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Public participation in monitoring programmes as a tool for lakeshore monitoring: the example of Lake Pyhäjärvi, Karelia, Eastern Finland

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Abstract

Lake Pyhäjärvi, on the border between Finland and Russia in Karelia, is a very valuable clear-water lake of the *Lobelia* type. It belongs to the European Union's Natura 2000 programme in Finland, and has been included in regional and national monitoring programmes since the 1960s. The main monitoring station is situated near the outlet of the lake. Deterioration of its water quality was suspected already in the 1980s because of decreasing Secchi depths (transparency) and increasing chlorophyll *a*.

The occurrence of algal blooms on the lakeshores is monitored weekly during each summer at one site on Lake Pyhäjärvi (site 1). This is a part of nationwide intensive algae monitoring programme organised by the environmental authorities together with voluntary observers at some 270 lake sites in Finland since 1998. Since 1997, Secchi depth observations have been carried out by volunteers biweekly or monthly at 17 sites on the lake. In the vicinity of one of these transparency observation sites (station 100), intensive monitoring of algae has been carried out. At this lakeshore monitoring site 69 algal observations were made, ten of which recorded algal blooms during the study period 1998–2002. The observed algal blooms were caused by algae of the *Anabaena* species, mainly by *Anabaena lemmermannii*. At Lake Pyhäjärvi the number of algal bloom observations received from the public have decreased from the 1990s to the 2000s. The range of Secchi disc transparency was 5.0–8.4 m with a mean value of 6.2 m at station 100 and 4.3–7.7 m (mean 6.1 m) at the main monitoring station 2 during the open water periods in 1998–2002. During this study period, the maximum values at site 100 seem to have increased slightly, which might indicate some improvement in the water quality due to decreased point source loading.

We conclude that the intensive algal monitoring results of 5 years at the lakeshore site and the transparency results – both compiled by trained volunteers – reflect an improvement in the state of Lake Pyhäjärvi in Karelia. This conclusion is in accordance with the long-term water quality and short-core studies of sedimentary diatoms in Lake Pyhäjärvi. We suggest that the intensive algal observations and transparency measurements are both suitable methods for the monitoring of lakeshores and lakes, and that both are suitable for voluntary monitoring. We found public participation a good tool for monitoring lakes and lakeshores.

Key words: Monitoring – voluntary monitoring – public participation – algae – cyanobacteria – transparency – lakeshore – clear-water lake – transboundary lake – Finland

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Introduction

The monitoring of lakes has a long tradition in Finland, a land with 187,888 lakes (RAATIKAINEN & KUUSISTO 1988). Monitoring has mainly been based on the physico-chemical variables of lake water, and especially that of the lakes' deepest sites. Nationwide biological monitoring of phytoplankton started in the early 1960s (HEINONEN 1980; LEPISTÖ 1999). This lake monitoring programme is still going on, by phytoplankton every third year at approx. 250 sampling sites and annually at 15 lakes intensively. The water quality monitoring programmes are now under reconsideration (NIEMI & HEINONEN 2003) in order to meet the requirements of the Water Framework Directive (European Commission 2000).

Local people are often the first to notice deterioration of their lake as sliming of the shoreline stones, algal disturbances, turbid water, increasing vegetation in the littoral zone and sliming of their fishing nets. The use and usability of the shoreline and shore waters decrease. Traditional monitoring programmes do not work well for observing these slow changes. In some places the local people and voluntary water protection associations have started voluntary monitoring for early warning of the state of waters. One of the key elements in such monitoring is the use of quick and simple methods for assessing the state of waters.

In 1997, the appearance of algal blooms in Finnish inland and coastal waters increased the need to improve the monitoring of algal nuisances (RISSANEN & LEPISTÖ 2002). As a result, systematic and intensive monitoring of algae started nationwide in 1998, based on voluntary observations made by both ordinary citizens and by the relevant authorities. In summer 2002 the observation network included a total of 344 sites, 271 of which were on inland lakes and rivers. One of the sites is at Lake Karjalan Pyhäjärvi, eastern Finland. On this particular lake the voluntary water protection association for the lake, Karjalan Pyhäjärvi r.y., started the year-round voluntary transparency observations in March 1997, in co-operation with the environmental authorities. These observations have been continued until the present day. Here we present results of the intensive algal monitoring and the transparency observations made by volunteers on Lake Pyhäjärvi during the open water periods of 1998–2002 with reference to public algal nuisance observations and to some spatial phytoplankton data in the lake.

