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Climate Impact Research—Contributions and Options of the German ESB

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Abstract—Previous forecasts about consequences of climate change have given rise to expectations of drastic changes to the composition of natural systems; the loss of biodiversity seems bound to continue. Whilst the focus is on organisms and biocoenosis, the intraspecific loss of allele diversity can play a very major role. Current strategies for monitoring and forecasting climate impact are pursued at two levels at the German ESB. Genetic monitoring is currently performed on selected sampling specimens, in order to be able to identify inferences about the automatic adjustment of population-biology processes in the environment and the contamination of habitats. These can be applied as warning signals of demographic change in the population. Studies at organismic level concentrate on evaluating biometric parameters in the common spruce (Picea abies). In combination with meteorological data, forecasts of future trends can be designed on the basis of regional climate models. To monitor biocoenosis changes, a "Species Information System" was developed additionally a few years ago. Carabid beetles, forest floor vegetation and freshwater fish have been selected as indicator groups in this pilot study; initial characterizations of all sampling sites have been completed.

Keywords: environmental specimen banking, climate impact, biodiversity, genetic monitoring, species information system

INTRODUCTION

We have been observing changes in the living environment caused or amplified by climate change all over the world in recent years. In many cases these involve changes to distribution which are directly controlled by the rise in temperature and ecological valence of species. Temperature-related secondary effects also frequently play a role in this, for example changes to competitive relationships or pathogens. In addition to distribution shifts, thermophilic species often demonstrate an expansion of their range while species adapted to cold, show reduced distributions. In some cases, these changes are well known in the general public. But there are a lot of other changes with high relevance for humans and our environment, which are not similar famous.

One example from Germany is the distribution of disease vectors. The objective of a study, which was commissioned from the Federal Environment Agency (Umweltbundesamt, 2003) in the context of climate change, was to look into whether diseases transmitted via insect vectors which had died out in Europe could spread again due to the temperature changes over the last few years or whether new diseases could appear. It appears that there are now stable populations of the Anopheles mosquito (*Anopheles* spp.) which could be a potential carrier of malaria and the Asian tiger mosquito (*Aedes albopictus*) which is a potential vector for yellow fever and dengue fever. If the temperature goes on rising, the appearance of malaria in temperate zones cannot be ruled out.

Another example is the Asian harlequin ladybird *Harmonia axyrides*. This beetle has a long and partly successful history in the biological control of aphids. The natural distribution range of this species, which occurs in a number of colour variants, stretches from Siberia via China and Mongolia to Japan and Korea. It was introduced to France in 1982 under quarantine conditions, the first free-living beetles were identified in Hamburg 1997. The beetle first bred on a large-scale in Germany in 2007. Now it has at least three high damage potentials in Germany:

(1) Ecological damage by displacing native ladybirds and other beneficial insects due to increased competitive ability in the ecological niche concerned and the capacity for intraguild predation (i.e. harlequin ladybird larvae and adults also eat other species of ladybirds).

(2) Capacity to become a nuisance or hygiene pest due to aggregation of large numbers of beetles in potential overwintering places in houses and around habitation e.g. entering houses and causing nausea or, in the worst cases, allergic reactions in the inhabitants due to the release of haemolymph which contains strong-smelling compounds such as methoxypyrazine.

(3) Damage to grape and fruit crops (especially apples, pears and berries). This is mainly caused during pressing, when any beetles present release relatively large amounts of their haemolymph fluid. Experience from Michigan is that this spoils the wine causing damage amounting to millions under certain circumstances when the following factors come together (Cai *et al.*, 2007; Koch and Galvan, 2007).

Independent from the examples, at any given place all the changes in distribution are expressed in a change in biodiversity—frequently even a loss of biodiversity. And conserving biodiversity is very important in relation to climate change.

