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Norwegian Institute for Nature Research

NINA

Annual report 2004

NINA
Norwegian Institute for Nature Research


TEAMWORK


ENTHUSIASM


INTEGRITY


QVALITY

Cooperation and expertise for a sustainable future

Cooperation and expertise for a sustainable future

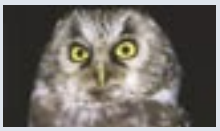
NINA´s company values:

- Teamwork

- Enthusiasm

- Integrity

- Quality



The Norwegian Institute for Nature Research (NINA) is Norway's leading institution for applied ecological research. NINA performs long and short term strategic and commissioned research projects, in support of local, national and international management of biodiversity and natural resources. We contribute to the implementation of international conventions and national policies. We collaborate closely with research and management institutions in Norway and abroad. Our research results enhance public awareness, and promote conflict resolution regarding management of natural resources.

NINA's staff totalled 169 persons in 2004. Total operating income was approximately 25 million USD.

NINA's major services are:

- Research
- Dissemination of scientific results
- Environmental impact assessments
- Environmental monitoring and status reports
- Consultancies and evaluations
- Courses and training

In 2004, NINA's researchers produced 74 scientific papers in international peer reviewed journals, 113 technical reports in our own series, and approximately 250 written contributions and presentations at conferences, symposia and workshops.

The institute have well-equipped laboratories and research facilities at six locations in Norway. NINA offers broad-based ecological expertise covering the genetic, population, species, ecosystem and landscape level, in terrestrial, freshwater, and coastal marine environments.

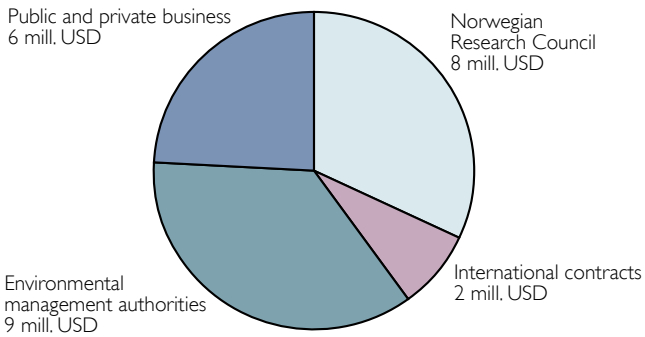
In addition, NINA addresses a wide variety of interdisciplinary scientific fields involving both ecologists and social scientists. We participate actively in European and other international research programmes. NINA is experienced in studies of natural and human aspects of resource and biodiversity management in developing countries and Eastern Europe. We contribute actively to capacity building and technology transfer by means of research cooperation and consultancy work.

NINA´s core competence

NINA's expertise is directed towards basic and applied research, consultancy work, and advice to management and industry. Selected issues related to management of natural resources and biodiversity are, e.g.:

- Land-use and nature management, including landscape analysis in the coastal zone and on land
- Harvest and sustainable use of game and fish stocks
- Community development and local participation in resource management
- Socio-economic issues related to recreational fishing and hunting, and nature based tourism
- Research on conflicts related to natural resources management, e.g. large predators vs. domestic animals, wildlife vs. agriculture, and outdoor recreational activities vs. forestry, agriculture or urbanisation
- Commercial development related to biological resources
- Red-list evaluations and conservation planning
- Monitoring and time series analyses regarding natural resources and biodiversity
- Environmental databases – development, operation, use, and public information
- Pollution impact analysis and monitoring, in particular acid rain, heavy metals, radioactivity, and eutrophication
- Environmental impact assessments associated with infrastructure development and land-use changes

NINA´s turnover in 2004



Total turnover: 25 mill. USD

Photo: Bengt Finstad

Talvik
Research
station

Photo: Karl Birger Strann

NINA Tromsø

Photo: Per Eide (Edelpix)

NINA Trondheim
(head office)

NINA
Lillehammer

NINA Oslo

Photo: Børre K. Dervo

Ims
Research
station

Photo: Jon Backer

Photo: Per Eide (Edelpix)

Collaborative networks

NINA has an extensive professional network in Norway and abroad:

