Good practices for forest buffers to promote good surface water quality in the Baltic Sea region — A handbook

Summary in English (28 Nov. 2018)

Forest buffers in a landscape in Finland. Photo by Erkki Oksanen.

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Preface

This report summarizes the main findings regarding forest buffers presented in the full report "Good practices for forest buffers to improve surface water quality in the Baltic Sea region" by Ring et al. (2018) and it will be translated to the national languages of the Baltic Sea region. The reports were produced as part of the WAMBAF-project (Water Management in Baltic Forests), financed by the EU Interreg Baltic Sea Region programme (activity period 1 March, 2016 to 28 February, 2019). The WAMBAF-project was initiated to tackle problems associated with forestry activities in relation to water quality. Special emphasis is placed on surface water quality, and the export of nutrients, suspended solids and mercury. Forest buffers may be valuable terrestrial habitats supporting important biota. In this report, however, the main focus is on how forest buffers and their management can be used to protect surface water quality. Many sections of this report are identical to the report by Ring et al. (2018), but contains no references. For the full report with a complete list of references, see:

Ring, E., Andersson, E., Armolaitis, K., Eklöf, K., Finér, L., Gil, W., Glazko, Z., Janek, M., Lībiete, Z., Lode, E., Małek, S. and Piirainen, S. 2018. Good practices for forest buffers to improve surface water quality in the Baltic Sea region. Skogforsk Arbetsrapport no. 995-2018, 59 pp. http://

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Terminology

The terminology used in this report is as follows:

Riparian zone is an area adjacent to a water body, including the bank of the water body, which has an impact on the ecology, hydrology or chemistry of the water body. The size of the riparian zone varies along a water body as well as between water bodies.

Riparian forest is the forest that grows in the riparian zone.

A **forest buffer** is a zone of forest left for protection adjacent to a water body (Fig. 1).

A **discharge area** is where groundwater is flowing out from the ground via spring seepage or to a stream or lake.

A **catchment** represents the area from which water flows into a surface water body.

Fig. 1. A forest buffer along a small stream in northern Sweden with the clear-cut area on the left. Photo by Eva Ring.

1. Recommendations in short

Forests and water bodies within the countries of the Baltic Sea region show great diversity and the recommendations presented here must be related and adapted to local conditions. **Before implementing any of the measures or approaches proposed in this report, make sure that they comply with national legislation, other regulations and forest certification standards.**

Planning forestry operations with respect to water

- Take both a short-term and long-term perspective to avoid short-term negative effects and secure long-term water protection.
- Protect all types of surface waters. Springs, small streams and rivers are more severely affected by forestry operations than large rivers and lakes.
- Determine if surface waters are present on or adjacent to the forest compartment.
- Plan the forestry operation well ahead of the on-site operation. Undertake a field inspection before starting the operation. Acknowledge that the extent of forest streams may vary with season and weather.
- Before the operation, explain the management of forest buffers to the machine operators, for example by providing them with written instructions and maps.
- Tell the machine operators how to act when the on-site conditions become unsuitable for carrying out or continuing the logging, for example if the soil bearing capacity is lowered by rainfall.

Delineation and management of forest buffers

- To mitigate elevated export of plant nutrients, suspended solids and mercury to surface water, establish forest buffers along springs, small streams, rivers and lakes.
- Adjust buffer width to local conditions such as soil type, topography, vegetation and discharge areas.
- Prevent soil disturbance adjacent to surface water, especially in discharge areas, to avoid increased erosion and export of suspended solids and mercury from the soil. Therefore, try to leave or create wind-resistant forest buffers, and, within the buffer, minimize off-road traffic and avoid site preparation, ditching, remedial drainage, and stump lifting.
- Logging residue can be used for soil protection when driving in the riparian zone cannot be avoided, but do not store logging residue within this zone.
- Do not apply or handle fertilizers, pesticides or other chemicals within the riparian zone.

Tree species composition and structure of forest buffers

- Try to leave or create a multi-layered and uneven-aged forest buffer, which is generally considered beneficial for functionality.
- Promote broadleaved trees near forest streams. Litter from broadleaved trees is an important nutrient source for aquatic life, especially in streams.
- Leave trees of all ages to secure the continuous supply of long-lived large woody debris to the streams. Both conifers and broadleaved trees can provide such long-lived woody debris.
- If necessary, adjust the tree-species composition and age structure in the forest buffer zone at pre-commercial thinning and thinning.

