RESTORATION OF MIRE HABITATS: EXPERIENCES FROM THE PROJECT 'CONSERVATION AND RESTORATION OF MIRE HABITATS'

HANDBOOK



JÜRI-OTT SALM, LIINA REMM, MARILIIS HALJASORG, EDGAR KAROFELD, KAUPO KOHV, MARKO KOHV, ANN KRAUT, LEEVI KRUMM, MART MERISTE, LAURA ORO, PIRET PUNGAS-KOHV, URMAS SELLIS & KAAREL SIKK

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In addition, volunteers participated in restoration work.

CONTACT:
Estonian Fund for Nature
Staadioni St. 67
51008 Tartu
Estonia
E-mail: elf@elfond.ee
soo.elfond.ee

Front cover photo: Mire restoration workshop in Kuresoo, Soomaa National Park. Example of a dam that no longer functions. Courtesy of J.-O. Salm
Back cover photo: Peat dams in Kuresoo, Soomaa National Park. Peat dams have raised the water level in former drainage ditches and directed the flow towards surrounding areas. Courtesy of J.-O. Salm
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FOREWORD

LIINA REMM & JÜRI-OTT SALM

As far as we know, the first attempts at mire habitat restoration in Estonia were made by Henn Vilbaste and Arkadi Irdt on Nigula Nature Reserve in the late 1960s, and later, in 1974, in Laukasoo in the recently established Lahemaa National Park when, on the initiative of its conservation inspector Juhan Lepik, drainage from Laukasoo was closed off with a dam made of stakes, boards and peat. Further attempts, with restoration on a smaller scale, were made in 2004 and 2005 in Tolkuse bog, on the cut-over peatland of Maasika bog (which forms part of Luitemaa Nature Reserve) and in the International Bird Area of Northern Livonia[1].The first major restoration project began in 2008 when a solution was presented for an 80-ha drained patch in the south-eastern part of Kuresoo in Soomaa National Park. Restoration work is ongoing there and has been a good learning experience for all involved, including the project's planners and designers, the construction companies undertaking earthworks and those monitoring the results.

From 2011-2013 the Estonian Fund for Nature drafted restoration plans for the 10 wetlands or parts of wetlands on the Ramsar List[2] most affected by human activity, and it could be said that this marked the start of a slight boom in mire habitat restoration. As such, we can extend the list of mire restoration work, either ongoing or planned, but let us turn back to the case on which the Estonian Fund for Nature has been working (together with the conservation biology working group of the University of Tartu, Archaeovision R&D, the State Forest Management Centre and the Estonian Environmental Board) since 2015 when the European Union's LIFE programme and the Environmental Investment Centre decided to finance the 'Life Mires Estonia' project (LIFE14 NAT/EE/000126)[3]. Since we have almost completed this work, we decided to summarise our experiences in this handbook in order to share them with experts and anyone else working on wet lands. The first version of the handbook was completed in 2020 (in Estonian).

Methods of mire habitat restoration were described in detail in the Finnish handbook[4] that served as the most important model in choosing the methodology for this project. However, it should be noted that this handbook pays only limited attention to species conservation and the cultural aspects of mires. Here we add the Estonian experience, focusing on dealing with the potential risks and dilemmas surrounding restoration that mainly came to light in the context of the 'Conservation and Restoration of Mire Habitats' project.

As mentioned, we have seen something of a boom in restoration: for one target listed in the national strategy for nature conservation, the goal has been achieved and surpassed, which can be considered a significant achievement. Namely, measure 2.2 of the Estonian Conservation Development Plan, 'Providing favourable conditions for habitats', stipulated the restoration of endangered mire habitats in protected areas, and within this measure 10,000 hectares of fen and transition mire habitats and bog margins should have been restored by 2020. By the end of 2020, restoration work had been completed on more than 11,000 hectares; in addition, work had started or been planned on a further 14,000 hectares. It should be noted that favourable conditions do not necessarily arise as soon as a drainage ditch is closed; however, this is the first step.

To put this in a wider context, the following may no longer be news, but it is (still) doubted by many: Humans are changing the ecosystems on Earth to an extent that endangers the existence of many species, including ourselves. One step that scientists are proposing in order to improve the situation is the extensive restoration of natural habitats[5]. Extensive ecological restoration is a global trend in conservation, but its aims are often seen as being very vague. The countries that signed the Convention on Biological Diversity set a target in Aichi in 2010 to restore at least 15% of damaged ecosystems by 2020[6], but this target has not been achieved. The aim set by the Aichi targets is often evaluated based on effort rather than achievements: the area under restoration is measured rather than changes in status of the ecosystem or specific species[7]. This leads not only to ignorance of the achievement of actual targets, but may even pose a danger to biodiversity. For example, if damage to the environment is tolerated as long as those responsible for it contribute to restoration activities elsewhere, then such unproductive restoration will still result in a damaged environment.

Thus, the above-mentioned boom-like situation can be positive, but if we take into consideration that since World War II the area of mires has decreased in Estonia (and in other countries; in Estonia alone two- to three-fold) and that restoration is not yet visible, it must be said that the goal of biodiversity strategy is not yet within reach. The 'Conservation and Restoration of Mire Habitats' project has been a drop in the ocean, and yet every drop has the power to carve stone. The goals for the new decade are planned to be set with the European Union's Biodiversity Strategy 2030. This year (2022) is designed for Member States to set their binding targets for the restoration of natural habitats. Let us hope that it will have more impact than a drop in the ocean, or indeed in our forests and wetlands.

[1] Kaitstavate soode tegevuskava [Action plan for protected mires]. 2015 (in Estonian): Ministry of the Environment.

[2] Kohv, M. 2013. Märgalade taastamiskavad [Wetland restoration plans] (in Estonian). Estonian Fund for Nature

[3] Website of the project: soo.elfond.ee

[4] Similä, M., Aapala, K., Penttinen, J. 2014. *Ecological restoration in drained peatlands – best practices from Finland. Metsähallitus* Natural Heritage Services, Vantaa.

[5] Ripple, W. J., Wolf, C., Newsome, T. M., Galetti, M., Alamgir, M., Crist, E., ... & 15,364 scientist signatories from 184 countries 2017. World scientists' warning to humanity: a second notice. *BioScience*, 67, 1026-1028.

[6] European Union's Biodiversity Strategy to 2020. 2011. European Commission.

[7] Jørgensen, D. 2015. Ecological restoration as objective, target, and tool in international biodiversity policy. *Ecology and Society*. 20, 43.

EXAMPLES OF THE STATUS OF MIRE SPECIES

LIINA REMM, ANN KRAUT & URMAS SELLIS

THE MOOR FROG (*RANA ARVALIS*) IS BY NO MEANS A RARE SPECIES, EVEN TODAY, BUT BEFORE MAJOR DRAINAGE WORK THIS SPECIES WAS MORE NUMEROUS.

The Moor Frog, whose range extends from Central Europe to Siberia, spends most of its life near wetlands. For reproduction, the species needs wetlands open to sunlight, at least in the Estonian climate. In places, the Moor Frog uses the same bodies of water as another similar species, the Common Frog. However, the Moor Frog is the only one of our amphibian species that is capable of reproducing in the waters of bogs and transition mires. The breeding grounds most suitable for the Moor Frog are transition mires, laggs, flood plains and fens (Fig. 1). However, these habitats have suffered extensively from drainage. The loss of frogs causes problems for other species dependent on them. The Moor Frog has not been extensively monitored in Estonia before and its population trends are unknown, but a clear downward trend is evident: older people recall deafening frog choirs and hordes of frogs jumping on the legs of passers-by in local wetlands during the 1960s and 1970s where today there are drained lands with forests or fields[8]. This kind of mass breeding remains in flooded areas, such as quaking mires and ditches with beaver dams.

The results of the 'Conservation and Restoration of Mire Habitats' project, as well as earlier research, clearly show that ditches in protected areas that have been drained and have become overgrown with forests are too shaded for the Moor Frog, and that only floods caused by beaver dams can improve the situation[9]. Population decrease caused mainly by loss of habitat is the reason why the Moor Frog is listed as 'near threatened' in the Estonian Red List of Threatened Species.

THE NUMBERS OF THE LARGE WHITE-FACED DARTER (*LEUCORRHINIA PECTORALIS*) MAY START INCREASING ONCE MIRES ARE RESTORED.

The ranges of Estonia's five whiteface species stretch from Europe to western Siberia, but during the 20th century their populations declined, especially in central and western areas of Europe. The main reason for this is thought to be loss of habitat due to changes in land use, especially from turning mires into fields, but also due to eutrophication, pollution and the introduction of fish populations in smaller bodies of water. The Large White-faced Darter, the Dark Whiteface and the Lilypad Whiteface are listed in Appendices II and IV of the EU Habitats Directive and are protected species in Estonia. The Large White-faced Darter, like other dragonfly species, spends its larval stage in the water. This species has been encountered in more diverse habitats than other whiteface species, but it requires varied vegetation in water everywhere and prefers bodies of water with no fish. Since its larvae live in the water for up to three years, the water must not evaporate during this period. Suitable bodies of water are ponds, lakes, beaver flooding areas and former peat-cutting pits filled with water[10]. In natural bog complexes, the Large White-faced Darter can be encountered in flood waters and bog pools. However, the number of such water bodies is in decline due to the drainage and destruction of mires. Most probably this has not caused population decline, since in other places new bodies of water suitable for the larvae have formed, such as ponds, ditches flooded by beaver dams and former peat-cutting sites. In the restoration of mires, water sometimes collects behind dams built on ditches and in hollows formed by removing the material for building the dam. As such, there may (temporarily)



Fig. 1. Spawning waters of the Moor Frog in Feodorisoo transitional bog. Photo: Liina Remm

[8] Fred Jüssi, Meeli Seepter suul

[9] Remm, L., Vaikre, M., Rannap, R., Kohv, M. 2018. *Amphibians in drained forest landscapes: conservation opportunities for commercial forests and protected sites.* Forest Ecology and Management 428, 87–92.

[10] Rannap, R., Kaart, T., Briggs, L., and Vries, W., D. 2011. *Project report 'Securing Leucorrhinia pectoralis and Pelobates fuscus in the northern distribution area in Estonia and Denmark'* LIFE08NAT/EE/000257. Tallinn

Torp, T. Väikeveekogude taastamise mõju ohustatud kiililiikidele [The effect on endangered species of dragonflies of restoring small bodies of water]. Master's thesis. 2014

[11] Remm, L., & Sushko, G. (2018). *Dragonfly fauna in rewetted mires in Belarus: diverse but different from natural sites.* Wetlands Ecology and Management, 26(6), 1173–1180.



Fig. 2. A bog pool in Ohepalu home to larvae of the Dark Whiteface. Photo: Liina Remm

be more breeding waters for this species than would occur naturally on this type of landscape.[11]

THE DARK WHITEFACE *(LEUCORRHINIA ALBIFRONS)* HAS AVOIDED THE WORST BECAUSE THE CENTRAL CORE OF THE MIRES HAS BEEN PRESERVED.

Although this species has also been found in gravel quarries and lakes, its main home is bog pools. Our data show that the Dark Whiteface prefers bog pools that are untouched by drainage, that have some free water and that are not overgrown with Sphagnum moss (Fig. 2). It is not yet clear whether it would be possible to restore such bog pools, but raising the water table should at least preserve the existing ones.

THE COMMON RINGLET *(COENONYMPHA TULLIA)* REQUIRES CONTINUITY IN ITS HABITAT OVER TIME

This Nymphalidae butterfly resides in moist, grassy habitats throughout its range, from the United Kingdom to Kamchatka, but due to the decline of these habitats (especially in Central Europe), its populations are shrinking rapidly. In Estonia, the Common Ringlet is rare: it may be encountered on the edges of mires and bogs, on the high-grass borders of mineral soils and sometimes on overgrown banks of floating mats. Its caterpillars feed on cottongrasses, sedges and grasses. The species likes its breeding site to be within a radius of a few hundred metres, which makes it especially sensitive to the loss of suitable areas. As such, occupying restored areas far from its current sites would also be complicated.

THE BALTIC GRAYLING *(OENEIS JUTTA)* IS NO LONGER COMMON

In Europe, habitats suitable for the Baltic Grayling are mainly found from Scandinavia to northern Russia. The species reaches its southernmost extent in Estonia and only lives in a few mires in the centre and eastern part of the country. It has very specific demands of its habitat: it requires a treeless bog with drier edges where there are pine trees with Labrador Tea beneath them and hare's-tail cottongrass and sedges growing nearby. In a good habitat, Baltic Grayling may be numerous; however, treeless areas and dense forests alike would be obstacles for them in finding suitable new habitats further away. Wetland draining causes a sharp decline in its populations.



Fig. 3. The Common Ringlet can be found in grassy mires. Photo: Kristiina Taits



Fig. 4. The Baltic Grayling likes open woodlands with Labrador tea and hare's-tail cottongrass. Photo: Ants Tull

THE WESTERN CAPERCAILLIE (*TETRAO UROGALLUS*)

In the early 19th century, the capercaillie was a game bird that was found all over Estonia. Today the species is extinct on Estonian islands and the number of males in lekking sites have only been stable or demonstrated a slight upward trend in large protected areas. One important risk factor is forestry, especially clear cutting and drainage. Capercaillie prefer old coniferous forests or pine forests with a few deciduous trees and with an abundant bilberry understorey. However, throughout the year these birds (especially the hens) utilise a variety of habitats. Their lekking grounds are usually situated in old pine forests close to a mire, and these grounds change over time depending on whether the mire grows or shrinks. Drainage has had a marked impact on these processes – predominantly in terms of shrinkage – and the change has been quick. The Capercaillie has not been able to adapt to quick changes. More than half of all lekking sites are on drained soils.[11] In some places, lekking has moved from too uniform or too dense commercial forests into drainage-afforested transition mires or bogs. The restoration of drained forests with a dense tree stand may favour the Capercaillie if the natural forest structure recovers slowly. At the same time, restoring the natural state of a site can (temporarily) harm its secondary habitat. If there are no suitable lekking grounds nearby, restoring the habitat on a secondary lekking site should be carried out with caution. Rapid changes, at least, should not be planned.

THE WILLOW GROUSE (*LAGOPUS LAGOPUS*)

The range of the Willow Grouse is extensive: its optimal habitat is shrub tundra, which in Estonia equates to open bog with dwarf shrubs. It is a resident species. In Estonia it prefers open bogs with dwarf shrubs and a few pine trees. Population decline began with hunting and mire drainage to turn the land into forests, fields or grasslands; later, snowless winters posed further danger. In snowless winters the Willow Grouse is easy prey for predators, since it changes its dappled brown plumage to white for the season. The Willow Grouse is not an endangered species globally, but it is in Europe. In Estonia too it is endangered: it is a category I protected species. Around 150 years ago the Willow Grouse was a common game bird throughout Estonia, including its islands. Since then its population has been in decline, and nowadays it has retreated to the mires of Ida-Viru County; some individuals may also be living in Pärnu County [12]. It is estimated that the Puhatu mires are home to the largest Willow Grouse population in Estonia today, with around 10 pairs of birds, while 20 years ago there were 50-60 pairs living there[13]. During the inventory of the project areas in 2017, signs of Willow Grouse activity were found in the Sirtsi and Tudu mires among 'Conservation and Restoration of Mire Habitats' project areas[14], but these encounters were rare (just one or two specimens per bog). Restoring treeless areas in large protected mire systems could provide the Willow Grouse with suitable habitats for the future, but guaranteeing permanent snow cover in winter is a far more intractable climate problem.



Fig. 5. Capercaillie lekking grounds in a mire pine forest in Tudusoo, with larger trees in which the males can roost at night and glades on the ground in which they can court. Nearby there are smaller spruces to hide in and the lines of sight are good for keeping an eye on the neighbours. Some draining impact is visible in the young birches in the underwood. Photo: Urmas Sellis

[12] Lõhmus, A., Leivits, M., Pēterhofs, E., Hofmanis, H., Ojaste, I., Zizas, R., & Kurlavičius, P. (2017). *The Capercaillie (Tetrao urogallus): an iconic focal species for knowledge-based integrative management and conservation of Baltic forests.* Biodiversity and conservation. Dordrecht: Springer, Vol. 26, iss. 1 (2017).

[13] Environment Agency. 2017. Madalsoode ja rabade haudelinnustiku seire 2016. aasta aruanne [Report on breeding birds in fens and bogs, 2016].

[14] Environment Agency. 2017. Madalsoode ja rabade haudelinnustiku seire 2017. aasta aruanne [Report on breeding birds in fens and bogs, 2017].

RESTORATION THAT TAKES EXISTING VALUES INTO ACCOUNT

LIINA REMM

Experiences in Estonia to date have shown that restoration is not always successful and that in areas under restoration there are endangered species and cultural values that must be taken into account in the course of extensive intervention. As such, the action plan for protecting mires emphasises that in restoring mire habitats neither valuable forest habitats nor cultural or natural sites should be damaged, including protected species sensitive to disturbances near mires[14]. The targets set for restoration should describe both the planned results and possible risks according to the best knowledge of how the ecosystem will develop after the restoration work. Let us take a look at how we can respect existing values in restoring mire habitats[15]. The same principles can be adopted in restoring other ecosystems. This approach could be used in setting restoration targets on a national scale, drafting management plans for protected areas and species, and for planning restoration work in specific ecosystems.

DETERMINING TARGET HABITATS AND SELECTING TARGET SPECIES

TARGET HABITATS

In the restoration of mire habitats, the main aim is usually hydrological restoration, i.e. raising the water level. However, it is not possible to undo all of the changes caused by ditches by simply filling them in, since during that period drainage has initiated a chain of collateral changes that can include accelerated tree growth, the decomposition of peat and changes in its chemical composition, and intensive land use for forestry or agriculture. It is never possible to restore a site to its exact pre-drainage state. In addition, restoration is strongly limited by other land use interests, and certain concessions should therefore be made in hydrological restoration as well. All of this increases the need to think about which target habitats could be restored (and which it would be realistic to restore) on a specific site. There would be no sense in cutting down the trees in a former treeless mire if it is not possible to raise the water level, since due to existing drainage the tree cover would return and a century or more would be added to the length of time it took to achieve old forest habitat. If the restoration of a former ecosystem is complicated, it is important to preserve existing values.

TARGET SPECIES

The success of restoration should also be measured by species, not just the general level of a habitat. Are specific species returning? Is the restoration work being carried out without harming current species? Usually target species belong to one of the following three classes[16]:

- Surrogate species. Indicator species, focal species, umbrella species and flagship species are well suited when introducing habitat restoration to the public and are also indicators of the success of restoration. But we must remember that these species only represent part of biodiversity and that their links to other species are not always proven.
- Endangered species Often, one reason behind the restoration of ecosystems is the recreation of habitats for endangered species.
- Species which must be present for ecosystem functioning and supportive species such as Sphagnum moss in bogs.

Target species should include both taxa that respond to restoration quickly (in the 'Conservation and Restoration of Mire Habitats' project these were the Moor Frog and whiteface dragonflies) and those indicating the long-term recovery of components (such as butterflies requiring recovered vegetation).

Observing target species helps to monitor the completeness of ecosystem recovery, as well as to pinpoint gaps in the recovery of its components and the connections between them. Complex links and the functioning of the ecosystem could not be monitored using simple indicators like the extent of the area restored. For example, mire habitat restoration in Finland has shown that some insects and spiders specific to mires return to restored mires within the first few years following restoration work[17]. However, with ants the change is not as rapid. The reason for this may be the long-standing nature of their nests, which they will not abandon in a hurry.

[14] Ministry of the Environment 2015. Kaitstavate soode tegevuskava [Action plan for protected mires]. https://www.envir.ee/sites/default/files/soode_tegevuskava.pdf.

[15] According to source: Remm, L., Lõhmus, A., Leibak, E., Kohv, M., Salm, J.-O., Lõhmus, P., Rosenvald, R., Runnel, K., Vellak, K., & Rannap, R. 2019. *Restoration dilemmas between future ecosystem and current species values: The concept and a practical approach in Estonian mires.* Journal of Environmental Management, 250, 109439.

[16] Lawrence, J. M. 2013. *Restoration ecology of the Seychelles giant millipede* (PhD thesis, Stellenbosch: Stellenbosch University).

Another reason may be that there is competition between ant species in which those already present have the advantage, as well as the fact that logging waste left at a restoration site forms suitable habitat for forest ants that are strong competitors to mire species[18].

TAKING NATURAL VALUES IN AREAS UNDER RESTORATION INTO ACCOUNT: SPECIES AT RISK

The restoration works are carried out in novel communities, so we must ask ourselves what values in the existing community the restoration work affects. In certain cases it may be wiser to protect existing values rather than try to restore the past (e.g. if there are endangered species or important cultural values on the site). It is not possible to foresee developments within the habitat after the restoration activities due to global environmental changes, unpredictable events and social and political changes.

Handbooks and best practice guidelines have been published for the restoration of various ecosystems. These usually include tips on how to avoid or alleviate possible negative impact.[19] Estonia's action plan for the restoration of mires states that restoration is not planned for areas where category I protected species or Red List species have been found if restoration could have a negative effect on their habitat, or for drained peatland forests over 90 years old and with established structure if it does not interfere with the restoration of the hydrological regime of the mire as a whole.

WHAT IS A SPECIES AT RISK?

Species at risk can be divided into two groups:

- Immigrants or species that moved into an area after it was changed through human activity. In the decades or even century since drainage, mire habitats have been replaced by communities of species that prefer drier habitats. Among the immigrants may be endangered and protected species, especially if drained mires have been turned into protected areas. For these species, the restoration of mire habitats may pose a new danger.
- Residual populations from the natural state of the ecosystem for which restoration may pose a certain threat by causing disturbances, such as a sudden rise in the water table. At the same time, these species are also target species. In restoring mire habitats, one example is hygrophilous species preserved solely in ditches or on ditch banks, where they will perish if the ditches are filled in or flooded.

WHEN SHOULD WE TAKE SPECIES AT RISK INTO CONSIDERATION?

In order to decide whether preserving existing values requires special measures, the importance of these values should be assessed and weighed up in comparison with the realistic targets of the restoration. Aspects like the life cycle properties of species, the extent of the restoration's impact and the predictability of the results should be taken into consideration (Table 1). The nature of immigrant populations should be carefully studied. For some species, ecosystems with a strong human impact (i.e. damaged communities) may currently be their main habitat, since their natural habitats have perished. For other species these habitats may function as an ecological trap. For example, waterbodies in drained areas may dry up too quickly for amphibians, leading to the deaths of their tadpoles[20].

Particular attention should be paid to cases where both the dangers to existing species and the possible benefits of restoration are great. On the other hand, cases with fewer dangers and benefits may be used for testing possible solutions. If the effectiveness of the restoration work is uncertain and difficult to predict, the focus should be on protecting existing values.

HOW TO JUXTAPOSE RESTORATION PLANS AND SPECIES AT RISK

Proper restoration projects include three stages: planning; implementation; and monitoring. Information obtained from the latter can then initiate corrective actions. Current values and values likely to be achieved through restoration should be compared in the planning stage. The most convenient way of doing so is with map layers (Fig. 1). Experiences from the 'Conservation and Restoration of Mire Habitats' project show that comprehensive planning is also important because learning while doing things and continuously changing works according to results already obtained is extremely complicated in the case of large projects. Planning based on geographical information can be done in four stages.

- Based on the historical and current status of an ecosystem, it is possible to set initial targets for restoring the ecosystem. Primarily it is the restoration of ecosystem

[17] Noreika, N., Kotiaho, J. S., Penttinen, J., Punttila, P., Vuori, A., Pajunen, T., ... & Kotze, D. J. 2015. *Rapid recovery of invertebrate communities after ecological restoration of boreal mires.* Restoration Ecology, 23, 566–579.

[18] Punttila, P., Autio, O., Kotiaho, J. S., Kotze, D. J., Loukola, O. J., Noreika, N., ... & Vepsäläinen, K. 2016. *The effects of drainage and restoration of pine mires on habitat structure, vegetation and ants.* Silva Fennica.

[19] Rehell, S., Similä, M., Vesterinen, P., Ilmonen, J., Haapalehto, S. 2014. *Planning peatland restoration projects, in:* Similä, M., Aapala, K., Penttinen, J. (Eds.), *Ecological restoration in drained peatlands – best practices from* Finland, Vantaa, 34–36.

Gann G.D., McDonald T., Walder B., Aronson J., Nelson C.R., Jonson J., Hallett J.G., ... & Dixon, K.W. 2019. *International principles and standards for the practice of ecological restoration.* Second edition. Restoration Ecology.

[20] Suislepp, K., Rannap, R., Lõhmus, A. 2011. *Impacts of artificial drainage on amphibian breeding sites in hemiboreal forests.* Forest Ecology and Management 262, 1078–1083.

FACTOR	THE DANGER TO SPECIES AT RISK WILL INCREASE IF...	ARGUMENTS FOR THE RESTORATION OF AN ECOSYSTEM
Experience to date	experience to date predicts harm to the species	the restoration of similar ecosystems has repeatedly been a success
Knowledge of the ecology	the ecology of the species predicts a harmful effect	our knowledge of succession accurately predicts the response of the ecosystem to the restoration work
Replaceability	may affect a large or key part of the habitat	the key part of the ecosystem will be restored
Permanence	the habitat is stable at present but may disappear due to the restoration of the ecosystem	a self-regulating ecosystem with no future need for intervention will be achieved
Succession type	late succession species, incl. those with slow development and poor distribution (alleviating the effect of which takes time)	the target community is a late-succession community (restoring which takes time)
Rarity	rare species in the area, the number or extent of its sites has diminished	an ecosystem which has become rare in the region
Liability	globally rare species	a globally rare ecosystem
Speed of effect	it is difficult to apply alleviation methods since it responds quickly to the changes caused by restoration	rapid transition to the target state

Table 1. Factors affecting contradictions between existing species and target habitats

processes that is planned. However, one aspect that needs to be considered in detail is the degree of intervention, e.g. whether, in addition to closing ditches, a stand that has grown more dense during drainage should be thinned out as well and whether old peat holes should be levelled out. Sometimes plans to restore a site to the ideal setting are changed due to technical restrictions.

▶ Potential conflict between existing values and restoration plans must be identified patch by patch. To identify existing values, all available data must be used (including data on the location of endangered and protected species from the Environmental Register, the Estonian Nature Observations Database and the PlutoF database, and key habitat inventories). If there are not enough data to be sure that important values will not be damaged, fieldwork inventories must be carried out. If the period between planning and construction is longer, the site should be re-examined immediately prior to work starting to identify any additional species at risk in the area affected by the work. Data on species under strict protection must be checked frequently. Site information from databases can change quickly, because these species are under constant monitoring and the ranges of species may change. The most recent data may not have reached the databases from experts, so direct communication with specialists is necessary. For example, in this project, cuttings to restore open fens were only planned outside of known lekking sites of the Capercaillie. However, in two locations national monitoring detected lekking sites during the time between planning and deforestation. Unfortunately, this information reached the Estonian Fund for Nature only after the trees had been removed. It seems the capercaillies were not seriously affected, since follow-up did not identify any decline in the number of courting males. However, the lekking grounds had shifted to suitable stands nearby.

▶ For key values, appropriate solutions should be chosen for the restoration plans.

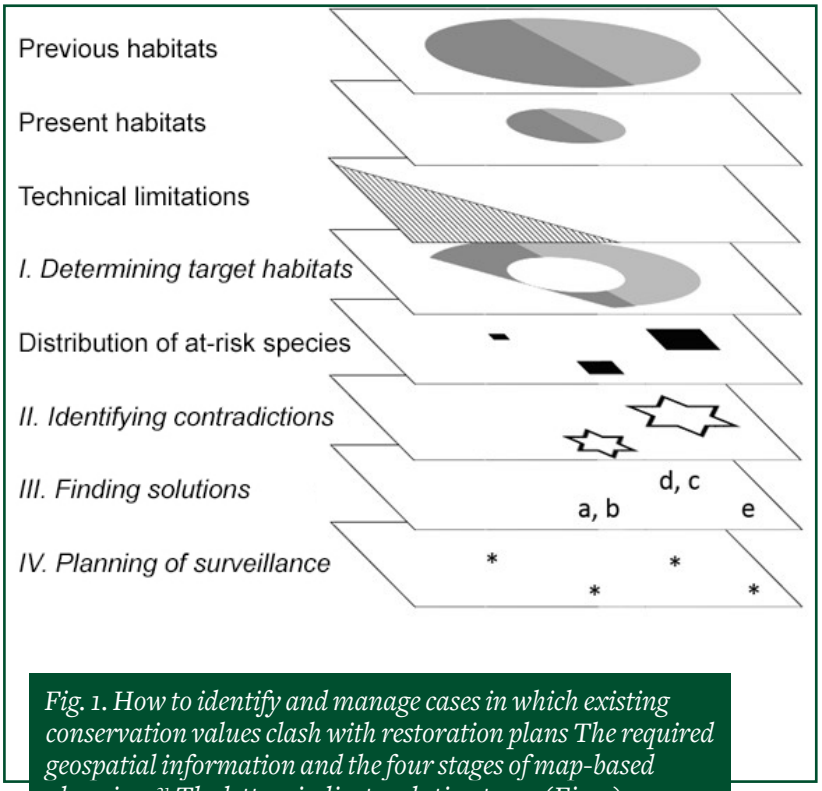


Fig. 1. How to identify and manage cases in which existing conservation values clash with restoration plans The required geospatial information and the four stages of map-based planning. [21] *The letters indicate solution types (Fig. 2).*

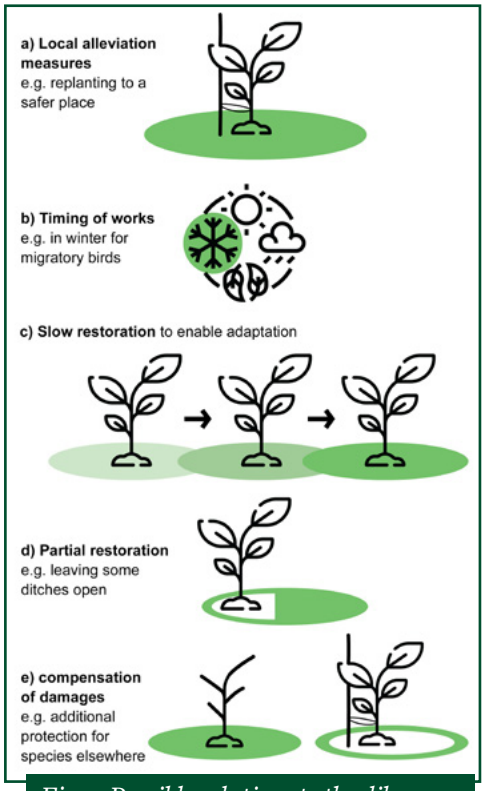


Fig. 2. Possible solutions to the dilemma of restoration and species at risk.

▶ To check the success of solutions, a monitoring plan should be drawn up. It is especially important to continue long-term monitoring after works are completed. Long-term monitoring of how species at risk respond (and of course whether the restoration targets are met) could be conducted in selected areas, but this would require initiative and support at the national level.

WHAT SOLUTIONS COULD BE USED TO TAKE SPECIES AT RISK INTO CONSIDERATION?

Scientific literature describes various solutions for taking species at risk into consideration (Fig. 2). The solution should be selected according to the nature of the dilemma and the situation under observation.

▶ Use of local alleviation measures. For example, in Finland, endangered saxifrages (*Saxifraga hirculus*) have been re-planted from ditch banks to places where predictions indicate the formation of suitable sites once the water level has been elevated. Ditch banks constituted a suitable habitat in drained fens, but these are flooded if dams are built.[1] Local alleviation measures in the 'Conservation and Restoration of Mire Habitats' project include constructing sediment ponds to catch moving sediment resulting from the closure of ditches before the sediment reaches a river where the endangered Thick Shelled River Mussel (Unio crassus) lives; also building dams manually in Tudusoo to avoid cutting down nesting trees of the Flying Squirrel to make more space for machines.

If restoration work influences seasonal processes in the life cycle of certain species at risk, it could be possible to schedule the work during a less harmful period, e.g. non-breeding time or the time of gathering in groups. For example, the work in the 'Conservation and Restoration of Mire Habitats' project was planned to take place outside of the mating season of the Capercaillie, i.e. during autumn and winter, but also in general the work was not carried out from April-July, i.e. during the nesting season of the birds.

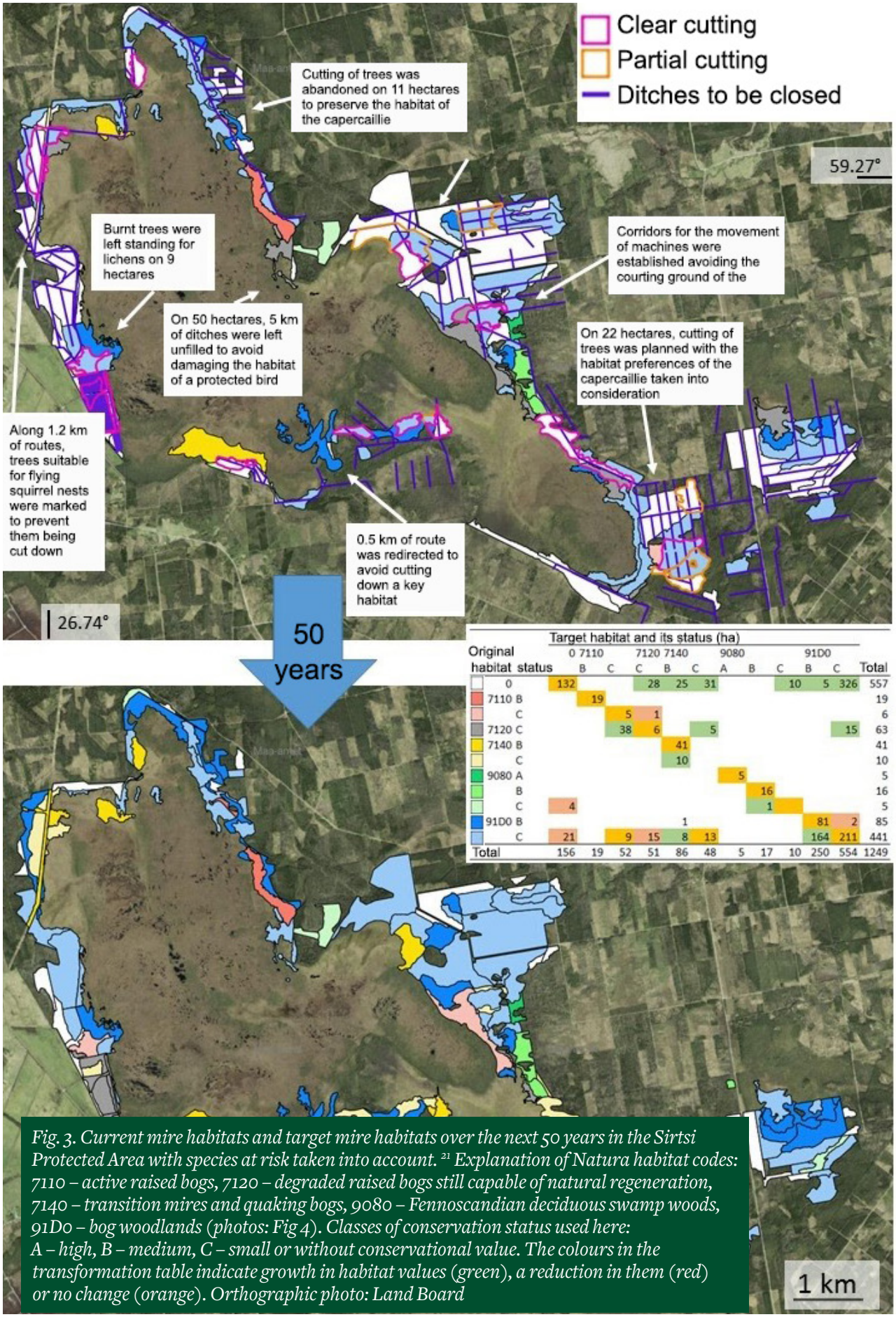
Slow or gradual restoration may help the population make the transition to the new situation. Scientists from California studied in detail how a local species of waterfowl, the Ridgway's rail (*Rallus longirostris obsoletus*), had adapted to living in the 'reeds' of the alien *Spartina alterniflora* cordgrass, which needed to be removed in order to restore the native vegetation. To relocate the species to recovering native vegetation, a gradual restoration technique was proposed.[22]

In risk mapping, it may become apparent that these are aggregated to specific sites. As such, the solution may be partial restoration: areas essential to the species at risk are left in their current state. For example, in the 'Conservation and Restoration of Mire Habitats' project an embankment on the edge of a ditch was not used for ditch filling and an educational trail was redesigned since Leathery Grapefern was found growing on the embankment. Also, a number of stands that had become suitable for the Capercaillie were left standing; see also Table 1 in the chapter 'The planning of felling in the restoration of mire habitats'.

One possibility for compensating the loss of species at risk is to do something especially for the species on another

[21] Figure is modified from article: „Restoration dilemmas between future ecosystem and current species values: The concept and a practical approach in Estonian mires." Remm, L., Lõhmus, A., Leibak, E., Salm J.-O., Lõhmus, P., Rosenvald, R., Runnel, K., Vellak, K., Rannap, R. (2019). Published in Journal of Environmental Management, 250. https://doi.org/10.1016/j.jenvman.2019.109439

[22] Lampert, A., Hastings, A., Grosholz, E. D., Jardine, S. L., Sanchirico, J. N. 2014. *Optimal approaches for balancing invasive species eradication and endangered species management.* Science 344, 1028–1031.



Target habitat and its status (ha)

Original habitat status	0	7110 B	7110 C	7120 C	7140 B	7140 C	9080 A	9080 B	9080 C	91D0 B	91D0 C	Total
0	132			28	25	31			10	5	326	557
7110 B		19										19
7110 C			5	1								6
7120 C			38	6		5					15	63
7140 B					41							41
7140 C					10							10
9080 A							5					5
9080 B								16				16
9080 C	4							1				5
91D0 B					1					81	2	85
91D0 C	21		9	15	8	13				164	211	441
Total	156	19	52	51	86	48	5	17	10	250	554	1249

Fig. 3. Current mire habitats and target mire habitats over the next 50 years in the Sirtsi Protected Area with species at risk taken into account. [21] *Explanation of Natura habitat codes: 7110 – active raised bogs, 7120 – degraded raised bogs still capable of natural regeneration, 7140 – transition mires and quaking bogs, 9080 – Fennoscandian deciduous swamp woods, 91D0 – bog woodlands (photos: Fig 4). Classes of conservation status used here: A – high, B – medium, C – small or without conservational value. The colours in the transformation table indicate growth in habitat values (green), a reduction in them (red) or no change (orange). Orthographic photo: Land Board*

[21] Figure is originally published in article:„Restoration dilemmas between future ecosystem and current species values: The concept and a practical approach in Estonian mires.“ Remm, L., Lõhmus, A., Leibak, E., Salm J.-O., Lõhmus, P., Rosenvald, R., Runnel, K., Vellak, K., Rannap, R. (2019). Published in Journal of Environmental Management, 250. https://doi.org/10.1016/j.jenvman.2019.109439

site outside of the area under restoration. The authors know of no examples where restoration has been complemented by external compensation of a species at risk.

EXAMPLE OF THE PLANNING OF MIRE RESTORATION IN SIRTSI BOG

The Sirtsi mire complex has been partially drained for forestry, agriculture and peat mining, but also to prevent the expansion of the bog. The first ditches were dug as early as the 19th century, but systematic drainage and peat harvesting took place from the 1960s to the 1980s. As is typical of Estonian mires, drainage has had less impact on the central part of the Sirtsi mire, but some of its margins and especially lagg zones have suffered from extensive drainage. In the course of compiling the restoration plan, existing Natura 2000 sites were mapped. To this end, previous inventories of the sites, historical maps and orthographic photos were assembled. Fieldwork was mainly carried out in areas where, according to the photos, treeless mires had once stood which were now covered with trees. Target communities were determined by deciding whether it would make sense to establish a treeless or almost treeless mire as a community and thus cut down all trees, or to only close the ditches.

To identify populations of species potentially at risk, the Environmental Register database was checked, some fieldwork was carried out and habitats were modelled. Mapping was followed by discussions with specialists on habitat restoration and species protection to find solutions suitable for both. Detailed mapping of existing and target communities enabled us to predict the results of the restoration based on visual expertise (Figs. 3 and 4).

The transformation matrix shows that in around a third of the area, restoration would preserve existing values. More significant changes would likely occur in the south-western corner of the mire complex in the Palasi peat fields, where Sphagnum mosses should start growing again where milled peat was once produced. Areas with forest cover restored as treeless mires also stood out. However, these form only a small part of the restored areas: just 0.33 km² or 2% and 1.4 km² or 11%, respectively. However, across a vast area the status of wooded bogs and wooded transition mires should improve.

For some target communities, obtaining the desired results is less certain than for others. For example, it is unsure whether cleared areas will remain treeless, since some may have been kept treeless through herding, by a climate different from the current climate. Another habitat with unclear development after restoration is drained peatland forests, where the chemical composition and structure of the soil have changed due to long-term drainage and where raising the water level would therefore not lead to the rapid restoration of the pre-drainage state.

