Orchidaceae de la région de Yaoundé (Cameroun)**

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Des inventaires réalisés ces dernières années sur la faune et la flore ont révélé que les collines des environs de Yaoundé sont des sites à haute biodiversité. Cependant la pression démographique due à la proximité de la capitale camerounaise met en péril leur conservation. Plusieurs espèces végétales et animales rares tels que *Microdracoides squamosus*, le gorille et le picatharte y sont soumis à des menaces sans cesse croissantes.

Nos récents inventaires dans le massif de Mbam Minkom ont révélé une grande richesse en Orchidaceae. En effet, nous y avons recensé 66 taxons appartenant à 26 genres sur moins de 100 km<sup>2</sup>. Parmi ces taxons, dix sont endémiques du domaine bas guinéen. Huit missions d'inventaires d'une durée totale de 44 jours ont permis la récolte de 113 herbiers fertiles et la mise en culture de 574 échantillons vivants en ombrière à Yaoundé. Actuellement 60 taxons représentés par 403 plantes y sont présents en culture. Trois espèces des genres *Diaphanthe*, *Rhipidoglossum* et *Stolzia* sont nouvelles pour la science. Deux taxons, *Oeceoclades maculata* (Lindl.) Lindl. et *Polystachya carnosa* P.J.Cribb & Podz., n'avaient pas encore été signalés au Cameroun.

Les milieux les plus riches en Orchidaceae sont les inselbergs (32 taxons) et les forêts secondaires (29 taxons). Les pics de floraison s'observent de juillet à août et de mars à mai. Cette richesse du massif s'explique essentiellement par la présence d'une grande diversité d'habitats. Le pied des collines est occupé par une forêt dense de plaine, déjà fortement secondarisée, tandis que les sommets abritent une végétation submontagnarde primaire, très riche en épiphytes. On y note également la présence d'inselbergs, milieux très favorables à la récolte des Orchidaceae.

### **Pollen flow and pollinator movements in fragmented *Primula elatior* populations**

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*Primula elatior*, an obligate outcrossing, insect-pollinated, long-lived perennial herb, is a widespread species in Belgium, but occurs in fragmented ancient deciduous forests. In the Brussels Capital Region, it is rare and its populations are usually small, located in small, isolated forest fragments. In such conditions we may expect genetic erosion, in particular in small populations. Gene flow is an important factor that has an influence on preventing genetic erosion. For many plant species, seed dispersal is restricted and gene flow mainly occurs by pollen. When the pollen vectors are insects, both the pollinator species present and their behaviour determine the efficiency of pollen transport and the distances over which pollen grains are exchanged. Therefore, it is important to characterise gene flow by pollen.

Using two highly polymorphic microsatellite loci we investigated (1) within- and among-population genetic variation and structure, including seedling and adult life stages, and (2) realized pollen flow within two small populations using paternity analyses. Pollinator movements and pollen dispersal were also investigated within four populations using fluorescent powdered dyes as pollen analogues, and the influence of individual plant size (recipient and dye source) and population size was tested. This indirect method was compared with the results obtained using paternity analyses (direct method).

There was a high genetic variation for seedlings and adults as expected for an obligate outcrossing species. Differentiation between populations of both age classes was not significant or low, which implies moderate or high levels of recent / historical gene flow. Within populations no inbreeding could be detected. Dye dispersal distances showed a leptokurtic distribution, resulting in deposition of the majority of pollen grains close to the source plant and only incidental dispersal over larger distances. The maximal distance of dye transfer was 314 m. Floral display of the recipient individuals was only significant in two populations when distance to dye source was held constant. When small and large dye sources were compared within populations, this was only significant for one population and there was a difference in response in distance to dye source.

When within-population patterns of large and small dye sources were compared between populations there was an influence of population size. For the paternity analyses with only two highly polymorphic microsatellite loci, it was possible to determine a potential father for almost half of the seedlings with 95% confidence in both populations. The estimates of pollen dispersal found for dye movement were in agreement with the effective pollen flow based on paternity analyses.