- **ENVIRA** (The Environmental Research Alliance of Norway; www.miljoalliansen.no) consists of six institutes in addition to NINA: **NIBR** – The Norwegian Institute for Urban & Regional Research; **NIKU** – The Norwegian Institute for Cultural Heritage Research; **NILU** – The Norwegian Institute for Air Research; **NIVA** – The Norwegian Institute for Water Research; **Jordforsk** – Centre for Soil & Environmental Research; **CICERO** – Centre for International Climate and Environmental Research .
- **NODE** (www.node.org) is a multidisciplinary research and consulting consortium consisting of The Chr. Michelsen Institute (CMI) and Centre for International Environment and Development Studies (NORAGRIC), in addition to NINA.
- NINA is a partner in the **ALTER-net** (A Long-term Biodiversity, Ecosystem and Awareness Research Network; www.alter-net.info), a network of excellence consisting of 24 European research institutions in 17 countries, funded by EU's 6th framework programme.
- NINA is involved in collaborative projects and programmes with institutions in approximately ten developing countries in Central America, Africa and Asia, as well as a number of institutions in developed countries.

NINA AND TAWIRI COLLABORATE ON CAPACITY BUILDING

Jørn Thomassen

NINA and Tanzania Wildlife Research Institute (TAWIRI) are jointly working on a five year programme on capacity building, where Environmental Impact Assessment (EIA) is a key task. Here the EIA is used as a training tool, where different training packages (proposal writing, project management, reporting, etc. are included). The Ngorongoro Conservation Area Authority (NCAA), TAWIRI and NINA have decided to focus on tourism and vehicle congestion in the Ngorongoro Crater as the EIA case in the capacity building programme.

The scoping process

A major challenge in EIA is to identify a limited number of issues to be addressed by the EIA. This process is called scoping and will normally include considerations of impact factors and potential impacts, decision makers, stakeholders, alternatives, access of baseline information, time schedule and also economic frames. The scoping phase in EIA is critical for an optimal use of limited resources in terms of personnel, time and funding, and should be accomplished as early as possible in the process. The EIA scoping for the vehicle congestion in the Ngorongoro crater was conducted as a participatory workshop process, with several important stakeholders involved. NINA facilitated the scoping process, using the Adaptive Environmental Assessment and Management (AEAM) approach.

Scoping results

A considerable reduction of the number of issues that should be focused on were achieved during the scoping process. Thirteen assessed impact factors were reduced to six, while 24 assessed focal components (in this system called Valued Ecosystem Components - VEC) ended up with priority to nine. When one or more impact factor(s) "hit" one or more focal components an effect may occur: impact hypotheses were formulated and evaluated for a number of potential impacts. Due to limited resources for conducting the EIA study, the number of VECs were further reduced and/or combined from nine to two VECs, namely: *A. Human aspects*; and *B. Ecological aspects*. For each issue, objectives, outputs, activities and budget, time frame and staffing were proposed.

The EIA work

The EIA work in the Ngorongoro crater will be implemented during spring 2005. The *Human aspect* consists of interview and questionnaire analysis of tourism issues and conditions related to the Maasai community, while the *Ecological aspects* will concentrate on analysis of vehicle impacts on endangered species, carnivores and sensitive habitats. The EIA is planned to be completed by early 2006.

Further reading:

Thomassen, J., Keyyu, J. & Haaland, H. 2005. The effects of congestion of vehicles on the environment – an EIA in the Ngorongoro crater. Results from the scoping process - NINA Report 17. 68 pp.

Thomassen, J., Mumbi, C. T. & Kaltenborn, B. P. (eds.) 2003. Environmental Impact Assessment (EIA) training course as part of the TAWIRI – NINA collaborative programme in capacity building. NINA Project Report 25. 34pp.

The Masaai are an important stakeholder group in the Ngorongoro crater area (photo: Odd T. Sandlund).

Lions are one of the tourist attractions in the crater. High priority was given to the VEC carnivores in the scoping process (photo: Jørn Thomassen).

The congestion of vehicles in the Ngorongoro Crater is a growing challenge for the management authorities (photo: Jørn Thomassen).

Telemetry and exploitation of natural resources

Tor F. Næsje and Paul D. Cowley (South African Institute for Aquatic Biodiversity)

Telemetry enables us to track the movements, behaviour and activity patterns of individual fish. Continuous recordings are made for extended periods, up to years, and the lives of fishes in their natural habitats can be studied in detail. Fish telemetry is used successfully in the project "Behaviour and management of important fishery species" in South Africa's Great Fish Estuary, which is a collaboration between NINA, the South African Institute for Aquatic Biodiversity (SAIAB), and Rhodes University in South Africa.