In Sirtsi, for example, all of the species at risk for the benefit of which these measures were taken were linked to trees or forests that had grown to open mires after drainage. For none of the natural values suspected at the beginning was there any need to amend the restoration plans. For instance, blocked ditches did not offer good breeding grounds for either frogs or dragonflies, but beaver dams did. In Feodorisoo, a beaver dam



Fig. 4. Examples of habitat types in Sirtsi mire by conservation status. Photos: Marko Kohv

should have been torn down to close a ditch, but a permit to do so was not obtained. Permanent dams were built to replace the beaver dams during restoration. This, at least, seemed not to affect the Moor Frog or Common Frog. In adjusting the original plans we also took into consideration our technical capabilities. For example, on wet peat soils where felling tractors encounter problems but where the forest is suitable for the capercaillie, the spontaneous formation of the forest structure was preferred to felling. A route corridor cutting through a key biotope was discovered in coordinating the work; this discovery was taken into consideration and the original plans were changed. In summary, solutions designed for species at risk were applied on approximately 7% of the restored area in the Sirtsi bog.

Special attention must be paid to the Flying Squirrel. Monitoring of the animal in 2021 found that close to the mire habitat restoration area in Sirtsi there were three uninhabited nest trees of the Flying Squirrel that had been used in the previous two years. Discussions held with experts and officials in September 2021 arrived at the conclusion that in future, better communication would help to avoid such situations, and that seeking expert opinions in the planning stage and immediately prior to starting work would be beneficial. Dams necessary for the restoration of the hydrological regime in the mire would have been established manually near the nests of the Flying Squirrel if the information on the nesting trees had been available, as was done in Tudusoo. Monitoring data from one year show that the site of the Flying Squirrel near the mire restoration area in Sirtsi is still inhabited, but that the three nest trees closest to the restoration area were not used in 2021. Nesting trees a little further from the restoration area are still being used. Thus we can conclude that noisy work, such as filling ditches or cutting down trees, may be disturbing the Flying Squirrel. The answer to the question of what effect mire habitat restoration can have on the Flying Squirrel will be obtained in the course of monitoring the species over the next 5-10 years.



Capercaillie on a recently constructed dam. Photo: Jüri-Ott Salm

RESULTS OF TARGET SPECIES MONITORING

LIINA REMM & URMAS SELLIS

MONITORING RESULTS FOR BUTTERFLY SPECIES

The main outcome of the monitoring of butterflies is that neither a positive nor a negative effect has been detected on either the target species of the project or biodiversity as a whole (Fig. 1). The abundance of butterflies showed a slight increase. The target species were sighted on only a few occasions. One of the target species, the Baltic Greyling, was found in the restoration area in Sirtsi mire prior to the restoration work being carried out, and in the reference area. Following restoration, in 2020, we found the species again in the same natural part of Sirtsi mire and also in the restored area of Laukasoo. The species was not sighted during monitoring in 2021. Another target species, the Common Ringlet, was only found on two occasions, in 2017 and in 2021, in the same place on the natural site on the eastern margins of Sirtsi bog. Since plant communities are still in the process of adapting to the post-restoration conditions, the areas may become suitable for the target butterflies in a few years or even decades. The target species also need time to reach the areas suitable for them.

As to methodology, we noted that monitoring in August made no sense since the flying time of bog-specific butterflies is over by that point and thus no new species would be added. Instead of August, it would probably make more sense to make observations during the last week of July.

MONITORING RESULTS FOR DRAGONFLY SPECIES

In monitoring dragonflies, we focused on catching the larvae of the protected whiteface species. With only a couple of years have passed since restoration, the results are not yet clear. The formation of vegetation in waterbodies and thus also dragonfly assemblages takes time. We hope that the target species will colonise the areas still uninhabited. In spite of this, the cautious conclusion can be drawn that restoration has had a positive effect on the Large White-faced Darter. No effect has (yet) been seen for the Dark Whiteface. This species was more numerous near natural bog pools in all years of monitoring, with no finds from drained reference areas. There may still be a positive effect on this species through the preservation of the bog as a whole by avoiding or alleviating the effects of drainage. Among dragonfly communities, a slight rise in abundance and species richness has been detected on the whole (Fig. 2). In restoration areas with and without felling (excluding route corridors), the change was similar in the number of individuals and of species. Among the places where more than one species was added, there were observation sites that were previously dry (e.g. the quaking bog by Lake Ohepalu); extremely narrow bog ditches that had flooded; shady and narrow forest ditches that had become wider, turned into permanent bodies of water and along some route corridors gained more sunlight; and bog ditches overgrown with Sphagnum moss and shrubs that had turned into flooded areas open to sunlight once trees were felled and dams were built. As such, the results are already as expected in this short intervening period: shallow flooded areas connected to permanent bodies of water with plenty of sunlight are becoming rich in dragonflies.

As a methodological experience, it seems that more emphasis should be placed on monitoring imagoes – conducting several

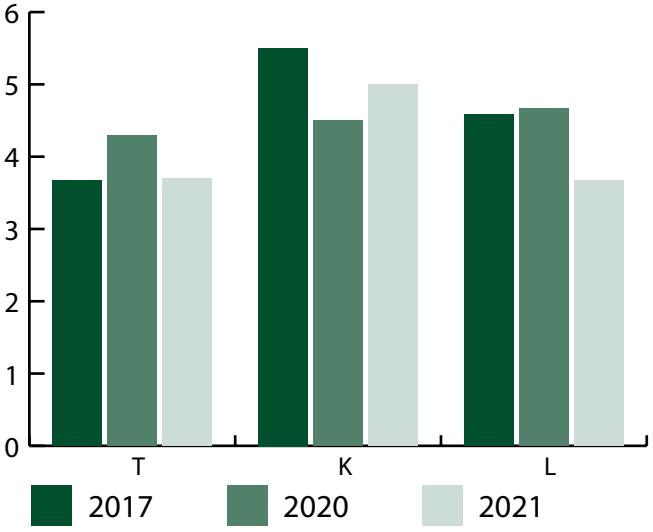


Fig. 1. Average diversity of butterfly species per monitoring line over all restored areas in mires (T), drained control areas (K) and natural control areas (L). 2017 - before restoration, in 2020 and in 2021 after restoration. Not all restoration work had been completed by 2020.

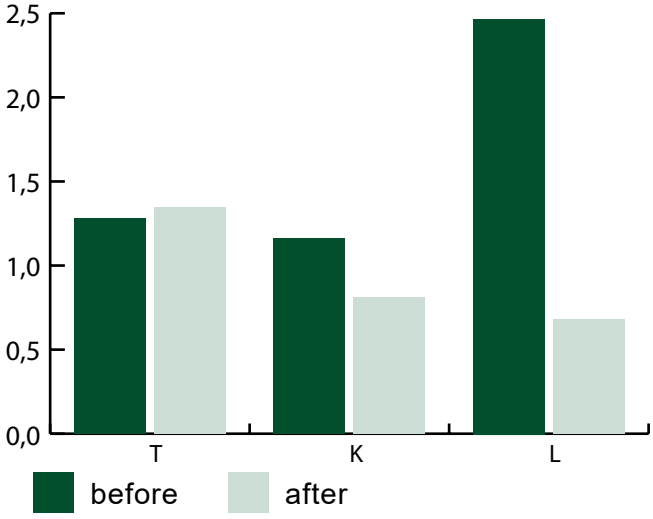


Fig. 2. Average diversity of dragonfly larvae per monitoring line over all restored areas in mires (T), drained control areas (K) and natural control areas (L). Lines where no larvae were found before or after are not included.



A ditch in the former mining area of Palasi where no dragonflies were found before restoration (left) and where three species of dragonflies were found after restoration (right). Restoration consisted of removing the tree cover and closing the ditches. Photos: Liina Remm (left) & Timo Torp (right)



A ditch in the north-western part of Laukasoo where before restoration (left) only larvae of the Downy Emerald were found, whereas after restoration four dragonfly species were found, including the Large White-faced Darter. Photos: Liina Remm (left) & Timo Torp (right)

rounds of observation in more places in a single year. Monitoring of imagoes usually finds more individuals, identifying them is easier (except for high-flying aeshnids) and observations have shown that adults are also habitat-specific (although they can fly several kilometres) and are mainly encountered near bodies of water (thus not by chance). If there is enough time, it would be appropriate to collect exuviae while inspecting bodies of water, since these indicate successful mating.

MONITORING RESULTS FOR FROG SPECIES

Restoration work has produced various aquatic habitats that could be suitable spawning sites for the Moor Frog. Spring floods are more extensive and smaller wetlands have also formed in areas where there were none before: flooded ditches in spring along route corridors and on felling sites; holes where material was removed to build dams; the fringes of dams. Spawn was also found in spring flood areas under sparse trees, but not in high abundance. In some places, floods caused by beaver dams were replaced by floods caused by human activity. Due to felling, the bodies of water became more open to sunlight. All of this has resulted in more spawning areas for frogs than there were prior to restoration (Fig 3). The largest increase in spawn was observed in areas where the ditches situated on fen peat at the margins of the bog were closed, e.g. in the north-western corner of Feodorisoo and at the head of the Tudu educational trail. A reverse example is the southern margin of Ohepalu bog, where the collecting ditch was not closed and thus no significant breeding grounds have formed. In Feodorisoo, the Moor Frog had even bred near the centre of the bog in bodies of water connected to closed ditches (behind dams, in peat-cutting holes and in the floodwater of ditches). In Laukasoo, one breeding ground especially suited to frogs has become dryer, most likely due to the closing of the ditch nearer to the bog, which has caused changes in flow directions. There the amount of spawn was less than in 2016.

The number of spawn clusters of the Moor Frog has grown since restoration. Numbers have decreased in both natural and drained control areas, while in restored areas the numbers have increased (Fig. 4). Given that spawn clusters of the Moor Frog are not always distinguishable from those of the Common Frog, we also checked changes in their total number, wherein the trend was similar. This trend is the same for areas with and without cutting. Spawn was likewise found in the forest near routes, although in smaller amounts.

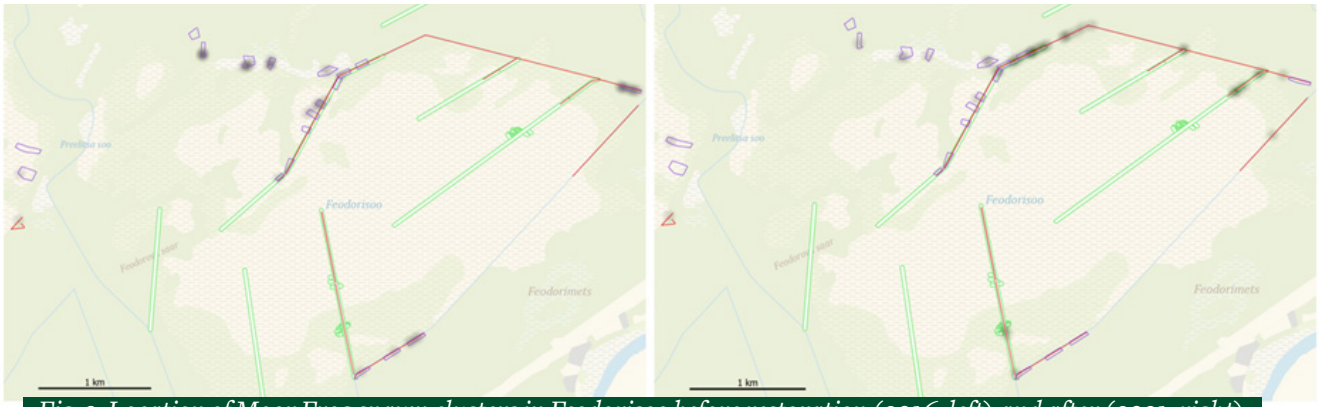


Fig. 3. Location of Moor Frog spawn clusters in Feodorisoo before restoration (2016, left) and after (2021, right). The grey to black patches mark spawn clusters of the Moor Frog (the darker the shade, the larger the number); the scale is relative, the numbers for before and after being 859 and 761, respectively. Green double line – closed ditches, thin red line – ditches searched for spawn (if the ditch flooded, the flood water was also inspected), polygons with violet border – areas delimited for searching for spawn. Land Board base map in background.

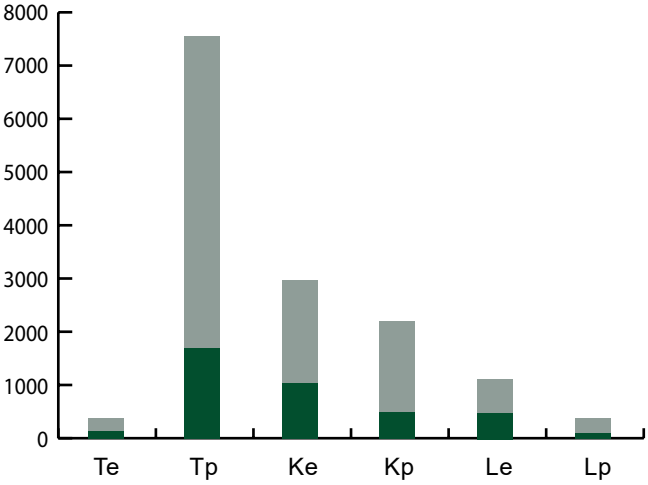


Fig. 4. Total number of Moor Frogs (filled part of column) and brown frogs (total column) over all restored areas in mires (T), drained control areas (K) and natural control areas (L) before (e) and after (p) restoration.

MONITORING RESULTS FOR BIRD SPECIES

Monitoring of birds took place in all of the areas selected for restoration (a total of 14 monitoring areas in Soosaare, Ohepalu, Laukasoo, Sirtsi, Tudusoo and Feodorisoo) and in four control or comparison areas with no restoration work taking place there. The monitoring and control plots were quite large (up to 50 ha), so no distinction was made between natural and drained control areas. Finding comparison areas unaffected by drainage would have been difficult. In addition, monitoring of target species (the Capercaillie and Willow Grouse) was carried out.

General bird monitoring proved to be most comprehensive, which we carried out as triple mapping of all breeding birds (from mid-May to late June) (Fig. 5). In one control area (Feodori 1), mapping was carried out five times to obtain a more detailed picture of the composition of breeding birds, but this is much more labour-intensive. In all of the monitoring and control areas the inventory of breeding birds was carried out before restoration began, and the same methodology was used when continuing with monitoring after the restoration work had been completed.

In some areas, three rounds of monitoring were carried out after restoration, while in others only one round was carried out, depending on the year in which restoration was completed. The summary chart (Fig. 6) presents the average numbers (of pairs) of birds in all of the monitoring areas and the average number of species for all areas, both before and after the restoration work was carried out. Where monitoring took place over a number of years following restoration, the average of all years was used. A similar procedure was used in the control areas, and for the field workers there was no difference what kind of area it was. The control areas were separated from the monitoring areas only during analysis. The following charts clearly show that in the control areas, significant impoverishment of breeding birds occurred during the LIFE Mires project period (5-6 years). We did not seek reasons for this decrease as part of the project.

At the start of the project, bird populations (the number of breeding pairs) in the control areas were larger than in the monitoring areas directly influenced by restoration. Moreover, the diversity of nesting birds has been slightly greater in the control areas than in the areas selected for restoration. As such, the control areas were not as degraded for the birds as the areas selected for restoration. The changes that took place in the control areas allow us to argue that birdlife would also have decreased without the project and in similar biotopes overall in Estonia. But would we have identified these changes?

The decline in birdlife in the control areas amplifies the changes observed in the restored areas during monitoring, and with them, the positive results of restoration. Without knowing the background (what was going on in the control areas) it would not have been possible to show clear positive trends in the early years after restoration, at least not on the basis of population size.

In the restored areas, bird diversity has increased in comparison with the pre-restoration situation. Since in the background of the control areas there has been a decrease in diversity, the real rise in the restored areas is actually much higher. Together with the formation (restoration) of open mire areas, new species have appeared that had been absent from these areas for decades. We might mention here a number of waders (the Wood Sandpiper, the Northern Lapwing, the Little Ringed Plover, the Common Greenshank, the Common Snipe and

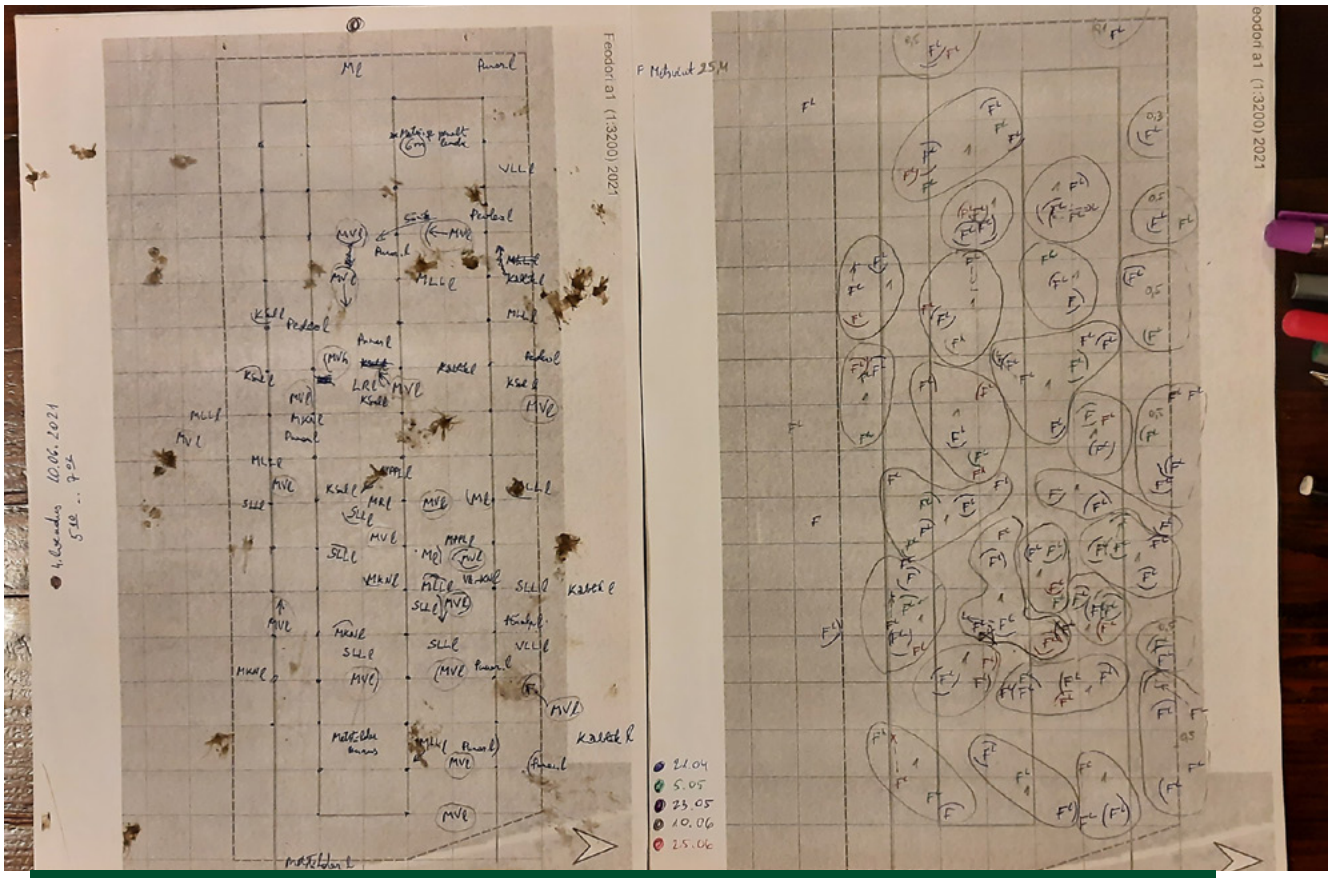


Fig. 5. Fieldwork form for monitoring of nesting birds and map for the territory of one species as a summary of different mappings, from which pairs can be counted according to corresponding methods.

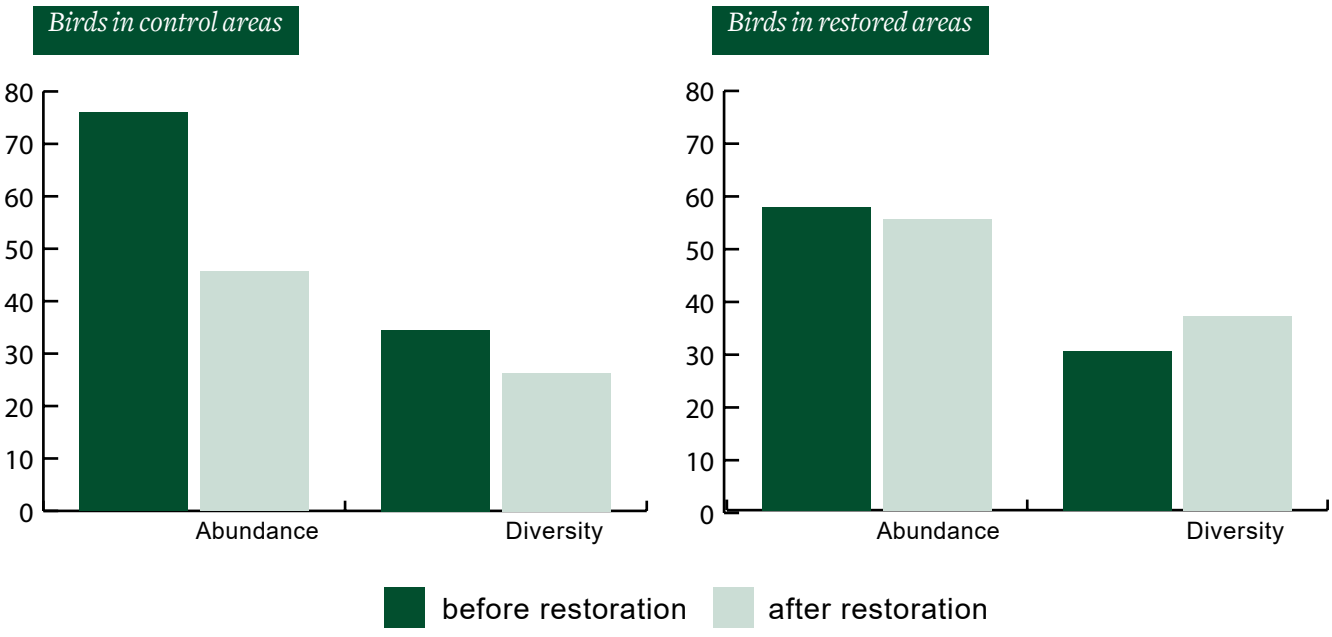
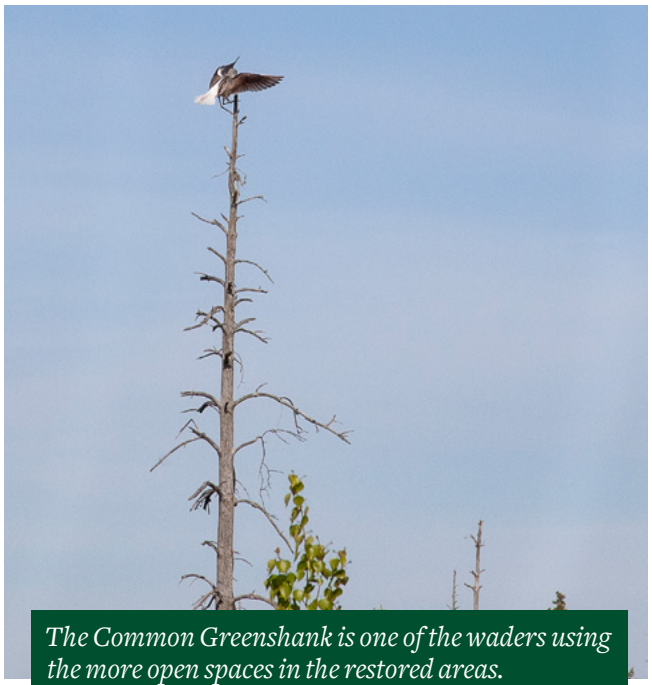


Fig. 6. Results of monitoring of breeding bird species as part of 'Conservation and Restoration of Mire Habitats' project from 2016-2021. No restoration work took place in the control areas, but monitoring was carried out there similarly.



The Common Greenshank is one of the waders using the more open spaces in the restored areas. Solitary trees are acceptable to them as well. Feodorisoo. Photo: Urmas Sellis



To find a capercaillie nest, one needs a little luck. Eight capercaillie chicks left this nest. Laukasoo. Photo: Urmas Sellis

even the Black-tailed Godwit), which need rather wet habitats. Some of these species will retreat when the vegetation grows higher. Among passerines, woodland generalists (the Common Chaffinch, the Willow Warbler, the European Robin et al.) are retreating while species characteristic of more open mires (the Meadow Pipit, the Red-backed Shrike, the Meadow Chat et al.) are appearing. Monitoring of target species was conducted separately from overall bird monitoring. Monitoring of both the Willow Grouse and the Capercaillie takes place during their lekking period, i.e. early spring, when lekking males are counted.

For the **Willow Grouse** we can say that the project has almost certainly come too late. Neither nests nor lekking were detected in the project areas. A major role in the disappearance of this species has likely been played by climate change, but declining habitats (degradation of open mires) have enhanced this trend.

The **Western Capercaillie** caused certain dilemmas as early as the planning stage. Some restoration work had to be scaled back or cancelled altogether due to the presence of the Capercaillie. In two cases, monitoring results obtained outside of the project went unnoticed by the project team and restoration of open mires took place on the lekking grounds of some males. The count of lekking males did not indicate a decrease on these sites; rather a slight increase was noted. However, we do not know how this long-living species will behave on these sites in the future. We observed the lekking that was taking place directly in the restored areas, also the survey was partially done as part of the national monitoring programme. All in all, we have before and after data for 14 lekking grounds. Prior to the launch of the project, 43 males were counted there; following restoration there were 48 males. It is improbable that the number of lekking males increased that much during the project period. Instead, it has likely been influenced by finds of shifting lekking grounds, or more thorough monitoring. At least one lekking ground was abandoned after water levels rose.

Such lekking area of the Capercaillie situated in a secondary biotope may have been (temporarily?) abandoned because of the regular rise in water levels during the restoration of mire habitats. On the lekking grounds affected by drainage, the surface may drop due to the decomposition of peat and water may collect in lower places. The results were the same with the lekking of 2-3 males in Laukasoo, where no males were observed following the rise in the water table. We cannot say for sure with those males that a new lekking site was found, but around 1 km to the south, a formerly unknown lekking ground was noted with two males (one of which was later killed by a predator). At least two males reside close to the old lekking site in summer, but we do not know where they court. In addition, a new and larger lekking site was found on the other margins of Laukasoo, but we cannot be sure that a direct link exists between these two events. If we lack the means to track specific birds and their movements during or after restoration, we can only obtain results through long-term monitoring. Restoration may lead to results that change later. For example, if the growth of mosses speeds up, then a lekking site which had become too wet for the Capercaillie may soon be suitable again. The lekking of the Capercaillie is not open to public viewing, so a web camera has been mounted in one project area to enable the lekking behaviour to be observed virtually.

We would advise not selecting individual rare or under-represented species as target species. These species may be attractive, but there are risks involved. When including birds in performance monitoring, much clearer results would be obtained from the general monitoring of breeding birds for some habitats, and the mapping of nesting pairs would also be suggested. In some cases, mapping during migration would also make sense. There are various statistically reliable methods for analysing such data. The shortcoming perhaps is the rather high workload this involves and the need to carefully plan the locations of the areas, as well as the practical work required.

As with all of the surveys launched as part of the project, this monitoring only makes sense if it continues after the project comes to an end. It is especially important to continue if restoration methods need to be tested.

CULTURAL HERITAGE IN MIRES

PIRET PUNGAS-KOHV

AN OVERVIEW OF HERITAGE IN ESTONIAN MIRES

Mires would undoubtedly function very well without humans, and much better without draining. Usually, a mire is defined as a natural habitat. But if we focus on people, it would make more sense to understand the world around us through the prism of landscapes. In this case the emphasis is not so much on the habitat but rather on how people experience a mire, feel it, explain it and value it. A landscape is an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors. [1] A landscape does not exist without heritage because landscape is a meaningful and constantly changing tangle of space and time. The archaeologist Laurajane Smith (2006:2)[2] conceptualises heritage through the idea rather than the thing(s). According to Smith, heritage is a cultural and social process that integrates memories – forming the basis of how we understand and relate knowledge of heritage to the present day.

When describing their relationship with the surrounding, Estonians normally accentuate forests, the sea or fields. However, people in Estonia have always been connected to mires as well. For example, if we take a look at the map of Estonian Stone Age settlements (see Map 1), many of these are connected to present-day mires and bogs. Especially significant here is the central part of Estonia. However, one must bear in mind that at the time both the climate and plant communities were different: an area defined as a mire today may have been a flooded meadow, a lake, a stream or some other body of water many centuries ago. Open water may have provided a much easier opportunity for moving around, since at the time there were no two- or four-lane roads between Tallinn and Tartu: cars only arrived in Estonia around a century ago[3].

The geographer Denis Cosgrove[4] has said that every socio-economic regime formation generates its own landscape. According to this definition, we have had at least five of these in Estonia[5] and even mires have felt the impact of socio-economic regime formation. Following Cosgrove's reasoning, we might say that each subsequent socio-economic regime formation develops in a way that somehow 'thins out' the previous layer or covers the existing layer with a new socio-economic regime formation. The palimpsest has been used at times as a metaphor to illustrate this idea[6] (see Crang, 1998[7]). Returning to mires and their drainage and restoration, there are clearly two different layers of landscape as defined by their meaning and nature. As can be guessed, draining has been one of the human activities that has had the greatest impact on mires. At the same time, draining and everything connected to it constitute an important and colourful chapter in our mire heritage. What is so peculiar about draining compared to the rest of mire heritage? The effect of draining on mire habitats is usually fatal in ecological terms. As such, other practices characteristic of cooperation between people and mires tend to vanish, since one critical component of a mire – its water – has been removed. At the same time, mires can be cunning: they do not signal at once that something is wrong, but do so gradually (see also Jõgisalu, 1974). As a result, people do not necessarily perceive the changes immediately.

In restoring mire habitats the activity is reversed: the water must remain in the mire, to which end the water flow in ditches is blocked. On a more theoretical level this means a new layer of landscape is created, or rather an attempt is made to 'erase' at least one of the previous layers of meaning and activities from the landscape by blocking the ditches. In turn, this kind of activity raises many questions, at both the ecological and social levels. For example, the ecological and hydrological functioning of mire habitats, their functioning as a home for species, the final aims of restoration and more come under discussion. From the viewpoint of humans, a question may



Map 1. Stone Age settlements (red dots) and mires today (blue colour on land).
Compiled by: K. Sikk, base maps: Land Board 2021[9]

[1] European Landscape Convention 2000 / entered into force in Estonia in 2018. https://envir.ee/rahvusvaheline-koostoo-valisrahastus/euroopa-noukogu-maastikukonventsioon

[2] Smith, L. (2006). Usages of heritage. Routledge Taylor and Francis Group. London and New York.

[3] Einer, V. (1988). Korilasrajast kiirteeni [From gathering trails to highways]. Tallinn. Valgus.

[4] Cosgrove, D. (1984). Social formation and symbolic landscape. The University of Wisconsin Press. Maddison.

[5] Palang, H., Mander, Ü. (2000). Maastikumuutused Eestis [Landscape Changes in Estonia]. In: Frey, T. (ed.). Kaasaegse ökoloogia probleemid [Modern ecological problems] VIII: Loodusteaduslikud ülevaated Eesti Maa Päeval [Scientific summaries from Estonian Earth Day]. Eesti VIII Ökoloogiakonverentsi lühiartiklid [Short papers from the 8th Estonian Ecology Conference], 169–179.

[6] Palimpsest: parchment on which earlier writing has been obscured or erased and overwritten with new text (EKI)

[7] Crang, M. 1998 Cultural geography. Routledge Contemporary Human Geography. London, New York.

[8] https://soo.elfond.ee/kkk/

[9] Sikk, K., Kriiska, A., Johanson, K., Sander, K. and Vindi, A. (2020). Environment and settlement location choice in Stone Age Estonia. Estonian Journal of Archaeology, 24(2), pp.89-140.

arise as to how human beings adapt to restoration work on the mire landscape they are used to and what people may think of it all[8]. It should also be mentioned that as part of the 'Conservation and Restoration of Mire Habitats' project we talked with a number of locals (24 interviews with 31 people in total) about traditions associated with mires and attitudes towards mires. Some expressed scepticism towards the restoration of mire habitats as part of conservation. At the same time, many respondents indicated that in recent years they have seen fewer berries in mires, sometimes to the extent that there is no longer any point searching the mires for them. We might suppose that the reasons for this lie in ditches, meaning that one specific activity of a small number of people has had a damaging impact on the mire habitat, as well as on the ways people relate to mires, such as their berry-picking traditions.

CLASSIFICATION OF MIRE HERITAGE AND DATA SOURCES

Although in its essence heritage is more of a process depending on ways of interpreting it, some kind of classification (such as dividing it into intangible and tangible heritage) helps. In terms of geographical extent we can talk (mainly in the case of tangible heritage) about point, linear and area spatial objects; a separate possibility for classifying heritage arises from thematic areas, different practices and research questions. In the context of classifying heritage we can also discuss the topic of what has survived of our mire heritage and how it has done so, as well as what is being maintained and why (see also Pungas-Kohv 2015). There are no doubt many other ways of classifying heritage as well.

The following information formed the basis for proposing a classification of mire heritage. References to sources have been added where possible. Mire heritage also covers the aspects of heritage that occur on bog islands or in bordering forests (e.g. the location of resin-gathering sites). Anyone is welcome to amend the following list or classification by e-mailing piretpk@elfond.ee.

BOG HERITAGE CAN BE DIVIDED BY TOPIC, FOR EXAMPLE:

References added after the dash and/or in brackets help to locate more information about the type of heritage or practice presented.

AREA SPATIAL OBJECTS:

- **Peat mining fields (both cut-over peatlands and fields with active mining) where peat was mined mainly for fuel. Today, peat is extensively used in gardening (Land Board geoportal, National Archives maps)**
- **fen grasslands (Land Board geoportal, National Archives maps)**
- **burnt areas – information from locals**
- **drained areas – clearly visible from analysing the maps (Land Board geoportal, National Archives maps) if we compare maps from the first half of the 20th century with current maps.**
- **resin gathering sites – occasional finds during fieldwork, information from locals**

LINEAL SPATIAL OBJECTS:

- **Digging ditches with the aim of draining a mire – maps pertaining to land improvement objects can be requested from the Agriculture Board, National Archives maps**
- **paths in mires – known paths through mires are marked, but many are probably (still) unknown (archaeological references, https://register.muinas.ee/, National Archives maps)**
- **winter roads – in many cases recognisable from aerial photos (Land Board geoportal, National Archives maps)**
- **duckboards, hiking trails and other infrastructure (cabins, information boards, campfire sites, etc.) – information (rmk.ee, additional information from locals if a private initiative)**
- **forest rides – various maps and orthographic photos**

POINT SPATIAL OBJECTS:

- **Refuges – known shelters in mires and bogs are usually noted as heritage sites (https://register.muinas.ee/)**
- **peat extraction sites – peat extraction sites and ditches are clearly visible from elevation models based on LIDAR data. This information is supported by older maps from the Land Board geoportal and interviews with local people**
  – peat used for animal bedding
  – peat used for fuel
- **iron-smelting sites – archaeological excavations, map analysis, earlier information from documents concerning the area, e.g. management plans and booklets.**
- **different types of buildings:**
  – bunkers of the Forest Brothers – cultural heritage layer in the Land Board geoportal, conservation management plans, fieldwork, interviews with local people

- hunting cabins, hunting stands – cultural heritage layer in the Land Board geoportal, fieldwork, interviews with local people
  – peat shacks, where peat was dried – cultural heritage map layer in the Land Board geoportal, fieldwork, interviews with local people
  – hay warden's cabins – cultural heritage map layer in the Land Board geoportal, fieldwork, interviews with local people
- trees with different types of meaning (and hence also use):
  – prominent residual trees (used e.g. as landmarks)
  – sacred trees (from Land Board maps)
  – cross trees (mainly in Southern Estonia)
  – individual resin trees
- stones marking boundaries – (Land Board maps)
- springs – not occurring as heritage sites in the areas studied
- multipurpose holes
  – flax-retting holes
  – holes for fermenting cucumbers
  – holes for cooling milk

As a somewhat liminal transition towards intangible heritage, the following group consists of items and traditions associated with mires:

ITEMS:
Large equipment associated with mire or activities taking place in mires, such as shovels, tractors and drones.
Smaller items associated with mires or activities taking place in mires:

- spades with various functions and appearances
- various items designed for gathering food, side dishes, medicinal or decorative purposes from mires and bogs – references to archive materials, interviews
- research tools for using and protecting mires
- snowshoes ('mire shoes') for moving around in mires and bogs, for people and horses; skis
- clothing
- footwear
- building a temporary shelter in a bog
- tricks for not getting lost – from ribbons tied to branches to mapping the best berry sites by GPS

Traditions and skills

- navigation skills
- knowing a mire, knowing how to move around in a mire, incl. knowledge of how to avoid hollows
- knowing plants and animals
- gathering tradition – (survey plans and correspondents' responses from the Estonian National Museum)

INTANGIBLE MIRE HERITAGE: If desired, this material could be divided into folk tradition and representations created by the author.

Folk tradition:

- **Folklore about mires; information available from various databases of the Estonian Literary Museum (e.g. Kivike – the museum's virtual cellar; Koobas – database of place-lore). Some information can also be found in the card index of place names of the Institute of the Estonian Language. Authors, titles, etc. of fiction can be found in the Estonian Literature Database. Another source of valuable information on local events is the database of old newspapers dea.digar.ee. Helpful information is also to be found in local museums and in the memories, experiences, descriptions, etc. collected from people.**
  – place-lore
  – place names
  – short texts (proverbs, figures of speech, riddles, metaphors, etc.)
  – folk songs

- Authored creations: library databases – ESTER, ETERA.ee – references collected from people in the digital library of the Academic Library of Tallinn University; database describing the cultural history of Estonian mires available online at soo.elfond.ee and initiated as part of this project. –
  Fiction – where, how and when mires and bogs are discussed
  – Songs and poetry
  – Popular science, articles, themed booklets and other popularising materials from the media
  – Films
  – Photos
  – Opinions, recollections, photos, etc. on social media

APPROACHES TO MIRE HERITAGE IN THIS CASE

In collecting heritage associated with mires we have tried to be as holistic as possible in this project, starting from familiarising ourselves with existing materials, then by providing information to those participating directly in mire restoration activities and also to the general public, and finally seeking to add something new to the available information. In order to not get hopelessly lost, research on tangible heritage, place names and folklore was limited to the project areas. However, fiction and poetry were studied in the context of Estonia as a whole (see soo.elfond.ee).

In studying the material methodically, the aim was to integrate the humanities and the sciences. The order of activities was usually as follows:

- **reviewing conservation management plans** – In Estonia, 73.4% of mires are protected at some level (response from the Environment Agency to a request for information, January 2015). Since it is highly probable that the majority of mires have some kind of conservation management plan, these documents provide us with background information. In many cases the management plan contains a chapter on heritage in the bog. Thus the first step is to find out whether a management plan has been compiled for a mire.
- **familiarisation with the area under study by examining maps** – Once a general description of the mire being studied has been obtained, then in the following stages free digital maps are used (e.g. Land Board maps, including their 'thematic map layers' on memory landscapes in national parks, on protected objects of heritage and on objects of cultural heritage of the State Forest Management Centre; and National Archives maps). By comparing older maps with those compiled nowadays we can find explanations for objects noticeable in nature today but with unclear 'content', or gain hints on what 'signs' we should search for in nature.
- **place names found on older maps** may give us clues as to whether it makes sense to repeat research on mire heritage and project areas with different (older) place names. During the mire restoration project, this work was mainly done by Eerik Leibak, who compiled maps with old place names on them for every project area.
- **keyword searches from digital archives** (dea.digar.ee) – Using different keywords (newer and older place names, mire place lore, keywords associated with the project area, etc.) this so-called media archive yields a remarkable number of descriptions of local life. References were found in the databases of the Estonian Literary Museum and elsewhere. It should be taken into account that such work is very time-consuming, and if time is limited, better planning and a limited number of keywords are advisable. It is also important to save unearthed material, since finding it again can be time-consuming work. An extremely useful skill in working with these materials is the ability to read Gothic script.
- **reading fiction on mires and bogs** – Earlier research [9] on the meaning of mires in which people were asked to note references in literature to mires and bogs helped us familiarise ourselves with fiction about mires and bogs. Based on the data obtained, a continuously updated database (soo.elfond.ee) has been created, one of the functions of which is to support teachers in integrating literature and nature studies. We hope this database offers teachers a quick source of information on reading suggestions containing descriptions of nature. Discussions of both literature and nature could be carried out in Estonian language, Estonian literature, natural science and geography lessons. The database will continue to grow after the mire restoration project has come to an end.
- **coordination and approval** of restoration work with and by the National Heritage Board and Centre of Sacred Natural Sites.
- **semi-structured interviews** with locals – The project plan included interviews with local people so as to collect all kinds of stories about the mires being restored. The average length of each interview was one hour. In the course of the 24 interviews we talked to 31 people, collecting 45 hours of material. In some cases we interviewed the people over the phone. An example of the questionnaire for Laukasoo can be found in APPENDIX 1 at the end of the chapter.
- **in every mire restoration plan** for all project areas there is a **chapter** on heritage. This includes an evaluation of certain heritage objects to be taken into consideration in the context of mire restoration
- **presentations** at **public** (**participation**) **meetings** outlining restoration work – Cultural heritage specialists have to attend such meetings to introduce their results to the local people. This is also a good way of getting to know locals, obtaining additional information about the project area and, where possible, reaching agreement on conducting interviews.

