G·BiKE

Genetic Variation - key to adapting to environmental change

Main Findings

Humans depend on ecosystems. We need to act and stand guard against the loss of biodiversity caused by human activities and climate change, also for our own sake.

- **Genetic diversity** is variation at the DNA level. Genetic diversity is the basis of biological differences, both between species and among individuals of the same species.
- Because of genetic diversity, some individuals are better suited to survive and reproduce in certain conditions, and will be favoured by **natural selection.**
- Genetic diversity increases the probability of species survival, especially during environmental change. **Genetic diversity is therefore crucial to the resilience of ecosystems** and the production of ecosystem services.
- Populations that are small and isolated rapidly lose genetic diversity. Therefore, management should focus on **enlarging and connecting populations** above critical thresholds, to retain the capacity to adapt genetically to change.
- **Measuring and monitoring** genetic diversity enables us to better evaluate species health, genetic variation and the exchange of genetic variation across different populations (gene flow) to improve the management of biodiversity and natural resources.

Key Recommendations

Preventing more extinctions and safeguarding ecosystems requires immediate and comprehensive action.

- Conserve and restore genetic diversity to sustain the viability of species and ecosystems and increase their resilience to climate change.
- Implement genetic methods for analysing and monitoring genetic variation in species of special concern for ecosystem services or conservation. These important conservation tools provide science-based information to managers and policy makers.
- Improve species conservation programmes so they safeguard and strengthen genetic diversity. Plants and animals have adapted to their environments for several hundreds of years, and their genetic adaptations make it more likely that they will survive environmental changes.
- Modify guidelines for national reporting on the EU Habitats Directive, Birds Directive, Marine Strategy Framework Directive and Water Framework Directive to explicitly recommend that genetic diversity and gene flow in species are assessed and monitored wherever it is relevant.

Photo: Adaptive colour variation among European pool frogs (*Pelophylax lessonae*). Dark individuals (outermost individuals, from northern Europe) heat up more easily than light-coloured individuals (central, from Southern Europe), which is advantageous in cold regions. (photo: Per Sjögren-Gulve).

The Research

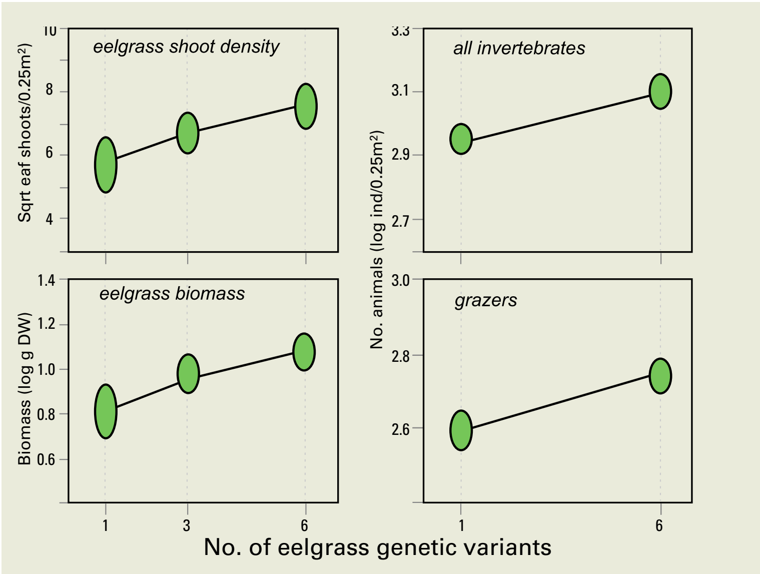
Species diversity increases resilience

Under predicted climate scenarios, maintaining healthy, intact ecosystems will become increasingly important to avoid the worst impacts of climate change.

A recent review of 46 independent scientific studies showed that biodiversity increases ecosystem resistance to a broad range of climate events: wet/dry, moderate/extreme and short term/long term. No matter the climate events, the research showed that low-diversity communities (1-2 species) changed by 50% while high-diversity communities (16-32 species) changed by only 25%. A global review of 85 independent studies showed that crop yields and ecosystem services were enhanced when there was a diversity of different species of pollinators and pest enemies. Of the negative impacts that landscape simplification had on ecosystem services, up to 50% were in fact caused by a lack of biodiversity among the service-providing organisms. Biodiversity has positive impacts on ecosystems and ecosystem services.

... and so does genetic diversity

A scientific investigation found that higher genetic diversity led to enhanced plant growth and density in eelgrass, even during an exceptionally hot summer. It also had a positive impact on the surrounding ecosystem's invertebrates when compared to eelgrass colonies with less genetic diversity. Similarly, another investigation found that higher genetic and species diversity increased the drought tolerance and productivity of grasslands.