Telemetry

Fish movements have traditionally been studied with so-called "mark-recapture" techniques, which only provides two data points; where the fish was initially tagged and where it was recaptured. Consequently, all movement of the fish between those two points, which could be days or even years apart, is lost. Telemetry, on the other hand, facilitates continuous recording of fish movement, behaviour and activity patterns over extended periods. The fish is equipped with a tag, which may transmit either a radio or an acoustic (sound) signal. Studies in the sea and in estuaries require acoustic signals, while radio signals are best transmitted in freshwater.

Telemetry research in aquatic environments has been successfully applied to investigate the impacts on fish of, e.g., pollution, fish-ways, weirs and hydropower development. Telemetry studies have investigated the interactions between native and introduced alien species, and provided information for planning and evaluation of marine protected areas. The aquaculture industry uses telemetry research to optimise commercial production, assess fish welfare, and the environmental effects of aquaculture. The management and sustainable utilisation of fishery resources has also benefited from telemetry research.

Resource utilisation

Many important coastal fishery species spend part of their life in estuarine habitats, where they may be heavily exploited by subsistence and recreational fishers. The exploitation of two of South Africa's most important estuarine fisheries species, spotted grunter (*Pomadasys commersonnii*) and dusky kob (*Argyrosomus japonicus*), may not be sustainable. An acoustic telemetry study on these species was therefore initiated in the Great Fish River estuary in 2003, to provide sound management advice based on knowledge of their habitat use and the fisheries targeting the two species. The aims of the project are to investigate the movement behaviour, periods of estuarine residency, and habitat utilisation of the species. Fishery statistics and angler catch data have been compared with daily movements of the fish in order to assess their vulnerability to local exploitation. The findings may help develop a sustainable exploitation strategy for the different fishery sectors (subsistence and recreational) on the estuary and contribute to the overall management of these important fishery species.

Altogether, 40 spotted grunter and 30 dusky kob have been equipped with acoustic transmitters to allow us to study their movements and behaviour in the estuary. The behaviour and area use of the two species were different as the spotted grunter had large individual variation in area use and local movements, whereas the dusky kob had more of a shoaling behaviour. Spotted grunter and dusky kob constituted 73% of the total catch in the estuary fisheries. The anglers were concentrated in the estuary sections most used by juvenile spotted grunter. Both fish and fishers were mainly located in the lower third of the estuary.

A reduction in the bag limit, currently five fish per person per day, would need to be substantial to have any effect on the fish population as most fishers (65%) did not catch any spotted grunter or dusky kob on a daily outing. Only 1-3% of fishers were affected by the legislated daily bag limit. However, approximately 30% of the retained fish was below the legal size limits. Consequently, effective management by way of bag limits and size restrictions would require improved law enforcement and/or better compliance by fishers. However, such changes would be difficult considering both that the Great Fish Estuary is situated in a rural area, and the high dependence on fish catch by the large subsistence sector. Other fishery regulation measures should therefore be considered. Alternative measures include closed seasons and protected areas. However, a closed season will have negative impacts on the subsistence fishers who might be deprived of food and income. Therefore, over-exploitation of the fish populations might be best controlled by establishing a protected area. If a no-fishing zone is to be implemented on the Great Fish Estuary it should be established in the lower reaches as this area represented a high use area by fish and fishers.

Further reading:

Potts, W.M., Cowley, P.D., Corroyer, B. & Næsje, T.F. 2005. Trends in fishery resource utilisation on the Great Fish Estuary. - NINA Report 50. 34 pp.

*Næsje, T.F., Childs, A.R., Cowley, P.D., Thorstad, E.B., Økland, F., Weerts, S., and Buthelezi, P. 2005. Movements and area use by small spotted grunter (*Pomadasys commersonnii*) in the Great Fish Estuary (South Africa): implication for management. - NINA Report 55. 46 pp.*

Subsistence fisherman with newly caught dusky kob outside his temporary home on the banks of Great Fish Estuary (photo: Tor F. Næsje).

Implantation of the transmitter took place in a boat at the catch site (photo: Tor F. Næsje).

Mammal communities and human land use in the Kalahari, Botswana:

Christina Skarpe

The utilisation in different ways of wildlife offers a diversification of land use and livelihoods for many dry regions of Africa where increasing human populations, increasing shortage of water and anticipated drying up of the climate calls for new sources of income. Two successive EU-funded projects, "Global Change and Subsistence Rangelands in Southern Africa: Resource Variability, Access and Use in Relation to Rural Livelihoods and Welfare" (1997-2000) and "Management and Policy Options for the Sustainable Development of Communal Rangelands and their Communities in southern Africa" (MAPOSDA) (2001-2004) have addressed different livelihood and rangeland related issues in southern Africa.