Biodiversity is very often interpreted purely as species diversity and a large number of survey programs are focussed on this. However, according to the Convention on Biological Diversity (CBD, Rio de Janeiro, 1992), the biodiversity of a region comprises different levels (stages) of diversity which can be structured (in simplified form) as follows: (1) Genetic diversity: on the one hand the genetic diversity of all genes within a species (=genetic variation), on the other hand the entire genetic variability of a biocoenosis or an ecosystem.

(2) Species diversity: the number of species in an ecosystem.

(3) Ecosystem diversity: the diversity of habitats and ecosystems.

(4) Functional biodiversity: the diversity of ecological functions and processes taking place in the ecosystem (for example catabolism capacity).

Whilst the focus here is on organisms and biocoenosis, the intraspecific loss of allele diversity can play a very major yet unfortunately underestimated role.

Regarding this background, the German ESB-Program developed strategies on three different levels for the observation, description and prediction of climate impact:

- a genetic monitoring,

- a phenological monitoring as evaluation of biometric data and climate prediction models, and
- a biocoenoses monitoring, that is called "Species Information System".

GENETIC MONITORING

Genetic monitoring is currently undertaken in the pilot study "Climate change and change in allelic diversity of ESB species". Main goal of the study is the explanation of the dynamics of population biology processes by analyzing the composition of natural populations using molecular methods. This study also contributes to quality assurance by elucidating alterations in ESB time series.

Concerning the interaction of climate change and biodiversity it is quite accepted that severe changes in the structure of natural populations have to be expected (Thomas *et al.*, 2004). Unfortunately the decrease of allelic diversity is more or less neglected in the focus of public opinion, even if it is the first step to a demographic collapse of populations and therefore can be used as warning signal of demographic change.

For this study four species of the ESB species set were selected: eelpout (*Zoarces viviparus*), bream (*Abramis brama*), common mussel (*Mytilus edulis*) and earthworm (*Lumbricus terrestris*). The study is divided into two parts: In part one the allelic compositions of populations of these species are analyzed by using individuals, in part two retrospective genetic analyzes of pooled samples of the ESB routine program are run.

In the years 2009 and 2010 a representative sample of 30 individuals per species is taken at three selected ESB sampling sites and screened by microsatellite analyzes (SSR). PCRs are run with ten microsatellite primers per species (Presa *et al.*, 2002; Ghasemi *et al.*, 2007; Velavan *et al.*, 2007; Gardeström *et al.*, 2008; Hamilton and Tyler, 2008, SSR primers for eelpout are currently in development). Fragment length polymorphisms are visualized with the aid of a Megabace 1000 sequencer (GE Healthcare). Aim of this particular project is to collect information about the status quo of allelic diversity in animals used as monitoring organisms and to check whether alterations in the composition of allelic diversity can be observed in these two years.



Fig. 1. Variation in needle weight and shoot lengths (left) and excessive cone production (right) on Norway spruce (*Picea abies*).

In the second part of the study retrospective genetic analyzes of stored homogenate samples of theses species are run. These samples are made up of cryomilled powder from a varying number of individuals. Aim of this particular part of the project is to verify the suitability of these samples for surveying alterations in the composition of alleles in the previous 25 years. These time series guarantee a sufficient number of generations.

A further goal of this study is the comparison of allelic diversity of homogenate samples to individual samples. For this reason individual bream plasma samples from 2002 to 2009 might be used as a helpful link for the interpretation of results.

PHENOLOGICAL MONITORING

Selected characteristic values of all sampled indicator organisms are evaluated in biometric sample characterization in the routine process of the German ESB. Essential conditional parameters of the samples are collected, e.g. size, age, weight and vitality parameters of the individual specimens. These biometrical data predominantly serve for standard verification purposes, facilitate the comparison of samples of different spatial and time origin and allow for normalization of analytic results. The biometric data may also be used as endpoints in the assessment of environmental effects (Paulus *et al.*, 2005).