The characteristics and the variation between individuals are embedded in their DNA. This variation also determines their vitality and ability to adapt to changes in the environment. Individuals with favourable adaptations and gene combinations survive better and/or produce more offspring. Provided that populations are not too small and do not lose too much genetic variation, the favourable genes will be passed on to future generations. In such cases, native species that are naturally part of the local ecosystem, having evolved together over several hundreds of years, may be better able to cope with climate changes. More genetic diversity also provides insurance for coping with future environmental change because the more gene combinations that are available, the greater the options in an uncertain future. A recent review found that gene flow through immigration has helped prevent population extinction in several species of animals and plants. Yet, augmented gene flow is rarely used as a conservation strategy. In conservation actions for small isolated populations, the authors advocate that actions should shift away from managing populations in isolation, and toward widespread restoration of gene flow.

How genetic tools can promote sustainability

Genetic tools for conservation can improve resource management and outcomes. A genetic assessment of Eastern tiger salamanders concluded that the populations of individual ponds had too little genetic variation. This finding led to targeted recommendations to improve conservation and the salamanders' access between ponds to reach conservation goals.

Genetic information can help make more effective environmental management decisions. Ash dieback disease is caused by an exotic fungus that decimated European ash populations within fifteen years. Research showed that detailed genetic information can accurately predict the sensitivity of remaining ash trees to this pathogen. This can greatly aid forest managers to select resistant trees and help reinforce forests. Other research demonstrated that genetic tools can identify which trees are better able to adapt to a warmer climate, with the potential to alleviate the predicted negative consequences of climate change.

Likewise, genetic information can aid forest managers to decide which genetic variants to plant in different sites under climate change scenarios, thereby increasing the future resilience of forests.

Simulations of forest growth indicates that without genetic selection of mother trees, the resulting growth of Valley oak (*Quercus lobata*) in California by the end of this century,will on average be negative, whereas use of genetically selected trees allows for a net positive forest growth.

Genetic techniques have helped save endangered species like the Florida panther. In the early 1990s, only 20-25 panthers remained and many had heart abnormalities and low sperm quality because of low genetic variation and inbreeding. On the basis of genetic screening, eight mountain lions from Texas were relocated to introduce new, favourable genetic material and restore the historical gene flow between the two subspecies. A scientific evaluation showed that this genetic intervention and other management actions have decreased the genetic defects and increased population size.

Figure: Expected % change in relative growth rate of Californian Valley oak by 2080.

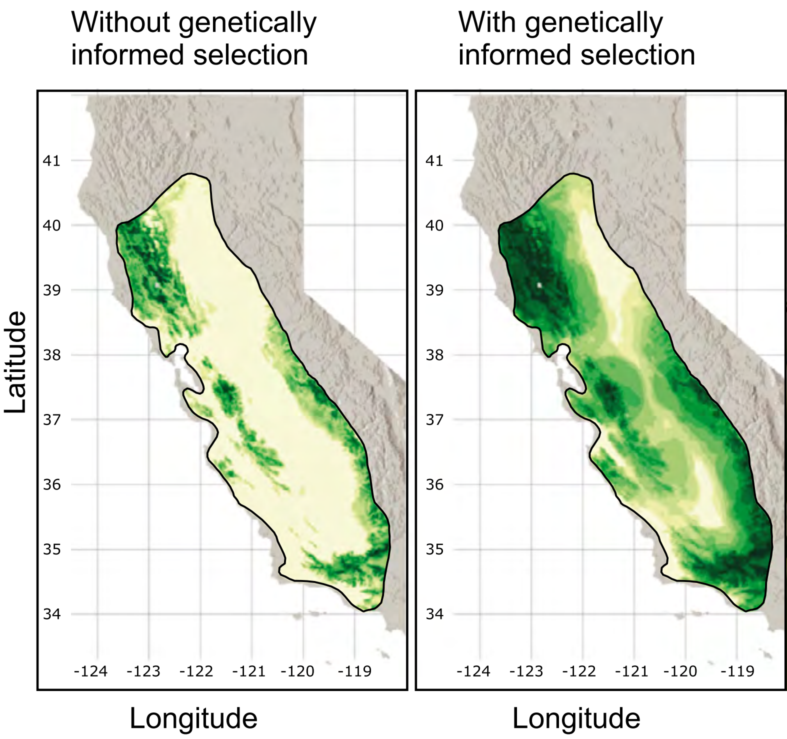
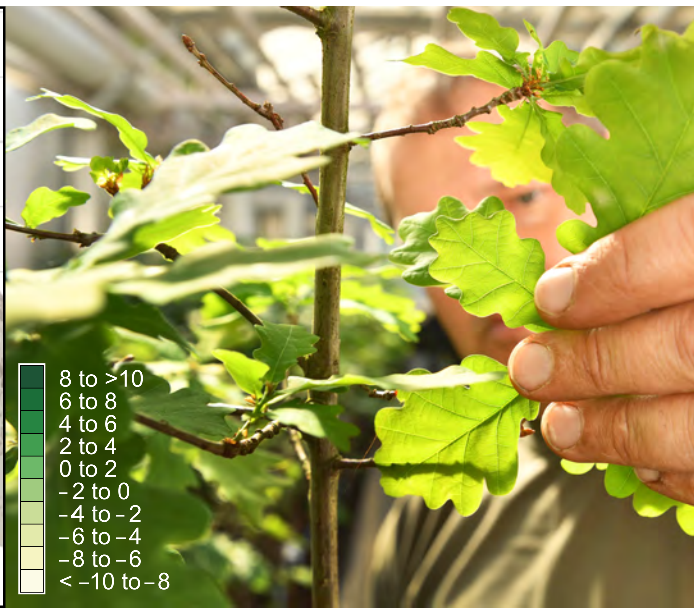