International projects

Both projects have been run jointly by researchers from three European (Great Britain, Norway and Spain) and three African (Botswana, Lesotho and South Africa) countries. Many aspects of social, economic and ecological research have been addressed, targeting one village or a group of villages in each of the African countries. NINA ecologist Christina Skarpe has worked with, among other topics, wild and domestic mammals and their environment at the Matsheng villages in western Kalahari, Botswana. One aim has been to describe densities and community composition of mammals in relation to human land use, and also to identify potential regulating forces for wildlife. Such knowledge of the status of the resource is a prerequisite for an economically as well as ecologically sustainable utilisation.

Mammal communities and land use

Most land in western Kalahari is used either as traditional communal grazing land, fenced cattle ranches, wildlife management areas, where wildlife utilisation is prioritised but also some livestock is kept, or as national parks and reserves, where tourism is the income generator. We studied how mammal distribution and community composition, in terms of species and functional types, varied with land use, with distance from villages and ranch centres (source of disturbance), and with distance from key resources like pans with mineral and clay licks, mineral rich grazing and temporary water supply. Road counts and modern "distance statistics" were used to estimate densities of mammals, from the size of mongooses (0.4 kg) and larger. Smaller terrestrial mammals, mainly rodents, were studied by live trapping. Multivariate statistics were used to describe animal communities, based both on species and on functional types.

Mammal communities were everywhere dominated (in terms of biomass) by large herbivores, but their dominance was about an order of magnitude higher in livestock communities than in wildlife communities. As expected, we found high densities of domestic large and medium sized herbivores in communal grazing lands and on ranches while wild animals of these types, e. g. gemsbok (*Oryx gazella*) and springbok (*Antidorcas marsupialis*), are more common in the protected areas. Habitat changes

Springboks in a dust storm (photo: Christina Skarpe).

caused by intense livestock grazing and/or direct competition for food between domestic and wild species may be a reason for this pattern. However, a wide gap between the distribution of livestock (up to ca. 20 km from the villages) and that of wild large and medium sized herbivores (from ca. 40 km from the villages) suggests that direct disturbance, possibly excessive hunting, may limit these wild species. There is little difference between land use types in the densities of many small wild herbivores like ground squirrel (*Xerus inauris*) and hares (*Lepus capensis* and *L. saxatilis*) and small and medium sized carnivores including mongooses and black backed jackal (*Canis mesomelas*). Rodents, potentially a pest in village areas, have here lower density and species diversity in livestock areas than in wildlife areas. This seems to be a result of the intact communities of small predators in combination with reduced protective vegetation cover in heavily grazed areas. Also, trampling by livestock probably destroys burrows for small digging mammals.

Our findings suggest that livestock husbandry as such exclude wild animals of similar functional types only locally, while more large-scale effects may be caused by direct human disturbances. Thus, with good management there seems to be potential for the recovery and sustainable utilisation of the wildlife resource besides livestock in much of the Kalahari.

Gradients of disturbance and key resources.

The disturbance gradient (distance from village centre) proved to be more important for distribution and abundance of wild mammal species and functional types than was the resource gradient (distance from pan). Large wild herbivores were most positively associated with distance to villages, which could be a result both of competition with domestic species for food and of excessive hunting, as pointed out above. Diurnal species were more positively related to distance from villages than were nocturnal species, including large predators like lions (*Panthera leo*) and leopard (*Panthera pardus*). Domestic mammals were obviously negatively related to distance from villages.

Most mammal species were positively associated with pans. For larger species, pans constitute a key resource of mineral and clay licks, and for some smaller species they form the living habitat. Burrowing species may take the advantage of the harder soil close to pans, offering a better substrate for digging than the loose sand. *Thus, the protection of some pan areas from humans and livestock may be important for many wild species.*

Changes over time

Old travellers' accounts describe the Kalahari as very rich in ungulates, particularly springbok, giving rise to the tales of the Kalahari cornucopia. Along one of the transects counted in this study, large mammals and ostrich (*Struthio camelus*) were counted with methods similar to ours during 1975 – 1983. Observation frequencies for all species, except steenbok (*Raphicerus campestris*), had declined between the two study periods. The change was statistically significant for common duiker (*Sylvicapra grimmia*), gemsbok, ostrich and springbok. Blue wildebeest (*Connochaetes taurinus*), ostrich and springbok had increased their minimum distance to villages, whereas cattle had increased their maximum distance to villages. There was no significant change in vegetation structure around the villages during the same time.

These results have been presented in 6 MSc theses and are currently written up as part of a PhD thesis.