Study area

Lake Pyhäjärvi in Karelia is a transboundary lake between Finland and Russia (Fig. 1). The lake is a very valuable clear-water lake of the *Lobelia* type belonging to the European Union's Natura 2000 programme in Finland (Finnish Government 1998). The lake has belonged to the national and regional monitoring programmes since the 1960s and to the Finnish Eurowaternet since 2000 (NIEMI et al. 2001; MITIKKA & EKHOLM 2003). The ecological state of the lake is being assessed in a Finnish-Russian joint research project "Assessment of the ecological state of the transboundary waters" under the Interreg IIIA Karelia programme during 2002–2003 (LUOTONEN et al. 2002).

Lake Pyhäjärvi is a moderately large lake loaded mainly by non-point sources, forestry and agriculture, but also by point source loadings from villages and a fish farm. Anthropogenic impacts are evident on the Finnish side of the lake, whereas the Russian side is considered pristine. The lake area is 247 km^2, of which 201 km^2 are situated in Finland. The catchment area of the lake is 975 km^2, of which 805 km^2 are in Finland. The maximum depth is 26 m on the Finnish side. The theoretical retention time is 7 years. The water quality of Lake Pyhäjärvi is nowadays mostly good or even excellent in terms of low phosphorus content (4–7 $\mu g\ l^{-1}$), very clear water (colour 5–10 mg Pt l^{-1}) and low chlorophyll *a* (1.0–3.0 $\mu g\ l^{-1}$). There are only minor differences in the chemical parameters in different parts of the lake.

Material and Methods

The transparency observations were made with a Secchi disk (diameter 20 cm) or the white cover of a Limnos or Ruttner type water sampler. Observations were started biweekly or once a month at 17 sites (Fig. 1) by 12 volunteers in March 1997 (NIINIOJA & TURKKA 2003). Here we deal with the transparency results for stations 2 and 100; station 2 is located some 20 km north of the intensive algal monitoring site (site 1) and station 100 is located only at a distance of 250 metres from site 1. Both stations (1 and 100) are observed by a local citizen, Mr. JOUKO TURKKA. There are also earlier Secchi readings from these stations, and some phytoplankton data as well as chemical and hydrobiological data on the whole lake compiled by the environmental authorities.

Intensive algal bloom monitoring was started in June 1998 in Finland (RISSANEN & LEPISTÖ 2002). The observers are trained persons in order to ensure standardisation of the criteria for the observations. The observations are made from lakeshores, not from pelagial areas. The observations are made weekly during June–August, but they were continued in 1999 for 3 weeks in September, and in 2000 for 2 weeks in September. Every observation is coded as 0 = no algae, 1 = observed, 2 = abundant and 3 = very abundant. Samples for species identification from abundant or very abundant algal mass were taken by the observers. No samples were taken for biomass determination.