Fig. 2. All types of surface water need protection, as do small streams. Photo from Zalvīte, central Latvia by Zane Lībiete.

2. Forestry and water quality in the Baltic Sea region

Nitrogen (N) and phosphorus (P) export from forest land is generally low. Elevated export rates typically occur after harvesting and fertilization. This may increase eutrophication in downstream aquatic ecosystems. Ditch network maintenance and other forest drainage activities increase the export of suspended solids to surface water. Moreover, site preparation exposes mineral and organic soil which can lead to increased erosion and export of suspended solids. Similar effects can occur if forestry machines are driven too close to surface waters. This can create wheel tracks which channelize water and deliver suspended solids directly to nearby streams and lakes (Fig. 3). Increased inputs of suspended solids and subsequent sedimentation may harm aquatic organisms such as filterfeeders and organisms attached to the stream bed and adversely affect or destroy habitats. Moreover, increased export of suspended solids can increase the load of nutrients and hazardous trace metals bound to organic or mineral soil particles. Forestry operations have been found to increase the loads of total mercury (Hg) and methyl-Hg to surface waters by increasing the production of methyl-Hg and mobilizing Hg from the soil.

Fig. 3. The wheel tracks thus created increased the risk of erosion and export of suspended solids and mercury. Photo by Eva Ring.

3. Forest buffers to reduce excess export of N, P, suspended solids and Hg

Negative impacts of forestry on water quality can be prevented or mitigated using forest buffers with vegetation that takes up nutrients and facilitates sedimentation and infiltration of suspended solids (Table 1). To reduce export of suspended solids, forest buffers should be protected from soil disturbance caused by activities such as driving, site preparation and stump lifting. The extension of stream length and width during high-flow periods must be taken into consideration to ensure forest buffer functionality during all hydrological conditions.

The gaps in knowledge about the forest buffer width required for retaining excess loads of nutrients, suspended solids and Hg in the Baltic Sea region prevent us from giving detailed recommendations about their width. The width required depends on the element in question, or function desired, and the characteristics of the site. For retention of nutrients and suspended solids, forest buffers are more important along watercourses than around lakes and seas, to which the main terrestrial load is transported via rivers, and less from surrounding soils.

Table 1. Proposed countermeasures which may reduce excess export of N, P, suspended solids and Hg caused by forestry operations. The forest buffers mentioned are assumed to include all discharge areas near surface water.

Element	Forestry operations which may increase export rates	Possible mechanism for reducation	Proposed countermeasures
N and P (dissolved)	Logging, site preparation[1] and fertilization	Nutrient uptake by vegetation, and volatilization (N only)	Promote and leave vigorously growing trees and ground vegetation in the forest buffer.
		No nutrient addition in sensitive areas	Any fertilizer used is applied outside the forest buffer as well as away from any other areas with high hydrological connectivity to surface water. Fertilizers are applied only during the growing season, avoiding periods with heavy rainfall. Logging residue is deposited outside the forest buffer unless it is used for ground protection.
Suspended solids[2]	Logging, driving forestry machinery, site preparation, stump lifting, ditching and ditch network maintenance	Sedimentation and infiltration within the forest buffer	Prevent export of suspended solids from adjacent clear-cuts and drained areas: Delineate an area for overland flow of sufficient size, where eroded soil particles can be deposited and infiltration can occur. Maintain the vegetation cover and prevent soil compaction and rutting within the overland flow area. Avoid sedimentation in discharge areas near surface water and areas which may become inundated at high streamflow.
		Elevated erosion prevented from the forest buffer itself	Prevent erosion and export of solids from the forest buffer itself. Avoid soil compaction and rutting within the buffer i.e. minimize driving in this area and use ground protection on soft ground. If a streamcrossing is necessary, build a bridge or install a portable bridge. No site preparation and stump lifting within the buffer. Leave wind-resistant forest buffers. Pay extra attention on highly erodible soils.
Hg	Logging, soil disturbance[3]	Formation of bioavailable methyl-Hg (Hg methylation) is not increased	Avoid damming. Therefore, do not drive across streams (without using a bridge) and do not leave logging residue in streams. Avoid disturbing the soil within the forest buffer, especially in areas with a peat layer. Thus, within the buffer, avoid (or minimize) driving, site preparation and stump lifting, and leave wind-resistant forest buffers.
		Mobilization of Hg from soil to surface waters is not increased	Avoid (or minimize) driving in the forest buffer: water channelized in wheel tracks may transport Hg released in more distant areas to surface water.