Further reading:

Bergström, R. & Skarpe, C. 1999. The abundance of large wild herbivores in a semi-arid savanna in relation to seasons, pans and livestock. African Journal of Ecology 37: 12-26.

Skarpe, C. 2000. Desertification, no-change or alternative states: Can we trust simple models on livestock impact in dry rangelands? Applied Vegetation Science 3: 261-269.

Wallgren, M., Skarpe, C., Bergström, R., Danell. K. & Granlund, L. - Functional structure of mammal communities in relation to human disturbance and key resources in southern Africa. Journal of Tropical Ecology - in press.

Traditional Tswana cattle in the Matsheng area (photo: Christina Skarpe).

Does "Living Forests" ensure living forests?

Hanne Svarstad, Erik Framstad and Anne Sverdrup-Thygeson

The Norwegian forest certification scheme is based on the environmental standards named Living Forests. *In NINA's evaluation of the system, one of the respondents claimed that "This has created an environmental revolution in Norwegian forestry!" We concluded that a major increase in environmental awareness has occurred in the forestry sector, while there still is a potential to improve the system.*

Unique forest type

Environmental sustainability may be achieved through various approaches. The government may impose regulations and prosecute resource users who fail to adhere to the rules. An alternative is that civil society develops sustainability tools on their own accord. Living Forests, a certification scheme that covers about 95% of all timber sold in Norway, was established in 1998 through a partnership between environmental NGOs, the forest industry, and forest owners. Why? The forest industry experienced increased pressure when consumers demanded environmentally improved forestry practices and sustainable resource use. Thus, industry requested a more sustainable forestry. At the same time, forest owners feared that government authorities might introduce very strict environmental regulations. Hence, they were caught in a cross-fire and thus motivated to adopt a non-governmental process of forest certification based on the environmental standards developed in *Living Forests*.

Certification: environmental branding

Certification is a voluntary process to develop and maintain a sector-specific brand of environmental quality. *Living Forests* encompasses a set of standards for sustainable forestry. These standards are a result of a broad process involving forest owners, industry, consumers, trade unions, and environmental NGOs. Independent qualified bodies are authorised to control and document adherence to the standards. The certification bodies are controlled by the national accreditation authority in order to ensure adherence to internationally acknowledged procedures. The system is voluntary, as forest owners are free to decide whether they accept the requirements and costs. However, non-certified owners face problems if they try to sell their timber through the ordinary commercial channels.

Win-win or lose-lose?

Has *Living Forests* become an effective win-win solution which satisfies the objectives of all interests? In 2004 the partners in the scheme decided to evaluate and revise the certification system. NINA was commissioned to take part in the evaluation, in particular to analyse how, and to what extent, the certification scheme and the environmental standards were effectively incorporated into practical forest management in Norway.

A more sustainable forestry

We concluded that *Living Forests* has contributed to a more sustainable forestry in Norway. The standards cover important aspects of sustainable forestry. They were developed through a broad, consensus-based process, and set minimum standards for forestry. The system is independent and voluntary, with internationally accepted procedures, and it is controlled by independent bodies with considerable expertise.

Needs for improvement

Although the forest certification scheme works well in many respects, there is considerable potential for improvement. Some of the *Living Forests* standards need to be more specific and clear in order to improve adherence and avoid varying interpretations. Several standards may be sharpened to reflect more ambitious environmental objectives. This will ensure continued improvement, which is required by the certification policy. Furthermore, we recommend that the various forest owners' associations harmonize their implementation of the certification scheme. The system should also become more transparent, with open access to all data from all interested parties. Finally, we proposed the establishment of a body, with representatives from involved parties, to ensure consensus in the interpretation of standards, harmonised implementation of the certification procedures, and continuous development of the certification scheme.

Certification or regulation?

Government regulations are often seen as the only acceptable tool to ensure environmental standards. However, the experience with *Living Forests* shows that environmentalists and resource owners together may be capable of taking significant steps towards more sustainable forestry operations without the involvement of government.

Norwegian wood: Certified through "Living Forests" (photo: Anne Sverdrup-Thygeson).

Norwegian forests: Sustainable exploitation? (photo: Anne Sverdrup-Thygeson).

Further reading:

Sverdrup-Thygeson, A., E. Framstad & H. Svarstad (2004): Miljørevolusjon i Skogen? En evaluering av Levende Skog i sertifisering av norsk skogbruk [Environmental revolution in the forest? An evaluation of the Norwegian forest certification system Levende Skog]. NINA Oppdragsmelding 849.

