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Experimental revegetation of the regulated lake Ontojärvi in northern Finland

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Abstract

Water level regulation causes large-scale ecological changes in the littoral areas of lakes in northern Finland. If the summertime water level is raised, intensive erosion processes begin, causing a sudden decline in shore vegetation. The need for shore protection is obvious in areas of high recreational value. At lake Ontojärvi, planting experiments with littoral helophytes and bushes were carried out during the years 1990–92. All the experiments were carried out in the eroded sandy areas, which were partly protected by mechanical barriers. Several plant species were planted on the shore which had been treated with different peat mixtures, etc. The frequencies of the different species were followed monthly. After the first summer, the average survival rates were about 45 % due to the drying of seedlings. A rapid decrease in the survival rates took place during the high water level period in 1991 at which point only 20% of the planted individuals were alive. The best results were obtained for the helophyte *Carex rostrata* Stokes, of which 30% had survived erosion. Tall willows (*Salix phylicifolia* L.) were also erosion-resistant with a survival rate of 80%.

Introduction

In Northern Europe there are numerous lakes in which the water levels are regulated. About 10% (33 522 km^2) of the total area of Finland is covered by lakes and over one third of this area (11 900 km^2) is regulated, mainly for hydroelectric purposes. Regulation is usually achieved by raising the water level during the summer (0.5–3.5 m) and lowering the winter minimum by 2–7 m. During the first few years of regulation, the littoral zone is subject to considerable erosion, depending on the rate of water level uplift (e.g., Alasaarela et al., 1989). At the same time, the changes in vegetation are obvious, including a decrease of the former macrophytic vegetation as reported in several Scandinavian lakes (e.g., Rørslett, 1985). If the erosion is continous the shoreline remains without vegetation and also without the erosion sheltering properties of littoral vegetation. Eroded shore areas without changes in the water level fluctuation or mechanical barriers, which diminish the effects of waves and currents, are a hostile environment for young seedling of plants. The aim of this study is to find possibilities for promoting the succession of vegetation by planting seedlings of typical shore plants and applying several soil treatment methods to the regulated Lake Ontojärvi.

Materials and methods

Study area

Lake Ontojärvi (102 km^2) is situated in the Oulujoki watercourse (Figure 1). Ontojärvi has been regulated for hydroelectric purposes since 1951 with an amplitude of 4.4 m (Figure 2). At the beginning of regulation, the mean summer water level was raised by one meter.

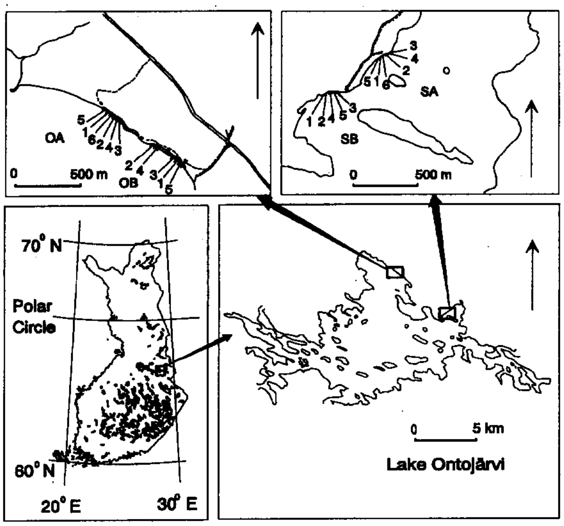


Figure 1. Location of Lake Ontojärvi in northern Finland. Study areas are enlarged in boxes, refer to the text for details.