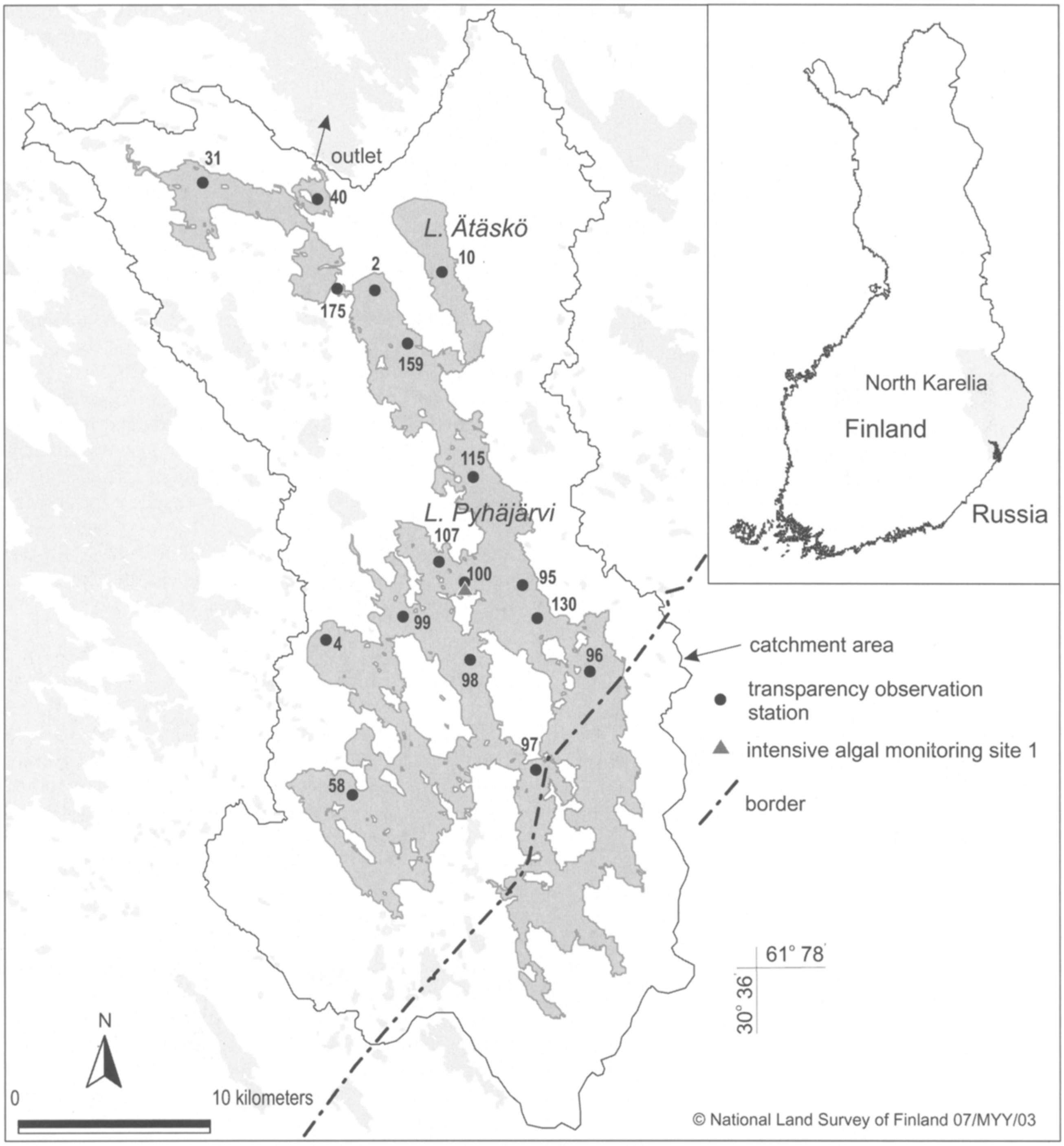

Fig 1. Study area of Lake Pyhäjärvi. Observation points (numbered points) given.

Phytoplankton samples were taken in July as compiled samples from the surface to depths of 2 metres at the deepest sampling station 2 in each of the years 1998–2002. The spatial variation of phytoplankton was studied in 2002 from samples taken from different basins of the lake at sampling stations 31, 2, 4, 58 and 96 (Fig. 1). The samples were fixed with acid Lugol's solution. Biomass and species composition were analysed by an inverted microscope, using a settling chamber technique (UTERMÖHL 1958). The phytoplankton studies were made according to the Nordic methods (OLRIK et al. 1998). We compare the intensive algal voluntary observations with the samples of algal nuisances collected by the public (only species determination, no biomass data) from the whole lake from the late 1980s onwards with reference material consisting of some spatial phytoplankton data from the lake.

Results and Discussion

Voluntary transparency observations

The mean value of transparency was 6.2 m at station 100 and 6.1 at station 2 during the summers 1998–2002 (Table 1). From time to time there were some fairly low values with a minimum of 5.0 m at site 100 (Fig. 2a) and a value as low as 4.3 m at site 2 (Fig. 2b). During the summers 1998, 2000 and 2001, heavy rains of short duration occurred in June and July with a monthly precipitation of over 100 mm. We suggested that one reason for the decreases in Secchi disk readings are rainy years with high precipitation in summer. This might cause high leaching of particulate matter and nutrients into Lake Pyhäjärvi. However, we could not find statistical evidence for this suggestion.