A separate group worked on **archaeological monitoring**[10] (see the chapter 'The archaeological experience') and visited protected natural and heritage sites with higher archaeological potential. The preparatory methodology for archaeological monitoring has much in common with general methods for studying heritage. It is important to synchronise action plans between working groups.

OUTSTANDING EXAMPLES FROM THE PROJECT

More detailed information related to heritage in the project areas is available online at **soo.elfond.ee**, wherein all restoration plans include a chapter on cultural heritage together with references, photos and maps. Below, notable **examples** directly connected to cultural heritage are given for each project area so as to illustrate the diversity within the concept of heritage and the problems associated with it.

LAUKASOO (LAHEMAA NATIONAL PARK)

One of the best-known places in Laukasoo is **Suurlaugas** (**'Great bog pool'**) with its 'manor ditch', which the local people still mention as an important toponym. Villu Jahiloo (interviewed in August 2017) said that the landlord, Von Pahlen, needed this ditch to get water for the Joaveski watermill built

[9] Pungas-Kohv, P. (2015). Between maintaining and sustaining heritage: The examples of Estonian mires and village swings. Dissertationes Geographicae Universitatis Tartuensis 58.

[10] In Estonian, special word - 'leire' - means 'archaeological monitoring'

on the Loobu River. However, the effect of this added flow was short-lived, and the bog water, rich in humin, turned the paper yellow. In 1899 Von Pahlen sold the mill and some land near it to Nikolai Dellingshausen, the lord of Loobu Manor, who turned the mill into a paperboard factory.

It could be said that in a sense, drainage has influenced toponyms: 'Suurlaugas' was also commonly referred to as '**Kuivlaugas**' ('Dry bog pool'), since it had almost dried up due to drainage. In the course of mire restoration, the biggest and longest dams ever made for the project (four in total, each over 100 metres long) were constructed to restore Suurlaugas. The water level has since risen, giving us hope that within a few years the names 'Suurlaugas' ('Big bog pool') and 'Laukasoo' ('Bog pool mire') will be justified once again.

OHEPALU (OHEPALU NATURE CONSERVATION AREA)

In the centre of Järvetee road, on the southern shore of Lake Udriku Suurjärv, there is a boulder known as the **Kükkaeide stone** which has rolled down from the bank on its own or with human help [source: cultural heritage application of the State Forest Management Centre in the Land Board geoportal]. According to legend, a hunchbacked witch who walked bent over once lived in Ohepalu, and when she died she turned into a stone [source: cultural heritage application of the State Forest Management Centre in the Land Board geoportal]. In the Koobas database of the Estonian Literary Museum there is another description of a stone. Unfortunately, it is not clear whether it is of the same stone: *"One mother had a very pretty daughter who used to visit the lake with fairies every Saturday night... The mother was curious and wanted to spy on her daughter and see how she danced with the fairies on the lake. Her daughter forbade this: "Do not come and watch me. It will bring me bad luck..." But the mother did not listen, and went along anyway. She wrapped herself in a great shawl so that only her eyes could be seen. She sat on a slope from which the entire lake was laid out before her. Then the fairies appeared, to dance out onto the water, and when they came closer to the shore and the mother saw her daughter among them, adorned with gold and crystals, she could not stop herself and exclaimed, "Oh, so pretty!" But then she heard a thunderous crash... The fairies had vanished from the water, and the mother has turned into a stone sitting on the slope. She sat there for generation after generation in peace and quiet until one day, in summer 1959, Russian soldiers fishing by the lake pushed her down the slope, seeking to drown her so as to save the daughter from the fairies. However, they could not drown her, and it is certain that her daughter is still dancing with the fairies."* [RKM II 97, 508/10 (3)].

On the southern shores of Lake Udriku Suurjärv there really was a large stone in front of a culvert, just as the legend says. During the mire restoration works we wondered whether we should lift the stone up onto the shore again. Then a local man, Heigo Vija, mentioned that the stone we had in mind was not the Kükkaeide stone: the right one was in the lake. In the course of the restoration work the 'wrong' stone was moved onto the shore, but the 'right' one was still in the lake, since pulling it onto the shore would have been too resource-intensive. One possible solution proposed is to add an explanation to the text on the sign next to the 'wrong' stone and to point out that the 'right' stone is still in the lake, which could also increase swimmer safety.

SIRTSI BOG

One peculiarity is that there is no chapter on heritage in the management plan drawn up for Sirtsi bog. Considering the popularity of the toponym 'Sirtsi' (its name is used in the popular expression "Into Sirtsi mire with you!"), the heritage of this mire deserves more attention.

The most spectacular cultural heritage object in the mire is **Viru Road**, which was once one of the most important winter roads in the region. *"The road ran over the mire in a north-east to south-west direction and helped many a wayfarer cross the mires in central Estonia on their way to St Petersburg. The lords of the manors in Püssi and Roela would take the first ride out to open the winter road season... Local lore has it that once, from a sledge forming part of a train of carts carrying spirits, an oaken spirits barrel fell through thin ice into a bog pool. This story is told even today, and people have tried to guess at the state of the barrel at the bottom of the mire and where exactly it might be. (pp 38–39) "In addition to vodka, glass bottles made at the Tudu glass factory were transported to St Petersburg along this road. But between 1922 and 1926, a narrow-gauge railway was built from Sonda to Mustvee, and with that the winter road lost its importance."*[11]

In addition to literature and old maps, information on the Viru Road was also sought in the course of archaeological fieldwork. The methodology included both observations and searches with a metal detector. The starting point of the road has been damaged in the course of land improvement, but its central section is clearly visible on the landscape, and in some places remains in use. This latter is indicated by the metal machinery parts found on the site. When bore holes were drilled, the wooden base of the road was unearthed, while the bog islands in the middle part of the road show clear indications of one or more former bunkers. Several objects associated with military activities (e.g. cartridge cases) were found in the course of the research, as well as resin-gathering cups and other more modern items. An 18th-century coin was also found, in Ruunassaare (a five-kopek piece from the time of Catherine the Great). Since mire restoration work is taking place at the north-eastern end of the road, it is possible that reaching the road will become more complicated during the warmer seasons in the future. However, the drainage work here was undoubtedly carried out after the road was used as a transport corridor. Based on existing information, we remain convinced that the Viru Road will still be visible as a mire road after the restoration of the mire habitats.

TUDUSOO

In the Tudu mires there are **two** refuges that are classed as **heritage conservation areas**: one in Seljamägi (no. 10658) on the south-eastern margins of Punasoo mire, not directly within any project area; and the other in the middle of Luussaare mire (no. 10294), which falls within one project area. Both sites require a protection zone of 50 metres, calculated from their outer contours.

Unlike other project areas, in this case one of the aims was to reconstruct the Tudu Järvesoo **educational trail** for people with special needs and to create informative texts for

[11] Lepasaar, J. (2011). Sooradadel [On mire trails]. MTÜ Pärandkaitse Koosluste Ühing.

the educational trail in Tudu and the hiking trail in Seljamäe. This latter trail was restored by the State Forest Management Centre and the Tudu Järvesoo educational trail by the Estonian Fund for Nature in cooperation with said centre.

Since there are two heritage sites (the **refuges** in Seljamäe and Luusaare) in the mires, the consent of the National Heritage Board was needed. In planning the restoration work, the decision was taken to preventively alter the location of one dam and to relocate it outside of the protection zone so as to avoid potential negative effects on the old refuge.

The Tudu Järvesoo educational trail, which takes visitors over what is known as the Master's ditch, was reconstructed. Earlier maps indicate that this is probably one of the oldest ditches in the mire, and local lore about the ditch has been integrated into the texts on the information posts.

A very particular event takes place in this area: the Tudu triathlon. This is the oldest continuous triathlon in Estonia, having been held 31 times. As at January 2020, the organisers consider the restoration work a threat to the event, since rising water levels may hinder its organisation. On the one hand, the restored educational trail will give visitors better access to the lake, but on the other, due to the higher water level between Lake Tudu and the Seljamäe road, it may be more difficult to walk along the trail (especially in rainy autumns and during the spring flood season). The triathlon organisers have estimated that higher water levels have made the area less passable. Since the triathlon has always taken place in July, the water level should not interfere with the event in dry summers. We truly hope that cooperation between locals and conservationists is possible in spite of the changes to the hydrological regime. The course of future cooperation will become clear in the wake of the project.

In fact, the rise in the water level in Lake Tudu has also been limited in order to take people's well-being into consideration. Namely, older maps and the lake shores indicate that the water level was higher in the past than it is today. During restoration, no dams were constructed in the Master's ditch (where the Tagajõgi River rises) that were high enough to help raise the water in the lake to levels that would have posed a danger to the cabin and campfire site by the lake.

SOOSAARE MIRE

Soosaare mire forms its own part of Alam-Pedja Nature Reserve, away from the main body of the reserve. A special feature here is the peat extraction holes that were separated from one another by a ridge and which were much deeper than e.g. in Tudu Järvesoo. This ridge likely consisted of a surface layer (of moss, plant roots, etc.) unsuitable for the cutting of peat loafs. Photos of the peat extraction holes serve as valuable material for input and comparison in creating the texts for Tudu educational trail.

FEODORISOO MIRE

A peculiar feature of Feodorisoo, compared to the other project areas, is its unique linguistic and cultural space. The large belt of mires and forests surrounding the settlements on the left bank of the Narva River has effectively cut off the settlements and made it difficult for outsiders to gain information on what goes on there. Unlike the other project areas, this is an important site of military heritage dating from World War II.

THE EFFECT OF (MIRE) RESTORATION ON CULTURAL HERITAGE AND THE EFFECT OF HERITAGE ON RESTORATION, OR WHY WE NEED A HERITAGE SPECIALIST

If we link the restoration of mires to the preservation of heritage, we create an additional landscape layer in a direct sense, an indirect sense and an ideological sense. Earlier 'layers of landscape' tell their own stories, which can sometimes help; at other times they can present an obstacle to creating new 'layers'. However, it is important to note such 'obstacles', and in some cases at least it is possible to reach a compromise through mutual respect, in word and deed, for the aims and wishes of different parties.

THE EFFECT OF HERITAGE AND THE VALUE OF TAKING IT INTO ACCOUNT WHEN RESTORING MIRES

Heritage is just one of the aspects addressed in the 'Conservation and Restoration of Mire Habitats' project. As such, it enables us to pay closer **attention** to this field, which otherwise often receives little of it if the focus is on nature conservation activities or activities bringing economic profit. In this way, restoration helps to maintain the heritage of mires, and through informative materials perhaps even breathe new life into it. Example:

- It makes it possible to **update public databases** with missing information.
- If a site has been attributed heritage status, this usually carries **meaning** for certain people or groups. The latter results in closer attention and indeed greater emotional closeness. Adding the viewpoint of heritage to restoration may help to prevent and de-escalate potential sources of conflict with target groups for whom restoration affects places that are important to them. Willingness to compromise on both sides is definitely of help.
- **Exchanging heritage-related knowhow** with locals – Locals have come up after a talk on heritage to say, "You know, I never knew that." Such feedback shows that there is a need for and a willingness among people to listen to stories about their local area, whilst indicating the need for attention to be paid to this field, including by locals.
- **Knowledge** about local heritage history **may elicit nuances** that could help to adjust restoration work to better suit local conditions. For example, during the public meeting about Laukasoo, locals talked of a fire

in the bog. An article found in a local newspaper (at dea.digar.ee) validated this information. The fire was caused by the wider afforestation of part of the mire, which at first raised questions in the assessment of the effects of drainage. For example, information on fires can rule out the felling of trees to restore treeless mires, since fires would have enriched the soil to the extent that the tree cover would soon return (as happened in Ohepalu).

THE EFFECT OF MIRE RESTORATION ON HERITAGE

▶ **The danger of the actual disappearance of mire heritage.** In general, restoration work is not affected by aspects of mire heritage that we are only just starting to define as heritage and whose origins date back to the pre-drainage period (e.g. refuges, old winter roads and paths in mires). In the case of a direct restoration effect, we are talking more about cases where the water level rising in the course of restoration may have an impact on tangible heritage objects. As these will remain partially or entirely under water, access will be more complicated, etc. (such as the start of the Viru Road). Closing/damming ditches can be considered a key example of such logic, especially those that were dug during the manor era. Although ditches form an essential part or mire heritage they have not gone unclosed in the project, since the total number of ditches is very large in Estonia and, especially in protected areas, conservation values are usually more important than the heritage value of the ditches themselves. Where there have been older, historical ditches, references to them are given in the restoration plan. For example, the Master's ditch in Tudu Järvesoo is mentioned in the informative texts; the trail also crosses this ditch. As such, it would be possible to 'partly preserve' aspects of heritage left under water (primarily the ditches) by using informative texts in special cases. And in the interests of history, information on the location of the ditches and dams built there will be maintained in the restoration plans.

▶ **'Revival' of heritage status.** Restoration (especially of open mires) changes landscapes in a way that can cause people to go on the defence. One 'lifeline' for heritage against restoration could be highlighting the heritage status of the site, which might otherwise have been forgotten about the area. As such, it is necessary to discuss the extent and effect of heritage status, and whether and how we can strike a balance between nature conservation and [mire] heritage. Here direct help could be gained from people who study mire heritage and can explain the need to restore mires via direct communication (interviews) – on the one hand, they collect information the relationship between the locals and the mire, and on the other, those people are more willing to air their concerns about the restoration work in interviews, which otherwise might have gone unsaid. Conversations and meetings could lead to compromise. The mire heritage amassed could be used in informative materials to preserve and in some cases also raise people's awareness of the world around them. Of course, the number of people interviewed is very small, but even few interviews per community would help the people behind the project understand what the locals' biggest concern is.

▶ **The possibility of new mire heritage and a new layer of meaning on the landscape.** Many people find it difficult to understand why ditches dug into mires long ago now need to be filled. Using this example, we can discuss the ideological impact of mire restoration, both on locals and the public generally. Such impact is most strongly felt during early restoration work, when changes to landscapes (especially if trees are cut down) causes disruptions in an ecological sense, but also in terms of heritage creation. This may lead to valid questions and reactions, since there is still no knowledge of or belief or confidence in the success and profitability of restoration. At the same time, restoration brings with it new practices that will help create a new layer of meaning and gradually also new heritage in mire landscapes. Thus we can in some sense talk about the enrichment of mire heritage through the restoration of mire habitats.

OBSERVATIONS TO TAKE INTO CONSIDERATION WHEN PLANNING SUBSEQUENT CASES

It is a value in itself that a discussion of heritage in the affected areas has been woven into a project focussing on nature conservation. Such integration increases empathy among specialists in different disciplines and gets them seeing the aims of the project from different viewpoints, thus improving their awareness of different types of research methods, values, worldviews and more. In terms of power, everything associated with the humanities is often at a disadvantage, being even more modest than the aims and activities of nature conservation. Integrating these fields would give both the possibility to empower their fields and boost their competitiveness, e.g. in achieving their economic objectives. In the long run this would help to create a more balanced society and more cohesive communities.

▶ In drafting such projects, it would be appropriate to organise introductory meetings with locals as early as the project-drafting stage or immediately after obtaining funding. If possible, the benefits to locals should be defined together. Such meetings could turn a NIMBY (*'not in my backyard'*) way of thinking into a PIMBY (*'please in my backyard'*) way of thinking.

▶ Since in this project one person has been responsible for both cultural heritage and nature education, and partly also for communication, their workload has been significantly greater than initially planned. Moreover, activities concerning education and communication led to a different order of work in researching heritage. This result in desynchronised progress and less effective communication between the group of archaeologists and

[32] Lowenthal, D. (1985). *The Past is a Foreign Country*. Cambridge University Press, Cambridge.

the mire heritage specialist. The project's timescale did not include e.g. the following aspects:

- processing of interview materials – The material gathered in a one-hour interview took 4-5 hours to process, which included the preparation of a list of keywords from the interview. Without this, it would be much more difficult to navigate in place lore and the descriptions given by local people. The usability of unprocessed interviews is more limited.
- whereas in applications for funding the fieldwork schedule of the heritage specialist mainly consists of conducting interviews with locals, then in reality additional hours must be included for simply going out to examine and become familiar with the area in question.
- interviews are very time-consuming, but the aim (depending on the size of the area, its population density, etc.) should be to conduct at least five interviews with locals per area.
- in conducting interviews with locals, it would make more sense to do so in pairs, one of whom is directly involved in the restoration work – making it possible to give detailed answers to questions locals may have about the locations of dams and so on. A variety of guidelines are available on carrying out fieldwork for collecting folklore.[12]
- writing of chapters for mire restoration plans.
- participating in public meetings in their actual amount.
- One particular result that has already become clear is collecting folklore as a way of talking to communities and getting the aims of the restoration project across in more detail. At the same time, the precondition for successful interviews and fieldwork is well-meaning interest and mutual respect between the project team and local communities. The aim of fieldwork is not to influence locals, nor is it lobbying or resolving ongoing conflicts.
- The application should also include activities in the form of summary articles on mire heritage for each project area for a local newspaper, which should follow a popular science format rather than simply quote the mire restoration plan verbatim.

APPENDIX 1. QUESTIONNAIRE FOR SEMI-STRUCTURED INTERVIEW (IN THE EXAMPLE OF LAUKASOO MIRE)

- When and where were you born? Where did you work and what as?
- How did you come to live here?
- How old is the name 'Laukasoo' and/or have there been any other names for the bog? Has there never been any desire to establish a hiking trail through Laukasoo?
- Are there parts of the mire that are known by other names among locals?
- What role has Laukasoo played among people in the area?
- Why do people go to the mire and what do they do there? Do people often go to the bog?
- What helps to move around in the bog?
  - Laukasoo and...
  - Laukasoo and hunting
  - Laukasoo and wild animals
  - Laukasoo and gathering and preserving activities
  - Laukasoo and mushrooms
  - Laukasoo and peat moss and medicinal herbs
  - Laukasoo and resin-gathering
  - Laukasoo and ditches, including the digging of ditches
  - Laukasoo and peat, peat mining and peat pits
  - Laukasoo and fires: when? how extensive? what effect?
  - Laukasoo and hermits?
  - Laukasoo and the Forest Brothers: were there bunkers here?
  - Moving around and getting lost in Laukasoo: any protection against getting lost? what is used to orient?
  - Is there a certain type of clothing you should wear in the bog?
  - Laukasoo and sinking
  - Laukasoo and special places: locations that attracted people/people tended to avoid? why?)
  - Laukasoo and folk tales (will- o'-the-wisps, mire spirits, etc.)
- Your personal experience of mires: What role have mires played in your life? FOR EXAMPLE:
- What other mires have you been to?
- Why did you visit those mires? Which one most of all?
  - Do you know any peculiar stories or incidents associated with the mire in general?
  - What are some works of fiction you associate with mires?

Can you recommend someone who might be willing to talk about the local mires?

APPENDIX 1. Questionnaire for semi-structured interview (in the example of Laukasoo)

THE ARCHAEOLOGICAL EXPERIENCE

KAAREL SIKK

Archaeovision R&D performed a preliminary archaeological study and undertook archaeological supervision for the project, which forms part of the wider discussion of heritage in the project. The aim of the preliminary studies was to guarantee the protection of cultural objects in the restoration area, but also to obtain new information on the cultural heritage of mires. Wetlands are famous among archaeologists, since on the one hand as places they are difficult to study, but on the other, intact find complexes, items of archaeological value and traces of events that took place far from settlements can be found in them. During the project, the wetlands were also presented to the general public from the viewpoint of archaeology.

Due to the size of the restored areas and the large number of archaeological inspections required, we had to select areas in which the project earthworks (as well as transport, gravel pits and logging) would not destroy possible finds or hinder future archaeological fieldwork. To map these areas and evaluate their archaeological potential, a preliminary study was carried out. During this study, relevant databases, archive materials, publications and historical maps from the National Archives collection (http://www.ra.ee/kaardid/) and Land Board collection (http://xgis.maaamet.ee) were analysed.

We applied our knowledge of the principles people in the past used to choose sites in the context of the environment and analysed the landscapes based on the maps. As a result, locations were chosen in which the probability of finding traces of human settlement was higher. Datasets from the Geological Survey of Estonia, LIDAR data from the Land Board, etc. were used to study pictures of nature.

Based on this, natural sites with greater archaeological potential were selected in the vicinity of the restoration work. Since there were archaeological sites near all of the restored areas, all of the area held potential.

THE FOLLOWING SITES OF INTEREST FOR FIELDWORK WERE CHOSEN:

- Soosaare restoration area: 11 sites (7 mineral hills, 1 drainage ditch, 1 peat field, 1 part of a sand quarry, 1 field)
- Feodorisoo restoration area: 14 sites (10 mineral islands, 4 parts of a mire road)
- Laukasoo restoration area: 21 sites (13 mineral islands, 3 other sandy hills, 4 parts of a mire road, 1 other area)
- Tudusoo restoration area: 18 sites (10 mineral elevations, 1 sandy area, 2 known heritage sites, 4 parts of a mire road, 1 landscape object)
- Sirtsi restoration area: 20 sites (12 mineral elevations, 1 peat field, 3 objects of cultural heritage, 3 parts of a mire road, 1 landscape object; see e.g. Fig. 1)
- Ohepalu restoration area: 19 sites (13 mineral islands, 4 sandy elevations, 2 parts of a mire road, 1 probable object of cultural heritage in the bog)

Among these were two heritage sites in Tudusoo (the Seljamäe and Luusaare refuges) where the preliminary plans indicated earthworks, but these were redirected based on the results of the preliminary survey. The location of the refuge in Seljamäe was noteworthy, since the heritage site had been incorrectly marked on the maps, allowing the location to be rectified. This rather typical error could have led to the destruction of the site.

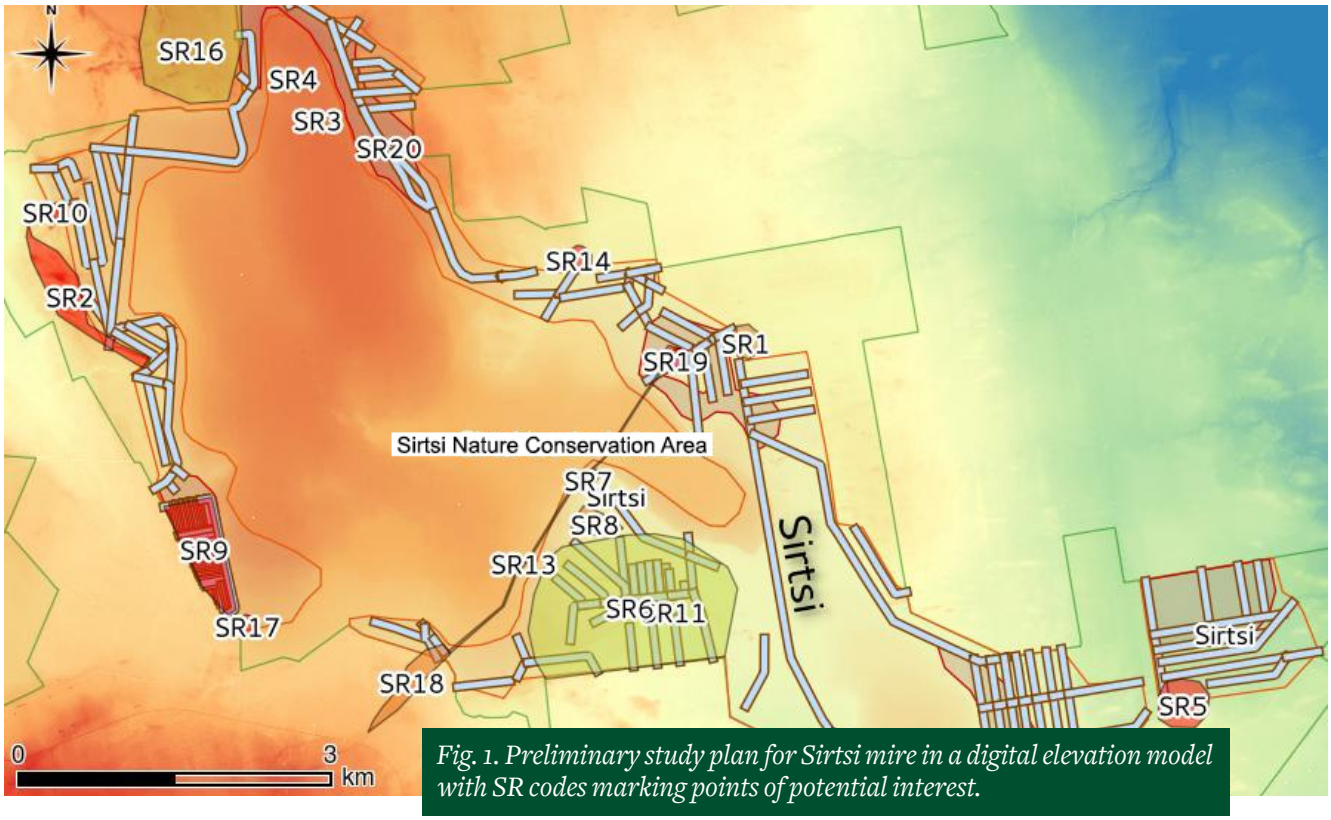


Fig. 1. Preliminary study plan for Sirtsi mire in a digital elevation model with SR codes marking points of potential interest.



Measuring the log structure of the winter road in Sirtsi as localised using a probe. Photo: Kaarel Sikk

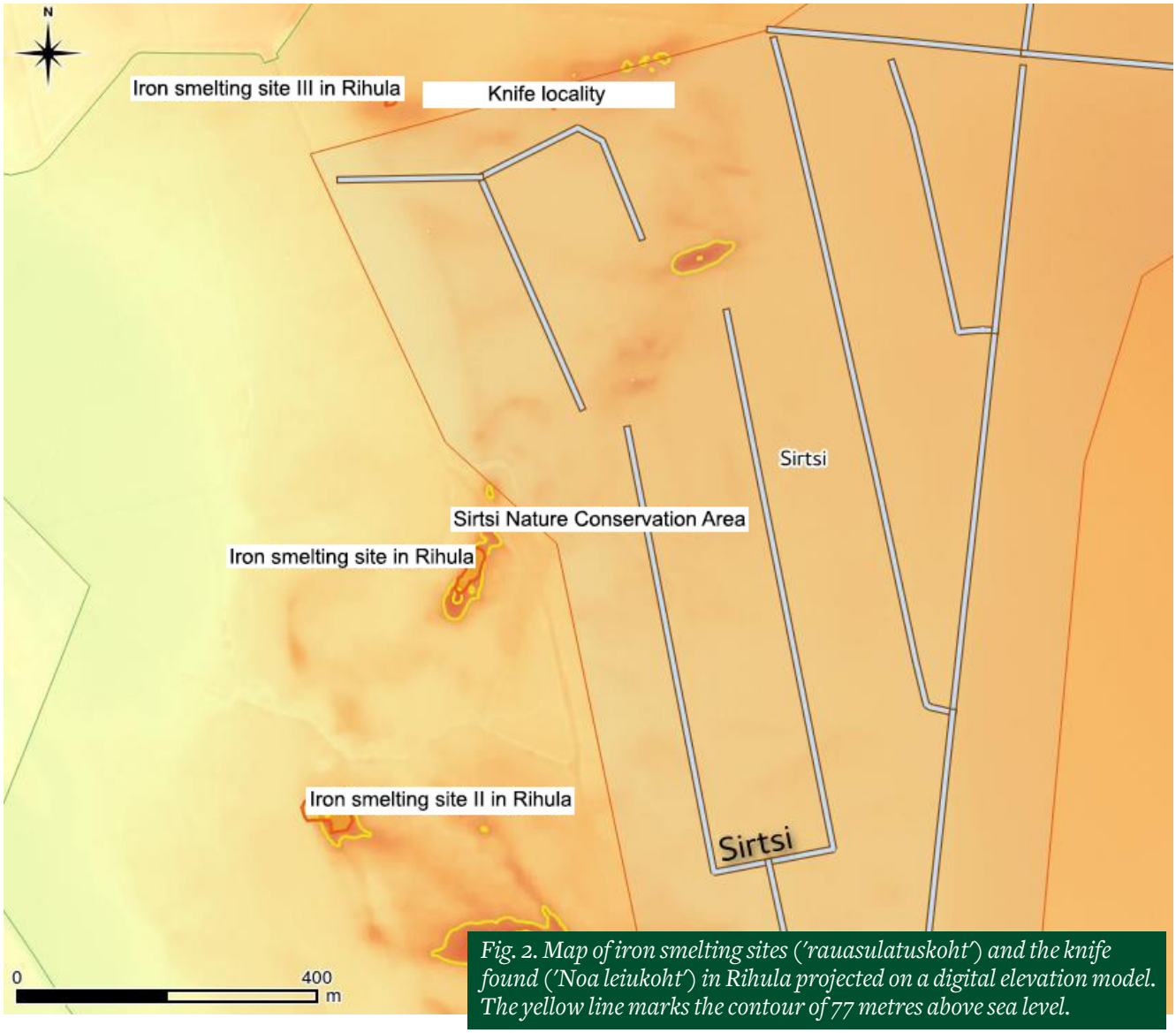


Fig. 2. Map of iron smelting sites ('rauasulatuskoht') and the knife found ('Noa leiukoht') in Rihula projected on a digital elevation model. The yellow line marks the contour of 77 metres above sea level.



Pieces of slag from the Rihula I settlement. Photo: Kaarel Sikk

Some of these sites were chosen for preliminary survey; others for monitoring in case earthworks started on them. In summer and autumn 2016, archaeological monitoring was carried out on sites assigned for preliminary study. Archaeologists from the University of Tartu, detectorists from the Kamerad club, students from the Estonian University of Life Sciences and others were involved in the fieldwork. Moreover, on 27 July 2016 a 'Bog Day' was organised for everyone interested in the course of which archaeological and heritage sites were explained. The methods used were visual monitoring of the landscape and ditches, metal-detector searches and the drilling of bore holes. One specific type of monument we wanted to locate was mire and bog roads. Many old maps show mire roads, so we have quite a lot of information about them. Since roads constitute heritage objects, the aim of the preliminary surveys was to avoid damaging them during restoration.

The amount of work (in hours) varied from site to site, mainly due to the numbers of volunteers involved. Archaeological monitoring took place for two to five full working days per restoration area. At the most prolific site, the restoration area in Sirtsi, work lasted for five days, with two to five people involved. All in all, 144 work hours were spent on archaeological monitoring. This larger workload was mainly due to the finds acquired and the limits of the area of the archaeological sites that were determined, but also the number of volunteers.

Some interesting objects were discovered through surveying, but in archaeological terms only a few of them are worth preserving. The search in Sirtsi mire turned up three previously unknown iron smelting sites (Rihula I, II and III; see Fig. 2) and a knife as a random find near the sites. Test pits were drilled near the iron smelting furnaces, with pieces of slag and animal bone being collected. The iron smelting complexes that were uncovered provide us with new information on the area's past and the history of iron processing in Estonia.

The Viru Road – a winter road passing through the mire – and wooden structures forming part of it were located in Sirtsi bog. Mire roads were also pinpointed in other restoration areas. At one end of the Viru Road an 18th-century coin and some agricultural tools were unearthed.

Traces of 20th-century activities were found in Sirtsi and other mires using metal detectors: a remarkable number of resin-gathering boxes and forestry tools, but especially remnants of war. In addition to shell shrapnel, cartridges and bullets, metal heel plates and horseshoes were found, as well as war-time bunkers.

While inspecting a ditch in Soosaare mire, a group of stones was found in the peat that probably ended up there in the course of flax-retting. Close by, an enormous number of glass bottle fragments was found. In Ohepalu mire, holes were found with the remains of wooden structures inside them, as well as smaller horseshoes possibly dating from the Iron Age.

The archaeological fieldwork led to the drafting of guidelines [34] to guarantee the protection of known refuges, iron smelting complexes and mire roads. These were used to adjust the planning of the restoration work, to avoid it damaging the monuments and so as to be a safe distance from the protection zone.

Archaeological supervision was also carried out in Laukasoo and Ohepalu, and visual inspections were performed on the ditches dug, but no material of archaeological interest was found.

The results were presented in the form of archaeological monitoring plans and project reports on the project website: https://soo.elfond.ee/projektist/aruanded/. Due to the danger of looting, the exact locations are classed as sensitive data; as such, this information was removed from the public materials. The full versions were solely meant for internal use. The results of the fieldwork were also showcased as part of informative events held near the restoration areas.

EXPERIENCE OF INDOOR METHODOLOGY

The fieldwork gave us good experience in carrying out preliminary archaeological surveys on large wetlands. As became apparent during the fieldwork, the survey sites were often too large and with difficult terrain. Therefore, for other similar projects the selected survey areas should be more specific. To this end, predictive archaeological environmental models should be used for the areas being studied. Although

[34] Archaeology – manual for earthworks and peat mining_09.2018. (In Estonian)

a lot of information on human activities on the mineral land in mires was obtained during the fieldwork, details of what was under the peat remained insufficient. As such, computer-created paleo-reconstructions would help us provide better evaluations so as to predict the extent of historical bodies of water later transformed into mires.

It became apparent that archaeological fieldwork which is usually targeted at study periods prior to the 20th century can also provide important information on cultural heritage from later periods. In other similar projects in the future, common interests should be mapped and the fieldwork methodology adjusted accordingly during the preliminary work stage.

In the course of this project, preliminary archaeological work was carried out before the exact nature of the restoration work was clear. Progress would be optimised if archaeological investigations were able to take existing restoration plans into account. It is important to consider the locations and transport corridors of earthworks and raw materials, since transport on sandy soil can also damage archaeological sites.

Although potential guidelines defined as a result of the work of archaeologists may lead to extra cost due to changes in restoration plans, the latter are localised and usually do not bring about fundamental changes in the plans.

EXPERIENCE OF FIELDWORK METHODOLOGY

The course of the large-scale fieldwork confirmed that preliminary visual surveys of an area are necessary and that only based on such surveys can we perform more detailed studies. Random checks with metal detectors proved especially productive, leading to almost all of our finds in this project.

Moreover, it emerged that drilling of test pits was not productive: these are only useful if finds have already been made or the location shows greater archaeological potential. Extensive drilling of bore holes, which has proven useful on Stone Age sites, is expensive and may only be used on very specific sites with high archaeological potential.

Although no archaeologically interesting material was found, visual inspection of peat ditches proved useful, since it led to the discovery of a flax-retting hole in Soosaare bog.

The workload was somewhat underestimated due to the large areas and their difficult terrain. Future preliminary work should ensure somewhat more accurately defined choices of areas. At the same, it is possible to evaluate sites in the course of preliminary visual observations on which nothing of archaeological interest is noted during archaeological monitoring and which, as a result, are not included in the survey. Such sites include areas that are difficult to access, but those that are especially important are areas with homogeneous topography where drilling test pits might be possible but it would be difficult to select locations with higher archaeological potential and the chances of making finds would therefore be smaller.

Supervision of restoration work yielded no materials of archaeological interest. In order to make optimal use of resources, no supervision was performed in the Sirtsi and Tudusoo restoration areas due to the volume of earthwork being carried out and the limited archaeological potential of the sites.

SUMMARY OF RESTORATION OF MIRE HABITATS AND ARCHAEOLOGICAL HERITAGE

To begin with, we should highlight the risks accompanying mire restoration as a project involving high volumes of earthwork. As in other similar projects, all sites of cultural significance must be protected, as stipulated by the Heritage Conservation Act. Some such objects were identified in the course of this



Stones in peat, probably brought to the site for flax-retting. Photo: Kaarel Sikk

project and the necessary changes made to the restoration plans. However, it is not possible to study entire areas, so those undertaking earthwork must follow the guidelines if they discover something. At the same time, it is necessary to train those doing earthwork so that they can recognise potential objects of interest.

Although there is no known research on this topic, the indirect effect of restoring mire habitats in itself (with the exception of earthworks on a specific site) does not damage cultural heritage. Due to these works, the water level stabilises in areas that had previously suffered from alternating dry and wet periods. It is possible, in principle, that access to some heritage sites may be lost, but in order to evaluate such situations and earthworks, each case must be examined separately.

On the other hand, the restoration of the mires brought us new information about the past, e.g. regarding iron smelting furnaces and mire roads, and also advancing research into mire heritage by providing new finds. The finds and the process of searching for them constituted new and interesting parts of the work done in the mires. One positive surprise was the level of public interest, reflected in the number of people willing to participate in the archaeological fieldwork and the feedback received about 'Bog Day'.



On the margins of Ohepalu mire searching for finds. Photo: Kaarel Sikk

(EDUCATIONAL) MATERIALS ON THE RESTORATION OF MIRE HABITATS

PIRET PUNGAS-KOHV

WHY ARE EDUCATIONAL MATERIALS NEEDED IN ADDITION TO RESTORING MIRE HABITATS?

In reality we can only restore mires outdoors. However, part of this work takes place in people's heads – without the knowledge and belief that mires are important and need to be restored, it is difficult to implement their restoration. This work in people's heads – known also as learning – is rather complicated as well. Learning is usually associated with sitting at a desk and training your mind and willpower. The learning process often becomes more complicated outdoors, since the physical conditions for it are not optimal: it may be raining, or too hot or too cold; sometimes you have to contend with mosquitoes and horseflies; your concentration can be affected as you keep a lookout for snakes; you get hungry a lot more quickly than you normally would; your legs start to ache. Sound familiar? Such hurdles make learning more difficult, and they pose an even bigger challenge when putting educational materials together. But in spite of this obstacle course, the drafting of educational and informative materials is designed to ensure the following:

- Children learn:
- what mires are and what it means to restore a bog;
- why mires and their restoration are important;
- how to recognise mire restoration taking place in nature; and
- what traces humans have left in mires.
- Learning is great!

INDOOR ACTIVITIES: WATCH, PLAY WITH AND READ ABOUT MIRES

EDUCATIONAL FILMS

In order to enjoy being outside more, it makes sense to do preliminary work (theory) indoors – for example, finding out what a mire is and how it forms. In this case, the function of outdoor activities is repetition or anchoring.

The processes that take place in the world around us are often difficult to explain, but pictures can be worth a thousand words. With this saying in mind, we produced a series of educational films[1] under the umbrella title 'Boggles the Mind' in which the life of mires is brought to viewers from nine different viewpoints.

The series consists of the following films:

- What is a mire and how does it develop? (5:59)
- Let's take a look at what types of mire there are (14:01)
- Peat (8:17)
- Mire restoration and recovery (5:22)
- Water and bodies of water in mires (7:12)
- Mire archaeology (8:39)
- Fear of mires in bog-lore (5:23)
- Traces of people in mires (9:18)
- How can we maintain and protect mires? (3:58)

All of the films come with subtitles in Estonian, Russian and English so that people with impaired hearing and those who don't speak Estonian can watch them. The videos can be found online at soo.elfond.ee/filmid/.

Passively watching an educational film is certainly better than nothing, but actively studying a subject guarantees better understanding and longer-lasting knowledge. As such, the aforementioned website presents a range of ideas on how these films can be used in teaching.

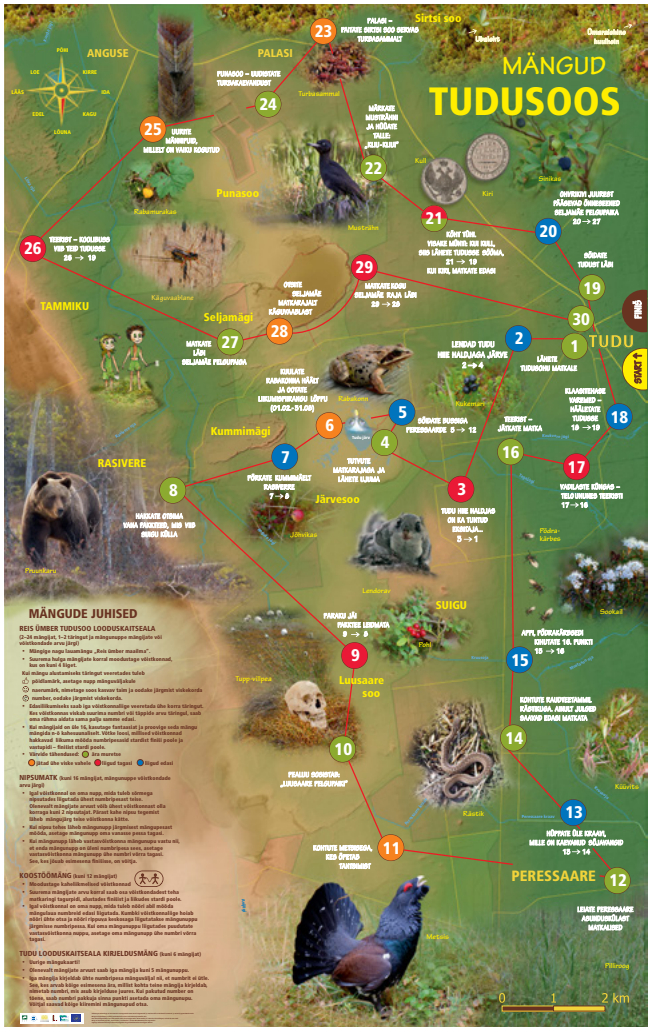


Screenshot of the opening frame of the film and the badge of honour for popularising science in 2018.