Photo: genetic selection of European oak (*Quercus robur*) to improve robustness to climate change



Recommendations for policy and management

This policy brief and its recommendations have been produced within the G-BIKE COST action, which involves more than 120 researchers and practitioners from 42 countries. Similar conclusions for the coming decade's environmental conservation and management work are made in the IUCN. To maintain and restore the adaptive ability of our ecosystems and their services, managers and policymakers need to pay much greater attention to genetic diversity and the adaptive potential of natural (non-commercial) species. This means more use of genetic techniques to improve species conservation. More monitoring and assessment of genetic diversity in all EU countries is advised by modifying the guidelines for status assessments of species in light of the Habitats Directive, the Birds Directive, the Marine Strategy Framework Directive and the Water Framework Directive.

Genetic diversity and gene flow should no longer be overlooked or assumed when implementing conventions and directives for biodiversity conservation and climate action. Explicit consideration of genetic variation and functioning gene flow in species is needed in the post-2020 work. Below are recommendations for the use of genetic tools within current frameworks.

AICHI TARGETS AND UN 2030 SUSTAINABLE DEVELOPMENT GOALS

Aichi targets 5, 6, 7, 12, 13: *prevent habitat loss, degradation and fragmentation; sustainable agriculture, aquaculture, fishing and forestry; biodiversity; genetic diversity* UN SDGs 11, 13-15: *sustainable cities and communities; climate action; life below water; life on land.*

Utilising genetic methods & approaches through collaborations with scientists will greatly increase chances for success.

EU BIODIVERSITY STRATEGY TO 2020

Headline target and Actions 9 and 10: retain biodiversity; conserve ecosystems; agricultural genetic diversity; biodiversity conservation and rural development.

Genetic knowledge, assessment and monitoring are key to efficient conservation, restoration and management.

EU GREEN INFRASTRUCTURE STRATEGY

This strategy stresses "the need for consistent, reliable data", which includes data on functional connectivity between sites in the Natura 2000 network.

Genetic analyses and genetic monitoring are critically important in validating whether or not local occurrences of species are or have been genetically connected, and if the green infrastructure is functioning in allowing and promoting movements and gene flow.

EU'S 7TH ENVIRONMENT ACTION PROGRAMME TO 2020

Article 2a, 2e, 2i: *priority objective to protect, conserve and enhance natural capital; improve knowledge and evidence base for environmental policy; increase effectiveness in addressing environmental and climate challenges.*

Genetic knowledge, methods and monitoring have key roles for effectively mitigating environmental and climate challenges for species and ecosystems that comprise the natural capital.

EU FOREST STRATEGY (2019)

maintain biodiversity; maintain, enhance and restore forest ecosystems' resilience and multi-functionality; green infrastructure.

Positive effects of genetic variation for trees' and forests' adaptive ability are exemplified in a BiodivERsA policy brief and directly address the strategy's call that "genetic diversity must be enhanced and endangered genetic resources protected."

EU COMMON FISHERIES POLICY (2014)

Environmentally and sustainable fishing and aquaculture; practices do not harm the ability of fish populations to reproduce; cautious approach which recognises the impact of human activity on all components of the ecosystem.

Too small and inbred fish populations will have lower reproduction and resilience. Genetic monitoring and science-based management is important for species' and ecosystems' resilience.

G-BiKE is a scientific network funded by the European Cooperation in Science and Technology under CA18134. It comprises more than 120 researchers from 42 countries.

This policy brief is published by G-BiKE, and is part of a series aiming to inform policy-makers and managers on key results from genetic research related to biodiversity and resilient ecosystems.

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