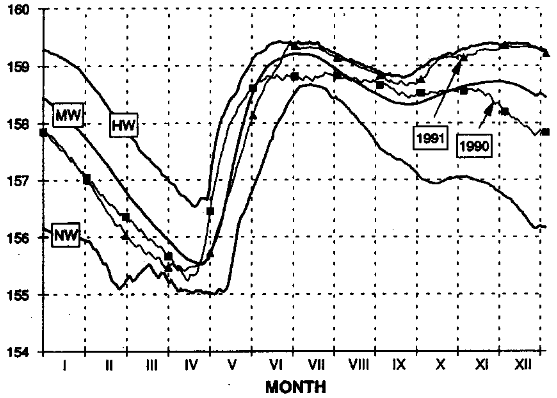


Figure 2. Water level fluctuation in lake Ontojärvi. MW, HW and NW lines calculated from daily values observed during the years 1964–91. Daily values during main years of the research project presented by filled squares (1990) and filled triangles (1991).

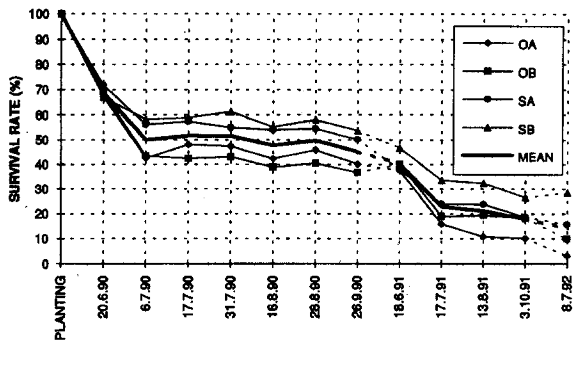
The water level uplift initiated an erosion of shoreline, which caused instability in the sandy shore areas.

Shore vegetation planting experiments

Open (O) and sheltered (S) experimental areas were established in the sandy eroded shore areas of Lake Ontojärvi (Figure 1). OA refers to an open (fetch = 3.9 km) shore area without any mechanical protection, while OB (fetch = 2.7 km) stands for an area protected by groins made of stones. A sheltered shore SA (fetch = 0.8 km) was without protection, while SB (fetch = 1 km) was protected by a chain of floating timbers (four parallel timbers stabilised by floating barrels). All the research areas were divided into six subareas (6 × 10 m), in which the soil was manipulated by the following methods (Figure 1). The first subarea (1) was a non-treated control area. In the second subarea (2), fertilized peat (VAPO C1) was mixed in to the soil (2.1 kg m^{-2}) to improve its fertility and moisture content. The rapidly growing oat (*Avena sativa* L.) was used as a protective plant against erosion in the third subarea (3). Peat treatment and oat were used together in subarea four (4). Subarea five (5) consisted of bunches of willows (mainly *Salix phylicifolia* L.) bound together into a carpet (Begemann & Schiechtl, 1986). An erosion carpet (Rejtex©) manufactured of easily degradable recycled fibre was used in the sixth (6) subarea.

All the aquatic macrophytes planted in the subareas were erosion-resistant species collected from areas situated near the experimental plots (cf. Lester et al., 1986; Comes & McCreary, 1986). *Carex rostrata* Stokes was planted as a piece of turf in two rows (50 cm between rows, planting depth 5–10 cm). *Juncus filiformis* L. was planted as a bunch of 3–10 individuals in four rows (25 cm between rows, planting depth 5–7 cm). Pieces of roots of *Phragmites australis* (Cav.) Trin. ex Steudel were planted in two rows (50 cm between rows, planting depth 10–15 cm). *Calamagrostis* sp. (mainly *Calamagrostis purpurea* (Trin.) Trin) was used as turfs of 1–5 individuals in four rows (25 cm between rows, planting depth 5–10 cm). Some typical shore bushes were also used as experimental plants. *Salix phylicifolia* was planted in two rows (50 cm between rows, planting depth 20–30 cm). Small seedlings of *Alnus incana* (L.) Moench were planted near the foot of shore cliff in one row (distance 50 cm, planting depth 10–20 cm). All the species were planted according the natural zonation observed in other parts of the lake. The planting order from the shoreline outwards was *Alnus-Salix- Calamagrostis-Carex/Juncus-Phragmites*. *Carex* was only used in sheltered (S) and *Juncus* in open (O) areas. In the sixth subarea (willow carpet), only tall (1.5–3 m) cuttings of *Salix phylicifolia* were planted near the foot of the littoral shelf.