The film crew in May 2017. Photo: M. Kohv

[1] Core crew of film series: Piret Pungas-Kohv – creator, promoter and scriptwriter; Indrek Kangro – cameraman, director, editor and graphic designer; Mart Kessel-Otsa & Anti Mäss – sound supervisors; Marko Kohv – drone operator and photographer; Jüri-Ott Salm – assistant; Siim Angerpikk – host and narrator; students from Põltsamaa Gymnasium – presenters of introductory discussions.





The size of the floor game is 2.5 x 4 metres, enabling many children to play at the same time. Photo: Piret Pungas-Kohv.



Kalli the bog sprite. Designed by Triinu Sarv

The films were also given the seal of approval for classroom use by the Estonian Research Council, which awarded the series 1st Prize in the audio-visual or digital media category of the annual Estonian competition for the popularisation of science and technology in 2018.

FLOOR-BASED GAME

The saying goes that the only job little kids have to do is play games, and this helped us come up with materials for the youngest of learners who are not yet able to read or write. The result is a floor-based game that was designed to give as many children in a class as possible the chance to play together at the same time. The players can hike around Tudusoo, and the game can be borrowed from the Estonian Fund for Nature without even visiting the bog. No doubt all of the players will end up walking around real mires at some point as well!

KALLI THE BOG SPRITE, MODRIS AND THE LOST WILLOW GROUSE: A BOOK OF FAIRYTALES

In addition to the floor game, there is a book of fairytales [1] for little mire lovers. In the book, Kalli and Modris, two little bog sprites familiar from the educational trail, use a flying carpet to go on a long journey through the mires of Estonia. Kalli's big wish is to find a willow grouse that might recall the time his relatives busied themselves by the bog. It is a collection of 21 tales into which ancient wisdom about mires and information on mire features and ecology are intertwined. Readers find answers to a range of questions: What are those strange bumps that have appeared in the bog? Should one use familiar or polite forms of greeting when you encounter a horse skeleton? How might one console the spinster of Sirtsi bog? And how does one go about finding a willow grouse when it is as rare in Estonian nature as some spirits? The events in the book unfold over the space of one year. The book is designed to be used with older kindergarten groups, but it could also be integrated into lessons in the early years of primary school. We hope adult readers find something for themselves as well while relating the adventures of Kalli and Modris to their children.

OTHER RECOMMENDATIONS FOR AVID READERS

As your child or pupil and/or their interest in mires and reading grows, you might want to continue exploring the soo.elfond.ee website. Another site worth visiting is the database of Estonian mire heritage, which contains more than 200 references to works of literature, books of poetry and such that showcase certain aspects of mires. Why not choose a book and read it with the class? Afterwards, in literature or biology lessons, it would be interesting to discuss why the mire was discussed in the way it was, and what the children think of mires.

[1] Pungas-Kohv, Piret (2021). Kalli the bog sprite, Modris and the Lost Willow Grouse: A Book of Fairytales Art and design by Triinu Sarv, Paar OÜ, 120 pages (In Estonian)



Information post on Tudu educational trail. Photo: Marko Kohv

HOW ABOUT GOING OUTSIDE?

If you already have some knowledge of mires regardless of your age, it is a good idea to visit a mire to put what you have learnt into context – whether things really are the way they were said to be. But where and how can you have fun in a bog?

TRAVERSING TRAILS ON YOUR OWN OR IN SMALL GROUPS

Bogs worth visiting from the point of view of restoration are those in Tudusoo Nature Reserve on the borders of Ida-Viru and Lääne-Viru counties. More specifically, there are three major mires here: Punasoo, Järvesoo and Luusaare. In Punasoo you will find the Seljamäe hiking trail (7 km), which forms a complete circuit. In the course of our project, the trail was provided with 13 new informative texts.

Järvesoo is home to the Tudu educational trail (1.4 km there and back), which was redesigned in parallel with the restoration of the bog. This trail boasts a whopping 108 information boards, mounted on nine spinning information posts. The trail is short but wide and equipped with benches, making it possible for people with prams or in wheelchairs to explore it as well. The texts on the information boards help curious visitors of all ages appreciate mire restoration, offering something for those who like to read and something for those who like pictures. In terms of methodology, the information boards mean you can follow the trail on your own if you wish to.

HIKING ALONG TRAILS IN LARGER GROUPS

If you visit in a larger group and provide everyone with extra information about mires, the question might arise: how can we make the lives of teachers/guides easier so that they retain their enthusiasm for using the trails for as long as possible? The members of the group can of course be tasked with reading the texts – all the more so since the paths through mires tend to be on duckboards that are usually very narrow. Moreover, rubber boots are not the go-to footwear for most children these days and the mire surface would rather avoid excessive random treading. All this favours dispersed learning or searching for a variety of technical solutions.

▶ A) One possibility is to get hikers looking for answers to various questions themselves. To this end I have compiled over 70 questions, from which every teacher/guide can choose those best suited to their participants. Archaeovision R&D helped generate a technical solution for the website (soo.elfond.ee) that enables a worksheet to be automatically created once the questions have been selected. The teacher simply chooses the questions, clicks on the link to create a .pdf and prints it out. The students then have to fill it in. Having to write down the answers can be inconvenient, but this helps the students memorise what they learned (see e.g. Arro, 2021)[1]. In compiling the worksheet it is a good idea to keep in mind that the tasks should fit on one A4 page – students are unable to learn more new material than that in one go. Moreover, the content of the tasks should depend on the group. For example, the teacher might choose tasks that support either individual or group work.

▶ B) If a teacher/guide needs help putting together a full-day educational programme, we have ready-made outlines of such programmes that are available in Estonian, English and Russian. They include tips and technical advice that will hopefully make organising the day easier.

[1] Arro, Grete, Mis on sinu naiivteooria? https://roheline.ee/grete-arro-milline-on-sinu-naiivteooria/ (In Estonian)

In terms of methodology, the possibilities are:

- 1) hiking the trail and answering questions about the informational texts – individually, in pairs or in groups;
- 2) combining the information in the texts with additional details and explanations (meaning the group must stay together); or
- 3) combining the texts with self-produced worksheets – the group learning together at first and then working individually.

- C) Prepare a programme that is largely independent of the texts along the trail wherein the group learns and stays together the whole time. Listening and writing is integrated into activities

If a learning programme involves active guiding, sound devices (audioguides; see photo) can prove very useful, with the teachers/guides speaking into their headset and the listeners hearing this in their headphones. This tool enables all of the hikers to participate in learning, saves a lot of time, avoids potential problems from arising and most importantly spares the voice of the instructor. Interest is greater if the participants really hears what is being said.

As far as we know, the use of audioguides outdoors is still something of a novelty in Estonia. As such, let us highlight their pros and cons:

- As always, much depends on the specific model!
- The system we have been using in recent years is already somewhat outdated. More user-friendly models exist which have shorter cords that do not tangle so easily. Unravelling cords is time-consuming: in the worst-case scenario it can take up to an hour! But the satisfaction of both teachers and students is worth it. For example, one teacher said of using audioguides: "I think this was the first time I really felt part of a tour, because I heard everything you were saying. Usually I'm chasing kids at the tail-end of the line!"
- Headsets can sometimes be uncomfortable on the ears and may be too large for little hikers. The latter problem can be solved by them wearing a cap under the headset.
- Another solution is for the participants to use their own headphones. *Bluetooth* headphones are quite popular these days, but unfortunately they are too modern for our receivers :)
- A charging case and headphone case are of help, since they make it easy to charge and carry transmitters and receivers.
- With audioguides, the way the headphones are connected must also be safe – you must point out that the charging port is not meant for the headphones, since forcing the plug into it could prove fatal for the little device.



Enthusiastic participants from NGO Händikäpp in Tudusoo in 2021. Photo: Krista Untera

HOW WERE THE EDUCATIONAL DAYS ORGANISED?

A total of 64 educational days were planned on the Tudu and Seljamäe hiking trails. The initial methodology foresaw children mainly from nearby schools visiting the Tudu trail, and doing so several times over the five-year period. COVID-19 and delays in restoration and trail construction led to changes being made to this plan.

Thus we arrived at a plan where 34 educational days would be organised by the Estonian Fund for Nature. I conducted 30 of these in autumn 2020 and spring 2021. In addition, six educational days were organised in Russian by Volha Kaskevich. Since the participants included children from kindergartens all the way through to senior high schools, I feel qualified to say that the number of educational days was enough to pinpoint the stronger and weaker aspects of the programme. A blog describing the days is available on our website at soo.elfond.ee. As attentive readers may have noticed, this leaves another 30 educational days 'hanging'. So what did we do with the rest of these days?

HOW TO INTEGRATE EDUCATIONAL DAYS AND TEACHER TRAINING

In addition to the educational days, we also planned teacher training workshops. These started in late spring 2021. They were intended to consist of three parts: theoretical parts online and a practical day in Tudusoo. We walked both trails and I proposed various methodological solutions for actively engaging children in learning to make them really start to understand mire restoration.



Cloudberry award for a well-devised educational programme, issued by the Estonian Environmental Education Society on the basis of reviews.

When we announced the workshop we added the proviso that teachers participating in the practical workshop would be obliged to independently organise an educational day in Tudusoo for their class. In order to make this prospect seem less intimidating, we offered the Estonian Find for Nature our support.

NAMELY:

If they wished to, the teacher could (and will be able in future to) add tasks to the exercises and questions presented on the website, and generate these automatically as a worksheet.

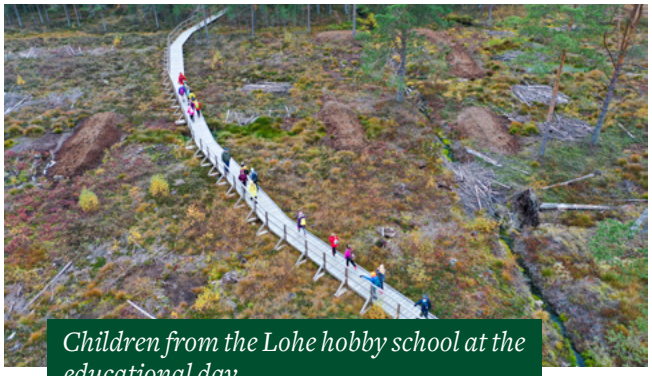
Around two weeks before the practical part of the teacher training, a calendar was provided for teachers to note their date and class and the number of meals needed so that the caterer would know when and where they had to serve meals. It is important to note times for both tracks separately on the calendar in order to avoid one track getting too busy. As the coordinator you have to think very carefully about all joint e-mails sent to teachers that contain instructions. In compiling them, it is very helpful if another person reads them before you send them, since this is likely to identify potential points of misunderstanding. The instructions will still be interpreted differently, but you should at least strive for clarity, since it will mean less time wasted later on.

FINANCIAL SUPPORT FROM LIFE AND THE ENVIRONMENTAL INVESTMENT CENTRE FOR ORGANISING EDUCATIONAL DAYS FOR TEACHERS:

We were able to cover 220 euros in travel costs per group, plus a meal (soup, dessert and drink) and a small bonus for one teacher (90 euros gross, around 50 euros net).

In addition to the educational day, teachers can use a timed, multiple-choice test to revise the topic in the classroom, but this is designed for older children. One drawback of the test site is that response date must be renewed once a month since the period of use is limited.

In addition to more substantial educational materials, we have been introducing (Estonian) mires and everything connected to them for the last six years via more than 60 presentations, TV shows, video clips and audio recordings. Among other things, we invited people to visit mires in 2016 and 2018. This campaign, known as 'Astu sohu!' (lit. 'step into a bog'), was planned to take place predominantly in winter, since World Wetlands Day is marked on 2 February. It has proven to be a colourful interlude to our biannual conferences. But this invitation is worth making whatever the year or season, sometimes at the top of your voice, especially given that the rules set to protect mire habitats allow it and it is not the nesting season for birds. It makes sense to review the protection rules of mires setting out limitations first.



Children from the Lohe hobby school at the educational day.
Photo: Stanislav Grebenjuk



A contour of Estonia with an educational site made by children from Miina Härma Gymnasium.
Photo: Marje Peedisson



But how do we divide up the bog?
Photo: Kersti Ojassalu



Little visitors from Taime kindergarten.
Photo: Marika Johason

THE ROLE OF COMMUNICATION IN THE RESTORATION OF MIRE HABITATS

LAURA ORO & MARILIIS HALJASORG

Every activity undertaken for the purpose of nature conservation should include relevant, broad-based communication at both the local and wider levels. This is necessary for better understanding of nature conservation and its methods, as well as for preventing or alleviating misunderstandings or even conflict. In restoring mire habitats, such communication has been unavoidable in Estonia, since it has been a complicated issue raising many questions from day one.

Also, in ideological terms, restoring mires is quite different from the approach to mires prevalent in the 1950s. In many places where mire habitats have been restored, locals once witnessed the digging of ditches, and were possibly involved in it themselves. Of course they will ask: Why are the same ditches now being closed? Also, the mire area being restored will not necessarily look attractive during or directly after the restoration process, and the felling of trees may raise questions (see also the FAQ at soo.elfond.ee). Regeneration takes time.

Our task is to inform people of the reasons for restoring mires, the activities this involves and how it will all look. At the same time, it is important to listen and appreciate the opinions, fears and worries of locals and, if possible, to take them into consideration. Talking to locals was also important to us because we wanted to carry out some of our work and needed to transport our machines across private land. We also collected mire heritage as part of this project, which gave us a reason and the chance to talk to locals.

In addition to local communities directly affected by mire restoration, we aimed our communication at other target groups: scientists studying mires; decision-makers; school children; journalists; environmental organisations and environmental activists; and the general public. A number of activities designed for younger audiences will take place over the next two years.

DIRECT COMMUNICATION WITH LOCAL COMMUNITIES

One of the most important ways of communicating in order to understand one another is creating what is known as contact of quality. Unfortunately, direct contact is only possible with a limited number of people – because one-to-one communication is resource-intensive, and also because people do not always show up to public meetings. However, where necessary, we have met for both group and one-to-one discussions with local communities, helped by phone and e-mail. We have spoken directly with all of the landowners whose land could be affected by restoration, if the plan indicated that this might be possible. One form of direct communication has been interviews for collecting heritage.

Wherever possible, we have tried to inform people via phone calls and encouraged them to take part in the meetings so that the restoration work does not come as a surprise to them. At the public meetings we have outlined the plans for the restoration and sought proposals from locals to specify and improve them. Let us present some examples.

An important nuance at these meetings was explaining that the changes in the hydrological regime during restoration would not flood the houses closed to the area being restored. Often it was enough to indicate outfalls and collecting ditches that would be left open and to explain that these would continue to function after restoration. In one case – the drafting of the restoration plan for Laukasoo – the decision was taken after the meetings to commission an additional report to determine whether restoration could cause significant changes to the hydrological regime on the private land around the bog. Although expert analysis indicated that there would be no significant impact, this did not convince certain members of the community, who continued to oppose the plans.

Feedback from these meetings was used to amend the parts of the restoration plans affecting the hydrological regime on private land (i.e. if the owners were present at these meetings and did not give their approval). In the case of Laukasoo and Ohepalu, the monitoring system was amended and additional monitoring points established outside of the restored areas.

MEDIA WORK

In the course of the project we have turned a lot of attention to media coverage at the local, national and international levels. By the end of 2021, media coverage of the mire habitat restoration project amounted to 300 articles or mentions since the launch of the project in 2015, the audience reach of which being millions of people. Since restoring mires is a relatively new thing in Estonia, media interest in the project was great, but it was still necessary for us to provide them with information and engaging topics. Interviews, opinion pieces, explanatory articles and video reports about restoration were published by the media. Direct links to them can be found on our website at soo.elfond.ee.

SOCIAL MEDIA, WEBSITE AND OTHER DIGITAL CHANNELS

We have provided ongoing coverage of restoration on our dedicated website soo.elfond.ee, as well as on the social media channels of the Estonian Fund for Nature and associated organisations. We have run campaigns, such as 'Astu sohu!' (lit. 'step into a bog'), and kept an eye on topical groups on Facebook (like 'Helping Estonian Forests') so as to answer any questions that arise there. In propagating our ideas we have also used other channels, like Instagram and YouTube, and showcased the project areas on Wikipedia.

In the future, real-time digital maps could be created for our website on which people can find information on where restoration work is currently taking place, how much has already been restored and so on.

A HANDS-ON APPROACH

One good way of bringing people closer to nature and conservation is to directly involve them in mire restoration work. As such, we have run events designed to get volunteers involved in building dams and searching for the signs of capercaillie in the forest. Members of the Defence Forces, students attending holiday camps and foreign visitors have also participated.

EDUCATIONAL TRIPS, CONFERENCES AND OTHER EVENTS

When it comes to discussions of mire restoration, it is important to hear about the experiences of others. We have invited officials, researchers, journalists, supporters and others from Latvia, Sweden and Finland to participate in educational visits to share their stories and experience. We also organise biannual wetland conferences on the restoration of mire habitats.

MIRE EDUCATION

A separate focal point of this project has been mire education, elements of which are to be realised in subsequent projects. Nine educational films were made as part of the current project, primarily for schools in Estonia, but we have used them extensively in our communication as well. A wide range of other resources has been produced, and educational trips have been arranged for people interested in mires.

HOW ELSE CAN WE APPROACH THE ISSUE?

In future we should think about how to get local communities more involved in restoration. A hands-on approach and joint activities would probably help everyone to better understand the activities we undertake and the value of restoring natural ecosystems. NGOs have more freedom to apply novel methods.

One way of better informing local communities would be to recruit volunteers who are versed in the topic to help with direct communication. We hope that in the course of restoring further mires we will be able to highlight lots more positive stories about recovering mires, as this would help at the local and national levels alike. In media work there should be more of a focus on species, and we should think about how to more effectively highlight the human aspect of mires. Connecting with local communities proved difficult, which is why attendance of public meetings was low. At the same time, the number of people interested in the project in small towns was rather high. Perhaps matters would have been simplified if contact with landowners had been possible.

Another bottleneck was the lack of communication, poor information exchange and entrenched (incorrect) notions that existed between the managers of protected areas and local communities. Such ignorance and potential conflict could be prevented if said managers or researchers working in these areas organised regular meetings, hikes, etc. For example, information about species protection was always welcomed.



Students attending holiday camps restoring a mire Photo: Jüri-Ott Salm

THE PLANNING OF FELLING IN THE RESTORATION OF MIRE HABITATS

KAUPO KOHV

Felling is widely implemented in the restoration of mire habitats in Estonia and in Scandinavia. Its main purpose is to eliminate the impact of trees on the light conditions and hydrological regime of a restored area. It varies in scope from extricating specific tree species to removing all trees. The official type of felling in protected areas in Estonia is formative cutting. Felling is used to restore both open mire habitats and mire forest habitats. If felling is planned as part of restoration work, it must first be justified and the planners must be sure that the benefits of felling outweigh the damage caused by the rapid changes in the environment.

The planning of felling begins once the work required to restore the hydrological regime has been planned. Felling may only be planned if the planners are sure that a consistently high water level will form in the area after the ditches are closed, thus hindering the regeneration of trees from seeds or shoots.

The second prerequisite for the planning of felling is a clearly defined target community whose development the felling should support (Fig. 1, Table 1). This is a plant community formed through ecological processes in the wake of restoration. The formation of a target community is a lengthy process which depends on the impoverishment of the existing community and the environmental conditions hindering its regeneration.

If the target is a treeless community that existed before the construction of drainage systems, the determination of felling is usually easier. In this case the aim of felling is to eliminate all tree cover. This should be done carefully, since treeless mires can also contain small groups of trees or even single trees that need to be preserved in the course of restoration. Such previous-generation trees tend to be easily recognised by experts. Care should be taken in identifying former treeless habitats, because mire grasslands were widespread in Estonia prior to World War II, and in some cases treeless habitats on maps and in old orthographic photos can in fact be semi-natural mire grasslands. In this case, the justification for felling requires further consideration.

When planning felling, it must be evaluated whether restoring every historically treeless mire is appropriate and justified. In order to make this decision, general changes and existing nature conservation values in the mire in question must be taken into consideration. If a mire has naturally started to overgrow with trees, it would be inappropriate to ignore this and start creating conditions for a treeless bog.

The situation is more complex if the target habitat is a forest community. In Estonia, formative cutting has mainly been used to influence the structure of transitional mire forest communities. For other mire forest habitats, felling has not been used. Using felling in the restoration of transitional mire forest communities means increasing the openness of the community. This is important, since a thick canopy significantly hinders the precipitation from reaching the forest floor and the large volume of trees uses a substantial amount of water in the dry growing season, and problematic lighting conditions are also exacerbated. Light and moisture conditions are the main environmental factors influencing the status of undergrowth plant species in transitional mire forests and fen forests. In describing the target community, it is important to acknowledge that in nature, the structure of forests in transition mires and fens can be highly variable, depending on events in the past (the last 50-200 years) such as fires, storms, droughts and biological impact. Thus we may encounter older forests that are extremely sparse as well as younger transition mire forests that are very dense. As such, a forest that is more dense or of a higher volume does not necessarily mean there is a need for felling. If a plant community is within the limits of natural variation or very close to it, it is best to abandon felling. As few trees as possible should be felled, albeit enough to help the plant community achieve a structure that is at least close to one of the many possible natural states.



As many large trees as possible should be left growing along routes to avoid creating linear elements that are not natural to forest landscapes. Photo: Jan Ruukel

In restoring forest habitats, felling is justified only if the thickening of the canopy and the increase in the volume of wood are unequivocally understood to be the result of draining. This means that in transition mire forests generally, the basal area is usually more than 21 m^2/ha. For example, measurements taken in the old transitional mire forests in Öördi produced a basal area of 13-21 m^2/ha, but there were also wetter places in which the basal area did not exceed 10 m^2/ha. A forest stand is characterised by spatial variability and the presence of both fallen and dead trees. The dominant tree species is pine, but downy birch and spruce also occur, with willow species and buckthorn in the shrub layer. In describing felling, general descriptions of reference communities for transitional mire and fen forests should be treated with caution and updated according to the field data for a specific area. It is also important to evaluate the thickness of the remaining peat layer and the composition of the existing forest. If the peat layer has already been worn away (to less than 50 cm) and buckthorn and birch are present in the undergrowth, care must be taken with felling: the recovery of the forest from stump and root shoots may lead to an extremely dense, young forest stand, at least in the short term. In the case of birch in particular, felling should not be implemented. If speeding up the thinning of the forest is still desired, then damaging growing trees could be one way of slowing their growth without causing regeneration from stump shoots.

When planning felling it is important to take landscape aspects into consideration. There is greater justification for felling if it results in the formation of one significantly larger treeless area. Ditch-digging often breaks former treeless mires up into open mire fragments with narrow strips of forest. Eliminating these strips can be a very cost-effective way of improving the status of a number of species that need large open mire habitats. The planning of felling can also be abandoned if removing the trees is economically unjustified and the water table is predicted to rise to a level that will cause the rapid death of the trees and the formation of a treeless habitat. Felling must be abandoned if the secondary forest that has formed due to long-term drainage is more than 90 years old. In this case, the slow death of the trees caused by the rising water level should be preferred (although the ditches must nevertheless be closed). Dead wood from trees with a large diameter is a valuable habitat for many rare and endangered species. In planning felling, it must be evaluated whether there are similar habitats in the area so that forest-dwelling animals have alternative places to go. For example, if a possible habitat for the capercaillie features a transitional mire forest that is planned to be turned into a treeless mire community through felling, the planners must make sure that there are enough suitable habitats outside of the felling area for the capercaillie to move into. The principle of precaution must be deployed and the work must be designed in such a way that danger to any local populations of endangered species is excluded (see also the chapter 'Restoration that takes existing values into account').

Special attention must be paid to landscape aspects in felling along movement routes. Establishing movement route corridors often leads to unnecessarily large treeless linear elements (around 10 metres wide). Felling along routes is important for creating the space needed for movement and work with excavators. It must be ensured when cutting down trees along routes that a number of large trees are left standing between dams. If possible, groups of trees should also be left growing along the route (with excavators simply having to navigate around them). This is needed in order to break up otherwise uniform linear elements that could theoretically encourage predation.

In Estonia, felling is usually planned in two stages. During the first stage, an expert studies and describes the source habitat and potential target habitat (Fig. 1). They describe the existing natural values and evaluate feasibility and cost-effectiveness. They also give a detailed description of the felling that is required. In the second stage, a group of experts analyses the felling from the perspective of the landscape and weighs up the accompanying risks to natural values, but also considers conflicting values. Such an approach almost always means a reduction in the felling area in comparison with the proposals made following fieldwork. As such, it is considered a cautious approach.

IN THE COURSE OF FELLING, THE FOLLOWING PRINCIPLES SHOULD BE FOLLOWED AT ALL TIMES:

- It is important to retain previous-generation trees, both living and dead; if there is a risk of damage being caused to them, the surrounding trees should also be left uncut.
- Fallen trees and stumps should be damaged as little as possible during the work.
- Trees with special features (holes in the trunks, gnarled trunks or thick branches) should be preserved.
- In creating a new forest community using partial felling, it is important to provide spatial variation in the forest structure, thinning unevenly and retaining some denser parts.
- In pine-dominated areas (i.e. the majority of the restored areas), spruce and birch trees should be left with neighbouring pines to create a more mosaic stand structure.
- In places where extricating timber is complicated or impossible, damaging the trees (ringing the trunk or removing the bark) should be preferred. This renders the stand structure more uneven and the trees will die over a longer period.
- As much logging residue as possible should be removed from the area, pressed into the peat or eliminated by other means. This is important because the residue could worsen the condition of the habitat for ground-nesting birds.

THE NEGATIVE IMPACT OF FELLING

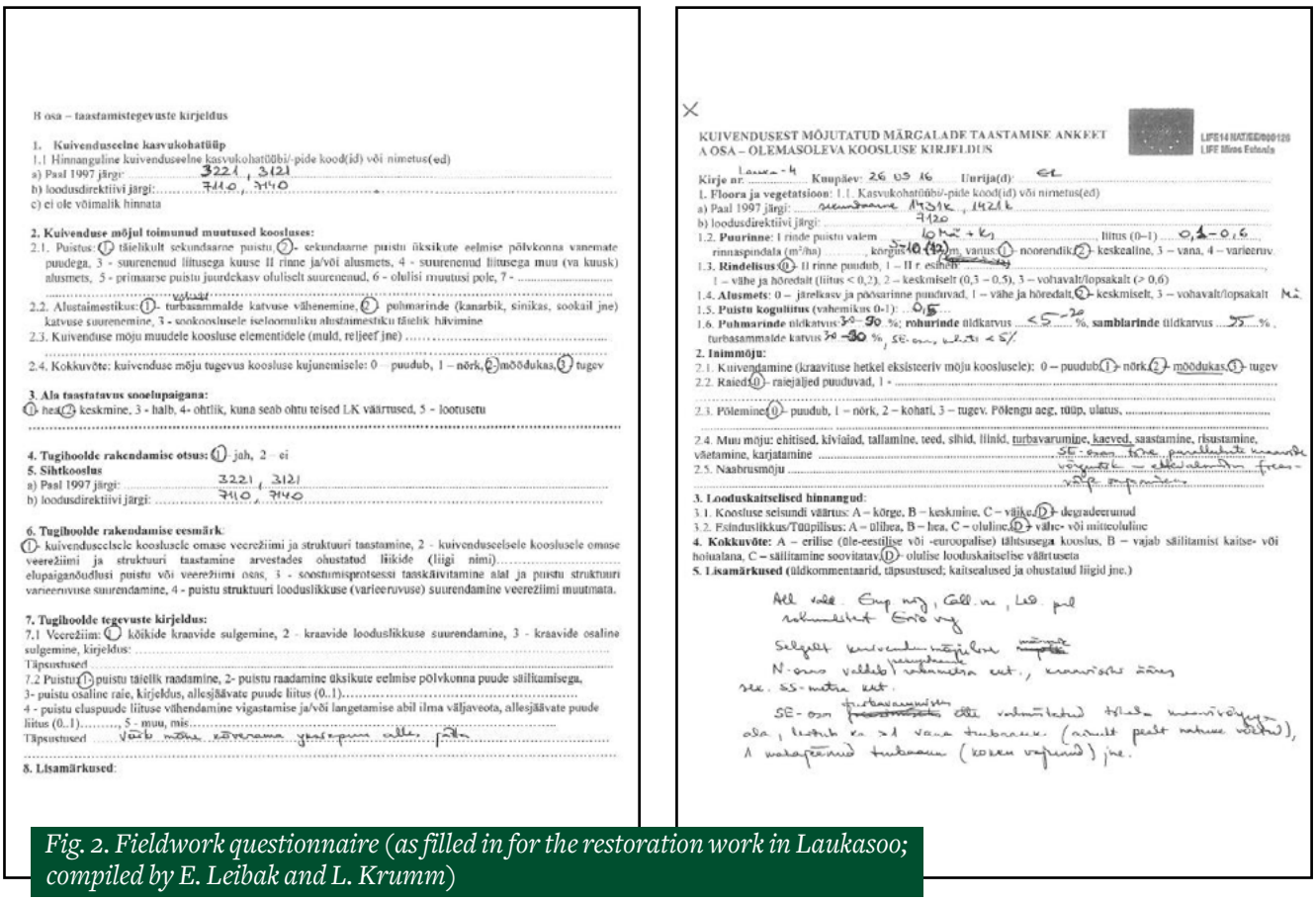
In planning felling, its negative impact must be taken into consideration. Potential negative effects include the following:

- There are protected species in the existing forest habitat and the restoration of mire communities will undermine their status in the long term.
- Biota requiring standing dead trees, stumps and lying dead wood are damaged in the course of felling.
- Undesirable regeneration of birch and buckthorn from stump and root shoots is initiated.
- Logging residue left on the ground has a negative effect on ground-nesting birds.
- elling creates linear structures and an edge effect which increases the predation risk to ground-nesting species of bird.

Table 1. Guidelines on planning restoration work where the source and target communities are taken into consideration. The guidelines in the table should be followed in conjunction with the general principles described in the previous chapters. The content of the table changes over time based on experience gained in restoration work and the emergence of new knowledge. The data presented in the table do not apply to neighbouring countries.

Source habitat	Target habitat (J. Paal (1997*) habitat type code/Habitats Directive code)				Comment
	3.1.2/7140	3.2 /7110	3.2.2p_1.4.3.1/7120	1.4.2.1_1.4.3.1/91D0	
	Transitional mire	Bogs	Secondary wooded bogs	Transitional bog and bog forests	
Bogs with thickened secondary tree layer	X	Close the ditches. Eliminate secondary tree layer	Close the ditches. Retain secondary tree layer	Close the ditches. Retain secondary tree layer	A bog should be the preferred target habitat if it connects large tracts of treeless bogs or forms an important part of a margin habitat
A bog with a thicker tree layer in an area designated as a capercaillie habitat to be preserved coinciding with evaluations from the capercaillie habitat model	X	Close the ditches. If the capercaillie population is viable on the landscape level and there are many suitable habitats within 2-3 km of the area under restoration, eliminating the tree cover may be considered	X	Close the ditches. If there are no suitable habitats for the capercaillie in the surrounding areas, tree cover should also be retained on the ditch routes wherever possible	
Ditched treeless bog	X	Close the ditches	X	X	
Ditched wooded bog without secondary tree layer	X	Close the ditches	X	X	
Ditched bog forests without secondary tree layer	X	X	X	Close the ditches	
Ditched bog forest with secondary tree layer	X	Close the ditches; consider removing the secondary tree layer	X	Close the ditches. Formative cutting on the secondary tree layer may be considered. Retain the stumps. It is advisable to create additional stumps.	A bog should be the preferred target habitat if it connects large tracts of treeless bogs or if the area forms an important part of a margin habitat
Ditched bog forest in an area designated as a capercaillie habitat to be preserved coinciding with evaluations from the capercaillie habitat model	X	X	X	Close the ditches. Route to be designed asymmetrically, i.e. wider in some places than in others. Leave groups of trees growing on the ditch routes	
Transitional bog with thickened secondary tree layer	Close the ditches; if the site constitutes a wet patch at the margin, remove the tree cover	X	X	X	
A transitional bog with a thicker tree layer in an area designated as a capercaillie habitat to be preserved coinciding with evaluations from the capercaillie habitat model	Close the ditches. If the capercaillie population is viable on the landscape level and there are many suitable habitats within 2-3 km of the area under restoration, eliminating the tree cover may be considered	X	X	Close the ditches. If there are no suitable habitats for the capercaillie in the surrounding areas, tree cover should also be retained on the ditch routes wherever possible	To be applied more widely if there is scientific proof of the effect on the capercaillie
Ditched treeless transitional bog	Close the ditches	X	X	X	
Ditched wooded transitional bog without secondary tree layer	Close the ditches	X	X	X	
Ditched transitional bog forest without secondary tree layer, 91D0, general protection value A, B	X	X	X	Close the ditches	There are plans to specify the content of evaluations of the status of 91D0 during the biogeographical seminars organised by the EU. If necessary, activities must be adjusted accordingly
Ditched transitional bog forest with secondary tree layer, 91D0, general protection value C, D	Close the ditches; if the site constitutes a wet patch at the margin, remove the tree cover	X	X	Close the ditches. Secondary tree layer designed with a canopy cover of up to 0.4-0.5 and a basal area of 13-21 m2/ha. Abandoning the cutting of trees may be considered if prerequisites exist for the spontaneous development of the habitat. When cutting the trees, attention must be paid to preserving the structural elements of dead wood	
Ditched transitional bog forest in an area designated as a capercaillie habitat to be preserved coinciding with evaluations from the capercaillie habitat model,	Close the ditches. If the capercaillie population is viable on the landscape level and there are many suitable habitats within 2-3 km of the area under restoration, eliminating the tree cover may be considered	X	X	Close the ditches; if possible, fill the entire length of the ditches. Route to be designed asymmetrically, i.e. wider in some places than in others. Leave groups of trees growing on the ditch routes	
Vaccinum myrtillus drained peatland forest	Close the ditches and remove the tree layer, if situated at the margin of a large bog	X	X	Close the ditches and thin out the canopy cover to 0.4-0.5 with a basal area of 13-21 m2/ha. Up to 10% of spruce may be left. When cutting the trees, attention must be paid to preserving the structural elements with dead wood	Another option: retain the ditches and the tree cover. Depending on the nature (and especially the age) of the tree cover, another equally possible option would be to close the ditches without redesigning the canopy.
Oxalis drained peatland forest	X	X	X	Close the ditches and thin out the canopy cover to 0.4-0.5 with a basal area of 13-21 m2/ha. Up to 10% of spruce may be left. When cutting the trees, attention must be paid to preserving the structural elements with dead wood	Another option: retain the ditches and the tree cover. Depending on the nature (and especially the age) of the tree cover, another equally possible option would be to close the ditches without redesigning the canopy.
Ditched drained peatland forest in an area designated as a capercaillie habitat to be preserved coinciding with evaluations from the capercaillie habitat model	X	X	X	Close the ditches. If the capercaillie population is viable on the landscape level and there are many suitable habitats within 2-3 km of the area under restoration, shaping the tree cover may be considered.	To be applied more widely if there is scientific proof of the effect on the capercaillie

*Paal, J. 1997. Eesti taimkatte kasvukohatüüpide klassifikatsioon [Classification of habitat types in Estonia]. TÜ Botaanika ja Ökoloogia Instituut. Tallinn.



B osa – taastamistegevuste kirjeldus

1. **Kuivenduseelne kasvukohatüüp**
1.1 Hinnanguline kuivenduseelne kasvukohatüübi/-pide kood(id) või nimetus(ed)
a) Paal 1997 järgi: 3221, 3121
b) loodusdirektiivi järgi: 7140, 7140
c) ei ole võimalik hinnata

2. Kuivenduse mõjul toimunud muutused koosluses:
2.1. Puistus: (1) täielikult sekundaarne puistu (2) - sekundaarne puistu üksikute eelmise põlvkonna vanemate puudega, 3 - suurenenud liitusega kuuse II rinne ja/või alusmets, 4 - suurenenud liitusega muu (va kuusk) alusmets, 5 - primaarse puistu juurdekasv oluliselt suurenenud, 6 - olulisi muutusi pole, 7 - .....
2.2. Alustaimestikus: (1) - turbasammalde katvuse vähenemine, (2) - puhmarinde (kanarbik, sinikas, sookail jne) katvuse suurenemine, 3 - sookooslusele iseloomuliku alustaimestiku täielik hävimine
2.3. Kuivenduse mõju muudele koosluse elementidele (muld, reljeef jne) .....
2.4. Kokkuvõte: kuivenduse mõju tugevus koosluse kujunemisele: 0 – puudub, 1 – nõrk, (2) mõõdukas, (3) tugev

3. Ala taastatavus sooelupaigana:
(1) hea (2) - keskmine, 3 - halb, 4- ohtlik, kuna seab ohtu teised LK väärtused, 5 - lootusetu

4. Tugihoolde rakendamise otsus: (1) jah, 2 – ei
5. Sihtkooslus
a) Paal 1997 järgi: 3221, 3121
b) loodusdirektiivi järgi: 7140, 7140

6. Tugihoolde rakendamise eesmärk:
(1) - kuivenduseelsele kooslusele omase veerežiimi ja struktuuri taastamine, 2 - kuivenduseelsele kooslusele omase veerežiimi ja struktuuri taastamine arvestades ohustatud liikide (liigi nimi).....
elupaiganõudlusi puistu või veerežiimi osas, 3 - sooshumisprotsessi taaskäivitamine alat ja puistu struktuuri varieeruvuse suurendamine, 4 - puistu struktuuri looduslikkuse (varieeruvuse) suurendamine veerežiimi muutmata.

7. Tugihoolde tegevuste kirjeldus:
7.1 Veerežiim: (1) kõikide kraavide sulgemine, 2 - kraavide looduslikkuse suurendamine, 3 - kraavide osaline sulgemine, kirjeldus: .....
Täpsustused .....
7.2 Puistu: (1) puistu täielik raadamine, 2- puistu raadamine üksikute eelmise põlvkonna puude säilitamisega, 3- puistu osaline raie, kirjeldus, allesjäävate puude liitus (0..1).....
4 - puistu eluspuude liituse vähendamine võgastamise ja/või langetamise abil ilma väljaveota, allesjäävate puude liitus (0..1)....., 5 - muu, mis.....
Täpsustused ..... Vürb mõni võrreama yastepunn valla. [illegible]

8. Lisamärkused:

KUIVENDUSEST MÕJUTATUD MÄRGALADE TAASTAMISE ANKEET
A OSA – OLEMASOLEVA KOOSLUSE KIRJELDUS

LIFE14 NAT/EE/000125
LIFE Mires Estonia

Kirje nr: Laukasoo - 4 Kuupäev: 26.09.16 Uurija(d): EL
1. **Floora ja vegetatsioon:** 1.1. Kasvukohatüübi/-pide kood(id) või nimetus(ed)
a) Paal 1997 järgi: 3221K, 3121K
b) loodusdirektiivi järgi: 7120
1.2. **Puurinne:** I rinde puistu valem 6M2 + K1, liitus (0–1) 0,1–0,6
rinnaspindala (m^2/ha) ....., kõrgus 10 (12) m, vanus: (1) - noorendik (2) - keskealine, 3 – vana, 4 – varieeruv
1.3. **Rindelisus:** (1) - II rinne puudub, 1 – II r. esineb
1 – vähe ja hõredalt (liitus < 0,2), 2 – keskmiselt (0,3 – 0,5), 3 – rohkelt/lopsakalt (> 0,6)
1.4. **Alusmets:** 0 – järelkasv ja põõsarinne puuduvad, 1 – vähe ja hõredalt, (2) - keskmiselt, 3 – rohkelt/lopsakalt
1.5. **Puistu kogukatvus** (vahemikus 0-1): 0,5
1.6. **Puhmarinde** üldkatvus 30–90 %; **rohurinde** üldkatvus <5–20 %, **samblarinde** üldkatvus 25 %, turbasammalde katvus 30–80 %, SE-osa, kohati <5%
2. Inimmõju:
2.1. Kuivendamine (kraavituse hetkel eksisteeriv mõju kooslusele): 0 – puudub (1) - nõrk (2) - mõõdukas (3) - tugev
2.2. Raied (0) - raiejäljed puuduvad, 1 - .....
2.3. Põlemine (0) - puudub, 1 – nõrk, 2 – kohati, 3 – tugev. Põlengu aeg, tüüp, ulatus, ...
2.4. Muu mõju: ehitised, kiviaiad, tallamine, teed, sihid, liinid, turbavarumine, kaeved, saastamine, risustamine, väetamine, karjatamine ..... SE-osas, kus puudlubute maandik vohandik – ebaloomulikum fraas – vaja täpsustada
2.5. Naabrusmõju .....
3. Looduskaitselised hinnangud:
3.1. Koosluse seisundi väärtus: A – kõrge, B – keskmine, C – väike (D) - degradeerunud
3.2. Esinduslikkus/Tüüpilisus: A – ülihea, B – hea, C – oluline (D) - väike- või mitteoluline
4. Kokkuvõte: A – erilise (üle-eestilise või -euroopalise) tähtsusega kooslus, B – vajab säilitamist kaitse- või hoiualana, C – säilitamine soovitatav (D) - olulise looduskaitselise väärtuseta
5. Lisamärkused (üldkommentaarid, täpsustused; kaitsealused ja ohustatud liigid jne.)