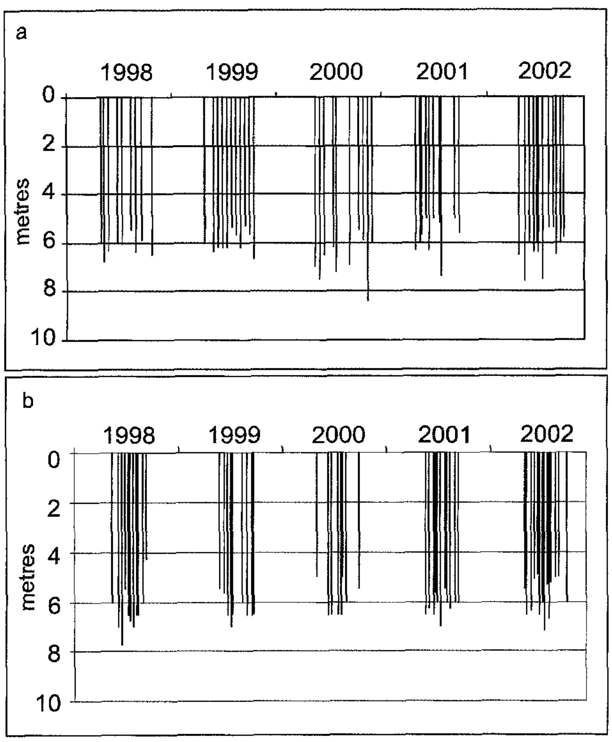

Fig. 2. Transparency (m) at stations 100 (**a**) and 2 (**b**) of Lake Pyhäjärvi during open water periods 1998–2002. Each vertical line = one observation.

During the open water periods in the years 1998–2002 the maximum values at site 100 seem to have slightly increased (Fig. 2a), which might reflect some improvement in the water quality. One reason could be the decreasing load near site 100. This central part of Lake Pyhäjärvi has for a long time been loaded with municipal wastewaters and by a fish farm. The farm reduced its fish production in the 1990's and was closed down in 1999.

An increasing trend in the transparency observations from 1981 to 2001 is reported from station 2 by NIINIOJA & TURKKA (2003). This result and our results during the summers 1998–2002 are in accordance with the decreasing trends in chlorophyll-*a* concentrations from early 1982 to 2000 and decreasing total phosphorus contents from the early 1970s to 2000 in Lake Pyhäjärvi documented by PIETILÄINEN & HEINONEN (2002). The dissolved nitrogen concentrations in the studied 173 Finnish lakes showed a statistically significant decreasing trend at 53 sites, including Lake Pyhäjärvi, during 1975–2000 (August results) as reported by RÄIKE et al. (2003). The preliminary results of the long-term sedimentary diatom monitoring (samples in 1985, 1990 and 2002) also reveal signs of improvement in Lake Karjalan Pyhäjärvi after 1990 (KUKKONEN et al. 2003).

Intensive algal observations and public algal samples

During the study period (1998–2002), 69 algal observations were made, ten of which recorded algal blooms at the intensive algal monitoring station 1 (Table 2). The observed algal blooms were produced by *Anabaena*

Table 1. Transparency values of the sites 100 and 2 at Lake Pyhäjärvi.

Year	Site 100			Site 2		
	Mean	Range	n	Mean	Range	n
1998	6.2	5.5–6.8	9	6.2	4.3–7.7	12
1999	6.0	5.3–6.7	12	6.3	4.3–7.0	9
2000	6.7	5.5–7.5	10	5.9	5.0–6.5	8
2001	5.8	5.0–7.4	10	6.2	5.5–7.0	11
2002	6.3	5.4–7.6	12	5.8	4.9–7.2	14
1998–2002	6.2	5.0–7.6	53	6.1	4.3–7.2	54

species, mainly *Anabaena lemmermannii*. This genus, as well as this species, is the most typical alga causing mass occurrences in North Karelian lakes and in other inland waters in Finland (LEPISTÖ et al. 2003).

Altogether 55 algal bloom samples, collected by ordinary citizens, have been analysed from Lake Pyhäjärvi during the open water periods 1989–2002. The species of *Anabaena* were the most common in these samples. Of those analysed, 14 samples (26%) were taken fairly close to the intensive algal observation site 1. However, only 14 algal bloom samples were taken in 1998–2002, 3 of which were taken near the intensive algal observation site. This decrease might be considered one sign of an improvement in the state of Lake Pyhäjärvi.