The experimental areas were prepared during May 1990 and the planting took place during June 1990. The areas were analysed twice per month in 1990, monthly in 1991 and once in 1992. All the living (green) plants were included in the survival rate estimation. The difficulties in distinguishing living plants from dead ones during spring and autumn caused a fluctuation in the survival rate.



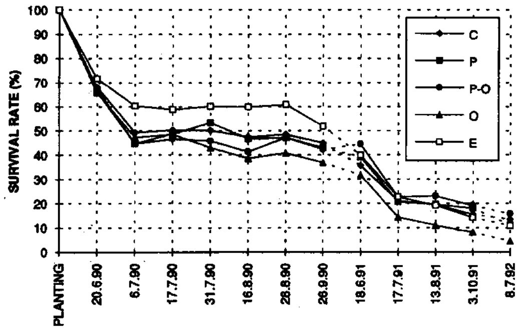


Figure 3. A. Mean survival rates of species planted in different subareas and total mean. Refer to the text for details. B. Mean survival rates of species planted at research sites with different treatments. C = control areas, P = peat treatment, O = oat as shelter plant, P–O = both treatments together, E = erosion carpet.

Results and discussion

The mean survival percentages in the different research areas are presented in Figure 3a. Quite soon after the planting, almost half of the seedlings became desiccated. The water level was almost 50 cm below the normal, and it reached the foot of the shore cliff and the level of planted vegetation only in the sheltered areas (SA, SB) (Figures 1, 2). Survival rate was 15% higher in that area (Figure 3a). The effect of ice-erosion was easy to recognize in the sheltered areas (SA, SB), where mortality was 10–15% during the first winter (Figure 3a). The high water level and wave erosion during the second summer of the research caused sudden changes in the survival rate which dropped in all areas (Figures 2, 3a). Only in the sheltered area protected by floating timbers (SB) did the survival rate stay above 20%.

The differences between the different treatments were surprisingly small (Figure 3b). Only the erosion carpet provided a better survival rate during the first summer, but the second-year erosion caused a rapid decrease in the survival rate (Figure 3b). Oats as a protective plant provided the lowest survival rates for planted helophytes, because ducks grazed on young oat seedlings and also plucked at the other plants.

The mean survival rates of the different species at the end of each year of the research programme provided quite a confused overall view (Figure 4). *Carex rostrata* was the only aquatic macrophyte which survived fairly well, but *Calamagrostis* also showed notable persistence against erosion. *Phragmites* and *Juncus* disappeared quite rapidly, even though the latter is quite common on open shores. Small willow seedlings also survived well, but the survival rate of *Alnus* was low although it also grows also on the eroded shores of regulated lakes (Figure 4). As a point of special detail tall willow cuttings (*Salix phylicifolia*) survived fairly well showing a survival rate of 85% at the end of 1991.

The zonation of littoral vegetation is usually formed by water level fluctuation (e.g., Spence, 1982; Wilson & Keddy, 1985). In this study, the planting levels were exactly the same as elsewhere in the littoral zone of lake Ontojärvi (S. Hellsten, unpublished data). In regulated lakes, the living area of macrophytes is usually narrower and moves downwards due to wave erosion (e.g., Rørslett, 1984). The effect of down-dwelling ice during the wintertime also causes scouring and freezing of the bottom sediment, as has been described for several other lakes (Rørslett, 1984, 1987; Erixon, 1981). In the uppermost part of the littoral there is an obvious possibility of desiccation due to regulation (e.g., Rørslett, 1984). The ecological environment, especially on sandy shores, is therefore extremely harsh for all living plants. On open shores, the foot of the littoral shelf is situated at a higher level (159.40 m.a.s.l) compared to sheltered ones (159.00 m.a.s.l.), and the possibility of drying out causes a higher mortality (Figure 3a). Sheltered shores with a lower height of the littoral shelf foot provide better moisture conditions, but they are also more easily eroded in the case of a high water level. Although species were used which are quite resistant against erosion, we did not get good results. In fact, most of the helophytes are typical C-strategists (e.g. *Phragmites, Juncus*) which are good competitors, but slow in extending their living areas (see Grime, 1977; Murphy et al., 1990). All the species with a good resistance against erosion are small R-strategists (e.g. *Ranunculus reptans, Eleocharis acicularis*) which are difficult to use as experimental plants.