Alt vale. Emp nõy; Call. n., LS. pil
rahuldab. Eriti nõy
Selgelt kuivendusmõjuline
N-osas valdab rahuldav, [illegible]
SE-osa [illegible] rahuldab [illegible]
osa, kohati ka >1 vana turbaraie. (ainult pealt natuke võetud),
1 madalpõhi turbaraie (koben vajunud) jne.

Fig. 2. Fieldwork questionnaire (as filled in for the restoration work in Laukasoo; compiled by E. Leibak and L. Krumm)

A lot of water right now, highlighting the weak points:
1) One big mistake is affecting the area as a whole – the felling that was carried out at some point along the route was done on the wrong side of the ditch, i.e. on the soft surface with no embankment. This has resulted in a second wide ditch (covered in machine tracks) next to the existing ditch. The design, however, foresaw quite small dams since the ditch to be closed was small. As things stand, the wing of the dam does not cover the route corridor and so the majority of the water is still flowing along the ditch, not over the side into the forest. Moreover, the existing embankment (which could not be eliminated because the trees were felled on the wrong side) is crosswise to the natural flow. We should probably consider making a flow channel, but this depends on how and whether it is possible to fix the dams. Basically, we have not been able to get the water flowing in the way the model shows.
2) Material for the building of the dams was taken from too wide an area – no holes were dug. As such, the surface area around the dam is damaged and in many places the dam is more or less in a hole, compared to the surrounding surface. Dams where only the disruption to the existing embankment had to be closed (i.e. a dam built) were the biggest failures. Instead, the worker scraped out the side embankment in its entirety (and 10 metres wider than the dam at that) and then constructed the dam there. There is a dam, but the water flows by it directly into the ditch and away. There were many flaws in logic in building the dams, indicating that what had to be done on the site and why was not explained to the worker.
3) Since the dams were built using sand, they are very sensitive to erosion. Unfortunately, several have already been carried downstream, i.e. the water has taken large 'bites' out of the dam body. It is only a question of time when the water will break through.
4) In many cases the water merely flows alongside the dam body, around the dam wing and back into the ditch. Something we definitely do not want to see.

Feedback from Leevi Krumm following inspection of the work, 2 October 2019 (Figs. 2-5; see the next chapter)

OBSERVATIONS ON DESIGN AND EARTHWORK

JÜRI-OTT SALM, LEEVI KRUMM & MARKO KOHV

DESIGN

Technical designs for restoration work are usually commissioned from engineering offices proficient in land reclamation. However, if experts are available, preliminary work (such as mapping the network of ditches, inventory of species, planning of monitoring, impact assessment for infrastructure, land ownership and conservation values, hydrological modelling and designing earthworks) can be carried out by the party commissioning the restoration project. The first thing to be developed as part of the 'Conservation and Restoration of Mire Habitats' project, under the aegis of the Estonian Fund for Nature and in cooperation with partners, was restoration plans, following the disclosure and approval after which engineering offices were engaged to produce technical designs. This preparatory work was done by project partners mainly within the framework of the drafting of the restoration plans, but additional fieldwork was carried out in the course of compiling the technical designs as well. Moreover, the engineering offices undertook geodetic work and surveys, and on the basis of their results drew up plans for reconstructing or renovating amelioration systems or parts thereof. Such work must be done by an engineering office licensed to undertake amelioration work.

The restoration plans and technical designs were approved by the Agricultural Board, the Environmental Board, the State Forest Management Centre, local authorities and, where necessary, by the National Heritage Board and the landowners affected.

The compliance of the design to the aims of the work in a specific location can then be assessed by inspecting the areas after the compiling of the project documentation and/or the felling, although this requires the planning of the time that will be needed for this. This work helps to come up with better solutions for a specific location or to prevent shortcomings in the design, such as eliminating an unmapped drainage ditch, more effectively connecting the location of a dam to the terrain and preserving and not damaging natural values (e.g. checking the nesting trees of the flying squirrel or retaining suitable trees, preserving the sites of protected plant species and preserving the lekking grounds and habitats of the Capercaillie). If there is a longer period between design and implementation, additional fieldwork is advisable in order to evaluate the status of natural values immediately prior to the implementation of the project, so as to take possible changes (e.g inhabited nesting trees) into account.

EARTHWORKS

Local material is used for building dams, usually peat, but there may be areas where peat is not available. Our experience on the southern side of Valgesoo in Soomaa National Park assured us that dams made from sand and clay were stable enough to achieve a permanent rise in the water level; a similar result was obtained in Laukasoo (Fig. 1). In building dams, material with too much grit should be avoided since it is too penetrable and does not guarantee a rise in the water level.

On the other hand, sand dams can also cause problems (as set out by Leevi Krumm from the State Forest Management Centre), as became apparent when restoring the hydrological regime in Laukasoo three weeks after the dams were built. Namely, a major problem was the rise in the water level due to the closure of the ditches and due to autumn rains.

In the area discussed, initial inspection of the dams was carried out directly after their construction, when the water level had not yet risen. Visual inspection did not identify the formation of any new flow channels.

Following the feedback from Leevi Krumm (p. 44), it was agreed with the contractor that if the weather conditions in



Fig. 1. Dam made of sand to close the ditch closest to the Loobu River in Laukasoo. Photo: Jüri-Ott Salm



Fig. 2. Erosion caused by autumn rains has eaten away part of the constructed dam over a period of three weeks. Photo: Leevi Krumm



Fig. 3. Water runs along the edge of the dam: this will lead to the rapid erosion of the body of the dam. Photo: Leevi Krumm



Fig. 4. In some places, the improved ends of the dams are still too low – water runs directly around the dam and erosion has already begun. Photo: Marko Kohv

autumn allowed (i.e. not snowing, with breaks between rain and the water level falling), repair would be carried out at the earliest opportunity. These took place in November 2019. If they had not, the repairs would have been postponed until the following August (after the intervening bird-nesting period in spring and summer).

Before repairs began, the problematic dams and the locations of the wings to be extended were marked in cooperation with the Estonian Fund for Nature, the State Forest Management Centre and the contractor's representatives, as were the locations of the flow channels and ditch berms to be eliminated. The majority of the necessary work was completed in three days, but the excavator driver failed to notice the markings for two dams and these were built by hand.

Problem: If the flow of water persists in the ditch being closed or in the flow channel, it will erode the dam whatever material it is made from. Where an excavator has been used to drive a small flow channel into the ends of the wings or material has been taken from the ends of the dam, it is necessary to extend the dam. Extension is also necessary where the excavator has been driven around the dam and parts of the surface with vegetation have been preserved, but driving tracks remain. The wings of the dams must be bound to a surface covered with so-called virgin vegetation.

It is important not to leave trunks, larger branches or stumps in the dams that would start to function as excellent water pipes in the body of the dam and leading it to burst.

Covering the dams with fallen tree-trunks to hinder animal crossings is worth considering. There have been cases of wild animals (especially elk) damaging dams through intensive trampling, resulting in the need for repairs or reconstruction. To prevent such damage, trees are placed on top of the dams, which also serve to break up route corridors visually (Fig. 6).

If trees are felled along routes, long, straight, wide corridors are formed. To break up route corridors, instructions have been given to leave individual trees or groups of trees growing if they do not hinder the closing of the ditches. The effects of storms and strong winds can also be imitated, using the shovel to knock down a few trees here and there. Trees with root balls have also been lifted onto the dam with the shovel. At the same time, these trees block the movement of ATVs and other machines.

The central part of the dam, which is usually above the closed ditch, must also be higher than the wings of the dam – a requirement that certain contractors had difficulty following. The main problem is that the body of the dam above the closed ditch usually subsides and that water can flood the dam, which may then be destroyed by erosion. Subsidence is most marked in dams made of peat. It also depends on the thickness of the body of the dam – the higher the dam, the more pronounced the subsidence. Experience shows that a typical peat dam will subside by 20-30 cm within a few years. As such, these dams must be over-dimensioned during construction. If dams are built from mineral materials (usually sand or moraine), there will be only limited subsidence and the dams should be constructed according to the technical designs – otherwise the dams will be unnaturally high.

For a dam at a higher elevation (i.e. on a bog island) there is no need to construct wings, since the higher level will fulfil this function. In this case the ditch must be filled up to the level of the surrounding land surface. Moreover, there is no point providing a dam next to a bog island with a full-length wing that stretches to the island, since it would be better to bind the wing to the incline of the island at its central height.

The holes remaining from digging up material for constructing the dams must be round in shape, and at least one side must have a sloped edge. The Metropol Group did very good work, placing timber from route-cutting, turf, etc. in the holes from which the material was taken so that the holes are no longer discernible on the landscape. However, in Feodorisoo the need arose to improve the area where work was done after the dams were built partly due to holes, which had unnaturally square angles and overly steep slopes. Since it was impossible to drive an excavator to the area without destroying the dams, the repairs had to be done by hand. Where work carried out in bogs with bog pools is concerned, in some cases leaving the holes open and designing them so that they are reminiscent of bog pools is one way of creating additional habitats suitable for this mire type.



Fig. 5. Near the Loobu River: erosion that started from passing tracks has already carried away half the dam. Photo: Marko Kohv



Fig. 6. Placement of logs on top of the dams to prevent the damage caused by animal movement and to visually break up the treeless route corridor that has arisen. Photo: Jüri-Ott Salm

The technical designs established a requirement to avoid the formation of deep holes: removal could only be taken from one hole two or three times. Material is usually taken from one or two larger holes; the requirement is therefore met in the case of smaller dams, but not in the case of larger dams. Otherwise, squaring the material is needed, and in some places also removing trees across a wider area. A large number of stumps is often a problem as well. This requirement could instead be a recommendation, since it is more easily fulfilled in areas with fewer trees than forested areas.

Working in snowy conditions should be avoided. Work can be carried out in the snow in larger ditches, but finding smaller ones under the snow can be problematic. In addition, there is the risk of frozen peat or pieces of ice ending up in the body of the dam. If work is carried out in winter, its acceptance may be delayed if snow makes it impossible to evaluate what has been done. Feedback from companies undertaking land improvement is that 20-30 cm of snow is the limit beyond which work can no longer be done. Snow is problematic first and foremost on surfaces with a soft but thick layer of peat where the surface layer of the mire may not have fully frozen, since it is more difficult to follow the terrain and traversing it is riskier. One possibility is driving paths into the surface, which then turn into roads of frozen soil. The solution is a site-based approach that takes all details into consideration before decisions are made. For example, the work to close the Great Bog Pool in Laukasoo mire was performed in winter conditions in January 2019. One of the problems that later emerged was the excavator tracks at the ends of some of the wings of dams, which had to be filled in by hand to prevent water flowing along these tracks.

In Feodorisoo, a small excavator (3 tons) was initially intended to be used for dam-building in the central part of the mire, but the work needed to be adjusted after the first approach because the dams were undersized and the body of the dams was not properly compressed. Improvement work was later carried out, but compared to work done with larger machines, the dams were barely of the right dimensions and there was a risk of subsidence. (That said, this has not happened in the two years since.) At the same, it was not possible to evaluate the competence of the excavator driver because it was not possible to supervise the work done with the light excavator on site and the problems only emerged subsequently.

CLOSING PEAT-DIGGING HOLES

These holes are mostly 'spade peat-holes' that were dug before World War II. They are often found on bog slopes; on average, they are 50 cm to one metre in depth and 3-10 metres wide. These holes are usually found in groups forming a dense network with drainage ditches (see Fig. 7). The ditches are frequently overgrown and therefore not clearly visible on the landscape. This makes mapping more time-consuming and complicated, and the locations and dimensions of all dams may only become clear in the course of work to restore the hydrological regime of the bog. Here the chance of mistakes

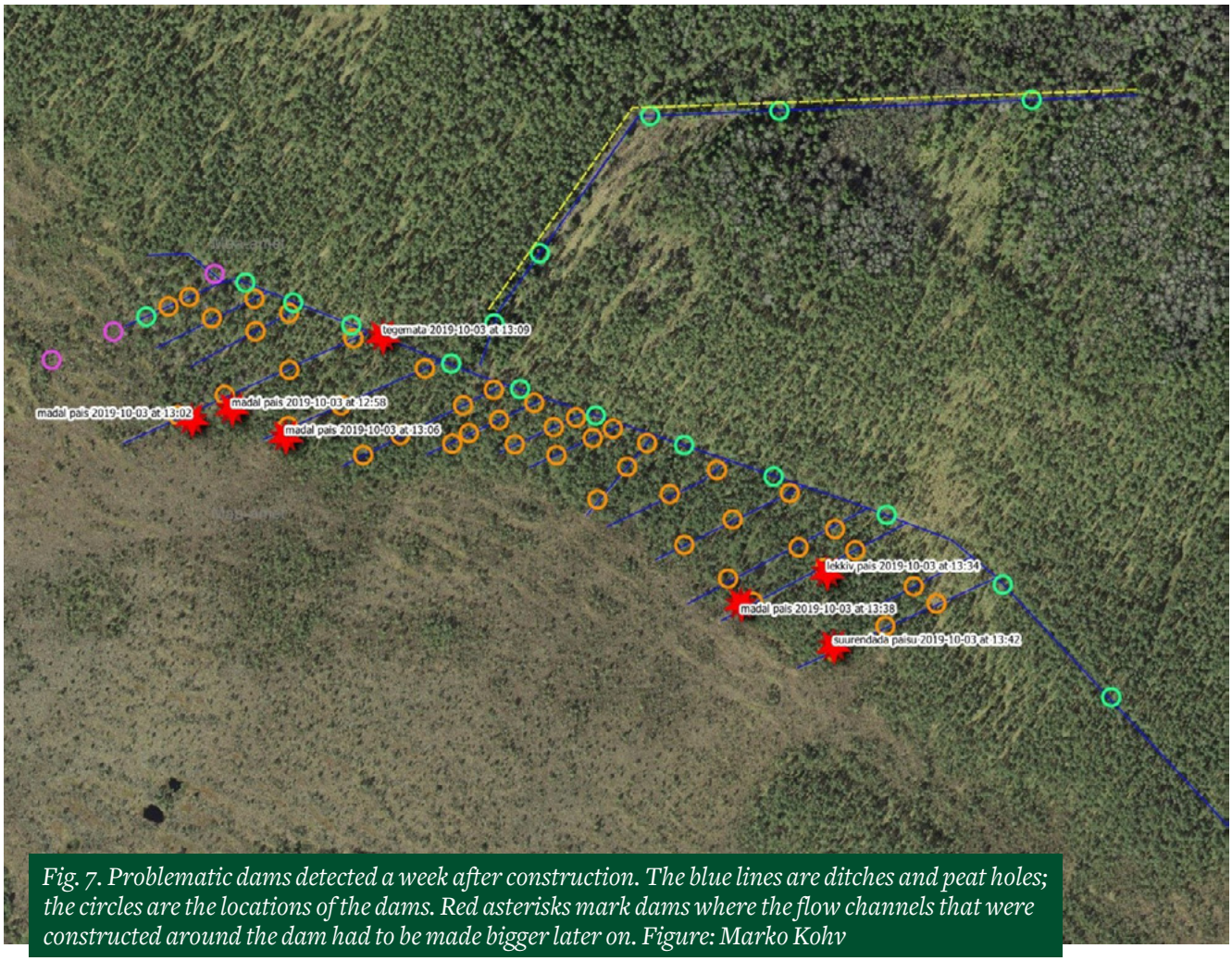


Fig. 7. Problematic dams detected a week after construction. The blue lines are ditches and peat holes; the circles are the locations of the dams. Red asterisks mark dams where the flow channels that were constructed around the dam had to be made bigger later on. Figure: Marko Kohv

is higher, since some ditches may not have been included in the technical design. In these areas, excavator drivers should be asked to report all ditches discovered and volumes should be calculated with a 20% reserve. Due to the bog slopes, the stream gradients are quite steep and the distances between the dams should be small (max. 50 cm of slope gradient per dam). In the 'Conservation and Restoration of Mire Habitats' project, such areas were found in Soosaare and Laukasoo mires. The following is an overview of the course of the work carried out in Laukasoo.

One week after building the dams a situation emerged where in many cases the part of the hole closest to the mire centre was filled with water and the body of the dam was quite wet (the downstream edge being walkable, but the upstream edge not bearing the weight of a person). At the same time, water collecting behind the dam did not flow the surrounding areas and the risk of the dams soaking through was considered great. The constructor warned that adding material to the problematic dams would cause them to disintegrate. The only thing to be done with the excavator was to form flow channels so that the water could flow past the dam onto the surrounding land, or around the dam downstream on the surface (Fig. 8). However, the constructor had followed the instructions set out in the technical design: "In the plan view, the dam must be at least 1 metre wide and as high as the edges of the peat holes. Dams must be established at least 0.5 metres into the banks of the peat holes." The technical design provided no solutions to the problem of the area close to the peat holes being lower than the land surrounding them due to soil compression. As such, designing dams with wings would have been necessary.

Although the water level rose to the edge of the hole, it must be said that the dams were undersized. Therefore, if the peat hole is deeper than 1 metre or if the edges of the hole have subsided due to soil compression (usually around 0.5 metres) then the design of the dams should have been with a ridge at least 2 metres wide and at least 0.5 metres above the surface level. Moreover, dams should extend over the margins of the ditch at least to the extent that the water level in the depression zone could be raised close to the level of the surrounding land surface.





Fig. 8. Two weeks after construction, the peat holes have filled with water and flow channels have been constructed to redirect water away from the dam. Photos: Jüri-Ott Salm



Fig. 9. Expanded dam. Photo: Jüri-Ott Salm



Fig. 10. Felling performed with a guillotine in Laukasoo. Trees along the ditch that have not been chopped up. Photo: Jüri-Ott Salm



Fig. 11. Using a n excavatorshovel to fell trees along a route (Metropol Group OÜ). Photo: Jüri-Ott Salm

Additional work in Laukasoo – expanding the dams (six cases) and building wings (Fig. 8) – were fortunately able to be completed within a few weeks (Fig. 7). First, the water level was lowered throughout the peat-mining area, and we managed to avoid the disintegration of the dams situated downstream.

FELLING OF TREES

Excessive felling along routes. In some places, the areas felled are too wide. The reason for this is that the company doing the logging was not the same as the one doing the earthworks and simply followed the predefined volumes. On the other hand, the routes planned to be 6 metres wide may be too narrow if an excavator moves on boards.

Felling of trees along routes. If trees are neither removed nor chopped up, they should be felled diagonally, top towards the ditch; this makes it easier to lift them into the ditch with a shovel. In Laukasoo there were situations where the trees were felled with a guillotine, without being chopped up, alongside the ditch or on the side of the route with no ditch, which made it quite time-consuming to lift them into the ditch or drive them into the soil (Figure 10).

The solution given in the design – driving the wood into the soil – does not work in areas with a thin peat layer.

There were also situations were no route had been cut through. In these cases, an excavator was used in Laukasoo to create a route. The tracks left on the landscape were smaller this way and more trees were left standing (Fig. 11). In areas with a denser network of ditches, e.g. when closing peat quarries, it makes sense to let the earthwork company create the routes, as it avoids excessive logging along the routes and routes that are too straight. Moreover, in the event of minor changes being made to the locations of dams, amending the routes may be necessary and it may be the case that not all routes are needed – a contractor hired for felling alone cannot usually predict this and thus the work may result in unnecessary routes or felling. On the other hand, the subcontractors of the earthwork company may not necessarily follow this either.

Another problem can be that a ditch berm that needs to be eliminated is under felled trees and the shovel operator does not find it, so removing the berms takes more time.



Fig. 12. Work area in Feodorisoo after the elimination of faults. In spite of this, the result remain sub-optimal. However, if the water level is restored, the area will probably be covered with mire vegetation and the timber left in the mire will partially turn into wood peat. Photo: Jüri-Ott Salm

Avoid felling trees when there is deep snow on the ground, since the stumps will be higher than officially permitted and will have to be removed later on.

In some cases, felling was too extensive, which added to the labour costs of the companies (sawing the protruding stumps and branches, lifting the trunks into ditches, etc.) (Fig. 12).

MOVING AROUND WITH MACHINES

When starting work, the rules for accessing the area must be reiterated. A problem can be created by the excavator operator deciding to follow a route over land where the approval of the landowner has not been obtained.

Depending on the specific location and the width of the tracks of the excavator, the use of boards may be necessary. With wide tracks (>1 m) it is usually possible to move around without using boards, but if the tracks are narrower, the use of boards is inevitable in areas with a thicker peat layer. Boards can also be used to transport other types of machines (Fig. 13).

If an excavator moves without damaging the turf, the tracks are relatively shallow and will have become all but unnoticeable within a few years (Fig. 14).

SUPERVISION OF WORK

Additional time should be planned for supervising workers in order to avoid mistakes and the need for improvements, which could turn out to be very expensive once the water level is higher. The rule of thumb is that work should be inspected at least once a week and that the supervisor should be there to assist when earthwork commences in a new type of area. In this regard, when work begins or the foremen change, it is necessary to ensure that those who do the work are equipped with all of the maps and other instructions they need to carry out their tasks.

It is also useful to provide brief written instructions (one laminated A4 page) with the dimensions of the dams etc. for reference in the cabin. Usually the excavator driver is not entirely familiar with the technical design and only receives information from the foreman on the project conditions. This information may be deficient.

All excavator drivers must be encouraged to report any need to change the technical design (e.g. additional need to eliminate ditch beams or change the location of dams).

Supervision should be individualised to the person carrying out the work (excavator driver or logging worker).

CONSTRUCTION OF MANUALLY BUILT DAMS

Manually built dams are usually designed in places where the use of machines is impossible for some reason (e.g. particularly sensitive habitat or highly complicated access). One option here is to recruit volunteers or outsource the work.

INSTRUCTIONS FOR CONSTRUCTING DAMS MANUALLY IN THE EXAMPLE OF LAUKASOO

Dams are made using local surface material (usually peat). The ridge must extend at least 0.5 metres above the surface level, and the width of the ridge should be at least 1 metre. The dam must extend at least 2 metres beyond the sides of the ditch in both directions, and in the case of natural turf, the dam must stretch from the ditch bank up to the turf. The surface of a dam must be flat or curving when viewed along the length of the ditch, and the central part must not be lower than the ends. The base of a soil dam must be cleared of vegetation and sludgy peat mud to a minimum depth of 0.2 metres both in the ditch and on the banks. The sides of the dam body must be gently sloped to avoid the dam starting to crumble from the sides. To construct the dams, peat is extracted near the dam in such a way that one side of the peat hole is gently sloped (so that any animals that fall into the hole can get out). If the peat layer is not thick enough to build a peat dam, the dam should be built from the material available on site. The ditches to be closed are typically 1 metre wide and up to 1 metre deep; some dams are also built on the narrower ends of spade peat-holes (which are 3-5 metres wide).

THE SOLUTION IMPLEMENTED IN FEODORISOO, WHERE THE CONTRACTOR CONSIDERED IT TOO RISKY TO MOVE THE EXCAVATOR INTO THE AREA

Since the issue with manual work is clearing the edges and bottoms of the ditches, manually constructed dams should



Fig. 13. Two birds with one stone – the Valmap Group in Ohepalu. An ATV was used to transport both fuel and the excavator operator. Often the excavator itself is used to move to the fuelling or parking area. Photo: Jüri-Ott Salm

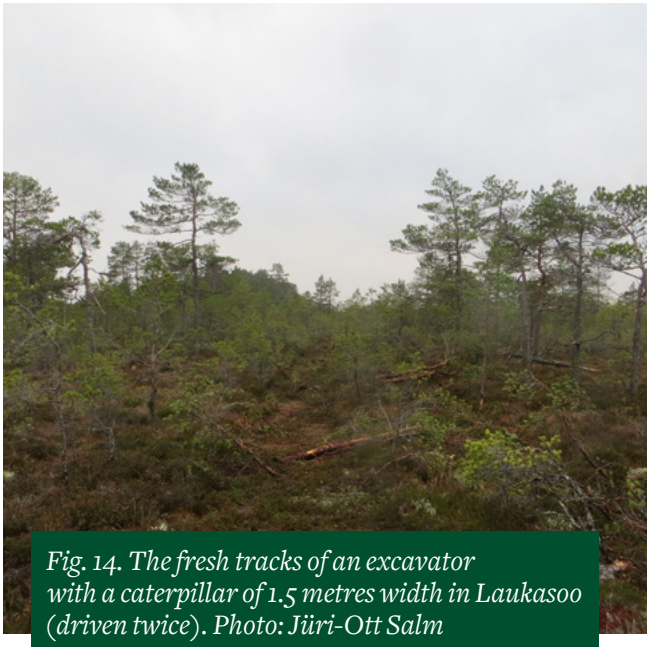


Fig. 14. The fresh tracks of an excavator with a caterpillar of 1.5 metres width in Laukasoo (driven twice). Photo: Jüri-Ott Salm

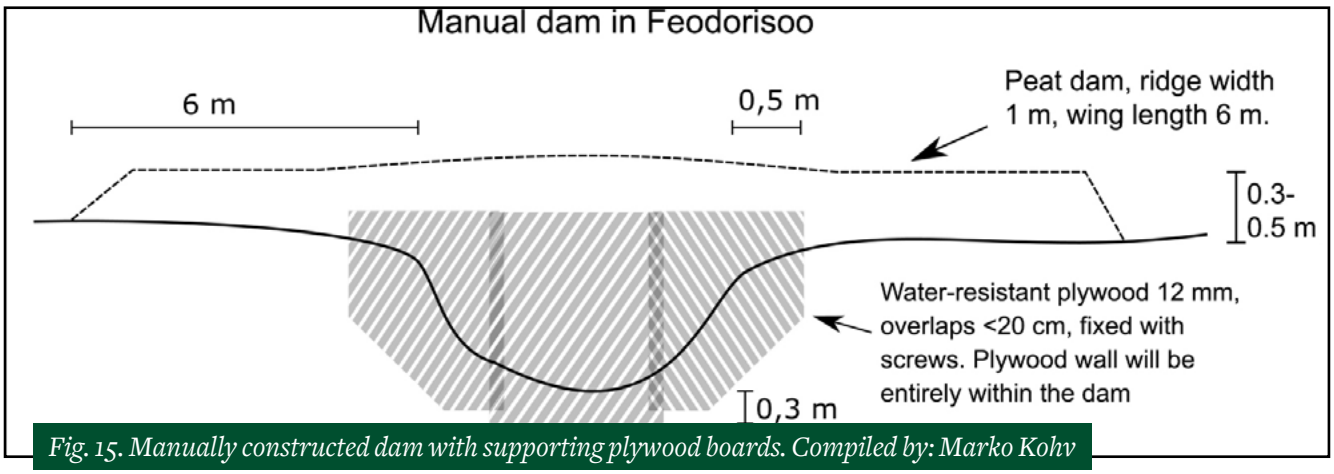


Fig. 15. Manually constructed dam with supporting plywood boards. Compiled by: Marko Kohv

be reinforced using plywood boards that are hammered into grooves cut into the peat, to a depth of at least 0.5 metres and at least 0.3 metres from the bottom (Fig. 15). The boards are mounted with an overlap and fixed together using screws. Next, the boards are buried under the manually constructed peat dam. Wings should be constructed with dimensions similar to those in the design: 6 metres from the edge of the ditch with a ridge width of 1 metre. Additional instructions were issued by the State Forest Management Centre (Leevi Krumm): "In this case it is very important that it is properly covered with peat so that the wall does not stick out in any way. Also, it is important to check that the wall is properly hammered down deeper than the bottom of the ditch and not left standing in the sludgy peat at the bottom, otherwise water will start flowing under the plywood wall."

This solution was implemented in January, in below-zero temperatures and with snow cover. The materials were transported to the site using ATVs, and four men carried out the work. A board pulled by an ATV was also used to move peat to the dam, with the peat first being loaded onto the board. This reduced the amount of resources needed to transport the peat.

DAMS WITH A PLASTIC SHEET PILING (GW 270/3.5 OR SIMILAR) TO CLOSE OVERGROWN DITCHES IN THE EXAMPLE OF RECONSTRUCTION WORK IN SIRTSI NATURE CONSERVATION AREA

These are built where felling along the route for machinery is not recommended. The water-tight sheet piling should be hammered at least 1 metre into the soil as measured from the surface level of the overgrown ditch using a wooden or rubber mallet (although in the case of mineral surfaces we did not always manage to do this) and it must be around 20 cm above the level of the overgrown ditch. The sides of the wall should go at least 0.5 metres into the ditch bank. Before mounting the wall, the peat layer must be probed with a spade up to the mounting depth. This facilitates the mounting and helps to check that the peat does not contain any large tree trunks, tree roots or stones. After mounting, the upper edge is covered with peat blocks.

GETTING VOLUNTEERS INVOLVED

When getting volunteers involved it is important to supervise their work and give them an overview of the aims of the project. It is also important that the work load is divided up between the days so as to avoid too big a workload on the first day. The time and energy needed to move into the area must also be taken into consideration. The precondition for the voluntary work run by the Estonian Fund for Nature is getting trained organisers of such work involved, and a person with a first aid training certificate participates in every event. Where tools are concerned, it is important that spades are sharpened, since this makes cutting the peat loafs easier. It is also recommended to use snowshoes to compress the peat dam or to use shorter boards to do so. A hike in a natural mire landscape before or after the work can make a positive addition to the voluntary event.

EXAMPLE OF INSTRUCTIONS GIVEN TO VOLUNTEERS

In building a dam, first the peat moss and vegetation under the dam are removed and, if possible, this material is put aside for later use. Then the base of the soil dam is cleared of vegetation and sludgy peat mud to a depth of 0.2-0.3 metres, both inside the ditch and on the banks. It is important to remove the turf from the ditch banks or edges, since there may be empty spaces underneath, and without filling in these spaces the dam will not remain watertight. Before constructing the dam, if enough material is available, the flow in the ditch should be blocked using peat, the boards brought to the site or plastic walls (and after the dam is finished, the plastic should be removed). Next, the dam is constructed. For this purpose, special peat holes are dug to extract peat for the dam. This peat should not contain any stumps, tree trunks or turf with larger roots. Before piling the peat, any water that has collected in the place where the dam is being built must be removed with a bucket, and after removing the water the material for constructing the dam (which is advisable to place in piles beforehand) is thrown in at once. The soil dam should be compressed gradually, for example by trampling the dam using snowshoes or boards (Fig. 16).

The surface of the soil dam should be slightly curved when viewed from the side, meaning that at the ditch the dam must be higher than the wings to compensate for possible subsidence on top of the ditch being closed. After building the dam, the former top layer from beneath the dam is placed on top of the dam to encourage the growth of vegetation. None of the vegetation removed from the ditch should be placed on top of the dam, but taken upstream, since the drier environment on top of the dam will not be suitable for the ditch vegetation, incl. dark green Sphagnum moss. Dams should stretch at least one width of the ditch away from the edge of the ditch. If possible, these should be bound to some turf on the site; this may also reduce the workload. The dams are constructed using

compressed peat turf. The ridge must be at least 0.3 metres higher than the surface around the ditch or peat holes, and in the plan view the width must be at least 0.5 metres. The dam must extend at least 1 metre beyond the sides of the ditch in both directions, and in the case of natural turf, the dam must stretch from the ditch bank up to the turf.

With manually built dams, the main problem is staying within the dimensions specified, or adjusting the dam to the specific location. The time needed to construct the dam will increase if roots have to be cut to obtain construction material, or hare's-tail cottongrass has to be removed in order to clear the ditch. Moreover, the peat should not be compressed too much, since this may cause changes in the peat's structure, rendering it more liquid, and the dam may significantly subside over time. Thus the time available for construction may run out and the dams end up shorter or lower than designed. Such dams will not fulfil their purpose, erosion will place them in danger and the majority of the dams will need to be rebuilt. First and foremost, the quality of a dam depends on the experience and time-planning skills of the foreman.



Fig. 16. Compressing of the dam body in the 0.5-metre wide and 1-metre deep ditch in Soosaare mire in Alam-Pedja Nature Reserve by attendees of the LIFE Platform Meeting 'Volunteering for Nature Conservation' international conference. Photo: Volha Kaskevich

STANDARD PLANS FOR MACHINE-CONSTRUCTED DAMS

The solutions presented in Figures 17-19 below are based on work carried out by Kobras AS. Detailed descriptions and plans are available in the technical designs for the restoration of the hydrological regime in the 'Conservation and Restoration of Mire Habitats' project.

- Type 1: Total filling of all small ditches in milled peat fields, together with soil dams with ridges 0.3-0.5 metres above the surface level. The soil dam reaches 2 metres from the ditches of the bank and is 1 metre wide at the ridge (Fig. 18).
- Type 2: Soil dams built with machines or by hand in smaller ditches. The ridge has to be at least 0.3 metres above the surface level and the top has to be at least 1 metre wide (or 0.5 metres for manually constructed dams). The wings are 2 metres long (Figs 16 and 18).
- Type 3: Large peat dams. The ridge must extend at least 0.5 metres above the surface level, and the top should be at least 2 metres wide. The slope of the dam is 1 : 1.5. The length of the wings is three times the width of the ditch, but no less than 4 metres (Fig. 18).
- Type 4: Overflow dams (Fig. 17). Peat protected with geotextiles is used for these dams. The geotextiles must surround the peat on every side: essentially a geotextile bag filled with peat. The geotextiles must be installed in the direction of the flow, with a minimum overlay of 1 metre. Dams made from geotextiles and peat must be a minimum

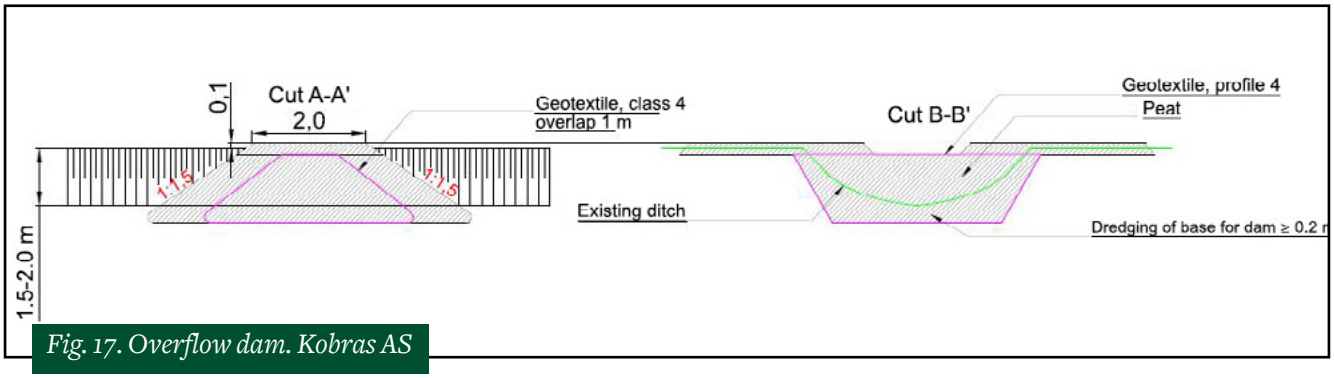


Fig. 17. Overflow dam. Kobras AS

of 2 metres wide in the top view. The lowest point of the dam is in the centre, and the ends must extend at least 1 metre into the bank.

▶ Type 5: Dams for peat holes. These dams must be at least 1 metre wide at the ridge and at last 20 cm higher than the edges of the peat holes. It is important to avoid sticks and branches poking through the dam. Soil dams must reach at least 0.5 metres into the banks (Fig. 18).

A dam reinforced with a wooden core (Fig. 19). A wooden core is constructed to stabilise the dam and increase the length of the filtration flow. To create wooden cores, round timber beams are pressed into the soil side by side, forming a wooden wall. The beams have to be pressed at least 3 metres into the peat soil. The height of the upper end of the wooden wall and the original width of the dam are shown in Figure 19. The wooden wall must also be covered with geotextiles (NGS profile 2), which should reach around 1 metre into the ground. The wall must be supported using round timber beams placed horizontally.

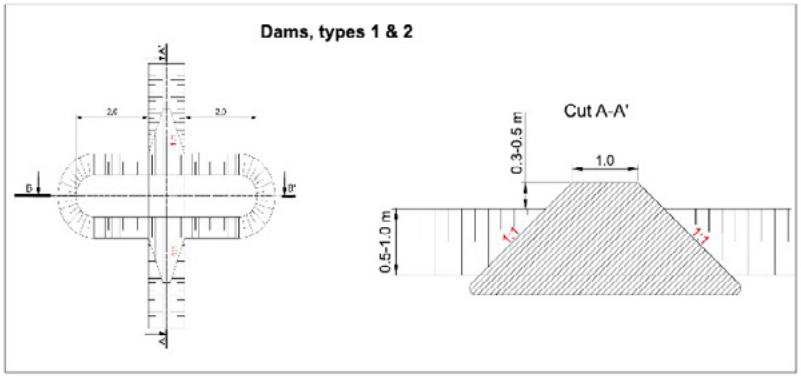
In the 'Conservation and Restoration of Mire Habitats' project, corresponding dams were used e.g. to close the outflow of Suurlaugas in Laukasoo, but the body of the dam (or the part under it) started leaking within two-and-a-half years. This may have been caused by the disintegration of the dam body due to subsidence, but movement due to frost heaving may have been the reason also – causing leaks around the wooden core. If the dam is reinforced with beams, these must be left to one edge of the dam, not in the centre. In this case there is less risk of the disintegration of the dam body or of splitting near the wooden core.

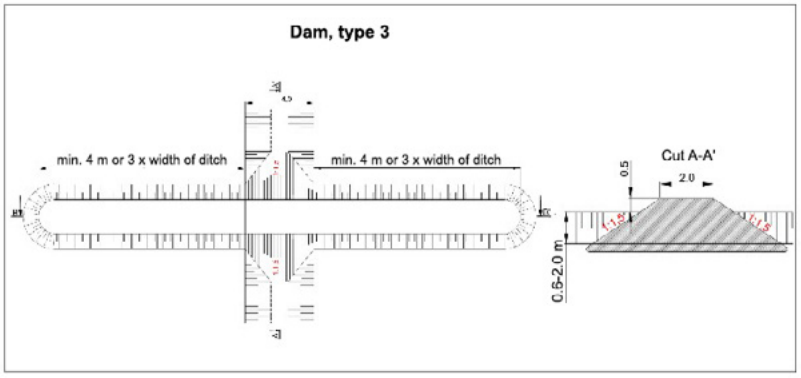


Inspecting work done in Sweden. Photo: Jüri-Ott Salm



A dam in Sweden constructed a few years previously. Photo: Jüri-Ott Salm





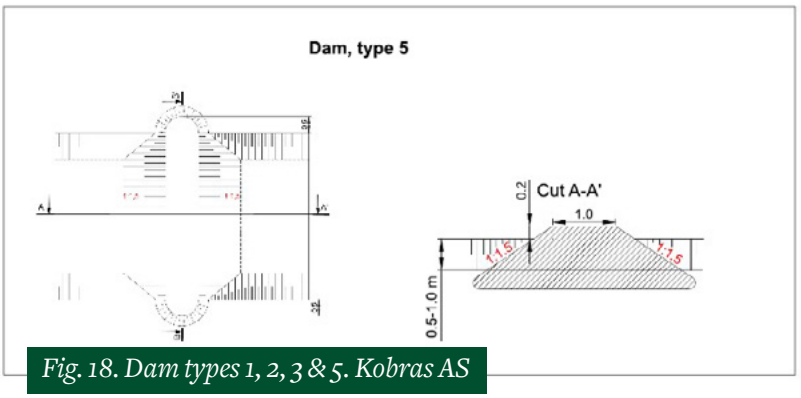


Fig. 18. Dam types 1, 2, 3 & 5. Kobras AS

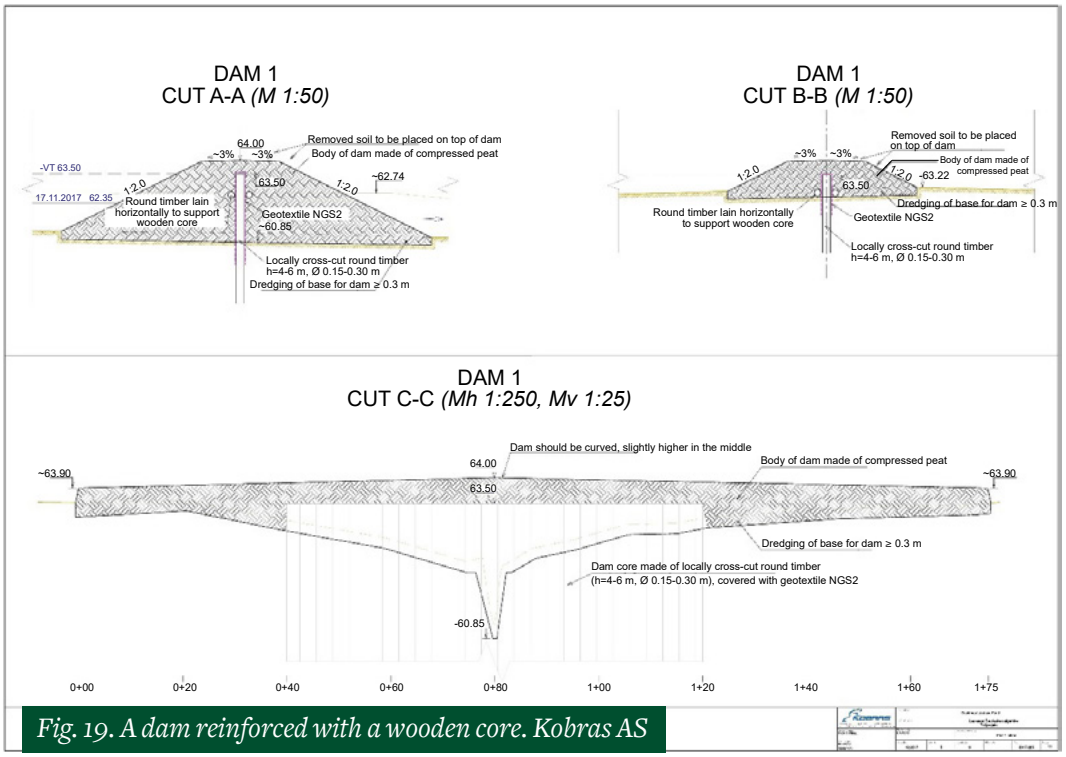


Fig. 19. A dam reinforced with a wooden core. Kobras AS

EXPERIENCES FROM THE RESTORATION OF THE PALASI FORMER PEAT-MINING AREA WITH THE SPREADING OF SPHAGNUM FRAGMENTS AND OIL SHALE ASH

JÜRI-OTT SALM, MART MERISTE, EDGAR KAROFELD & MARKO KOHV

The restoration area of the former peat mining area in Palasi is situated in the Palasi special management zone in Sirtsi Nature Conservation Area (Fig. 1). According to the current management plan, the objectives for conservation are the restoration of natural habitats, followed by ensuring the development of ecosystems through all-natural processes and lastly the protection of the habitats of protected species.