[1] Catchment studies separating the leaching caused by clearcutting and site preparation, respectively, are generally lacking. Results from two soil water studies indicate that N leaching from below the main part of the root zone may increase, while the effect on phosphate seemed insignificant.

[2] Suspended solids may include P and N.

[3] The connection to specific forestry operations appears more complex than for the export of N, P and suspended solids.

4. Forest buffers to protect aquatic life

Apart from retaining nutrients and suspended solids, forest buffers can maintain other important functions especially along springs, small streams and rivers (Table 2). Forest buffers along larger rivers and lakes have similar functions as along smaller watercourses, but their impact is different. For example, forest buffers may control shading of small streams entirely while the shading provided along large rivers and lakes affects only the zone near the shore line. Moreover, a harvested area within a headwater catchment may affect the entire headwater stream, while a harvested area of the same size within a catchment of a large river would only affect a minor part of the entire river length.

Table 2. Functions provided by forest buffers along small and medium-sized streams and examples of how these functions can be promoted. Consideration of scenic values is outside the scope of this report.

Function	Proposed management
Protect aquatic and terrestrial habitats	Delineate the forest buffer so that important habitats are included and protected. A multi-layered and uneven-aged forest buffer is often considered beneficial for its functionality. Avoid any soil disturbance within the forest buffer caused by driving forestry machinery, site preparation, ditching, remedial drainage, and stump lifting. Try to leave wind-resistant forest buffers.
Supply aquatic organisms with food (e.g. fallen leaves, insects)	Promote broadleaved trees near surface water in conifer stands.
Provide shading	Leave trees, shrubs and other vegetation that can provide shading over time. If necessary, the tree-age and canopy structure can be modified at thinning.
Supply large coarse woody debris (deadwood) to watercourses	Leave trees of all ages in the forest buffer to ensure the continuous supply of long-lived large woody debris to the streams (note: this does not include deposition of logging residues at harvesting). Both conifers and broadleaved trees can provide such long-lived woody debris. However, large amounts of deadwood causing damming should be avoided.
Protect the soil adjacent to surface waters	Try to create forest buffers resistant to wind felling and, within the buffer, avoid driving forestry machinery, site preparation, ditching, remedial drainage and stump lifting.
Stabilize streambanks	Try to create forest buffers resistant to wind felling.

5. Forest buffer implementation in practice

5.1 Map the location of surface waters

To take adequate measures for water protection, it is vital to know the location of surface waters, but to be aware that this information may be incomplete. In boreal forests, the extent of the stream network may vary considerably through the year (Fig. 4). During high-flow periods, the length and width of small streams may increase and connect new areas to the permanent stream network. Any soil disturbance within these temporarily connected areas could negatively affect the permanent streams and springs. A field inspection of the site to be managed or harvested provides valuable information and is strongly recommended.

Cartographic depth-to-water maps (DTW-maps) are a useful tool for locating wet areas and streams (Fig. 4). These maps are generated from digital elevation models based on high-resolution elevation scans using LiDAR technology, and they model the depth to a hypothetical groundwater surface. Thus, the closer the groundwater level is to the ground surface, the wetter the soil.