Spatial differences of phytoplankton assemblages

In 1998–2002 altogether 114 phytoplankton taxa were found in Lake Karelian Pyhäjärvi. Chlorophyceae (*Monoraphidium dybowskii*, *Oocystis* and *Botryococcus* species) and Crysophyceae (*Uroglena* sp. and *Dinobryon divergens*) were the most abundant groups. Chrysophyceans were common in the lake during the mid-summer period. Cryptophycean flagellates *Cryptomonas* sp., *Rhodomonas lacustris* and heterotrophic katablepharid *Katablepharis ovalis* were abundant in all areas, especially in the southern part of the lake. The phytoplankton biomass was low (0.10–0.47 mg l^{-1}) at the main sampling station 2 (Fig. 1) during 1998–2002, indicating oligotrophic conditions.

Since the 1960s only minor changes in phytoplankton biomass and in species composition have been recorded.

However, exceptionally the phytoplankton biomasses and also the amount of Cyanophyceae were notably high in the 1980s (LEPISTÖ et al. 2003). Despite small differences in water quality, some spatial variation in phytoplankton biomass and species composition was seen in Lake Pyhäjärvi (Fig. 3). Biomass was almost twofold at sampling station 2, close to the outlet of the lake, as compared with the other basins in 2002.

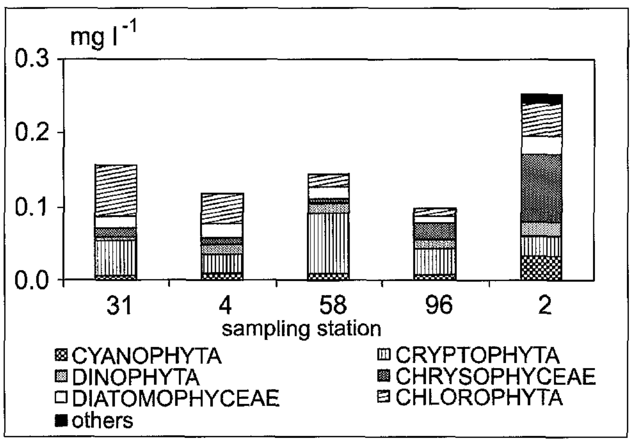

Fig. 3. Phytoplankton biomass (mg l^{-1}) of five sites in Lake Pyhäjärvi in July 2002. Monitoring site numbers are indicated, see Fig. 1.

Table 2. Intensive algal observations at Lake Pyhäjärvi during open water periods 1998–2002. Algal observation codes: 0 = no algae; 1 = observed; 2 = abundant; 3 = very abundant. n = number of observations.

Year	Codes				n
	0	1	2	3	
1998	11	2	0	0	13
1999	14	2	0	0	16
2000	9	4	1	0	14
2001	12	1	0	0	13
2002	13	0	0	0	13
1998–2002	59	9	1	0	69

Conclusions

The voluntary transparency results and intensive algal monitoring results of 5 years reflect an improvement in the state of Lake Karelian Pyhäjärvi. We suggest that intensive algal observations of lakeshores and transparency measurements are both suitable methods for monitoring, also by the volunteers. The intensive algal observations made on lakeshores seem to be more suitable for lakeshore or littoral zone monitoring, because they tell ordinary people directly about the usability of the water. The results are readily understandable, and they enable people to see the situation for themselves. There are some weaknesses in lakeshore algal monitoring: for example the situation is not stable, and the chosen site can affect the results (how wind-sheltered the site is, *etc.*).

One strength of the voluntary observations is that the local people know "their lake" and they have a real interest in keeping it in a good state. They also want to know if it is possible to manage it even better. Voluntary transparency monitoring enables rather intensive observations in several parts of such a large lake, even though some profound studies should simultaneously be compiled on the same area. The first step towards voluntary monitoring is the training of volunteers in order to get reliable results. Such voluntary monitoring programmes should include a clear protocol of the monitoring praxis. For example, it is important to make all the observations in good conditions, preferably at the same time of day. The results also tell us how important continuous measurements are, because there is great variation due to weather conditions. There are many items that affect the observations, such as weather (clouds, wind), hydromorphology of the site etc., which should be studied in detail. There is also a need to evaluate the programme from time to time.

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References

European Commission (2000): European Union, EU Water Framework Directive 2000/60/EC, 22.12.2000, 72 pp.