Human Interactions with the Mountain Birch Forest Ecosystem (HIBECO): Implications for Sustainable Development

Hans Tømmervik

The main purpose of the EU-funded HIBECO[1] -project was to improve our knowledge about the human impacts on the Northern birch forest ecosystems, and to assess the future sustainability of these ecosystems.

Unique forest type

Birch forests on the alpine or arctic treelines are unique to north-western Europe (Fennoscandia, Iceland and Greenland). One reason for the success of this type of forest in the rather extreme environment is that the mountain birch has evolved through introgressive hybridisation between the downy birch (*Betula pubescens*) and the dwarf birch (*B. nana*). This is likely also the reason for the large variability in many characteristics among the trees in this forest. For example, there are two rather distinct growth forms of birch; one-stemmed (monocormic) and multi-stemmed (polycormic) trees, dominating moist nutrient rich, and dry heath forests, respectively.

Birch forests are usually dominated by relatively young trees (stems), rarely older than 100 years. Age class dominance as well as growth form varies due to the recurrent outbreaks of various insects that may kill individual stems, local stands or even large areas. In coastal areas the winter moth (*Openophtera brumata*) and one microlepidopteran (*Argyresthia retinella*) are the most important tree predators, while the autumnal moth (*Epirrita autumnata*) is most important in more continental areas. Outbreaks of the autumnal moth often lead to a polycormic growth form.

The production of these forest types is usually too low to be of interest for traditional forestry. The rich mountain birch forests, which are mainly found in the coastal areas, may reach a standing biomass of 25-35 tons per ha, while the poorer dry heath forests may be as low as 10 tons per ha. Annual production is 1.4 to 2.2 tons of biological matter per ha, but wood constitutes only about one third of this; 0.4 to 0.7 tons.

Climate impacts

The climate has a major impact on birch performance. While damage by extreme winter and spring temperatures presently is of restricted importance, the projected climate change may make a great difference. The HIBECO project has shown that particularly southern alpine birch ecotypes may lose their winter hardiness too early in spring and become more subjected to spring frost damage. This leads to reduced growth during the following season. However, mountain birches show large phenotypic plasticity regarding phenology and other characteristics. This improves their ability to cope with a changed climate. Transplant studies demonstrate that the ability to adapt to different photoperiods and temperature changes was higher in northern coastal birch provenances than in birch of a continental origin.

At Finnmarksvidda mountain plateau in northern Norway, vegetation cover in the mountain birch forests has changed over the last 40 years. Bilberry (*Vaccinium myrtillus*) and dwarf cornel (*Cornus suecica*) have become more common, whereas the lichens (*Cladonia* etc.) preferred by reindeer have decreased. This change is probably due to a combination of a changed climate, changes in reindeer husbandry, and human use of these areas. Similarly, there has been an increase in the extent of the birch forests in some areas (at Màze, Finnmarksvidda, mountain birch coverage has increased by about 90% since 1960).

[1] *HIBECO: Human Interactions with the mountain Birch ECOsystem, funded by EU's 5th Framework Programme.*

Further reading:

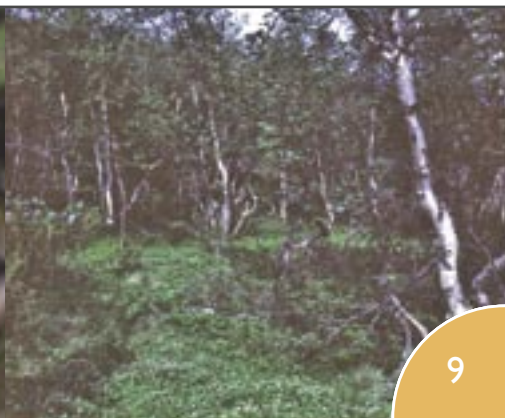
Laine, K., Skre, O. and Wielgolaksi, F-E. (eds). 2003. Human Interactions with the Mountain Birch Ecosystem: Implications for Sustainable Development (HIBECO). Final report for The project EU FP5, QLK5-CT-1999-01515. University of Oulu. Oulu 2003. 121 pp.

Tømmervik, H., Johansen, B., Tombre, I., Thannheiser, D., Högda, K.A., Gaare, E., Wielgolaski, F.E. 2004. Vegetation changes in the mountain birch forests due to climate and/or grazing. Arctic Antarctic Alpine Research, 36: 322-331.