Peat mining in Palasi started in 1970 on 32 ha (Fig. 2). Peat was produced by milling and was intended to be used as bedding in state and collective farms around the bog. The area is thought to have been abandoned in the 1980s. According to the revision of abandoned peat-mining areas carried out by the Geological Survey of Estonia from 2005-2009, the thickness of the residual peat layer here is 1-1.5 metres, made up of predominantly fen and transition mire peat, with bog peat only being found in a thin surface layer.

The restoration of the former peat-mining area in Palasi was planned by the Estonian Fund for Nature and Kobras AS. Marko Kohv, an expert from the fund, undertook the majority of the

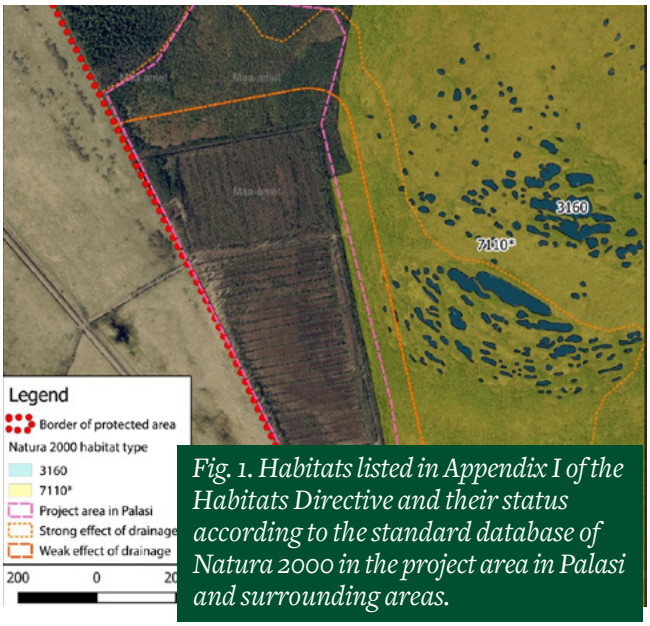
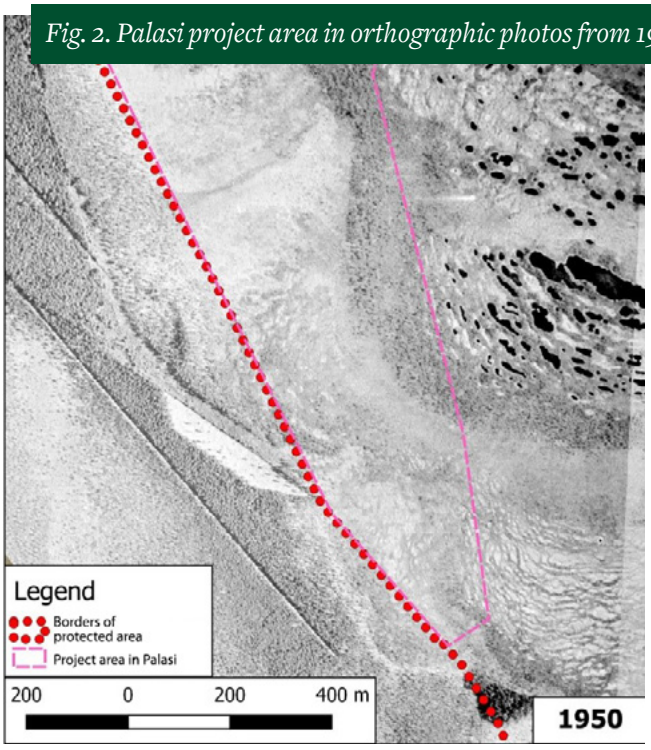


Fig. 1. Habitats listed in Appendix I of the Habitats Directive and their status according to the standard database of Natura 2000 in the project area in Palasi and surrounding areas.

Fig. 2. Palasi project area in orthographic photos from 1950 and 1971. Land Board.



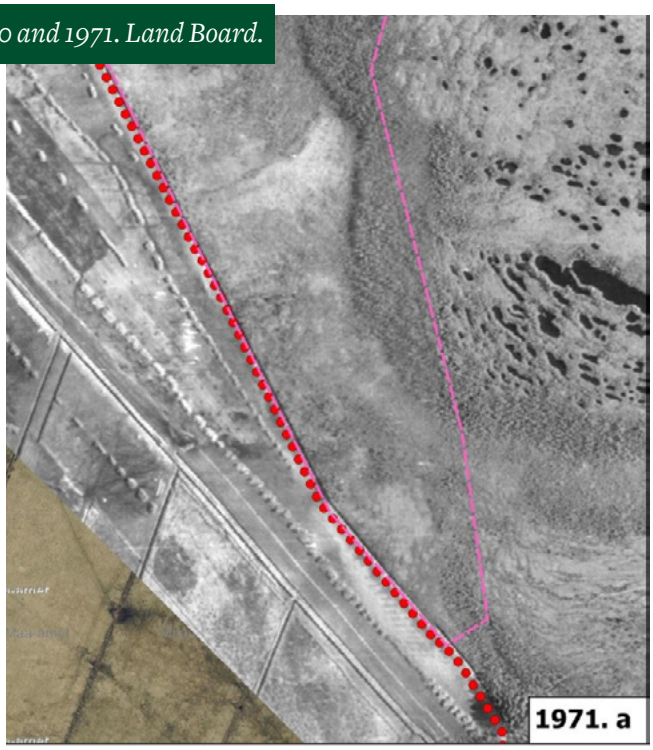




Fig. 3. The former Palasi peat-mining area following the closure of ditches and levelling of the surface and before the distribution of Sphagnum fragments in 2018; on the right, one of the storage sites for the Sphagnum peat fragments (marked with an arrow). Photo: Marko Kohv

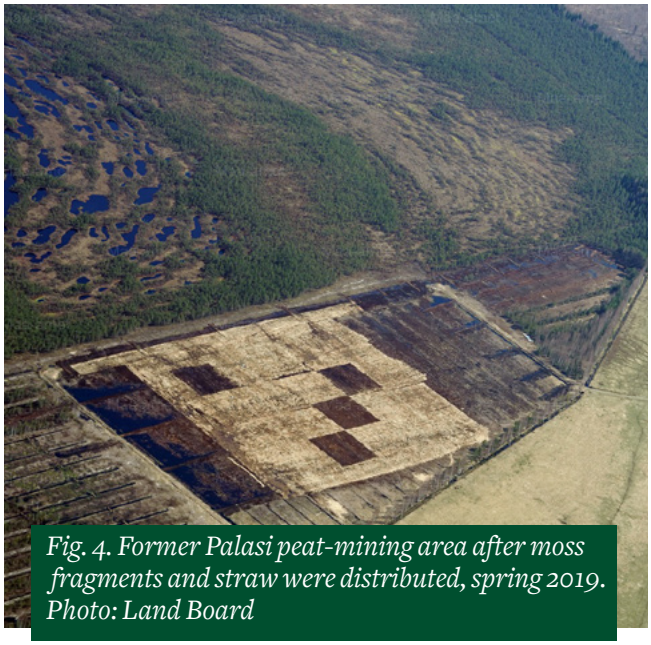


Fig. 4. Former Palasi peat-mining area after moss fragments and straw were distributed, spring 2019. Photo: Land Board

necessary fieldwork, hydrological modelling and the planning of the locations and dimensions of the dams. The project was approved by the Environmental Board, the Agricultural Board, the State Forest Management Centre and the local municipality. A public meeting was also held in Rakvere to present and discuss the aims of the project and its planned activities. The full project can be reviewed online at https://d.soo.elfond.ee/index.php/s/ZlBVSzOEcihdPIO (In Estonian).

In order to create hydrological conditions suited to the regeneration of mire habitats, ditches were closed with an excavator using surface peat, and the area was levelled with bulldozers. This took place from 16 July-27 August 2018 and the contractor was Metropol Group OÜ.

Next, following the Moss Layer Transfer Technique or Canadian method[1], plant fragments were collected from a donor area and were spread across the prepared surface of the restoration area to speed up the growth of mire species and the re-initiation of peat formation. This work followed the recommendations of Edgar Karofeld[2], although not all of his recommendations or the suggested order of the work were followed – the ditches were closed before the moss fragments, straw and oil shale ash were spread; in some places machines drove over the plant fragments that had been spread out; and the spreading of straw and oil shale ash was uneven in parts. It was also recommended to distribute the Sphagnum fragments as soon as they were harvested, but they were spread several months later. Edgar Karofeld took part in the execution of certain stages of the work as an expert.

The cutting of Sphagnum fragments from the donor area, their transportation to Palasi, their covering with the straw mulch and spreading of oil shale ash were done by OÜ Nordic Botanical (NB) in cooperation with the companies named below. This work was carried out between August 2018 and July 2019.

The donor area for the plant fragments was situated in a wooded bog with bog pools and hollows around 50 metres from the collecting ditch in the Punasoo peat-mining area. It featured continuous Sphagnum moss cover with sparse pines and a few lawns where brown (*Sphagnum fuscum*), red (*Sphagnum rubellum*) and mire (*Sphagnum medium*) Sphagnum moss dominated. Heather (*Calluna vulgaris*), hare's-tail



Fig. 5. An ATV on tracks and with a trailer was unable to haul the load. Photo: OÜ Nordic Botanical

[1] Quinty, F. and L. Rochefort, 2003. Peatland Restoration Guide, second edition. Canadian Sphagnum Peat Moss Association and New Brunswick Department of Natural Resources and Energy. Québec, Québec.

[2] Karofeld, E. 2018. Instructions for using of Sphagnum moss fragments and oil shale ash for the restoration of former Palasi peat-mining area. (In Estonian)



Fig. 6. The eight-wheeled amphibious Argo was unable to haul the load either. Photo: OÜ Nordic Botanical



Fig. 7. Lifting the Sphagnum fragments onto the Seiga reed harvester. Photo: Edgar Karofeld



Fig. 8. Spreading the Sphagnum fragments from the reed harvester with forks. Photo: Edgar Karofeld



Fig. 9. Spreading the straw on the Sphagnum fragments. Photo: Edgar Karofeld

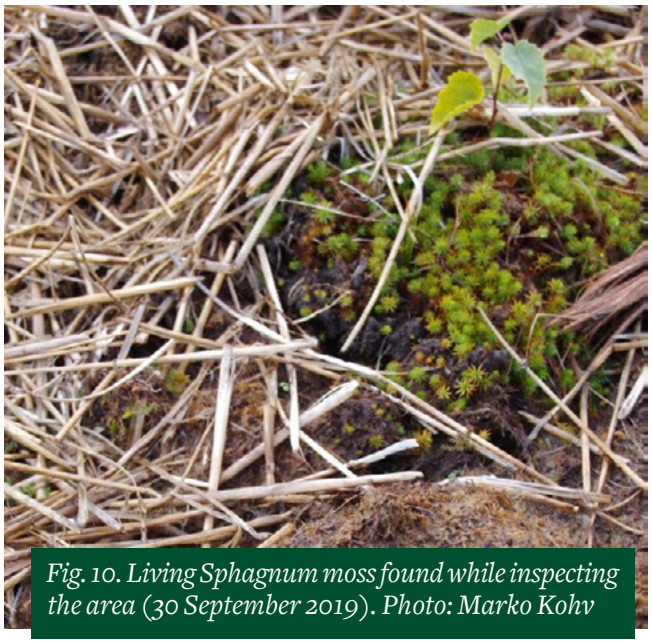


Fig. 10. Living Sphagnum moss found while inspecting the area (30 September 2019). Photo: Marko Kohv



Fig. 11. View of the restored former peat-mining area of Palasi in autumn 2019. Small ridges created by the wheels of the reed harvester are visible. Photo: Marko Kohv

cottongrass (*Eriophorum vaginatum*) and bog-rosemary (*Andromeda polifolia*) were dominant vascular plant species.

To cut the Sphagnum fragments, the PF-1 soil-milling device developed by Rakvere Põllumajandustehnika OÜ was used. Operated at a lower rate of revolutions, it proved to be successful in cutting the moss fragments to a suitable size (1-3 cm, but there were also longer fragments). The peat fragments were collected from the donor site and transported to restoration area by Rakvere Põllumajandustehnika OÜ.

The Sphagnum fragments were cut on 4 September 2018 and transported to the restoration area a few days later on a tractor trailer, then piled up at the western edge of the distribution area. A double-wheeled tractor entered the donor area, and the wide bucket of an excavator was used to lift the moss fragments onto it. Later assessments showed that the Sphagnum fragments were partially in clumps, likely because there were clumps of peat from deeper layers due to the plant fragments being collected by an excavator (not using below-standard milling) or from clumps that should have been chopped up beforehand. The total cost of cutting and collecting the fragments from the 0.5-hectare donor site (with transport) was 5000 euros.

The cutting took one day (10 hours, ca 0.5 ha, Sept 4th 2018), while collecting the fragments and transporting them to the temporary storage area (ca 100 m) took a day and a half. From there to Palasi, the fragments were transported on tractor trailers (lifted onto a tractor trailer using an excavator bucket). In total there were 13 trailer-loads, around 160 m^3 of material (a layer of 10 cm on average being cut from half a hectare, i.e. 500 m^3 in calculated volume, but this compacted significantly under its own weight). Distribution of the Sphagnum fragments commenced on 9 October, but it became apparent that the planned machinery (an ATV on tracks and with a trailer) was not suitable for the work, since September rains and the rising water level following the ditch blocking had waterlogged the soil and made it difficult to move around. An eight-wheeled amphibious Argo was then tested, but it was not able to pull the load of Sphagnum fragments or straw; turning with the load was particularly problematic. The use of a Milrem small military crawler was also considered, but these plans were not realized. As such, we did not manage to spread the fragments from the donor area within the few weeks recommended in the instructions.



Fig. 12. Photos characterising the hydrological regime of the area (30 September 2019). Photo: Marko Kohv

Spreading of the plant fragments and straw was finally completed using a Seiga reed harvester (four wheels, weight: 2.5 t) from 5 November-11 December 2018. Nordic Botanical contributed with its machines in loading the peat onto the Seiga; a hoist pulled by an ATV was used, and the straw bales were opened manually before spreading. The Sphagnum fragments and straw were usually stored at one end of the restoration area, on the lower part of the slope, which was not the best solution logistically since the Seiga was planned to move perpendicular to the slope to avoid creating ruts and the movement of water along the slope.

COMMENTS AND ADVICE

For various reasons, it was not possible to follow all of the recommendations given on the basis of previous experience. We have no information on whether or to what extent the sprouting ability of the Sphagnum fragments that lay in the piles for several months (partly during the warmer months) has been affected, but most likely it was decreased. Since the fragments were spreaded during the cold season, the conditions for their sprouting were not favourable. Moreover, the dry and sunny spring that followed may have been equally unfavourable for their sprouting. On the other hand, the instructions said that in exceptional cases plant material could be preserved until the following spring, and based on this, the decision was made to continue with the work in late autumn and not to abandon what had already been started.

Another risk was the ratio of Sphagnum fragments to peat from a greater depth. In the Punasoo donor area, plant fragments were only cut from the top layer (10 cm), but when the fragments were collected it is likely that peat from deeper layers was also picked up. In early September the temperature of the bog surface may have been around 20°C, and decomposition processes may have begun to take place in the piles of plant fragments and peat, while the lack of oxygen and light may have diminished the regenerative ability of the fragments. The sprouting of the plants on the cut-over peatland was hindered by drought in subsequent years.

At the same time, Edgar Karofeld's recommendations to close the ditches bordering and between the peat mining fields only after the plant fragments and oil shale ash had been spread were not followed (since this would have hindered the movement of the machines for the spreading of plant fragments and straw) and the Sphagnum moss fragments should have been spreaded across the cut-over peatland over a period of a few weeks to encourage their growth. Spreading the plant fragments with an ATV would probably have been possible as soon as the ditches were closed and before the September rains, as was initially planned. The order in which the work was carried out was guided by the initial technical design, in which the spreading of the Sphagnum fragments was earmarked to take place shortly after the removal of the topsoil and the closing of the ditches.

The machines used for this work in Canada would probably not have been suitable in Palasi, as they are too heavy. Such was the assessment made by Rakvere Põllumajandustehnika OÜ in early September, before the rains set in. In the peat-mining area where extraction had ended just before the restoration and spreading of the Sphagnum fragments, the work probably could have been done with heavier machinery (and consequently better performance) similar to the type used in Canada.

Levelling the area with a bulldozer before the plant fragments had been spread resulted in a very low surface-bearing capacity after the rains. Once the oxidised top residual peat layer was removed and the ditches were filled with the bulldozer, the next step – additional smoothing of the surface with an angle-dozer – may not have been strictly necessary (since caterpillar tracks, some depressions and unevenness remained thereafter, e.g. due to stumps). Subsequent surface-levelling was also helped by the peat compaction of the wheels of the Seiga, which was used on the soaked peat surface.

In these conditions, the reed harvester was rather effective for carrying out the tasks, but the extent of manual labour required (five to six men per area) made it expensive and there were difficulties in spreading the plant fragments and straw evenly. In theory, one way around this would be to mount on the Seiga two simultaneously operating spreaders: one for moss and the other for straw. On the other hand, wind can cause problems in the use of spreaders, and additional raking of the straw on the surface for even distribution might have been easier in some conditions. Nevertheless, it is advisable to break down the straw piles mechanically before loading them onto the reed harvester. For better spreading, the straw should be dry, i.e. with a moisture content of less than 20%. The amount of straw per surface area also depends on the characteristics of the straw (length, abundance of leaves, etc.). For this work, lighter manure spreaders with wider tyres or crawlers (as used on small farms) could be suitable, but in drier conditions.

Some spreading of the plant fragments and straw was done on snow (ca 3 cm, less after being driven on with the Seiga) and some directly on peat.

In Canada as well, under the supervision of Line Rochefort, Sphagnum fragments have been spread on snow in some cases, and no significant difference has been noted in comparison with work carried out in warmer seasons. Due to the higher bearing capacity this may even be advisable for some areas, but in these cases one problem is the even spread of the plant fragments – it will freeze in the top layer of the piles, but also on the machines and equipment used, thus making it difficult to spread evenly.

VOLUME AND COST OF WORK

The technical design covered the restored cut-over peatland and former peat-mining areas surrounding it: a total area of 53.5 ha and a total cost of 3600 euros (Table 1). The cost of work done by the Estonian Fund for Nature (salaries and transport) is not included.

Improvement of the hydrological regime over 15 hectares of a former milled-peat production field using two excavators and two bulldozers, incl. a special excavator for the preparation of peat- mining areas: 61,616 euros. The work included the following: dams, Type 1 (long dams), 9 dams, construction, 5940 euros; Type 2a (dams without wings on ground built into ditches), 92 dams, construction, 9384 euros; Type 3 (large soil dams), for the surrounding collecting ditches, 18 dams, 4752 euros; levelling of area and removal of soil, 29,750 euros; sediment basins, 1176 euros; spreading of peat pile and removal of ditch berms, 10,614 euros.

[36] Evaluation by Edgar Karofeld.

	ACTUAL COST	ESTIMATED COST OF RESTORATION AFTER MINING	COST 1 HA
Planning 15 ha	3600	5000	
Restoring hydrological regimen 15 ha	61616	28344	1890
Distributing of Sphagnum moss 5 ha	48124	25000	5000
Cutting of fragments of Sphagnum moss and transporting them to storage plot (ca 100 m) 0.5 ha	5000	5000	
Covering with straw (without moss), incl. material, 2 ha	2000		
Distributing of oil shale ash 1 ha	3600		
Reed harvester, 138 h	22524		
Management, loading, spreading, experiments	15000	20000	
TOTAL	113340	58344	

Table 1. Cost of restoring the former Palasi peat-mining area and projected cost of restoring the mining area

Almost half of the budget went on levelling the areas and removing soil – in hindsight, this seems to be the main possible saving item at this stage (e.g. if we use the work hour of a bulldozer rather than the volume count). In reality it was not possible to remove the top layer of residual peat – after the topmost layer was removed (with most of the material being pushed into the ditches separating the fields), the bearing capacity of the area became so poor that the bulldozer did not remove the soil but rather just mixed up the upper peat layers. To some extent, levelling is necessary for filling the ditch depressions, because the ditch berms are usually not enough to fill them. However, the wish to remove the uppermost 10 cm appeared to be technically impossible in the conditions existing in Palasi. At the same time, likely enough driving took place all over the area to break the crust that has formed over time and compress and mix the mineralised part of the peat with the proper peat beneath it.

Cutting of Sphagnum fragments and transporting them to the site: 5000 euros.

NB contributed two men and machinery: an ATV on tracks, a hoist and a trailer. Originally, the time planned for distributing the Sphagnum fragments and straw was 20 days for two or three men, but in reality it took 80 days, incl. time for testing. The total cost was 15,000 euros.

The reed harvester team comprised three or four men; their total working hours were 138. The total cost of 22,524 euros included the transportation of the harvester from and back to Hiiumaa. This amount was added to the 20,000 euros initially budgeted for the spreading of the Sphagnum fragments and straw.

Total cost of spreading Sphagnum moss with straw mulch over 5 hectares, incl. collecting and transporting moss from donor area 6 km away: 35,000 euros. There were additional costs of 3600 euros for spreading oil shale ash over 1 ha (with spades from the box on the ATV) and 2000 euros for straw mulch over 2 ha without distributing the moss fragments.

The cost of restoring the 15 ha of milled peatland together with the spreading of the Sphagnum fragments and straw (over 5 ha) and processing with oil shale ash (over 1 ha) was 105,456 euros (ca 7000 euros/ha).

The cost of the work is not in direct correlation with the restored former peat-mining area, since it includes the closing of the large collection ditches around the milled peat production fields, long soil dams on the marginal lower parts of the milled peat production fields to raise the water level there, and the elimination of a peat pile and a roadway. In restoring similar areas, possible cost saving points would be: a) avoiding the construction of sediment basins (1176 euros), since the earthwork was done in dry weather and thus no sediment reached downstream, plus the effectiveness of these basins is doubtful had there been heavy rain, since the time for settling would have been rather short and water would have run quickly through the basins; and b) avoiding the construction of long dams in flat areas (9 dams, 5940 euros), and in some areas also reducing the number of other dams. Scattering or removing peat piles, eliminating ditch berms and removing soil in large volumes are not always necessary either. In order to improve flat former peat-mining areas that has long been out of use,

[3] González, E., Rochefort, L., 2019. Declaring success in Sphagnum peatland restoration: Identifying outcomes from readily measurable vegetation descriptors. Mires and Peat, Vol. 24 (19).

ditches should be closed with dams for every 30 cm of slope gradient and filled, e.g. by pushing the mineralised surface layer of the peat or milled peat into them. Thus the optimal cost of shovelling for areas of a similar size would be 28,344 euros, i.e. 1900 euros/ha (calculating the costs of building 92 smaller and 15 larger peat dams and filling in the ditches).

Another important way of optimising costs is more effectively planning the logistics of spreading the Sphagnum fragments (i.e. the location of intermediate storage areas to speed up the work process) and a better choice of machinery. Thus the possible cost of reintroducing Sphagnum moss over 5 hectares would be 25,000 euros or 5000 euros/ha.

Line Rochefort has said that the success of spreading Sphagnum fragments should become evident within around three years. In the first years much depends on the weather and it can be very patchy, plus it is difficult to see plants under the straw. An article by Gonzaleze and Rochefort published in Mires and Peat in 2019 described, on the basis of the Canadian experience, three scenarios of the sprouting success of plant fragments 5-10 years after sowing.

- The best-case scenario is a plant community with Sphagnum moss and hare's-tail cottongrass, both covering around a third of the area.
- A very good outcome is a plant community with haircap moss (*Polytrichum*) and Sphagnum moss. In Palasi, such a community would be expected on the areas processed with oil shale ash, with haircap moss coverage of more than 40% and Sphagnum moss coverage of more than 20%.
- A meagre but nevertheless hopeful result would be many species typical of mires, but with small coverage (Sphagnum moss at 5-10%). The site may transform into a proper mire in the longer term. Analysis should be made of what is hindering the recovery of the vegetation in the area and, if needed, additional work should be carried out.

The directions of waterflow in restoration areas turned out as predicted by the hydrological model in the implementation design. Neither the amount of water nor seasonal water levels were modelled – there were insufficient data to do this. The water level falling by up to 50 cm during summer droughts is the main obstacle to regeneration in the central area (where the experiment was run). Vegetation formation was most successful in the wettest (north-eastern) corner of the restoration area, with some moss fragments that had been spread starting to grow.

The vegetation square analysis performed by Kai Vellak in 2020 showed that general coverage of vegetation was more than 10% on fewer than half of the permanent squares of the areas restored with plant fragments and straw. General coverage was particularly poor in one of the Sphagnum moss and straw spreading areas (named as SFP), where it exceeded 5% in just one square. In areas restored with oil shale ash and straw, only a few squares exhibited general coverage of more than 10%. Since the water level had not stabilised sufficiently in the restored areas (partly because of the long periods of drought in 2019 and 2021), the sprouting of plant fragments and recovery of vegetation also slowed. In the course of the vegetation monitoring carried out in summer 2021, the general coverage in the areas improved with Sphagnum moss fragments and straw had decreased further. In two of the four areas (SPF 1 and SPF 3), no squares showed Sphagnum moss coverage of more than 5%. However, in the areas improved with oil shale ash and straw, in some squares general coverage had increased to approx. 50%. The dominant plant species were heather and hare's-tail cottongrass, but there were also several plant species not characteristic for mires. As such, according to the scenario above, the level of success of the work in Palasi should be evaluated as meagre. How promising it is in the long term remains to be seen once the water regime has improved.



Fig. 13. A drone photo characterising the development of the area (9 September 2020). Photo: Marko Kohv

THE COST OF RESTORATION WORK

JÜRI-OTT SALM

Estimations of the cost of restoration in the 'Conservation and Restoration of Mire Habitats' project were based on the mire habitat restoration work commissioned by the State Forest Management Centre in 2015 and on the prices given in the handbook summarising Finnish experiences[38]. To assess the volume of work, map analysis was done to collect information on the network of potentially closable drainage ditches, the possible volume of work and the effect this work might have on different habitats; also on the extent of forested areas to obtain a preliminary assessment of the possible volume of felling. Due to the requirements of the LIFE programme, felling was undertaken by the State Forest Management Centre, and the volume of work was determined during the drafting stage of the restoration plan, the total volume diminishing significantly. One reason was the high cost of felling that was projected.

Table 1 shows the volumes and prices of the work in the project application and in different stages of project execution – in the evaluations given when drafting the restoration plan and the implementation design. Since the cost of the work was estimated as being lower during the drafting of the restoration plans compared to the estimates in the application, it was possible to plan additional restoration work in the protected areas covered by the project.

The final price was formed via public procurement procedures or asking for quotes. The costs of execution presented in Table 1 exclude the costs of felling, the contribution of project partners (the Estonian Fund for Nature, the University of Tartu, Archaeovision R&D, the State Forest Management Centre and the Environmental Board), the cost of organising voluntary activities and other organisational costs.

The costs of felling are presented separately in Table 2. Here we see that the price of felling was almost twice that of



Building a dam with an excavator in Laukasoo. Photo: Jüri-Ott Salm

[38] Similä, M., Aapala, K., Penttinen, J. 2014. *Ecological restoration in drained peatlands – best practices from Finland.* Metsähallitus Natural Heritage Services, Vantaa.

[39] Kull, A. 2013. Determining the buffer zones needed for the ecological functionality of mires to stop or alleviate the spread of long-term disturbances, 2nd stage. Report on government grant 2386 SFL contract no. 3-2_15/45-8/2011. Institute of Ecology and Earth Sciences of the University of Tartu
Kull, A. 2016. Determining the buffer zones needed for the ecological functionality of mires to stop or alleviate the spread of long-term disturbances, 2nd stage. Report of the government grant 8286 SFL contract no. 3-2_15/835-14/2014. Institute of Ecology and Earth Sciences of the University of Tartu Report available online at http://ainkull.wixsite.com/sood (accessed on 7 January 2020).

earthwork and that the earnings from selling the timber did not cover the cost of the felling. By adding together the earthwork and felling we obtain the price per hectare restored, which ranges from 78-1041 euros (see tabel 1, last column).

The cost of restoration work per hectare is given according to the extent of the impact of the drainage network eliminated. According to research on 20 mires by a working group from the University of Tartu led by Ain Kull (Kull, 2013; Kull, 2016), the drainage ditches in bogs and bog forests have a significant impact radius of around 100 metres, while a weak effect is discernible up to 200 metres away. In transition mires these zones are shown to be twice as large.

The higher price per hectare was the result of the density of ditches (the spade peat-holes and abandoned mining area in Soosaare), the need for special solutions (closing the Great Bog Pool in Laukasoo – almost 70,000 euros alone) and the need to implement alleviating measures (renovating some ditches in Sirtsi and Tudusoo Nature Conservation Area and redirecting outfalls with the aim of guaranteeing the functioning of the preserved drainage network – approximately 50,000 euros per area).

The cost of the work done includes improving the former peat-mining area in Palasi; an evaluation of this work is given in the chapter 'Experiences from the restoration of the Palasi former peat-mining area with the spreading of Sphagnum fragments and oil shale ash'. Therefore, the cost of restoring and recreating the vegetation on the cut-over peatland is many times greater than the values given.

It should also be taken into consideration that the price per hectare depends on the specific location (its accessibility and distance from roads, the number of dams per area unit, special solutions and the total volume of work) and may be bigger than is presented in Table 1. Moreover, the corresponding evaluations may vary based on differences in defining the affected area: the cost is greater if the affected area is estimated as being smaller.

	Ditches (km)					Felling (ha)				Affected area, ha	
	application	execution	execution	execution	fuel consumption, l	application	Execution			applica-tion	execu-tion
Restoration area			number of dams	volume of peat removed m^3			Thinning	Deforestation	Routes		
Feodorisoo	13	10	88	1000	unknown	110	0	0	8	614	597
Tudusoo NCA	65	71	468	68,700	22,423	794	90	83	44	1548	2089
Laukasoo	38	43	500	35,085	15,510	461	0	54	17	1009	1149
Ohepalu NCA	6	28	200	12,710	unknown	0	3	43	12	524	1120
Soosaare	16	52	528	13,113	4165	30	4	40	3	100	167
Sirtsi NCA	90	112	700	160,780	16,017	703	84	126	64	1989	2778
Total	228	317	2484	291,388	58,115	2098	181	346	147	5785	7900
						Total felling, ha			674		

Restoration area	Cost of project design (EUR)	Cost of works (EUR) Application	Evaluation in restoration plan (EUR)	Evaluation in execution design (EUR)	Cost of procurement (EUR)	Price, design and execution per ha	Price per ha: design, execution and logging
Feodorisoo	5760	66,075	40,000	32,677	40,537	78	78
Tudusoo NCA	18,360	333,819	120,000	436,117	270,681	138	357
Laukasoo	14,400	195,396	108,000	114,937	232,382	215	328
Ohepalu NCA	9497	30,081	60,000	30,000	50,140	53	124
Soosaare	6860	63,057	24,000	30,900	64,165	425	1041
Sirtsi NCA	15,840	448,428	258,000	675,140	404,888	151	295
Total	70,717	1,136,855	610,000	1,319,771	1,062,792	143	291

Table 1. Calculating the volume of work in the 'Conservation and Restoration of Mire Habitats' project

	Logging (ha)	Fuel consumption (l)	Removed from forest (CBM)	Left in area (CBM)	Cost of logging (EUR)	Revenue from timber (EUR)
Soosaare	47	5700	676	1239	126,198	23,082
Ohepalu	38	4600	676	*	107,083	27,449
Laukasoo	68	*	838	*	171,126	41,308
Tudusoo	217	29,200	2689	*	575,255	118,940
Sirtsi	274	30,000	10,100	*	946,978	523,600
Sirtsi Palasi	27	6200	1471	338	23,785	47,933
TOTAL:	671	75,700	16,450	1577	1,950,425	782,312

*not known or not evaluated

Table 2. Volume of felling, total fuel used and statement of revenue and expenditure

THE EFFECT OF DRAINING AND RESTORING MIRES ON THE EMISSION OF GREENHOUSE GASES AND THE CARBON FOOTPRINT OF RESTORATION WORK

JÜRI-OTT SALM

The most important functional property of a natural mire ecosystem is the formation and depositing of peat. This is also seen as an ecosystem service characteristic of mires that helps, among other things, to alleviate climate change caused by anthropogenic carbon dioxide (CO_2) emissions. Scientific studies have calculated the long-term average speed of carbon (C) storage in the Estonian climate and conditions similar to those in mires to be [40,41] 0.18 to 0.23 t C ha^{-1} a^{-1}.

If mires are drained and the vegetation characteristic of mires destroyed, peat ending up in an aerobic environment will start decomposing, resulting in carbon emissions. Thus the ecosystem service of mires – binding and storing carbon and CO_2 – will be disrupted. In Estonia, annual emissions caused by drained mires have been calculated as being between 1 and 8 million tonnes of CO_2 (cf. emissions from transport sector, which are approx. 2 million tonnes of CO_2). In some cases, the effect caused by drainage could be compensated by forests growing on a former mire, but when trees are felled, the carbon stored in the drained mire is usually removed in the form of timber.

With the decomposition of peat caused by drainage, in addition to emissions of CO_2, other strong greenhouse gases – methane (CH_4) and laughing gas (N_2O) – are emitted which are 25 times and 310 times more effective than CO_2, respectively, in causing the greenhouse effect. Although methane is also formed in low-oxygen environments like natural mires with a high water level, in the case of drainage the flow does not stop (one significant difference with natural areas being that in natural mires, the carbon emitted within methane is compensated by binding it in CO_2). The main source of methane is drainage ditches. Emissions of all three gases enable us to calculate the greenhouse effect (i.e. the contribution to climate change) of an area.

To restore the hydrological regime and habitats in mires, some work is done (designing, leading and supervising restoration work, felling trees, closing ditches, reconstruction work, etc.) which has its own carbon footprint. In calculating the carbon footprint, the following was taken into consideration in this paper: i) the amount of carbon bound in timber removed from an area through felling; ii) the amount of used fuel and related emissions of CO_2; and iii) the amount of fuel used by project partners. The aim is to assess the carbon footprint of the 'Conservation and Restoration of Mire Habitats' project.

The following are calculations based on the effects of drainage and restoration on the 33.6-hectare former peat-mining area in Palasi situated in Sirtsi Nature Conservation Area (Fig. 1).

Before restoration began, around 20 hectares of the former mining site were covered in trees around 30 years old (its habitat type being identified as bog woodland); the rest of the area was covered in either sparse vegetation (incl. trees growing on ditch banks) or vegetation was missing altogether.

Preliminary estimates of the carbon balance of the abandoned mining area in Palasi were given in the mire restoration plan[42]. This was a simplified approach, since the carbon balance of the wooded area (i.e. the carbon bound in trees) was not taken into consideration.

One way of obtaining more accurate estimates is drawing on the conclusions made by the Finnish Natural Resource Centre[43]: in draining mire forests, carbon emissions from peat decomposition are 2.9-3.7 t/ha a year for oligotrophic habitats. Trees, peat litter and other dead plant matter return approximately the same amount of carbon to the soil. This allows us to presume that before restoration started, the carbon balance in the forested area – in oligotrophic conditions – in the Palasi peat production fields was positive due to the trees that were growing there, i.e. the area was binding more carbon than it was emitting. According to the Forestry Register[44], the volume of the growing stand was 1139 m3 (not including the trees growing on ditch embankments

[40] Turunen, J., E. Tomppo, K. Tolonen & A. Reinikainen. 2002 Estimating carbon accumulation rates of undrained mires in Finland – application to boreal and subarctic regions. Holocene 12: 69–80.[39] Kull, A. 2013. Determining the buffer zones needed for the ecological functionality of mires to stop or alleviate the spread of long-term disturbances, 2nd stage. Report on government grant 2386 SFL contract no. 3-2_15/45-8/2011. Institute of Ecology and Earth Sciences of the University of Tartu

[41] Gorham, E. 1995. *The biogeochemistry of northern peatlands and its possible response to global warming.* In: Woodwell, G. M., Mackenzie, F. T. (Eds.) Biotic Feedbacks in the Global Climatic System: Will the Warming Feed the Warming? Oxford University Press, New York, pp 169–187.

[42] https://soo.elfond.ee/wp-content/uploads/2016/12/Palasi-taastamiskava-FINAL.pdf.

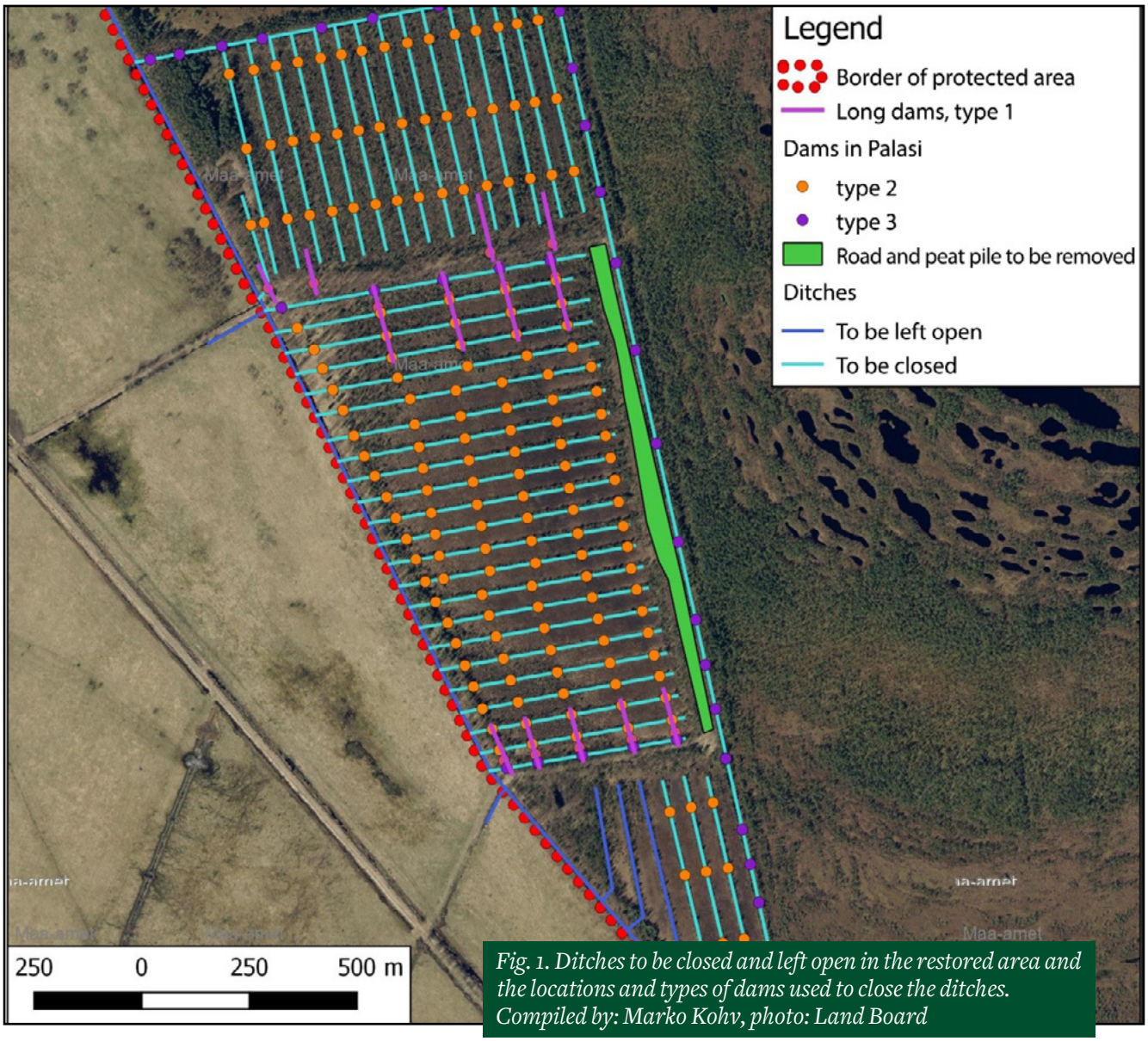


Fig. 1. Ditches to be closed and left open in the restored area and the locations and types of dams used to close the ditches. Compiled by: Marko Kohv, photo: Land Board

on more open landscapes) before restoration. Taking into consideration its average density (0.45) and carbon content (50%), the trees growing in the area had bound 256 tonnes of carbon.