The substrate quality or, more precisely, the grain size and the amount of organic matter, is one of the

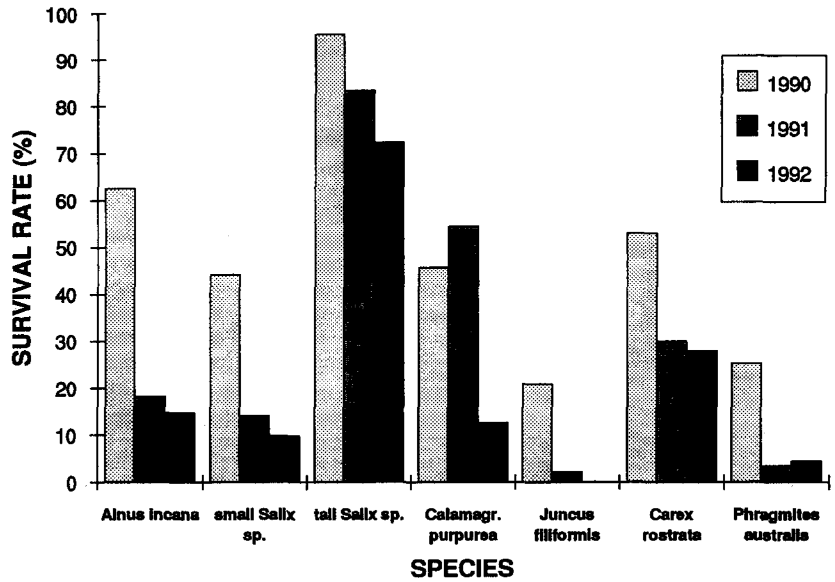


Figure 4. Mean survival rates of different species at the end of different research years.

most important factors affecting aquatic macrophytes (e.g. Barko & Smart, 1983). If the erosion is at low level, the content of organic matter in the sediments is usually high. Low erosion can be affected by erosion barriers, as described in Allen et al. (1984). Another way to improve sediment quality is to add fertilizers (Fowler & Maddox, 1974; Broome et al., 1988) or organic matter, as in our study. Our results showed clearly that these methods were not beneficical in lake Ontojärvi, where intensive wave erosion flushed the shoreline regularly. Bache & MacAskill (1984) found that the use of protective plants gave a good shelter for young seedlings whereas, in our case, duck grazing reduced the value of oats as a protective plant. The use of an erosion carpet was successful in experiments carried out by Allen et al. (1984) but in lake Ontojärvi, wave erosion broke the carpet or it was covered by a thick sand layer. Tall seedlings of willow yielded one of the most promising results in our experiments. Willows are easily collected and resistant against flooding. The willow carperts did dry or erode during the first year of our study. The carpets should have been covered with wet sand for better results. Comes & McCreary (1986) and Bache & MacAskill (1984) also found similar carpets to be convenient for shore protection. Willow carpets are also commonly used for stabilizing river banks (Bagemann & Schiechtl, 1986). In our experiments we did not shape the littoral shelf in any way, as was recommended by Allen & Klimas (1986). A milder slope should give better protection against erosion, as has been seen in lake Oulujärvi studies.

Acknowledgments

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