Wielgolaski, F.E., Karlsson P.S., Neuvonen S.,.Thannheiser, D., Tömmervik, H.,and Gautestad, A.O. 2005. The Nordic mountain birch ecosystems - challenges to sustainable management In: Wielgolaski, F.E. (Ed.). Plant Ecology, Herbivory, and Human Impact in Nordic Mountain Birch Forests. Berlin: Springer-Verlag. Ecological studies 180: 343-356.

*Dwarf cornel (*Cornus suecica*) (photo: Odd T. Sandlund).*

The dwarf cornel covers the ground in the birch forest (photo: Dietbert Thannheiser).



The polymorphic Lake Femund whitefish: a case of post-glacial ecological speciation?

Kjartan Østbye, Tor Fredrik Næsje, Louis Bernatchez (Université Laval, Quebec, Canada), Odd Terje Sandlund and Kjetil Hindar

Genetic, morphological and ecological analyses of the European whitefish* Coregonus lavaretus *(L.) in Lake Femund indicate that four different morphs have developed within the lake, likely due to specialization into distinct ecological niches, from one ancestral form which colonised the lake after the area was deglaciated approximately 10000 ybp.

Evolution at work

The extensive polymorphism observed in the north temperate salmonid fishes have puzzled evolutionary biologists for decades due to the occurrence of ecologically different forms within lakes. These forms differ in morphology and life history characters, as well as their diet and habitat use. Due to the pronounced polymorphism, and the very short evolutionary time after deglaciation, sympatric forms represent ideal organisms to study speciation in its early stages.

Femund whitefish

In Lake Femund, Norway's second largest natural lake, local fishermen recognize 5-6 forms of European whitefish based on phenotype and spawning. However, in order to better understand their evolutionary history and the mechanisms behind polymorphism within this lake, extensive morphological and genetic analysis were performed on 11 spawning populations. We compared patterns of diversification within and between morphs within this lake, and in addition included seven whitefish populations from other lakes in four adjacent watercourses to search for potential founders along post-glacial immigration routes.

Genetics and morphology

The first study using allozymes, gill-raker numbers, and life history characters (age and length at maturity) suggested the presence of two major ecotypes of whitefish in the lake; the deep water spawners and the river spawners. In addition, populations spawning in shallow water in the lake formed a diverse additional group with the populations spawning in semi-isolated bays being the most divergent. In order to resolve these patterns further, we conducted a study using DNA analysis based on 6 microsatellites, and a more thorough morphological analysis based on 20 meristic and morphometric parameters.

These new analyses show that the deep-, shallow-, river- and bay-spawning populations are distinct morphs in Lake Femund (Fig. 1). Within morphs, populations range from being genetically very similar among deep-spawning populations, to being highly differentiated between bay-spawning populations. Between morphs, genetic differences range from a low level between deep- and shallow-spawning populations to a large difference between shallow- and bay-spawning populations. A higher proportion of molecular variance is seen among (3.9%) than within morphs (2.8%). In particular, the number and length of gill rakers were more differentiated between morphs than expected from the selectively neutral microsatellite differentiation, suggesting that diversification result from natural selection.

Assessment of the genetic relationships between the whitefish forms in Lake Femund and those in adjacent localities, suggested a tight clustering between Lake Femund whitefish and whitefish populations from other lakes in the same watercourse. Immigration of whitefish into Lake Femund therefore is most likely to have occurred through this watercourse alone. This is interesting in relation to the origin of ecological forms, as whitefish in the nearby Lake Isteren feature another type of ecological differentiation

Lake Femund in early autumn (photo: Odd T. Sandlund).

Fishing for whitefish on Lake Femund (photo: Odd T. Sandlund).

(dwarf- and normal-sized) than occurs in Lake Femund. Although more than one whitefish colonization of Lake Femund cannot be excluded, their adaptive gene combinations seem to have originated within the lake. Thus, the most parsimonious explanation of the occurence of the four morphs in Lake Femund seems to be ecological speciation accompanied by build-up of reproductive isolation.