Calculations were made for the carbon balance of the area with minimal or missing vegetation (13.6 ha) based on measurements of carbon dioxide and methane emissions in abandoned peat production areas in Estonia.

Emissions of CO_2 per hectare were measured in abandoned mining areas in Estonia as being 2.5-15.9 t ha^{-1} a^{-1} (per hectare per year), with an average value of 6.8 t ha^{-1} a^{-1}. Reduced to carbon, the average value is 1.8 t ha^{-1} a^{-1}. In addition, water erosion washes 0.19-0.46 tonnes of carbon (average 0.3 tonnes) ha^{-1} a^{-1} from dried-out soil, which later decomposes in bodies of water and ends up in the atmosphere as carbon dioxide. The emissions of CH_4 as measured on the abandoned peat fields and reduced to carbon are between -4.8 and 20.4 kg or 0.06 kg ha^{-1} a^{-1} on average. In addition, there is gas flow from the surface of drainage ditches: 406.5 kg C ha^{-1} a^{-1}. The emissions of laughing gas were 0.27 (0.03-1.68) kg ha^{-1} a^{-1}. (An overview of relevant research and more detailed data can be found in the paper by Salm et al. [45], and in the article published by Salm and Kull in the journal Eesti Loodus[46].)

The area with minimal or missing vegetation in the former mining area in Palasi measured approx. 13.6 ha. Annual emissions of CO_2 (including carbon removed by water erosion and emitted into the atmosphere as CO_2) before the hydrological regime was restored in the area, based on the average data above, were 122 tonnes of CO_2 (reduced to carbon: 33 tonnes). Annual emissions of CH_4 were calculated based on the total length of the ditches (7.5 km) and their area (0.75 ha), which emitted 405 kg of methane annually (reduced to carbon: 305 kg); from the land (13.6 ha), 1.1 kg of methane was emitted (reduced to carbon: 0.8 kg). Laughing gas emissions were 3.7 kg. The greenhouse effect calculated in CO_2 equivalent is 143.8 t a^{-1}, of which 85% is from CO_2.

In addition to all of the above, there are emissions caused by the decomposition of mined peat and a reduced or non-existent ability to bind carbon in areas outside the mining area affected by drainage. No calculations are given for these factors in this paper.

As such, in the 30 years since mining was abandoned, around 1000 tonnes of carbon have been emitted due to the mineralisation of peat and 3300 tonnes due to destroyed peat (calculated volume of standardised moisture content 40%) from this 13.6-hectare area. Rebinding this amount into peat

in a mire of a similar size would take approximately 300 years (calculated binding speed: 0.18-0.23 t C ha^{-1} a^{-1}).

If favourable conditions for mire habitat recovery were created, it is presumed that peat formation and depositing processes would also be revived. Many restoration projects have managed to achieve the return of vegetation typical to mires, but we need additional analysis on whether and how quickly the carbon-binding function will be restored. The problem here is the lack of long-term studies measuring the balance of greenhouse gases over 10 or more years following restoration. However, several studies show that carbon loss may be significantly lower (50%) in restored areas compared to the situation prior to restoration (see e.g. results from Estonia: Järveoja et al. 2016[47]).

CARBON REMOVED THROUGH FELLING

Felling (incl. cutting trees along ditch banks) covered around 15 hectares; the forest was preserved on close to 5 hectares. The use of timber removed through felling also releases the carbon bound in these trees, but depending on the type of use, this process can take decades. Since the timber cut from the area in question was predominantly used for energy production through burning, we presume that carbon emissions took place within a year of felling. As such, felling is one of the activities that increases the carbon footprint of restoration work.

On the other hand, the carbon bound in the residue left in the area will be partly preserved after restoration, since with a higher water level it will remain in anaerobic condition and the carbon will be deposited as wood peat. Forest left standing will increase carbon binding in the area, both in trees above the surface and in tree roots.

Through felling, 1343 m3 of timber was removed from the area. Taking into consideration its average density (0.45) and carbon content (50%), the amount of carbon removed from the area was calculated as being 331 tonnes. This value is greater than that given above. The reason for this is the timber collected from ditch banks, which was not reflected in the Forestry Register data.

THE CARBON FOOTPRINT OF WORK NEEDED TO RESTORE THE HABITATS AND HYDROLOGICAL REGIME OF MIRES

To evaluate the carbon footprint of the work, the procurements organised by the Estonian Fund for Nature obliged the contractor to present a report on the amount of fossil fuels used. Since the fund only organised the earthwork, the same information on felling was sought from the State Forest Management Centre, which was responsible for this work. This information can be found in Tables 1 and 2 of the chapter 'Cost of restoration work'.

The data given below are based on the reports from the felling company Praktov OÜ and the earthwork company Metropol Group OÜ. Emissions from fuels burned were calculated according to information published on the Ecoscore Information website [48]. Since mainly diesel fuel was used, the emissions from its use were evaluated based on the following indicators: the weigh of 1 l of diesel fuel is 835 g and it contains 86.2% carbon. Thus, burning 1 l of diesel fuel releases 720 g of carbon.

A total of 6.2 tonnes of fuel was used for felling (incl. for the felling and transport tractor and the transporting of workers) and its carbon emissions came to 4.5 tonnes. At the same time, fuel consumption also covers the fuel used for thinning on almost 9 hectares outside the mining area, where the work was done manually and with an excavator (pressing the wood swaths into the soil), but no timber was removed. Thus the emissions associated with mining area were actually smaller, but there are no detailed calculations for this.

For earthwork (building dams, filling in ditches, eliminating peat piles and part of the road in one mining field, levelling and transporting soil and transporting workers), 7.4 tonnes of fuel were used with a corresponding carbon emission of 5.3 tonnes.

CARBON FOOTPRINT OF THE 'CONSERVATION AND RESTORATION OF MIRE HABITATS' PROJECT

Based on the project costs, the quantity of fuel and its carbon emissions were also analysed for the project's partners (the Estonian Fund for Nature, the University of Tartu and Archaeovision R&D). All car journeys made in the course of the project are included. If fuel consumption was not declared in the cost statements, it was taken as being 8 l per 100 km. From September 2015-October 2021 a total of 15,233 litres of fuel were used. As such, the carbon footprint of the project is 11 tonnes of carbon (40 tonnes of CO_2).

In conclusion, we can say that the biggest component in the carbon footprint of mire restoration work is the amount of timber removed through felling and its use. Emissions from using machines is smaller by two orders of magnitude.

[43] Penttilä, T., Laiho, L. & Mäkipää, R. Suometsien ilmastoviisas metsänhoito. Luonnonvarakeskus. http://www.ilmase.fi/site/wp-content/uploads/2018/06/valmis_suometsatietokortti_nettiin.pdf (accessed on 9 January 2020).

[44] http://register.metsad.ee.

[45] Salm, J.-O., Maddison, M., Tammik, S., Soosaar, K., Truu, J. & Mander, Ü. 2012. Emissions of CO2, CH4 and N2O from undisturbed, drained and mined peatlands in Estonia. Hydrobiologia.

[46] Salm, J.-O., Kull, A. 2016. Sood kui süsiniku sidujad [Bogs as binders of carbon]. Eesti Loodus, August 2016. (In Estonian)

[47] Järveoja, J., Peichl, M., Maddison, M., Soosaar, K., Vellak, K., Karofeld, E., Teemusk, A. and Mander, Ü. 2016. *Impact of water table level on annual carbon and greenhouse gas balances of a restored peat extraction area*. Biogeosciences, 13, 2637–2651.

[48] https://ecoscore.be/en/info/ecoscore/co2.

LET'S KEEP OUR EYE ON RECOVERING MIRES!

MARKO KOHV

Restoration work requires a lot of time and effort and is therefore quite expensive. The question as to whether the money used will produce the desired results is entirely justified and indeed should be asked. Answering it starts with formulating the expected outcome, followed by choosing the appropriate methods to obtain the answer, then applying them and analysing the results.

This analysis may lead to the realisation that the method was not suited to answering the original question, or that the method selected was too expensive or labour-intensive to apply in reality. Since the aim of restoration in itself is to change the status of an area, it is possible to 'go back in time', if needed, by using a similar area elsewhere and/or long-term monitoring data warehouses, such as the old orthographic photos of the Land Board or satellite photos. Since resources are typically insufficient to have control areas of equal dimensions for land surveys, and since long-term monitoring does not provide a sufficiently detailed view, asking the right questions and choosing the right methods become extremely important. And no better help is available in making decisions easier than earlier works and experience. Therefore, documenting the entire monitoring process is extremely important, since without it, it would often be impossible to repeat the work methodically, and the comparability of the results may turn out to be poor if recovery takes decades.

Ideally, the restored area should be screened prior to restoration using the same method so that it is possible to make a 'before-and-after' comparison. Screening carried out and old data analysed beforehand provide valuable additional information for planning the restoration work, for example by giving some idea of the extent of treeless mires before drainage.

WHAT DO WE WANT TO ACHIEVE THROUGH RESTORATION?

The aim might be to restore vegetation, to restore mire vegetation and the regeneration of peat, to restore one specific mire type as a habitat, to reduce or stop CO_2 emissions, to limit the risk of fire or to improve the visual appearance. Often the aim primarily depends on the financing requirements, but it should nevertheless be agreed upon during the initial stage of discussions. The aims can also be placed on a time scale, one after the other. Example: First, quickly reduce the risk of fire by raising the water level; next, keep the water level near the surface to create conditions suitable for mire plants; then partially eliminate trees to stabilise the water level in order to create a canopy typical of a natural mire forest; in designing the forest, retain older trees that are more important for biodiversity but also visually more attractive; and so on.

The aims of restoration should be defined in both the short term (3-5 years) and long term (decades). Short-term aims are set in order to obtain initial confirmation that the dams et al. that are constructed are having the desired effect and that the mire habitats in the restored area are moving in the direction of the long-term aim as a result. For example, in order to restore a treeless mire, after closing the ditches the water level should rise to near-surface levels, remaining at this level in summer as well; the effect should be to increase the coverage of plant species typical of treeless mires, such as Sphagnum mosses and white beak-sedge. The recovery of a treeless mire together with its characteristic structural elements (such as complexes of watery patches and plant beds) may take decades, but the premise for it is a stable water level near the surface level of the bog.

In defining the aims, indicators of positive developments and signs of risks should both be considered. For example, a large number of young trees is a clear sign of danger when a treeless mire is being restored – in this a criterion is needed (e.g. coverage of up to 20%) as to when a decision on intervention should be made. In this case there would be various options for intervention: redefining the long-term restoration aim from treeless mire to wooded mire or mire forest; cutting down the young trees; looking for ways to induce a further rise in the water level or stabilise it; etc. In any case, the possible effect of the weather must also be analysed – relatively dry years, for example, favour the growth of trees.

HOW TO MAKE SURE YOU ARE MOVING TOWARDS YOUR AIMS

In restoring mires, the quickest change (in number of days) is in the relative water level, which is also relatively easy to monitor. The most cost-effective way of doing this is using automatic sensors. In mounting these sensors, it should be taken into account that different monitoring points should be equidistant from the ditches to be closed/left open (we used a distance of 15 metres from the edge of the ditch as our rule of thumb). The sensor should be deep enough in terms of the surface of the mire to remain in the water even during years of drought (1 metre is usually enough) and be properly fixed so that it remains at a similar depth even after taking it out and putting it back. If possible, measuring point for hydrological monitoring should also be mounted in the control areas near the restoration area so as to record the water level when 'nothing is being done' in similar weather conditions as well. In the case of pressure sensors, atmospheric pressure should be measured separately, with the barometer located no more than 20-30 km from the water monitoring point.

A WORD OR TWO ON MISTAKES

Automatic sensors can create a false sense of security, especially at first. In long-term monitoring, errors emerge in data series. Firstly, problems can arise in their

configuration, such as giving the device the wrong initial point for calculating time, or the wrong altitude. Secondly, over longer periods the time calculations of the sensor can drift from real time; the sensor's measurements may start shifting in one direction; its position may change due to a collapsed well or broken cord, or due to the cord becoming stuck when taking it out or putting it back in; etc. In order to note these errors, manual measurements from the same well are essential, since they highlight the wrong position of sensors or a gradual shift in pressure measurements. In order to check the data, a continuous dataset on temperature that generally accompanies sensors is also very useful. In water, the temperature usually changes very slowly and consistently – abrupt changes unambiguously indicate the collapse of the well or that the sensor is no longer affixed.

The main problem with automatic measurements from monitoring wells is that they are essentially point measurements providing no information about the restored area as a whole. We can only presume that if the hydrological regime has been successfully restored at the point being monitored by the sensors, then the situation is similar in all areas undergoing similar manipulation. Experimental solutions for distant monitoring over an entire area have shown, with quite some success, e.g. the stress on vascular plants caused by a lack of water (e.g. Harris et al. 2006), but the majority use multispectral or hyperspectral cameras and complicated/time-consuming data-processing, thus making themselves unavailable to 'ordinary users'. Cheap, well-timed drone monitoring could map dried Sphagnum moss patches, but this method cannot be used to obtain a solid dataset from larger areas.

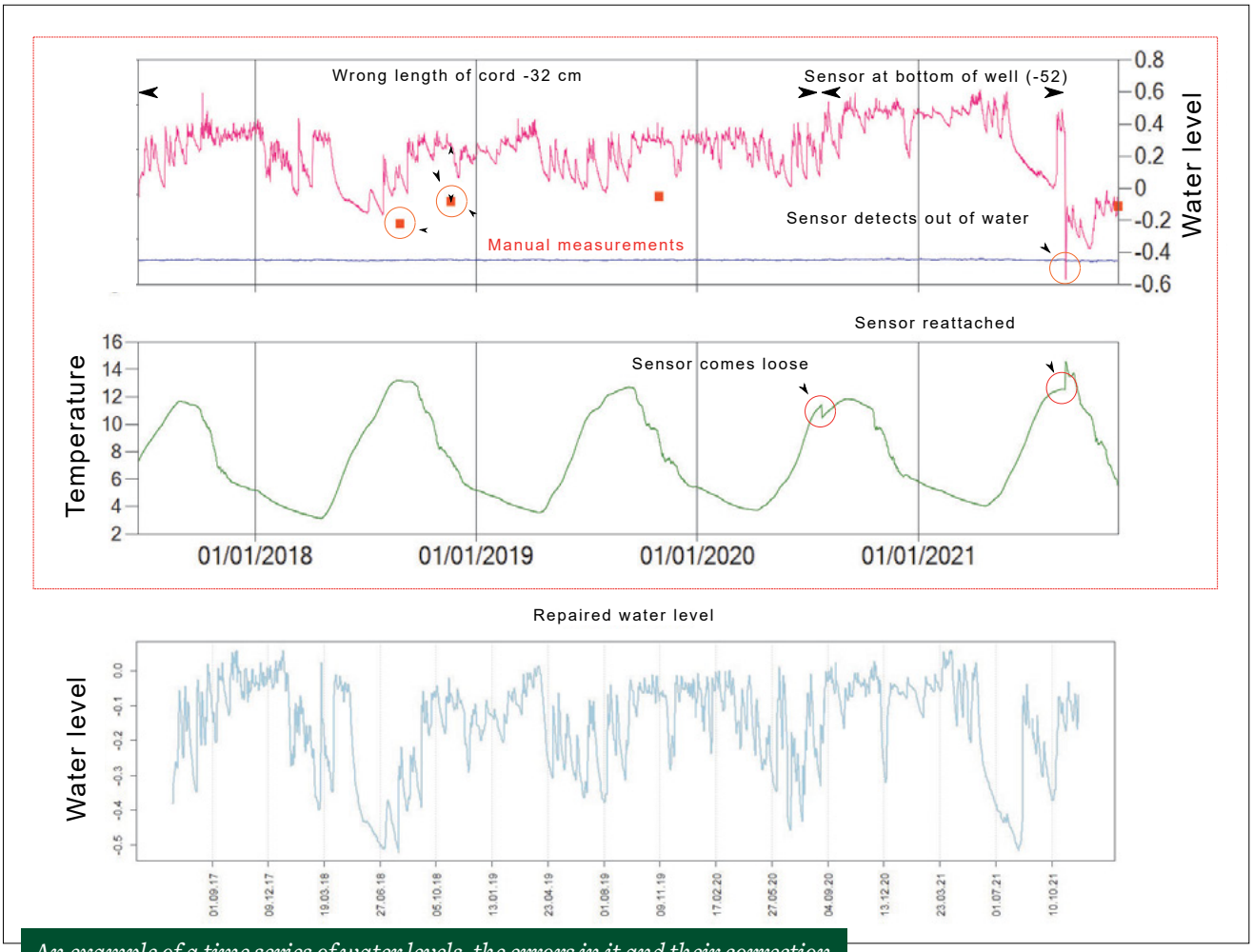
The standard spring flight time of the Land Board is usually suitable for mapping flooded areas/areas with a high water level within all restored areas. This could be used, for example, to detect dams that are probably leaking, since the amount of water amassing behind the dam will not be the same as that collecting in intact dams. Unfortunately, spring flights cover points in Estonia at four-year intervals.

Vegetation also reacts to changes in the water level, but this change is a long-term process and is very 'patchy'. Therefore, especially during the early years of recovery, it is very expensive and labour-intensive to describe an entire restored area using classic square- and species-based vegetation monitoring. Less demanding in terms of skills and man hours is describing the state of the area by species group (Sphagnum mosses, shrubs, sundews, lichen, etc.) and easily recognisable indicator species (birch, pine, cranberry, white beak-sedge, etc.) on the surface. Combined with geo-referenced photos, this provides quite a good overview and can be done while walking around.

To evaluate changes in coverage, this method can be effectively tied to drone monitoring, with the data collected from the surface being extrapolated to a wider area of up to dozens of hectares. In the case of drone monitoring, multispectral cameras should be preferred, but even basic RGB cameras provide usable results. One of the most important positive aspects of drone monitoring is the possibility to time flights to coincide with the best light conditions (i.e. when there is even cloud cover in Estonia) and key phenological moments when species we are interested in are at their most visible – when blooming (white beak-sedge), during bud burst or when their leaves turn yellow (birch). With drone monitoring, the most limiting aspect is the view from above – it is not possible to detect lower layers of vegetation. For example, if pine makes up more than a third of the canopy, it is rather difficult to determine the nature of the vegetation beneath the trees.



For water monitoring, improvised wells made from 50-mm sewer pipes can be used, the hole for it being made with a peat drill.



An example of a time series of water levels, the errors in it and their correction.

As previously mentioned, the strongest argument in favour of drone monitoring is the possibility it offers to select the best possible moment. In practice, abandoning flights in bad weather has been a difficult decision. For example, in summer, fast-moving cumulus clouds are often a problem, since the light conditions change in a matter of minutes. The software used to create orthographic photos assumes that the objects monitored will not change (incl. light and shadows) while being photographed. Thus, pictures taken in these conditions are not very useful for creating orthographic photos for monitoring vegetation. However, this play of light is fascinating from the point of view of ordinary drone photography/aerial videos, since it provides the possibility of additional sharpness. It makes sense to undertake initial inspection and processing as quickly as possible after a flight, since this makes it possible to correct errors. The main indicators of errors are 'seeing' the flight corridors on orthographic photos and systematic errors from elevation models. [Illustrate this with a picture where these errors are visible.]

Another monitoring method is repetitive videos made by drones where one and the same flight path is used several times over several years. By implementing some simple video-processing techniques, this material gives us highly convincing and easily understandable visual materials on changes in an area. Unfortunately, such information does not produce any quantitative data, but for obtaining a quick and informative overview it is an excellent option.

From Land Board data, summer flights are better for monitoring changes in vegetation, but all points in Estonia are covered every four years, and in early summer the phenological variation between years can be great. As such, although this dataset is not very good for making comparisons between years, it is useful for comparing different parts of an area being monitored. To monitor the development of tree cover, the LIDAR data produced by the Land Board is very useful, as it provides information on tree cover and heights.

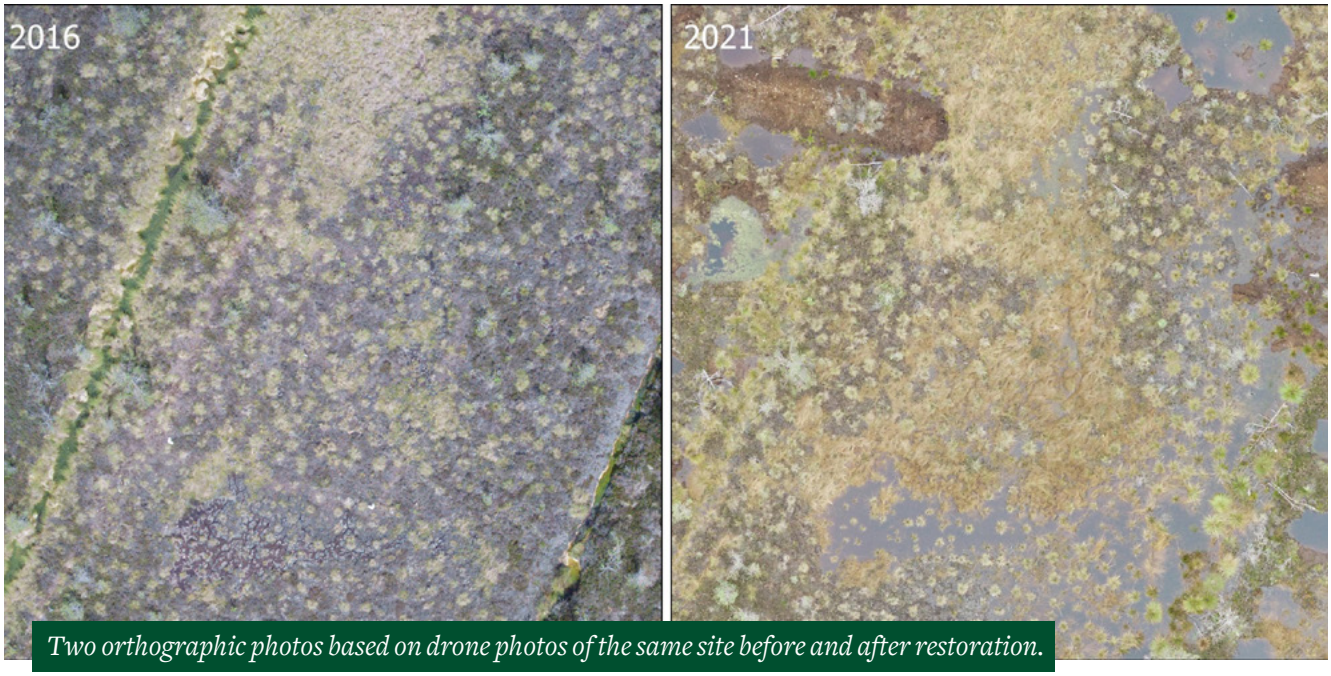
For general and long-term vegetation monitoring, the most suitable method at present is arguably satellite data, especially the EU Sentinel mission. With Sentinel, the monitoring interval is short enough (five days) to be able to use phenological variations to identify vegetation. The weakness of satellite data is their limited resolution, with a minimum pixel size of 10 m, which only makes it possible to register slower and more extensive change. Since the precondition for obtaining a satellite picture is no cloud cover, shadows pose problems in image processing. However, it is possible to reduce this effect by using indexes (NDVI, SAVI, etc.) in spectral channels where the effect of the shadows is smaller.

Monitoring of vegetation can take place in the following way: At the same time as (within an hour of) the overflight, a drone monitoring flight with a multispectral camera with a similar spectral range as the drone is undertaken, covering 20-30 hectares. This drone, together with the camera, costs 25,000-30,000 euros. In drone monitoring, the pixel size should be

less than 25 cm. No more than a week later, a 'stroll' should be taken to obtain geo-referenced photos and descriptions of key habitats. The person(s) doing this should have the (classified) orthographic photo from the drone monitoring available to them so as to visit as many different habitats as possible. The data collected on land are used to make adjustments or reclassify the drone photo. Habitat quadrants designated in this way can then be used as teaching datasets for classifying the satellite photos of a restored area as a whole.

Since there may be several plant communities with more limited distribution, the areas of land survey and drone monitoring must cover all of the major plant communities and manipulation types in a restoration area. Since the image from Sentinel 2 covers Estonia every five days, there should be enough possibilities to cover different areas in summer.

One major advantage of this approach is that all stages provide us with material that can be reused/rechecked later. As such, in improving algorithms of classification, old data can be recalculated and it is also possible to go back in time on the surface with the use of geo-referenced photos. The disadvantages are the large volume of data and the logistics, since only one area can be done in a day and will later need to be revisited in person. With today's powerful laptops, preliminary data-processing (with fewer spectral channels and larger pixels) can be done in a few hours on site, with the walk around the mire taking place that same day. Before wider implementation, the entire monitoring chain should be checked in an experimental area to optimise the methodology, to identify its limitations and real data volumes and workloads and to determine the reliability of the results.



Two orthographic photos based on drone photos of the same site before and after restoration.



Powerful drones can carry several cameras, fly for almost an hour at speeds of up 70 km/h and record the locations of the photos within an accuracy of 2-5 cm.

ECOSYSTEM SERVICES

JÜRI-OTT SALM

One task carried out as part of the 'Conservation and Restoration of Mire Habitats' project was drafting a report on ecosystem services with the aim of assessing the impact of restoration work.

Here, ecosystem services are understood as the benefits we gain from nature: those emerging from the functioning of ecosystems that support the well-being of humanity (food and water supply, physical and mental health, cultural identity, etc.) and the preservation of the living environment.[1] The status of a mire ecosystem is mainly influenced by changes in its hydrological regime, and to a lesser extent development activities (road construction, extension of settlements and mining), pollution (in Estonia: alkaline material from the Kunda cement factory and fly ash from oil shale power plants) and fires. The most pronounced changes have been on thin peat soils where the majority of mire ecosystems are irreversibly damaged due to agricultural or forestry drainage. In the case of thick peat soils, the main pressure is from peat mining in (former) bogs (see also Helm et al. 2020).

This report uses methodology developed by Helm et al. (2020)[2] and the evaluation of mire ecosystems together with national evaluation and mapping of the base level of ecosystem services using this methodology. Since no detailed landscape map with accurate locations of habitats and their status in certain periods was created as part of this work, the report presents a qualitative evaluation of the changes in different services. It also describes the methodological challenges in evaluating the status of mire ecosystem services if mire habitats or wetlands are restored.

THE FOLLOWING ASPECTS ARE ADDRESSED IN EVALUATING ECOSYSTEM SERVICES:

- I State of mire ecosystems
- II Supply services:
  - natural berries: cranberries and cloudberries;
  - wood as a raw material: timber from mires.
- III Regulatory and preservation services:
  - inhibition of erosion;
  - regulating water flow – field capacity;
  - provision of habitats: ensuring species diversity;
  - global climate regulation: binding of greenhouse gases.
- IV Cultural services:
  - the recreational value of nature;
  - natural attractions and recreational infrastructure;
  - mental breaks, or seclusion;
  - nature observation.

STATUS OF MIRE ECOSYSTEMS

The main aim of the 'Conservation and Restoration of Mire Habitats' project is to significantly and continuously improve the status of the European Union's priority habitats – active raised bogs (7110*), bog woodlands (91D0*), western taiga (9010*) and Fennoscandian deciduous swamp woods (9080*). In addition, restoration activities will improve the status of the following habitats: natural dystrophic lakes and ponds (3160), degraded raised bogs still capable of natural regeneration (7120), transition mires and quaking bogs (7140) and Fennoscandian herb-rich forests (9050).

These aims are compared with the analysis of Helm et al. (2020). In evaluating the status of mire ecosystems, Helm et al. (2020) divided these ecosystems into five classes, identifying mires in their natural state (undrained, with no felling, hay harvesting or herding), incl. Class A1 areas in strict nature reserves and in special management zones of nature conservation areas (Class A2 without those parameters); mires with a weak drainage or collecting ditch effect where herding takes place and where hay has been harvested (extensively) (divided into classes B1 and B2 by protection status, similar to the division in Class A); mires with drainage, restored/recovering mires (for Class C1 the areas are situated in strict nature reserves or in special or limited zones, for Class C2 outside these zones); intensively managed or drained mires, mires incapable of recovering on their own and former peat-mining areas – Class D; and areas of peat extraction or areas with lost peat layer – Class E.

The data presented in the analysis of Helm et al. (2020) allow us to conclude that the restoration work carried out as part of the 'Conservation and Restoration of Mire Habitats' project mainly took place in forest ecosystems and that the majority of the affected areas were situated outside of mire ecosystems. On the other hand, this result is a logical conclusion: since drainage was primarily designed to expand forested areas, these areas were defined in the analysis of Helm et al. (2020) as forest ecosystems – all the more so given that drained peatland does not usually function as a mire. In defining the status classes of forest ecosystems, key features for Helm et al. (2020) were stand composition and age, the amount of dead wood and data from Natura and valuable habitat inventories. Drainage was not considered. As such, only the main part of the mire habitat restoration area in Feodorisoo was defined as a C1 mire ecosystem.

[1] This definition was given in research done for the Environment Agency; information is available online at https://keskkonnaagentuur.ee/elme#kossteemide-seisun (accessed on 17 August 2021).

[2] Helm, A., Kull, A., Veromann, E., Remm, L., Villoslada, M., Kikas, T., Aosaar, J., Tullus, T., Prangel, E., Linder, M., Otsus, M., Külm, S., Sepp, K., 2020 (revised, 2021). Final report on the evaluation and mapping of the status of forest, mire, meadow and agricultural ecosystems and the base level of ecosystem services at the national level. (In Estonian) ELME project. Client: Environment Agency (public procurement no. 198846).

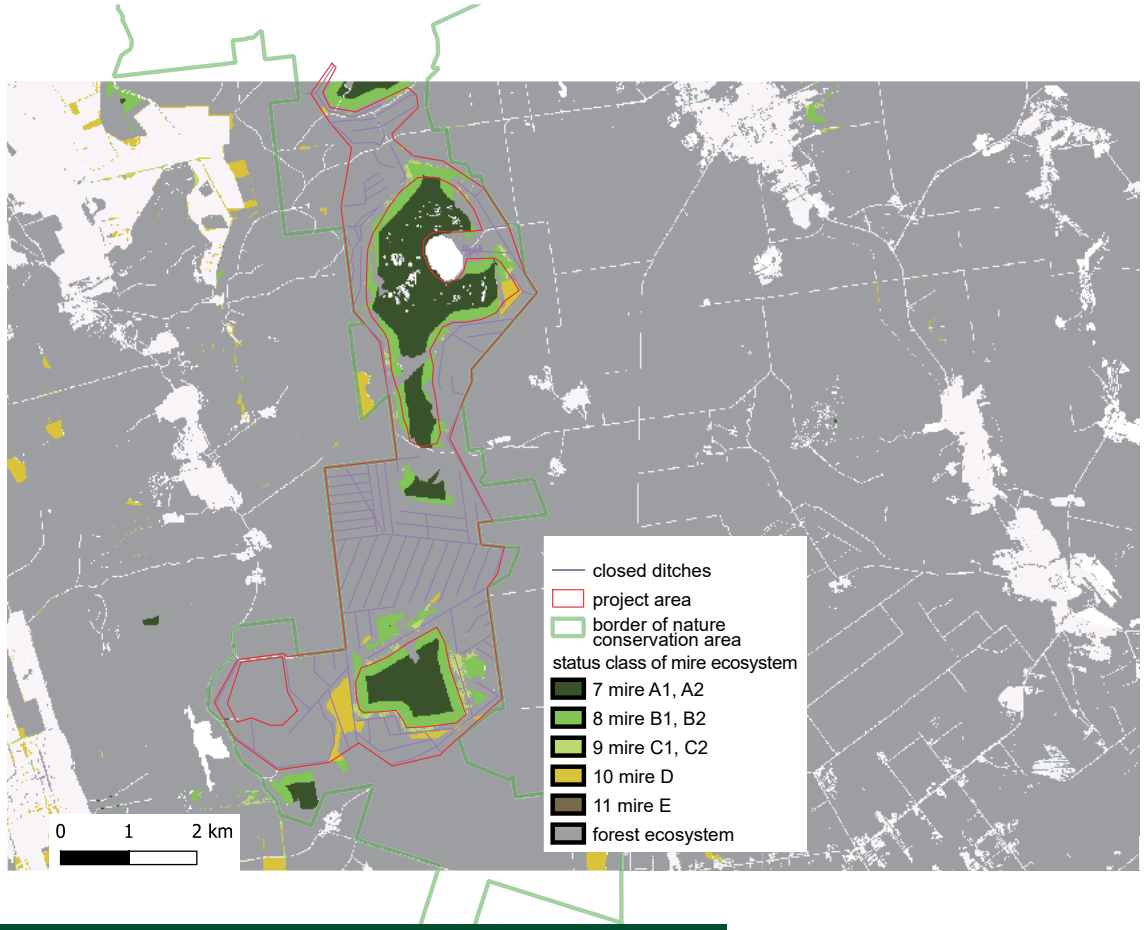


Fig. 1. The project area and ecosystems affected by closed ditches in Tudusoo Nature Reserve according to Helm et al (2020).

We hereunder present the evaluation of the impact zone for the work done in Tudusoo Nature Reserve in relation to the mire ecosystems (see Fig. 1). Only a few patches in the project area are defined as a Class B1 or D mire ecosystem, but the majority of the area is identified as a forest ecosystem. The major part of the latter is identified as forests of Class A (criteria: located in a protected area and with a stand over a certain age) and Class D (criteria: the weighted mean age of the stand of the first layer must be above 10 years and the area must have been forested land for at least the last decade), but also Class C (criteria: the weighted mean age of the stand of the first layer reserve must be above 40 years). The effect of drainage in the forest ecosystem is not decisive here.

In the project, the aim of the restoration work in Tudusoo was to close the drainage system in order to improve the status of the following Natura 2000 habitats: 26 hectares of natural dystrophic lakes and ponds (3160); 902 hectares of active raised bogs (7110*); 4 hectares of transition mires and quaking bogs (7140); 80 hectares of western taiga (9010*); 6 hectares of Fennoscandian deciduous swamp woods (9080*); and 33 hectares of bog woodlands (91D0*) (Fig. 2). In addition, restoration activities have a positive impact on 1038 ha of wetlands that are not defined as Natura 2000 habitat in the Estonian Nature Information System (EELIS) and that are identified mainly as forests by Helm et al. (2020). The aim of restoration activities is for these areas to have the potential to develop into some type of Natura 2000 habitat. Evaluation of the effect of drainage on mire habitats is based on the research conducted on 20 mires by a working group from the University of Tartu led by Ain Kull (Kull, 2013[3]; Kull, 2016[4]) and the overview it provided of the scope of the impact of drainage ditches: in bogs and bog forests it is around 100 metres, while

Natura 2000 habitat type	3160	7140	9050	7110*	9010*	9080*	91D0*	Other areas
Affected area, ha	172	33	15	3670	398	296	700	2616

Table 1. Areas affected by restoration, incl. Natura 2000 habitats

[3] Kull, A. 2013. Determining the buffer zones needed for the ecological functionality of mires to stop or alleviate the spread of long-term disturbances, 2nd stage. Report on government grant 2386 SFL contract no. 3-2_15/45-8/2011. (In Estonian)

[4] Kull, Ain 2016. Determining the buffer zones needed for the ecological functionality of mires to stop or alleviate the spread of long-term disturbances, 2nd stage. Report of the government grant 8286 SFL contract no. 3-2_15/835-14/2014. Institute of Ecology and Earth Sciences of the University of Tartu

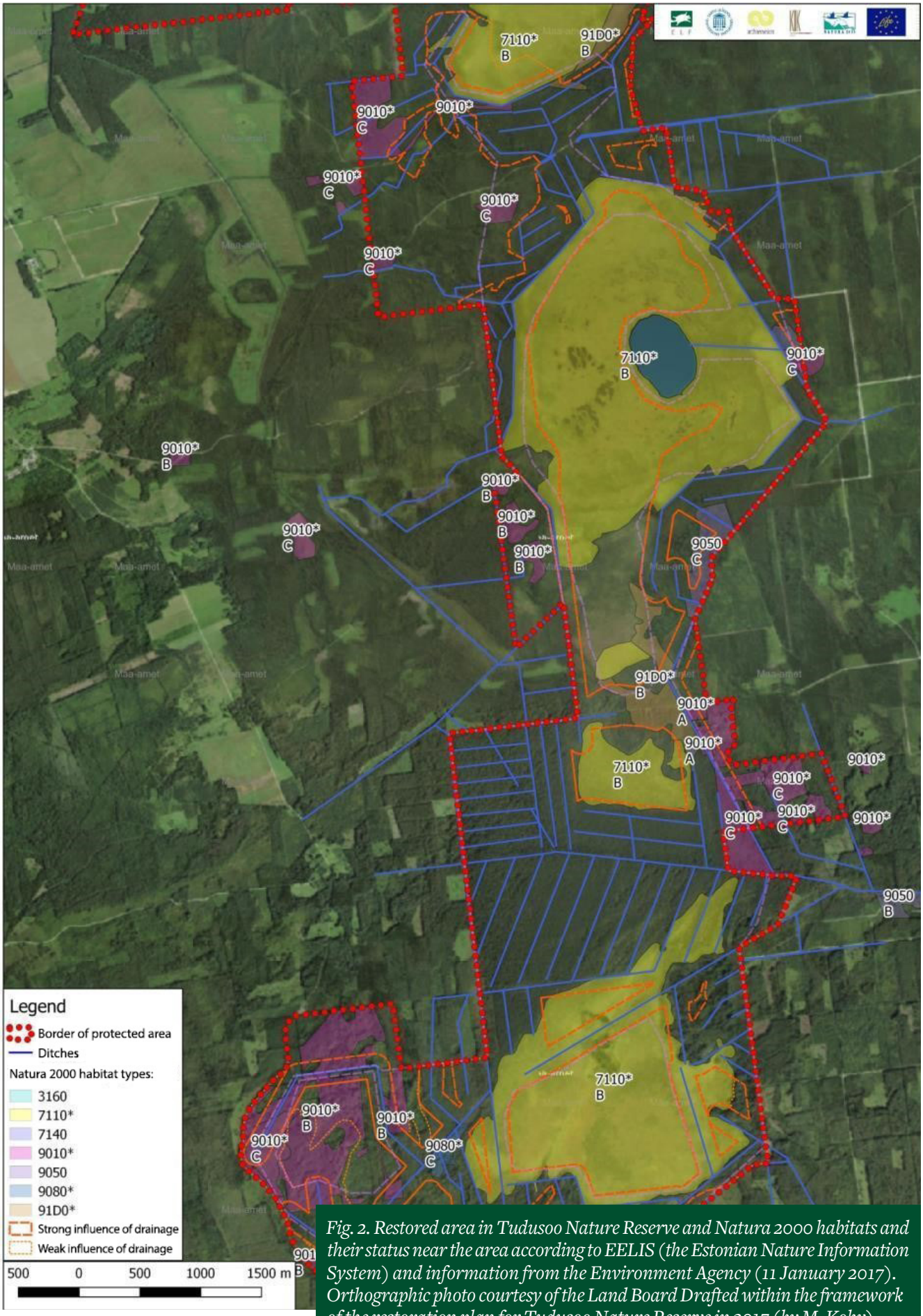


Fig. 2. Restored area in Tudusoo Nature Reserve and Natura 2000 habitats and their status near the area according to EELIS (the Estonian Nature Information System) and information from the Environment Agency (11 January 2017). Orthographic photo courtesy of the Land Board Drafted within the framework of the restoration plan for Tudusoo Nature Reserve in 2017 (by M. Kohv).

a weak impact is discernible 200 metres from a ditch. For transition mire habitats, the same research concluded that the zone of impact is 200 metres and 400 metres, respectively. The areas influenced by drainage shown in Figure 2 are based on the above-mentioned research, fieldwork done as part of this project and earlier inventories.

Based on the status classes of Helm et al. (2020) and the impact assessment carried out by Kull (2013), we can say that the set of strongly degraded mire habitats (e.g. forests and former peat-mining areas most affected by drainage (class D)) and current mire habitats (classes B1 and C1; Natura habitats in the areas affected by drainage) improves, regenerates and/or expands as a result of restoration work. Based on the data presented in the technical designs for mire habitat restoration, the affected areas of the 'Conservation and Restoration of Mire Habitats' project are 7900 ha of mires, incl. 5285 ha of habitats corresponding to Natura 2000 criteria (of which 5064 ha are priority habitats) (Table 1).

