Abstract

Charophytes are macro-algae that colonise a wide variety of brackish and freshwater ecosystems and are widely recognized as pionneer and bioindicators of oligo-mesotrophic waters. Moreover, charophytes play a major role in several processus driving the ecological and biochemical conditions of water bodies : they provide habitats, refuges and foods for several organisms, enhance water transparency and can accumulate heavy metals and organic pollutants. The erosion of the diversity of these plants as a consequence of habitats destruction, loss of dynamism of lentic and lotic ecosystems and eutrophication has been noticed. The Red Lists published in various European regions prove that most species are strongly threatened and thus must be protected urgently. The setting up of long-term efficient conservation plans requires that precise knowledges on ecological requirements of species have been acquired. Nevertheless, the ecology of charophyte species has been few studied until now.

This thesis work aims at determining the responses of different charophytes species present in alpine regions to environmental gradients at the regional and the local scale, in order to predict the potential evolution of their distribution in a climate warming context and to propose relevant management recommendations.

At the regional scale, environmental information acting at the scale of water body or watershed and data on species occurrence were obtained in 1402 localities distributed accross the whole swiss territory. They were used to fit species distribution models. The obtained models were used as a basis for the prediction of current and future (under a climate change scenario) species occurrences in the 21'000 localities listed in Switzerland. Then a sub-sample of 78 charophytes water bodies was considered to analyse inter-species differences in macro-habitats by considering supplementary physico-chemical parameters.

At the local scale, a 4 years survey realized on a single site offered the opportunity to study the response of a maximum number of species to proximal variations in water level and temperature. The data collected during this survey allowed the analysis of the response of the aquatic plants community, in term of composition and diversity, to water level fluctuations and in particular to droughts. Moreover, the relationship

between biological and phenological traits of one species particularly and the accumulated heat over time and the water depth was also addressed.

The two first studies demonstrated that regional environmental parameters related to the water body size (whose depend the system functionning and the micro-habitats diversity) and to climate play a major role for the distribution of charophyte species in Switzerland, the water quality taking part lastly. All species do not occupy the same habitat and display different tolerances to the considered environmental parameters. On the horizon 2050, under a scenario that predicts a warmer and drier climate, the species that currently inhabit preferentially large deep lakes would decrease (potential « losers », eg. *Nitellopsis obtusa*) whereas species associated to small water bodies susceptible to dry out at the end of summer will probably increase their distribution area (potential « winners », eg. *Chara vulgaris*).

The following studies related to the temporal monitoring of a semi-permanent gravel-pit showed that the variability of inundation conditions drives the dynamic of macrophyte community, i.e. its composition, richness and heterogeneity. The diversity of the assemblage, and particularly the charophyte species richness, was maximised the years following an autumnal drought-spring inundation cycle (timing) and by intermediate intensity of disturbance (duration of drought from 6 to 10 weeks). The variety of responses of species to depth, to duration and seasonality of droughts contributed to the variability of the community structure in space and time. Charophyte species succeed each other along a gradient of duration of drought that occurred during the year preceeding the observation, from *Nitella batrachosperma* which colonises shorelines exposed to the air during 3 months to *N. obtusa* which grows in permanently inundated areas. For *N. obtusa*, the low growth rate and the preferential resources allocation in the development of vegetative organs and propagules explains its sensitivity to disturbances, hence its preference for permanently inundated habitats. This thesis work also showed that *N. obtusa* is able to adapt to permanent shallow habitats by reproducing sexually.

Consequently, according to the species responses to local variations in water temperature and water level and to their distribution in other geographical regions, several species would have adaptation abilities to a wider variety of habitats than those

listed in Switzerland. Thus, the vulnerability of species to global changes will depend on their inherent biological traits (adaptative capacity, life cycle) and on extrinsic factors related to habitat modifications and to the politics and tools that the governments will adopt.

Finally, despite there is still a lack of data that would help to understand and predict precisely the evolution of species distribution facing environmental changes, human pro-active means have to be established to insure the survival of species by insuring a sufficient number of suitables habitats. Strategies focused on fight againt eutrophication, on the promoting of water level fluctuations and on the conservation of cold waters habitats would be of great significance.

In order to enhance the understanding of charophyte vulnerability to global changes, researches at a larger scale of study (eg. Europe) and temporal monitoring of charophyte sites would both be necessary. The creation and the improvement of monitoring programs of aquatic ecosystems are essential for the development of integrated and precise species distribution models. This integrated approach is necessary for the establishmnent of long-term efficient management plans.

Keywords : charophytes, characeae, physico-chemistry, land-use, climate, climate warming, occurrence, abundance, diversity, life cycle, degree-day, depth, disturbance, drought, plasticity, resilience.