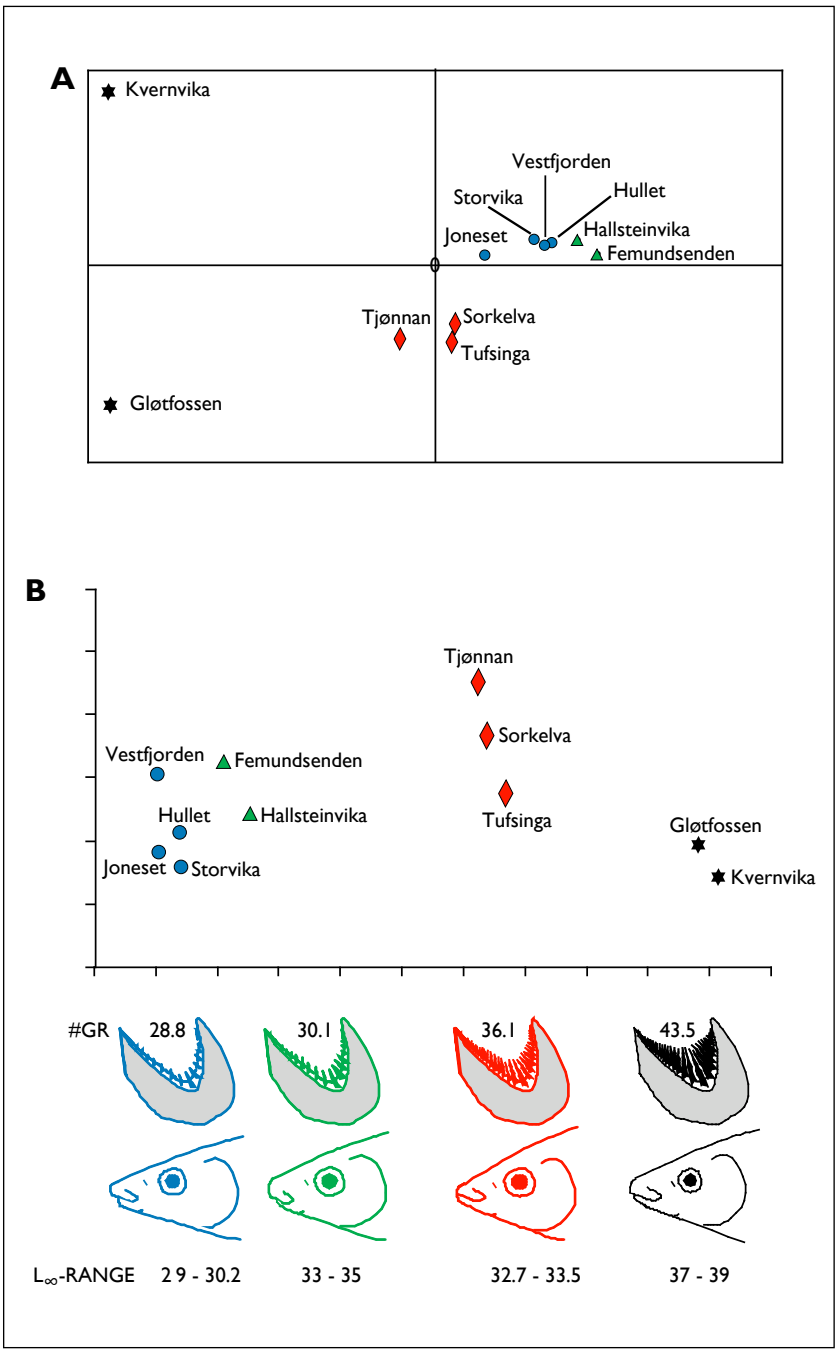
Management

Management consequences of these results are that the monitoring of commercial catches, based on morph separation through gill-raker counts, generally provide valuable information on the populations of the lake. It is also obvious, however, that the bay morph consists of small spawning populations with a high degree of differentiation. These populations are vulnerable to fishing due to their rapid growth rate, and may require specific protection measures in order to conserve genetic and ecological diversity of whitefish in this lake.

Further reading:

*Næsje, T.F., J. Vuorinen & O.T. Sandlund 2004. Genetic and morphometric differentiation among sympatric spawning stocks of whitefish (*Coregonus lavaretus *L.) in Lake Femund, Norway. – Journal of Limnology 62: 233-243.*

*Østbye, K., T.F. Næsje, L. Bernatchez, O.T. Sandlund & K. Hindar 2004. Morphological divergence and origin of sympatric populations of European whitefish (*Coregonus lavaretus *L.) in Lake Femund, Norway. – Journal of Evolutionary Biology 18: 683-702.*



Relationships among 11 spawning populations of whitefish in Femund, based on A: six DNA microsatellites, and B: 20 morphological characters, and the resulting four whitefish types from grouping based on genetics and morphology (left to right: deep-, shallow-, river-, bay-spawning). #GR: Mean number of gillrakers; L_∞-range: asymptotic lengths (cm) within the whitefish type.

Beach seining for river whitefish during October in the inlet river Tufsinga (photos: Odd T. Sandlund).

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