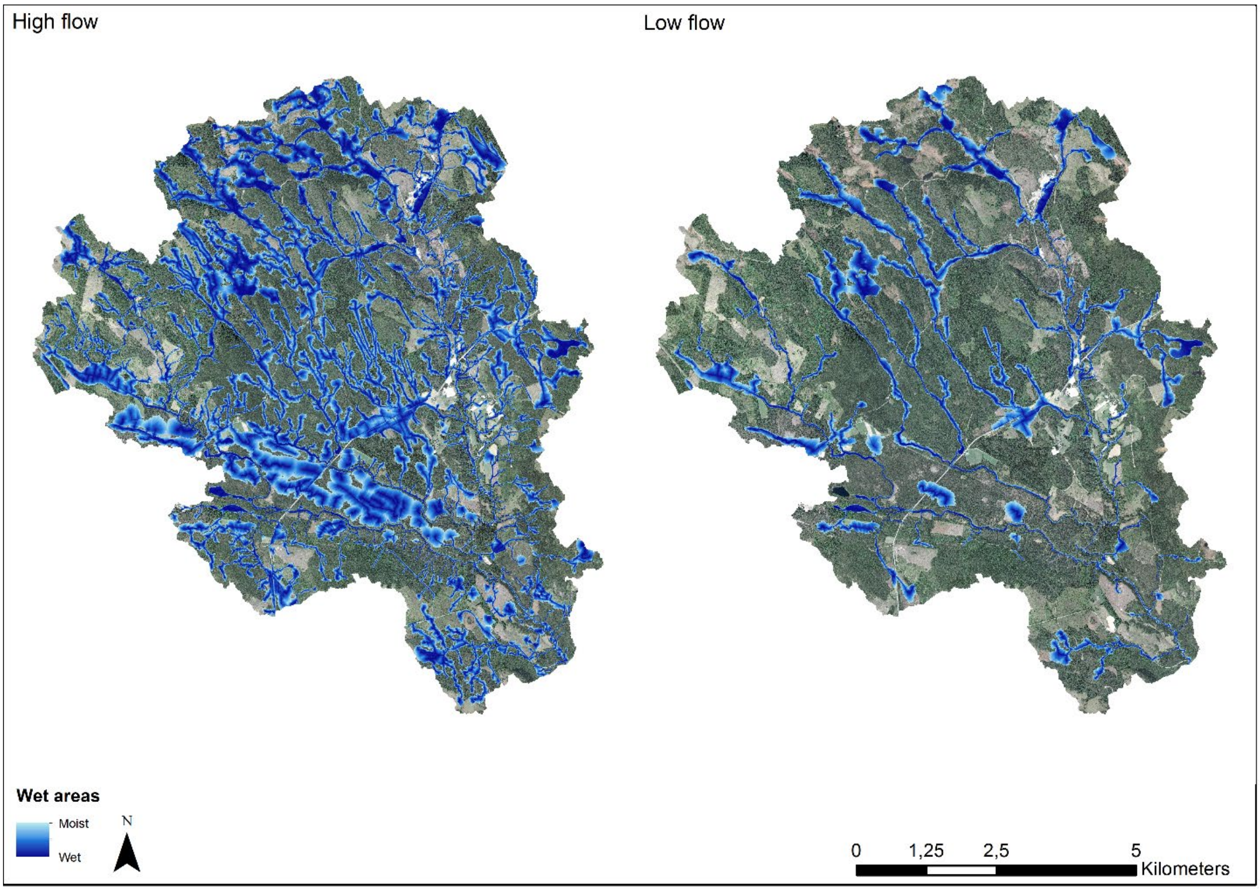

Fig. 4. Depth-to-water maps of the stream network in the Krycklan Catchment, northern Sweden, during high flow (left) and low flow (right). Illustration by William Lidberg.

5.2 Identify the aims

Identification of clear and long-term aims for forest buffers and their functionality is likely to improve the benefits delivered by them. Such aims provide the basis for the management of forest buffers. One option for customizing the management of forest buffers is to manage them as a separate forest compartment.

5.3 Fixed or variable buffer width

Forest buffers with a fixed width are common in many parts of the world. Creating forest buffers with variable widths, including groundwater discharge areas, may be a way to concentrate the environmental considerations on areas where the greatest benefits are obtained. Fixed-width buffers are also efficient if they cover all essential areas such as permanent discharge areas and valuable habitats.

Fixed-width forest buffers are easier to implement than variable-width buffers, since the same width is defined along the entire water body. For variable-width buffers, the border must be uniquely identified along its entire length. This can be achieved in the field by interpreting the topography and factors reflecting the groundwater conditions such as the tree-species and field-layer composition or the cover of *Sphagnum* spp. Variable-width forest buffers can also be delineated using DTW-maps (Fig. 4). In mountain regions, the climatic-vegetation zone should be taken into consideration when leaving forest buffers.

5.4 Predict and prevent impact

Taking the environment into account during planning involves foreseeing possible negative impacts and putting in place adequate mitigation measures. However, forestry operations are carried out in a dynamic environment, where local conditions may change rapidly because of changing weather. Rainfall can rapidly reduce the soil bearing capacity and increase the area with soft soil. Moreover, seasonal variation must be kept in mind (Fig. 4). For instance, a wheel track created during low streamflow conditions may not affect sediment transport at the time, but during future rainfall events and snowmelt, erosion in the wheel track may increase sediment inputs to nearby surface waters. Thus, planning must include both short-term and long-term perspectives.