### **Variation in seed germination and seedling growth of *Aster tripolium* within and among populations in northern French and Flemish salt marshes**

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This study aims at assessing the effect of population size and age, population density, flooding frequency, infection by *Paroxyna plantaginis* and herbivory on germination percentage and seedling growth of *Aster tripolium*. The study was realized in six populations along the northern French and Flemish coast. We established 40 plots in each of the six populations. We measured vegetative (plant size and biomass) and generative plant (number of flowers, number of seeds per flower head) characteristics of the central individual in each plot, and randomly collected three flower heads. The pappus of these seeds was removed, and the seeds were put in Petri dishes with filter paper moistened with distilled water. The number of germinated seeds was counted every five days until stagnation occurred. We measured the length of the cotyledons, and transplanted the seeds in potting soil. The number of leaves, leaf size, and shoot length were measured on a regular basis.

Each of the factors had a significant impact on both generative and vegetative characteristics of the maternal plant and its offspring. Maternal plant biomass was positively correlated with ger-

mination percentage, cotyledon length and shoot length. Since individuals with the highest biomass occurred in the oldest and largest population, seed germination percentage and seedling growth increased with population age and size. Similarly, herbivory negatively affected plant biomass and hence seed germination and seedling growth. However, the strength of this effect decreased with time since germination and differences were no longer significant after 15 weeks. The same applies for flooding frequency: a high flooding frequency resulted in smaller individuals of which the seeds had a lower germination percentage and the seedlings grew slower.

### **Germination cueing in seeds of four Caryophyllaceae emerging in vegetation gaps**

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Every species has its own specific requirements for breaking dormancy and inducing germination, depending on species' phylogeny, geographic distribution, habitat and life cycle. In this study we focused on germination requirements of four closely related species, *Moehringia trinervia* (Clairv.) L., *Stellaria nemorum* subsp. *nemorum* L., *S. holostea* L. and *S. graminea* L. These species all rely on some sort of disturbance in the vegetation for seed germination and subsequent seedling establishment. They are phylogenetically and geographically closely related, which means that differences in dormancy breaking and germination requirements between the studied species can be attributed to differences in habitat or life cycle. In a first experiment, timing of seedling emergence was recorded for seeds sown in natural conditions simulating disturbed sites in an experimental garden or under a forest canopy. A second series of experiments was performed in controlled conditions to test whether or not (1) seeds of these species have primary dormancy; (2) dormancy can be relieved or induced by after-ripening treatments; (3) nitrates, light

and fluctuating temperatures can induce germination. Our results show that seeds of all species, except *S. nemorum*, are dormant at the moment of dispersal. This prevents the seeds from germinating immediately after dispersal, increasing the seeds chances of becoming buried. Dormancy was relieved by either moist storage at high (23°C) or low (5°C) temperatures or by dry storage at room temperature (about 20°C). Once dormancy was broken, seeds could germinate in response to environmental signals such as light, fluctuating temperatures and nitrates, which are indicators of disturbances in the vegetation. We concluded that the response to dormancy breaking and germination inducing treatments was different for each species and, in our opinion, mainly related to habitat preferences of the species.

**Pollinator movement in the intensive agricultural landscape using fluorescent dye particles: *Primula vulgaris* as a model species**

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*Primula vulgaris* is a self-incompatible, insect-pollinated perennial herb that is rare and declining in Flanders, northern Belgium. It is restricted to a network of fragmented populations connected through linear landscape elements (such as ditches) in areas of intensive agriculture around the city of Bruges. Modern intensive agriculture has led to a decline in biodiversity in Western Europe, with habitat loss and fragmentation being a key issue for many plant species. The resulting small and isolated populations are susceptible to genetic, environmental and demographic stochasticity and are likely to express inbreeding depression, high levels of genetic erosion, low reproductive success and disruption of gene flow patterns. Pollen flow between populations can counteract the negative effects of habitat fragmentation. However, insect-dependent flowering plants are more sensitive to habitat fragmen-

tation since there is a widespread decline in pollinators and there seems to be a limited capacity of pollinators to move between isolated plant populations in fragmented habitats.

The movement of pollinators of *P. vulgaris* in the intensive agricultural landscape was studied using fluorescent dye particles as pollen analogues in five dye source populations and 15 recipient populations. We investigated (1) whether there was transfer of dye particles within source populations and between source and recipient populations; (2) whether pollinators use the linear landscape elements between populations for foraging; (3) what is the effect of the length of the linear landscape elements connecting source and recipient populations.