II SUPPLY SERVICES

NATURAL BERRIES: CRANBERRIES

The link between the occurrence and crop yield of cranberries and the hydrological regime and status of the tree layer influenced by it has been assessed as being strong. This is confirmed by models designed and discussed by Helm et al. (2020) where statistically significant parameters were east longitude, the height of the trees and the average water storage capacity of the soil. Of these criteria, mire restoration work has affected (increased) one: mainly the water storage capacity of the soil. To a certain extent, the height of the trees will somewhat decrease – the limiting factor being the higher water level.

Of the benefits evaluated and mapped as part of the ELME project, the potential benefit of offering cranberries (crop yield kg/ha) was good in Feodorisoo (419 kg/ha); although for the restoration areas in Sirtsi and Tudusoo the values were very small (e.g. 4-8 kg/ha in Tedresoo) to good (200-300 kg/ha), and in Ohepalu usually good (200-300 kg/ha); in Laukasoo the values were 66-271 kg/ha, while the crop yield was not evaluated in the northern part of the mire, which is a former mining area covered in forest and where cranberries may yet emerge (Fig. 3); the crop yield for Soosaare was determined as being 285 kg/ha, and on its margins 104 kg/ha. We can presume that the crop yield of cranberries will increase around closed ditches due to the rise in the water storage capacity of the soil and conditions that limit the height and spread of trees being created. Moreover, treeless areas have been created that establish favourable conditions for cranberries.

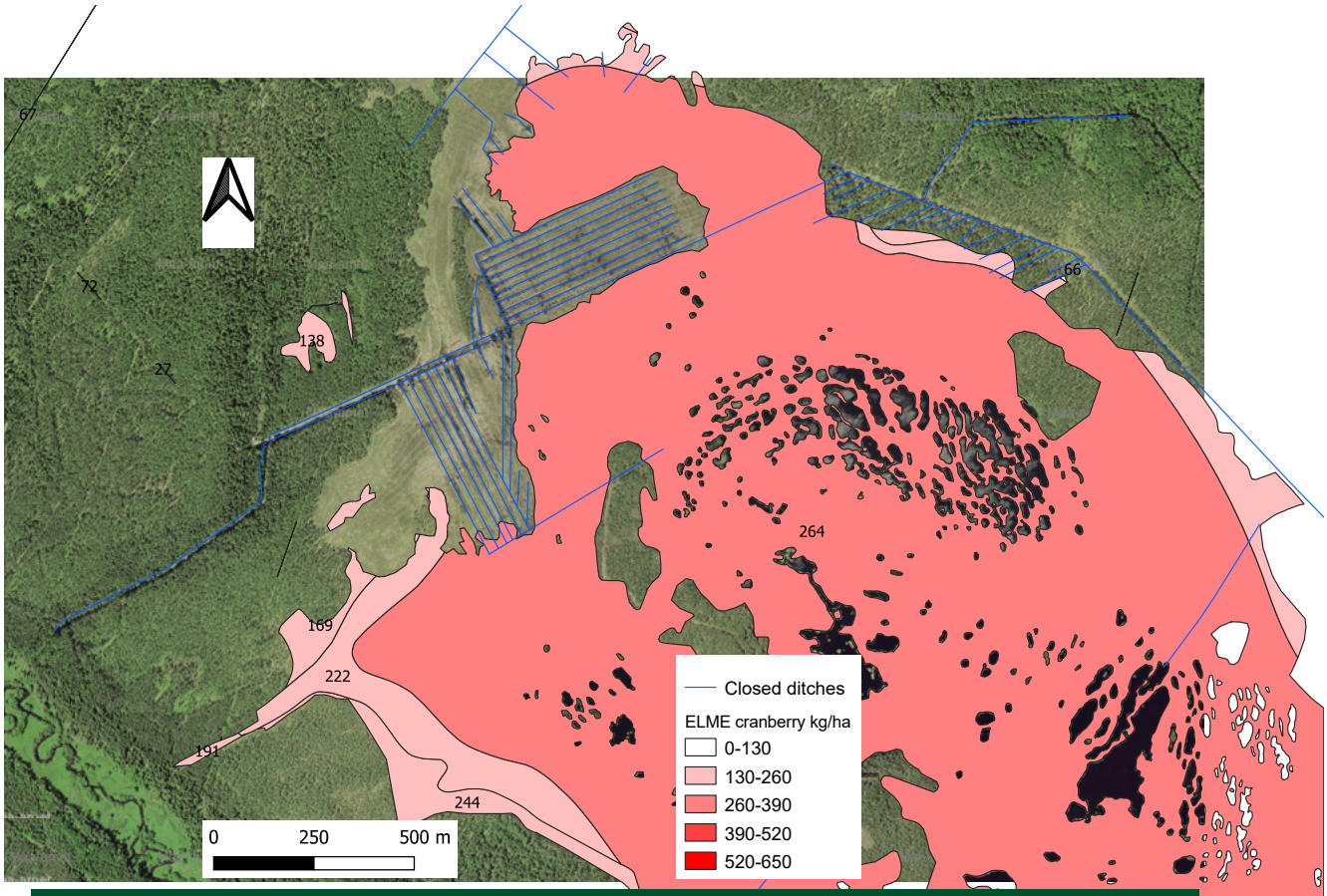


Fig. 3. Crop yield of cranberries at the north-western end of Laukasoo mire according to the ELME project, around the former mining area (the dense network of ditches in the orthographic photo). Orthographic photo courtesy of the Land Board

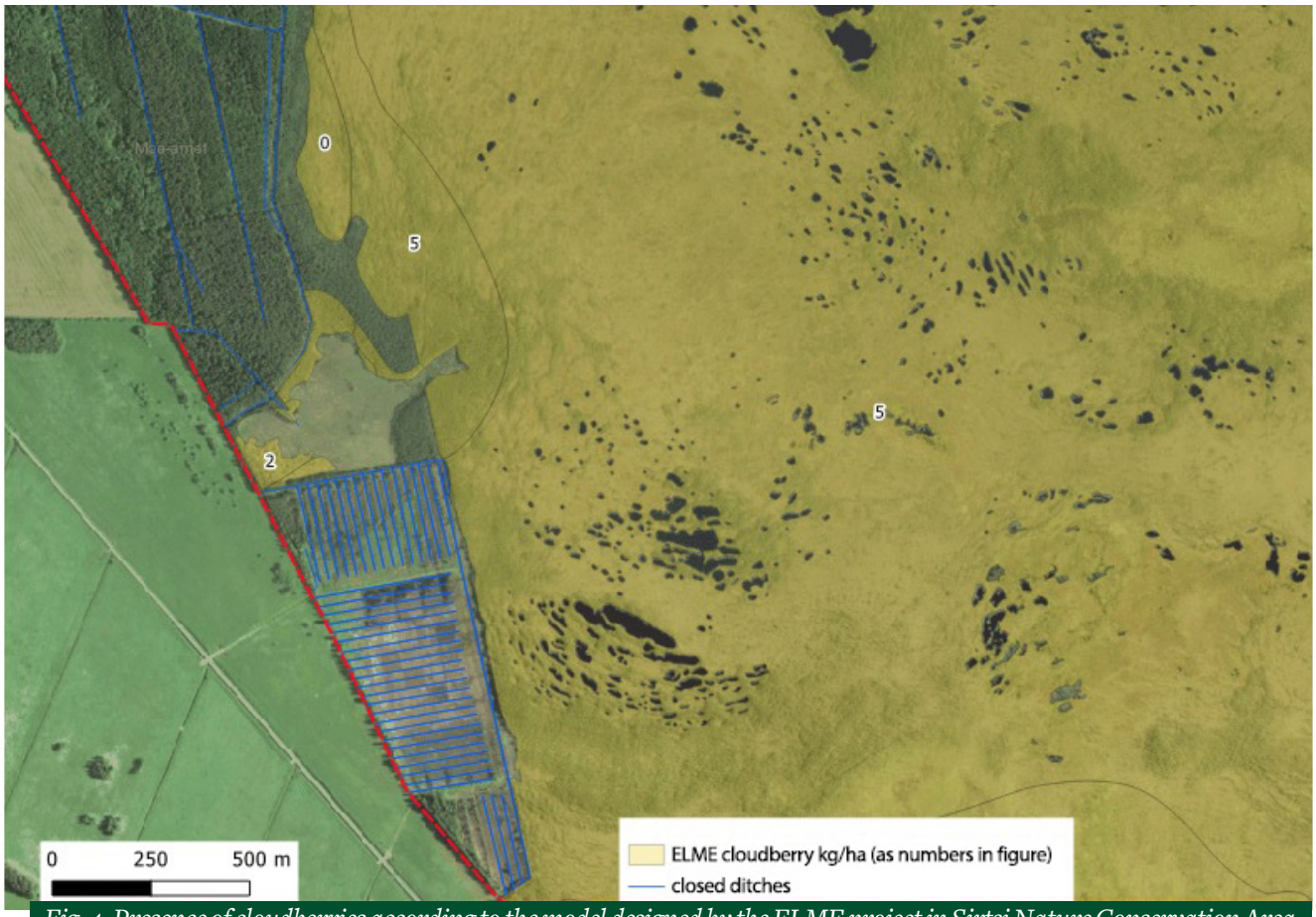


Fig. 4. Presence of cloudberries according to the model designed by the ELME project in Sirtsi Nature Conservation Area, directly north and east of the former mining area. Just above the more dense network of ditches is an area cleared of trees. Orthographic photo courtesy of the Land Board

In the course of restoration work, several cranberry-pickers were seen in the Sirtsi Nature Conservation Area and in Soosaare bog. The berry-pickers were members of the older generation and told us that the tradition was likely to die out, since their children did not go to mires to pick berries.

NATURAL BERRIES: CLOUDBERRIES

Current monitoring data on cloudberry yield is limited: no known crop yield inventories have been taken in Estonia and the evaluation is based on suitable habitats. The ELME project developed a probability model for cloudberry occurrence on a scale of 0-7 (0: no cloudberries, 7: cloudberries in abundance) based on soil, hydrological regime, vegetation height and coverage, and habitat type. Undrained transition mires (values 4-6) and bogs (7) have been identified as areas with more dense spread.

Of the benefits evaluated and mapped as part of the ELME project, the potential benefit of offering cloudberries (crop yield) was given an assessment value in the restoration areas in Ohepalu, Sirtsi and Tudusoo of 0-5; in Laukasoo a value of 2-5 (cloudberries not being evaluated in the northern part of the mire, which is a former mining area covered in forest where it is already present); and in Feodorisoo and Soosaare a value of 4 due to the effect of drainage.

During the public consultation organised to discuss the restoration of the Palasi former peat-mining area and the surrounding areas situated in Sirtsi Nature Conservation Area, one area indicated as producing reduced yields prior to restoration was the area with natural outflow north of the Palasi production fields. The area had become covered in forest, most likely due to drainage. The ELME model indicates values of 0, 2 and 5 for the area (Fig. 4). In the course of the restoration work, the hydrological regime was partially restored and part of the area was shaped as a treeless mire. These changes may increase the crop yield and distribution area of the cloudberry. However, we cannot be sure of this, so it would be a good idea to monitor cloudberry yield in this area.

WOOD AS A RAW MATERIAL: TIMBER FROM MIRES AND CARBON STORAGE IN WOODEN BIOMASS

One indicator in the ELME project is offering wood as a raw material in mires, or the reserve of wooden biomass in mires (m3/ha). Offering wood as a raw material in mire restoration areas is given here with reservations, since economic activities and the use of natural resources is usually prohibited in the special management zones of nature reserves. On the other hand, the reserve of biomass could be seen as a reservoir and binder of carbon (up to 5 t of carbon per hectare according to ELME evaluations).

In areas untouched by drainage, ELME evaluated the reserve of stemwood as being very small (0-50 tm/ha) – the trees are short and grow very sparsely (see Photo 1). On the margins of mires affected by drainage, the reserve of stemwood can exceed 300 m3/ha, especially where higher trees are growing on the banks of the ditches.

Map analysis by ELME only looked at areas that are outside the impact range of known drainage ditches. Correspondingly, in the restoration areas the reserve of stemwood is very small.

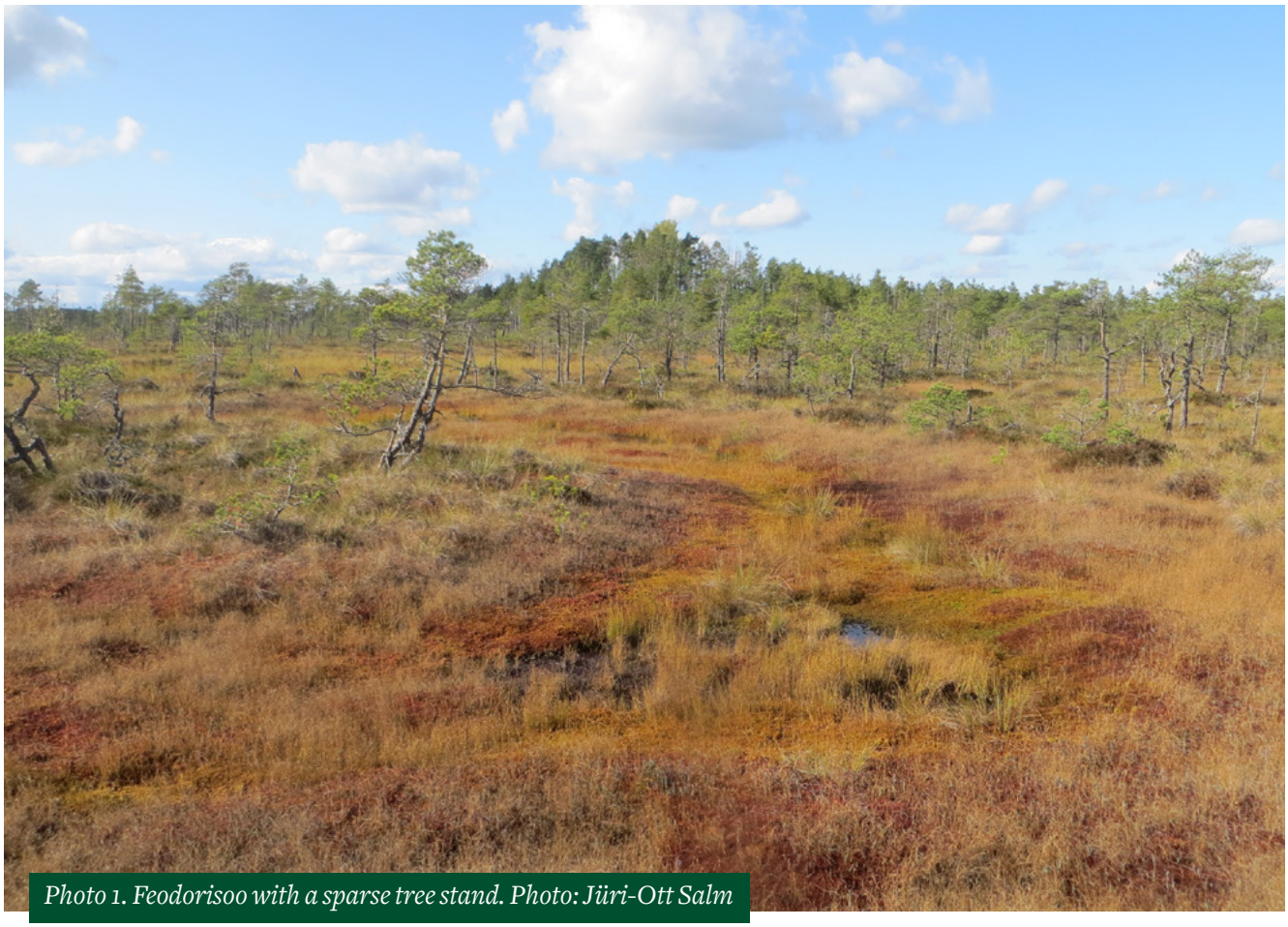


Photo 1. Feodorisoo with a sparse tree stand. Photo: Jüri-Ott Salm

Because of the closing of ditches to restore the hydrological regime and due to the treeless mire habitats designed (with trees cleared on almost 325 hectares), the size of such areas tends to be growing. Moreover, the growth and reserve will also decrease in forests situated on former drained peatlands which, due to mire restoration work, will probably develop into mire forests, wooded mires or in some places also treeless areas.

III REGULATORY AND PRESERVATION SERVICES

INHIBITION OF EROSION

ELME defines the inhibition of erosion and sediment transportation (kg/ha/year) as one indicator.

Mires are important natural sources of organic carbon found in water (humus, dissolved carbon compounds, etc.). Due to drainage, the speed of peat decomposition increases, which in turn increases the outflow of these compounds. Research carried out on bog water shows that the greater the effect of drainage, the higher the amount of the organic carbon compound. According to the IPCC, surface water removes 170-260 kg of carbon per hectare per year from natural temperate mires and 190-460 kg of carbon per hectare per year from drained peat soils. In addition, wind erosion can take place in former peat-mining areas without vegetation. As such, restoring the hydrological regime and re-establishing vegetation in such areas play important roles in sediment transportation and reducing its environmental impact. As part of the 'Conservation and Restoration of Mire Habitats' project, action was undertaken to restore the natural state of the former peatlands in Palasi and Soosaare that will likely result in reduced erosion and peat loss in these areas and the formation of new peat after re-vegetation.

REGULATING WATER FLOW – FIELD CAPACITY

ELME used a specific indicator to evaluate the ability to regulate potential floods on the basis of field capacity. The evaluation of real regulatory ability is based on actual moisture in the soil (m^3/m^3).

We know that the field capacity of natural (undrained) mires is greater than that of drained peatlands (former mires or mires damaged by draining). This is caused by the outflow of surface water and the compression of the soil due to drainage. Peat in natural mires can contain more than 90% water.

Closing the drainage systems would change the ability of the restored areas to regulate water flow, creating favourable conditions to improve the field capacity of the soil (with the surface water level rising and mire vegetation and the peat layer starting to grow again). The latter could in turn alleviate the decrease in flow volumes caused by drought in the basin connected to a certain area and alleviate potential floods during the rainy season.

PROVISION OF HABITATS: ENSURING SPECIES DIVERSITY

The activities of the 'Conservation and Restoration of Mire Habitats' project are meant to create suitable conditions or improve existing conditions for species linked to mires. The selected target species are the Western Capercaillie, the Willow Grouse, the Moor Frog, protected dragonfly species, the Common Ringlet and the Baltic Greyling (see the chapter 'Results of target species monitoring').

In the ELME project, maps of potential species richness were drawn up based on habitat suitability models for target species (incl. the Moor Frog, Western Capercaillie and Willow Grouse) that indicate potentially the most suitable areas for species characteristic of the habitat group. These are defined as possible 'hot spots' of biodiversity where a wide range of criteria are likely fulfilled for covering the needs of the species of a certain ecosystem type (field, forest, meadow or mire). Here the authors of ELME (Helm et al., 2020) noted that in determining the service of providing habitats, many species were left out due to lack of information on target species that are not very rare, but whose range is insufficiently documented.

If we look at the values for potential mire species richness given in the ELME project for Tudusoo Nature Reserve and the project restoration area, we see that these values are higher for areas untouched by drainage than for forest areas affected by drainage (Fig. 5). Further species monitoring and the collection of an additional dataset would be the basis for observing potential changes in their status.

GLOBAL CLIMATE REGULATION: BINDING OF GREENHOUSE GASES

One special feature of mires, compared to other land ecosystems, is the depositing of peat, in the process of which the plants bind atmospheric carbon dioxide (CO_2). Natural mires also emit methane (CH_4). More details can be found in the chapter 'The effect of draining and restoring mires on the emission of greenhouse gases and the carbon footprint of restoration work'. At the time this analysis was written, the ELME dataset had yet to be published, so it was not possible to use it to form a more detailed evaluation.

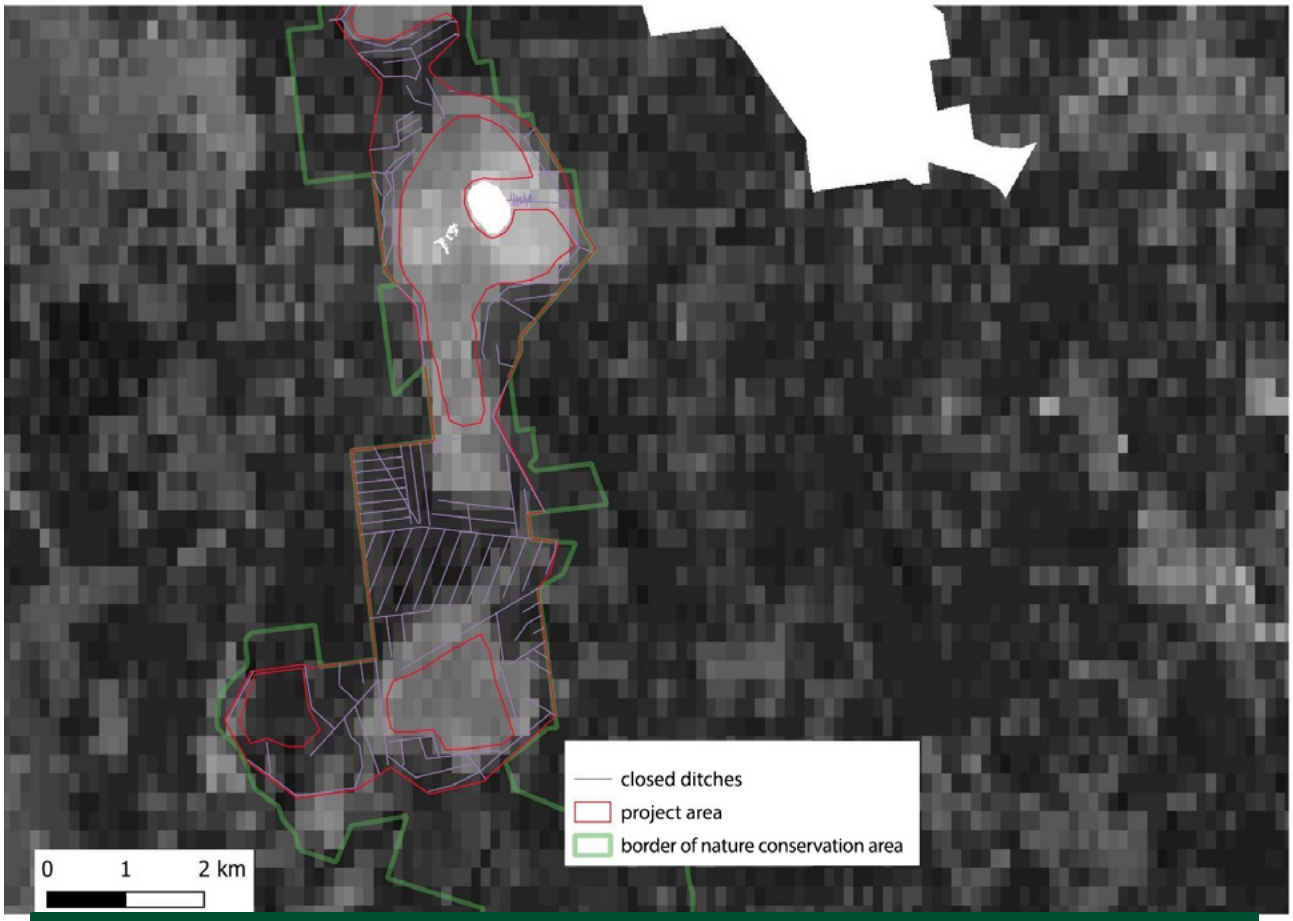


Fig. 5. Potential species richness of target species characteristic of mire species according to the ELME project in Tudusoo Nature Reserve and the restoration area therein. The lighter colour indicates greater potential species richness. The locations of forest and mire areas are shown in Figure 1.

IV CULTURAL SERVICES

THE RECREATIONAL VALUE OF NATURE

A corresponding indicator in ELME is evaluations of the properties of an ecosystem that attract people to spend time in it. These evaluations, based on expert opinions, were given on a scale from -2 to 8. In the case of mires, bogs and transition mires, a value of 5 was favoured; for fens, a value of 4. Points were added or deducted according to the status class determined in the ELME project.

ELME was guided by data that defined the status of the mire before restoration. Figures 5 and 6 present recreational values for the restored areas in Soosaare and the Järvesoo mire in Tudusoo Nature Reserve before restoration, showing that the mire habitat damaged by drainage received low evaluations for recreational value. On the other hand, the area stretching from the restored areas to the centre of the mire (for Soosaare, the area in the left-hand corner of Fig. 5; for Järvesoo, the left-hand side of Fig. 6) received high evaluations for their recreational value due to their well-preserved bog habitats. After work to restore the hydrological regime is done, we can presume that the recovered bog and transition mire habitats will increase the recreational value of the areas. On the other hand, it is likely that immediately after restoration the recreational value of the areas will remain low, since there will be traces of logging and earthwork on the landscape. If the mire habitats recover, these traces will become barely noticeable within 5-10 years (see Photo 1).

NATURAL ATTRACTIONS AND RECREATIONAL INFRASTRUCTURE

The ELME project assessed the density of natural attractions and recreational infrastructure (hiking routes and campfire sites). The 'Conservation and Restoration of Mire Habitats' project mainly contributed to this by developing and maintaining the recreational infrastructure in Tudusoo Nature Reserve – a hiking track and cabin were restored, information boards were erected and an educational programme was compiled in Tudu Järvesoo mire; and information boards were provided for Tudu Punasoo. This has helped the region retain the opportunities it presents for recreation and visits to natural sites of interest. Information boards will support this in other restoration areas as well.

At the time this analysis was written, the ELME data application had yet to be published, so it was not possible to use it to form a more detailed evaluation.

MENTAL BREAKS, OR SECLUSION

One indicator in ELME is seclusion – distance from human activity and sources of man-made noise. This indicator indicates habitat potential for species which prefer to avoid contact with people, and for people the potential for the cultural service of enjoying quiet and peace without encountering others.

Based on these criteria, the stand-out location was Laukasoo (Fig. 8), as confirmed by the experiences of the experts who took part in the project: they encountered no other people there. Moreover, it is a home to protected species who prefer to avoid contact with humans. At the same time, seclusion does not necessarily mean low levels of noise – now and then the sounds of target practice and helicopters from a nearby military training area can be heard.

In the course of restoration, a dirt road leading to the former mining area in the north-western part of Laukasoo was removed, which will make Laukasoo a little more secluded again, since access by motor vehicle will now be more difficult. On the margins of Laukasoo, ATV tracks were spotted along the route of a closed ditch, showing that moving around in noisy machines is still possible in these parts of the mire.



Fig. 5. The recreational value of the restored area in Soosaare before restoration. The darker the colour, the lower the recreational value.

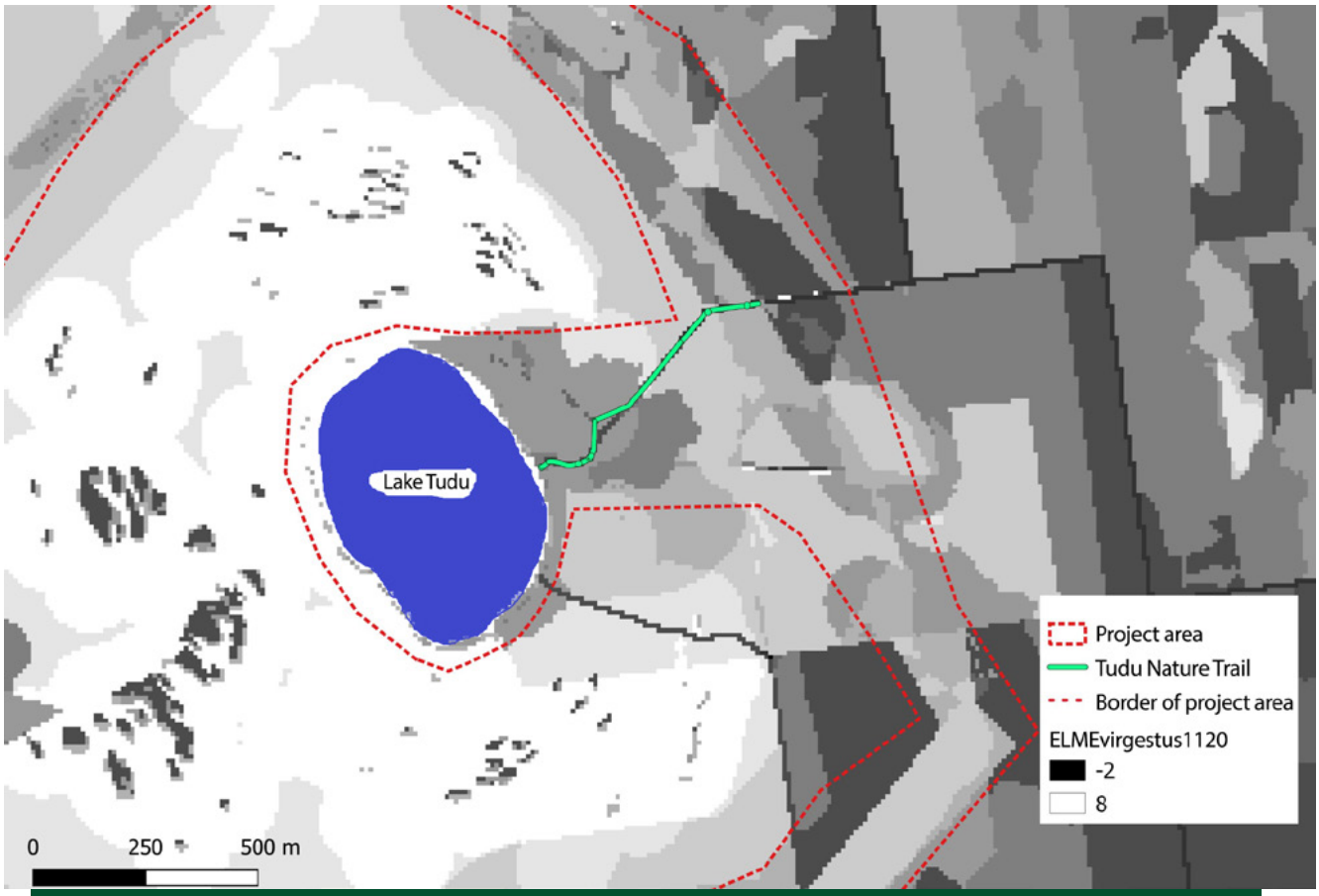


Fig. 6. The recreational value of the restored area in Järvesoo mire (Tudusoo Nature Reserve) before restoration. The darker the colour, the lower the recreational value. No such value is given for Lake Tudu.



Photo 2. A restored transition mire in central Finland in which felling and the closing of ditches took place five years ago. Photo: Marko Kohv



Fig. 7. Restoration areas in Tudusoo Nature Reserve. Compared with Laukasoo mire (see Fig. 8), almost no areas brighter in colour are visible here, which could indicate that the distance from man-made objects is greater. In the ELME project, the maximum value for any isolated area is 5884 metres from man-made sources of noise. The areas in the 'Conservation and Restoration of Mire Habitats' project have been defined as LIFE ME restoration areas.

Other restoration areas were less secluded (e.g. Tudusoo Nature Reserve, see Fig. 7) based on the ELME criteria, also people were seen there, albeit very few. Such encounters mostly took place in late summer and early autumn – the picking season for berries and mushrooms.

NATURE OBSERVATION

In the ELME project, it was found from the species finds in the nature observations database that the largest number of observations are done in ecosystems with open views and good status where it is hoped to find more remarkable species. Accessibility was not taken into consideration as a factor that might increase the probability of observation. The probability was given as either 0 or 1.

Based on the restoration areas situated in Sirtsi and Tudusoo, we can say that the probability of nature observations is higher in better preserved mire areas (e.g. on the western edge of Järvesoo in Tudusoo and the central part of Sirtsi bog) than on margins affected by drainage or in Tedresoo, a mire with a dense drainage network in the Sirtsi Nature Conservation Area, or in the central part of Tudusoo Nature Reserve (Fig. 9). When the restoration takes effect, the status of the ecosystem should improve, which may increase the probability of encountering species of interest to naturalists.

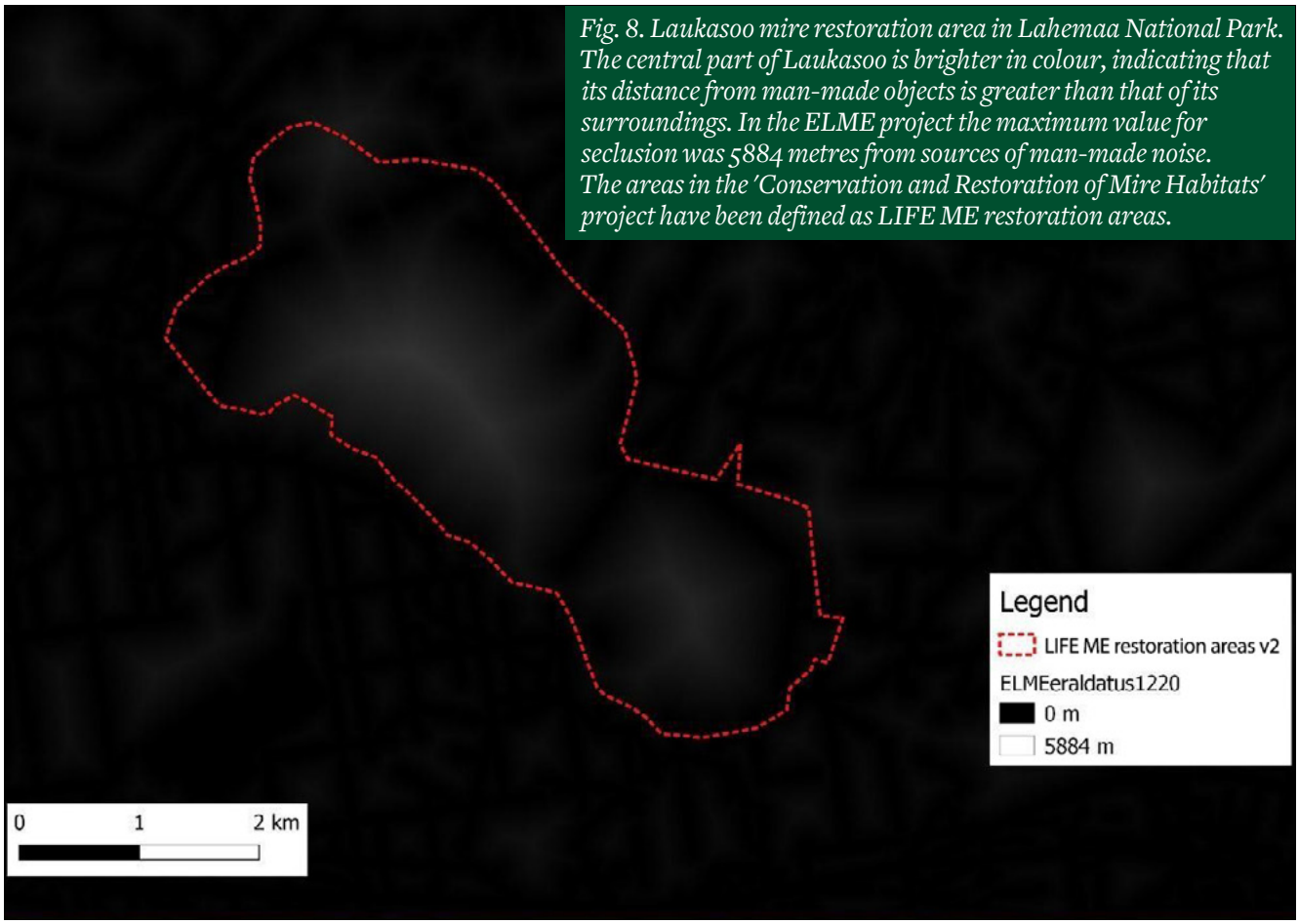


Fig. 8. Laukasoo mire restoration area in Lahemaa National Park. The central part of Laukasoo is brighter in colour, indicating that its distance from man-made objects is greater than that of its surroundings. In the ELME project the maximum value for seclusion was 5884 metres from sources of man-made noise. The areas in the 'Conservation and Restoration of Mire Habitats' project have been defined as LIFE ME restoration areas.

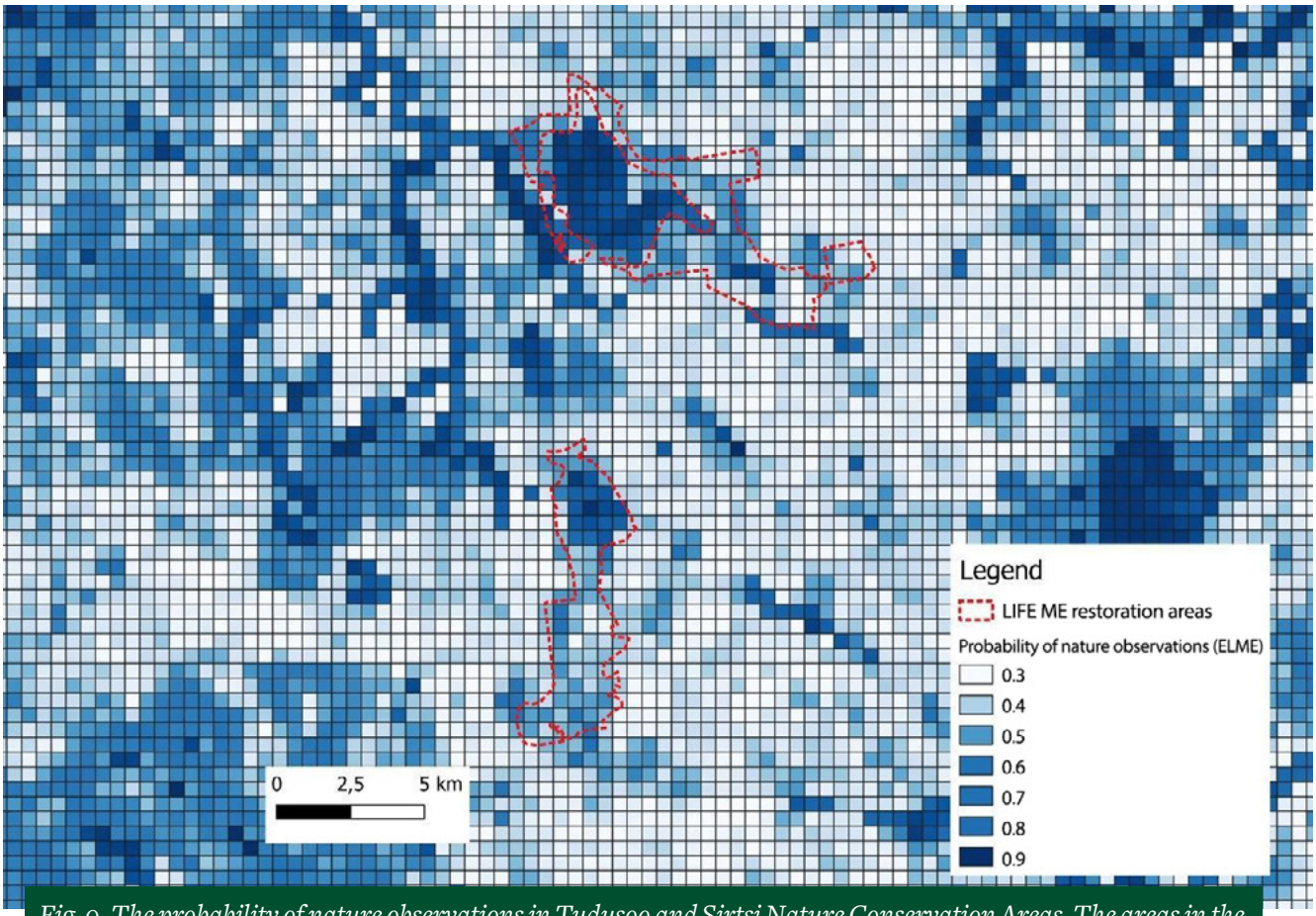


Fig. 9. The probability of nature observations in Tudusoo and Sirtsi Nature Conservation Areas. The areas in the 'Conservation and Restoration of Mire Habitats' project have been defined as LIFE ME restoration areas.

SUMMARY

HANDBOOK: 'RESTORATION OF MIRES: EXPERIENCES BASED ON THE "CONSERVATION AND RESTORATION OF MIRE HABITATS" PROJECT'

The handbook summarises the experience gained in the framework of the 'Conservation and Restoration of Mire Habitats' project and the methods used in planning and carrying out restoration work. The handbook provides an overview of species linked to mires and their monitoring, the monitoring of changes in the flora and water regime, cultural heritage, communication regarding the restoration of mires, educational activities, the design and execution of earthwork, the remediation of abandoned peat mining areas by spreading sphagnum moss and oil shale ash, the cost of restoration actions, the evaluation of ecosystem services, the impact of the drainage and restoration of mires on greenhouse gas emissions and the carbon footprint of the restoration work itself. Guidance on the planning of restoration that takes into account existing values and target species is also included in the handbook. The authors involved mire experts and participants in the actions. The first version of the handbook was published on World Wetlands Day 2020 before being updated in 2021 based on the experience gained in the interim.



Restoration area of an open bog in Järvesoo mire, Tudu Nature Reserve. This area is also home to the Järvesoo mire educational trail, which was reconstructed as part of this project. Photo: Marko Kohv


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