In highly sensitive sites, areas or water bodies, extra care should be taken during delineation to avoid unforeseen negative impacts of, for example, heavy rainfall or unexpectedly low soil bearing capacity. In these cases, we recommend that wider forest buffers are defined than normally required, to ensure that the desired functionality is obtained.

Finally, negative environmental impacts may be avoided by providing clear instructions to the machine operators about how to act when on-site conditions become unsuitable for carrying out or continuing the forestry operation. Having an overall policy for the entire forest company, regarding for example rutting, can support decision-making for production leaders when guiding on-site personnel in difficult situations.

5.5 Planning routine for an individual forest compartment

Forestry operations are typically planned at the compartment level. To facilitate planning for individual forest compartments, it is useful to **start at a company or state-forest level by**

1) finding out the environmental protection requirements defined in legislation, forest certification standards (if applicable) and guidelines for forest buffers, and
2) identifying the short-term and long-term company aims for leaving forest buffers.

While acknowledging that many factors in addition to surface water quality must be considered when planning a logging operation, for example profitability, logistics, and protection of terrestrial biodiversity and cultural remains, we propose the following **procedure for forest buffer planning**:

1. Start planning in the office:
   a) Does the forest compartment contain surface water?
   - If so, what kind of protection does the surface water require?
   - How should the forest buffer be delineated to achieve this protection?
   - How should the logging be carried out to ensure protection?
   b) Map on-site characteristics using available maps, planning tools and other information concerning, for example, tree species composition, habitats, soil type, slope inclination.
2. Undertake a field inspection in snow-free conditions to check the tree species composition and age structure of the riparian forest as well as sensitive or problematic spots or areas. Make use of GPS/GIS when collecting field data. Mark out the border of the forest buffer in the field, for example using marking tape, and on maps.
3. Tell the machine operators and other persons carrying out the logging operation how the forest buffer should be created and managed.
4. Save details of the delineation of the forest buffer for future operations, for instance on digital maps, along with recommendations for management of the buffer.
5. Follow up and analyse the results and give feedback to personnel involved.

6. Planning tools

Planning is the key to successful forestry work, including management and implementation of forest buffers. Here, some tools are presented, which can be useful when planning forest buffers.

6.1 Plan for Water

A simple model developed in Sweden for water planning, “Plan for Water”, can also be useful when planning forest buffers. The model includes the following five questions:

1. **What special characteristics of the landscape and local environment need to be considered?** This includes factors such as topography, climate-vegetation zone in mountain areas, topographic gradient, soil types, erodibility, network of surface waters and their dynamics (e.g. flooding frequency), aquatic and terrestrial species composition, and characteristics of the riparian forest. Other factors that need to be considered are acidification, eutrophication, and trace metal loads and regulations related to protected areas, for example Natura 2000.
2. **What type of water is it?**
   A temporary or permanent spring or stream, a rivulet, lake, pond or other.
3. **What are the goals?**
   For example, to reduce inputs of suspended solids and nutrients, maintain or improve the water quality status defined by the EU Water Framework Directive (2000/60/EC), maintain habitats, scenery and recreation values, preserve biodiversity.
4. **Which factor is the most critical for achieving the goals?**
   Soil type (erodibility), local topography, groundwater levels, soil disturbance, size of the managed forest area compared with the riparian zone, characteristics of the riparian forest, for example tree species composition.
5. **How can the goals be reached?**
   At the local scale, long-term planning of forestry operations may be a successful strategy, whilst at broader spatial scales forestry must also be considered in the context of other types of land use.

6.2 Depth-to-water maps

Knowing the location of surface water is essential for planning and carrying out water protection measures. Depth-to-water maps are useful tools for locating wet areas and streams (Fig. 4).

6.3 Systematic design of strip-road networks

Methods for systematic design of strip-road networks have been developed in Sweden to prevent soil damage during off-road driving as part of logging operations. The basic idea is to start the logging operation by preparing the main extraction roads and place these in areas with the highest soil bearing capacity within the forest compartment. These roads are reinforced with logging residue to the extent needed and then used for transporting the largest volumes of wood to the landing.