Our experiment showed a high activity of pollinators within dye source populations, with 81.8% to 96.7% of the individuals showing fluorescent dye deposition on stigmas. Also between source- and recipient populations dye transfer could be detected: 0 to 80% of the individuals in recipient populations showed dye deposition on stigmas. The distribution of dye dispersal was leptokurtic, with the majority being deposited within close proximity of the source and long-distance transfers being rare. The maximum average distance over which dye was transported varies from 96.3 m to 1087.4 m. Dye particles were found on stigmas of other flowering plant species occurring in the linear landscape elements separating populations. On population level, the distance to the dye source was significantly correlated to dye transfer.

**The differentiating effect of macrophytes on zooplankton composition in five eutrophic shallow ponds of the Woluwe river, Brussels**

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Shallow, nutrient-rich ponds tend to be either in a clear or a turbid water state. Macrophytes play a key role in maintaining the clear state,

thanks to a series of feedback mechanisms. One of these is the control of phytoplankton by large zooplankton that finds shelter in the vegetation. In many studies, only the pelagic zone of ponds is sampled, so there is not much information available about the possible effect of different macrophytic vegetations on the zooplankton communities. The main objective of this study was the determination of the relation between vegetation type and the densities and community structure of the zooplankton associated with vegetated habitats. Five vegetated ponds in the Woluwe valley were monitored monthly from July till October 2005. Only those vegetated habitats that made up a significant part of each pond were considered. Environmental variables (e.g., vegetation biomass and cover, water depth and nutrient concentrations) were measured and different zooplankton samples were collected within the vegetated zones or in the open water. Three potentially influencing factors were considered: the habitat type (seven macrophyte species or combinations of species, and open water), the between-month variation (a part of the seasonal evolution) and the between-pond variation. To test for which of these factors differences in the zooplankton communities were the most pronounced, the absolute and relative abundances were compared and multivariate analyses (PCA and cluster analyses) were performed. A RDA was undertaken to correlate zooplankton subgroups with environmental variables. Also, Shannon-Wiener diversity indices were calculated for each habitat type.

Zooplankton density as well as taxon composition varied between the different habitats. One pond (Grote Mellaertsvijver) contained high densities of small, pelagic zooplankton (mainly rotifers) as a result of its turbid character. Relative abundance comparison, PCA and cluster analyses revealed higher affinity of zooplankton between habitats within the same pond than between habitats of the same macrophytic species in different ponds. There was considerable between-month variation, with *Daphnia* populations increasing in autumn. Shannon-Wiener indices of total zooplankton were the lowest in structurally open habitats, and higher in the denser vegetation. Possible explanations for the high within-pond simi-

larity are: (1) the influence of dominant (with respect to cover) macrophytic species; (2) the homogenizing effect of high flushing rates; (3) the determination of the zooplankton communities by local (i.e., characteristic for one pond) environmental conditions. Future studies should focus on rare zooplankton taxa in order to reveal typical associations with macrophyte species, irrespective of the location of these macrophytes.

**Distribution and ecological niche of the *Armeria arenaria* (Plumbaginaceae) population from Cap Lardier (Var), bio-indicator of the Maures littoral flora conservation state**

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*Armeria arenaria* is a rare littoral species, growing in a haloresistant plant community. Within protected areas, habitats of *A. arenaria* are situated in vulnerable zones where paths for tourists are often installed. Our study, supported by the National Park of Port-Cros, deals with the distribution and the ecological niche of a population of *A. arenaria* localized in the protected site of Cap Lardier (Var, France). Our approach was based on an exhaustive cartography of *A. arenaria* demes, and on species relevés in presence or absence of *A. arenaria*. The OMI (Outlying Mean Index = "Marginality") distinguished the two types of stations (where *A. arenaria* is present/absent). Moreover, the slope, the slope orientation and the value of pH delimit the realized niche of *A. arenaria*, whereas the availability in fine soil and trampling act on demographical structure and stability of *A. arenaria* demes. At the sampling stations level the relevés support the haloresistant community associated with *A. arenaria* and show an appearance of ruderal species, revealing the disturbance of this littoral zone.