Examples of biometric parameters are growth length and thousand needle weight for spruce trees (*Picea abies*) and pines (*Pinus sylvestris*) and shell length and shell or soft body weights for blue mussel (*Mytilus* spp.) and zebra mussel (*Dreissena polymorpha*) as well as shell thickness of eggs of herring gull (*Larus argentatus*) and feral pigeon (*Columba livia* f. domestica).

For climate impact studies, the Norway spruce (*Picea abies*) and other tree species can be used as ideal phenological indicators. Thus, for example, there is an evident correlation between climatic conditions and changes in needle weight and shoot length, the production of so called stress shoots ore an excessive cone production (Fig. 1), which is under influence of higher temperature very often



Fig. 2. Initial characterization of carabid beetle biocoenoses by a) dominance structure, b) ecological guilds, and c) selected indices, exemplarily for a sampling site in the Dübener Heide (Lermen, 2005).

accompanied by the Spruce Bark Beetle *Ips typographus*. So could Teubner (2005) demonstrate that periods of drought of at least 20 days in the year of bud development cause lower needle weights in regions with shallow soils. High precipitation (rain) during winter in regions with planosols causes lower shoot growth as an effect of the sensitivity of Norway spruce to stagnant moisture.

Options of biometric parameters of Norway spruce in the German ESBprogram for climate impact studies are:

(1) To find out, which weather parameters have an influence on which biometric parameters in the individual sampling areas.

(2) To find out, how weather parameters, which affect biometric development, vary according to the predicted climate change (regional climate prediction models).

(3) To predict the development of the biometric parameters and hence the physiological condition of the spruce in Germany.

BIOCOENOSIS MONITORING

A further option of German ESB for observation, description and prediction in the context of climate impact is a "Species Information System" in the form of biocoenosis monitoring, which was developed a few years ago. The objective thereby is a systematic recording and evaluation of selected groups of animals and plants as indicators of habitat quality and habitat change. As indicator groups have been selected:

- the freshwater fish for all freshwater sampling sites,

- the carabid beetles for all forest sampling sites, and

- the forest floor vegetation, also as indicator for all forest sampling sites in the German ESB.

Results of this pilot study are in addition to the selection of the indicator groups the standardisation of survey methods, a baseline survey on freshwater fish and carabid beetles for all sampling sites and also the derivation of suitable indicator variables. These indicator variables are commonly used to describe animal biocoenosis. In combination with each other, they are excellent indicators for long time changes in the environment, caused for example by climate change: In this respect, examples for carabid beetles are number of species, abundance, dominance, species diversity, species turnover rate, flight dynamics, body size, annual cycle, endangered status, and forest-affinity index. Using these variables, a initial characterizations of all sampling sites have been completed (Fig. 2) and can be used as starting point to detect changes over time.

SAMPLING CONTINUITY

For all these studies it should not be forgotten that the presence and therefore the availability of the sample species itself can also be endangered by climate impact. This applies, for example, to the eelpout (Zoarces viviparus) in the marine sampling areas, which is known to be displaced by increases in water temperature through the oxygen limitation of thermal tolerance (Pörtner and Knust, 2007). It also applies to the spruce (Picea abies), which is increasingly endangered by the bark beetle *Ips typographus*. This secondary pest benefits from high temperatures and can then, due to high population density, become a primary pest destroying large areas of spruce forest. This happened a few years ago in the Bavarian Forest National Park and currently similar disasters appear to be developing at higher altitude in the Berchtesgaden Alps. And it applies to the zebra mussel (Dreissena polymorpha), which is coming under competition pressure in some watercourses in Germany from its sister species Dreissena bugensis. This invasive species is a stronger competitor and colonises more readily than D. polymorpha (Baldwin et al., 2002; Ricciardi, 2004; Wilson et al., 2006) and may benefits from the increase in temperature (Thorp et al., 2002).

The vigour and distribution of the sample species therefore need to be constantly monitored at the sampling sites. At the same time possible replacement species must be investigated in order to continue to ensure ecological information if a specimen type is lost.

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