6.4 Terrain classification systems

Terrain classification systems for forestry work can aid the planning of prevention of excess export of suspended solids due to off-road driving. Such classification can help to identify sensitive areas or forest compartments in need of ground protection, for example by using logging residue, corduroy bridges or portable logging mats.

6.5 Blue Targeting/NPK+

"Blue Targeting/NPK+" is a stream scale decision-support tool for assessing the biodiversity values of streams and their sensitivity to changes which can be useful when planning forest buffers.

7. Managing riparian forests and forest buffers

Forest buffers can be narrower or wider than the riparian zone, depending on how they have been delineated. However, from a water protection perspective, forest buffers should preferably include the entire riparian zone, since this zone has an impact on the ecology, hydrology and water quality of the water body. The characteristics of riparian forests may vary considerably depending on vegetation zone, topography, and climate, but previous forest management may also have shaped the riparian forests of today. Riparian zones/forest buffers can be managed to promote features characteristic of unmanaged riparian forests and thereby improve their value for conservation. Moreover, to prevent or mitigate excess export of nutrients, suspended solids and Hg, it is important to protect the soil of the forest buffer against physical disturbance. Against this background, we present the following **options for managing riparian forests and forest buffers**:

1. Multi-layered and uneven-aged forest buffers are often considered beneficial for forest buffer functionality. Thus, if considered necessary, species composition and age and canopy structure can be modified at pre-commercial thinning and thinning to promote multi-layered and uneven-aged forest buffers.

2. A larger proportion of broadleaved trees is often warranted in riparian zones of conifer stands on productive forest land.
3. Trees are not planted in forest buffers for commercial purposes.
4. Where large woody debris in streams is sparse or lacking, single logs may be put into the streams to increase habitat diversity.
5. Any harvesting of the riparian forest should preferably be performed using selective harvesting methods to maintain a continuous tree cover alongside the surface water. Pay attention to the risk of wind felling.
6. Try to avoid excessive wind felling by preparing the trees in the buffer to withstand strong winds. More severe thinning in buffers than in adjacent stands can strengthen the tree root system and increase wind stability. At wind-exposed sites, a wider buffer can mitigate excessive tree fall close to the water. Another option could be to leave high stumps instead of some of the most wind-sensitive trees.
7. Minimize off-road forestry traffic near surface water. At logging, the harvester may use the full range of the boom to place the harvested timber away from the water. Intermittent patch or strip cutting may also be considered.
8. If forestry machinery must enter areas near surface water, take precautions to avoid rutting and soil compaction, for example by applying logging residue for ground protection and carry out the operation when the soil is dry or frozen. Furthermore, when extracting wood from sensitive areas near water, less impact may occur if the forwarder enters the sensitive area unladen, and subsequently start loading from the sensitive area towards the main extraction road or the landing.
9. If a stream crossing is necessary, identify a suitable location and build a permanent skid road and bridge across the stream if possible. Otherwise, build a temporary bridge or use a portable bridge (Fig. 9).
10. Do <u>not</u> fertilize the riparian forest.
11. Do <u>not</u> apply or handle pesticides or other chemicals within the riparian zone.
12. Do <u>not</u> carry out site preparation or stump lifting within the riparian zone.
13. Do <u>not</u> leave or store logging residue in the riparian zone, except when it has been used for ground protection associated with off-road transportation.

Fig. 9. An example of a temporary bridge. Photo by Eva Ring.

8. More information from WAMBAF

More information from the WAMBAF-project can be found on:
https://www.skogsstyrelsen.se/en/wambaf/

Information about the Blue targeting method:
Henrikson, L. 2018. Blue targeting – Manual. How to do Blue targeting for best management practice (BMP) for forestry along small streams. Swedish Forest Agency, EU Interreg project Water Management in Baltic Forests, WAMBAF.

Good practices for ditch network maintenance:
Finér, L., Čiuldienė, D., Lībiete, Z. Lode, E., Nieminen, M., Pierzgalski, E., Ring, E., Strand, L & Sikström, U. 2018. WAMBAF – Good Practices for Ditch Network Maintenance to Protect Water Quality in the Baltic Sea Region. Natural Resources and bioeconomy studies 25/2018. Natural Resources Institute Finland (Luke), Helsinki. 35 pp.