Finnish Government (1998): Proposal into the Natura 2000 Network to EU Commission. Decision in August 1998 by the Finnish Government. http://www.vyh.fi/eng/environ/naturcon/natureco.htm, 19.12.2003.

Heinonen, P. (1980): Quantity and composition of phytoplankton in Finnish inland waters. Publ. Water Res. Inst. **37**, 91 pp.

Kukkonen, M., Simola, H., Niinioja, R. & Luotonen, H. (2003): Long term monitoring and short-core studies of sedimentary diatoms of Karelian Pyhäjärvi, a transboundary lake between Finland and Russia. In: M. Ruoppa, P. Heinonen, A. Pilke, S. Rekolainen, H. Toivonen & H. Vuoristo (eds.), How to assess and monitor ecological quality in freshwaters. TemaNord **2003** (547): 136–140.

Lepistö, L. (1999): Phytoplankton assemblages reflecting the ecological status of lakes in Finland. Monographs of the Boreal Environment Research **16**, 43 pp.

Lepistö, L., Jokipii, R., Niemelä, M., Holopainen, A.-L., Niinioja, R., Hammar, T., Kauppi, M. & Kivinen, J. (2003): Kasviplankton järvien ekologisen tilan kuvaajana. Vuoksen vesistöalueen vuosien 1963–1999 seuranta-aineiston käyttö arvioinnissa ja luokittelussa. Suomen ympäristö **600**, 80 pp. (in Finnish).

Luotonen, H., Niinioja, R., Karttunen, K., Rask, M. & Viljanen, M. (2002): Transboundary Lake Karelian Pyhäjärvi on the Finnish – Russian Border Area – Assessment of the Ecological Status. In: M. Ruoppa & K. Karttunen (eds.), Typology and ecological classification of lakes and rivers. TemaNord **2002** (566): 98–101.

Mitikka, S. & Ekholm, P. (2003): Lakes in the Finnish Eurowaternet: status and trends. Sci. Total Enviroment **310** (1–3): 37–45.

Niemi, J., Heinonen, P., Mitikka, S., Vuoristo, H., Pietiläinen, O.-P., Puuponen, M. & Rönka, E. (eds.) (2001): The Finnish Eurowaternet with information about Finnish water resources and monitoring strategies. Finnish environment **445**, 62 pp.

Niemi, J. & Heinonen, P. (eds.) (2003): Ympäristön seuranta Suomessa. 2003–2005. Extended summary: environmental monitoring in Finland 2003–2005. Finnish environment **616**, 176 pp.

Niinioja, R. & Turkka, J. (2003): Transparency measurements - a tool for environmental monitoring? An example from Lakes Pyhäjärvi and Ätäskö, Finland. In: H. Simola, A. Yu. Terzhevik, M. Viljanen, & I. J. Holopainen (eds.), Proceedings of the Fourth International Lake Ladoga Symposium. University of Joensuu, Publ. of Karelian Res. Inst. **138**: 393–399.

Olrik, K., Blomqvist, P., Brettum, P., Cronberg, G. & Eloranta, P. (1998): Methods for quantitative assessment of phytoplankton in fresh waters, part I. Naturvårdsverket, Rapport **4860**, 86 pp.

Pietiläinen, O.-P. & Heinonen, P. (eds.) (2002): Monitoring of international lakes. Background paper for the guidelines on monitoring and assessment of transboundary and international lakes. UN/ECE Working Group on Monitoring and Assessment. Finnish Environment Institute. Lake Pyhäjärvi, pp.72–75.

Raatikainen, M. & Kuusisto, E. (1988): Suomen järvien lukumäärä ja pinta-ala (The number and surface area of the lakes in Finland). Terra **102** (2): 97 - 110.

Räike, A., Pietiläinen, O.-P., Rekolainen, S., Kauppila, P., Pitkänen, H., Niemi, J.A., Raateland, A. & Vuorenmaa, J. (2003): Trends of phosphorus, nitrogen and chlorophyll *a* concentrations in Finnish rivers and lakes in 1975–2000. Sci. Total Environment **310** (1–3): 47–59.

Rissanen, J. & Lepistö, L. (2002): Systematic monitoring of algal blooms in Finnish inland and coastal water. In: M. Ruoppa & K. Karttunen (eds.), Typology and ecological classification of lakes and rivers. TemaNord **2002** (566), pp. 101.

Utermöhl, H. (1958): Zur Vervollkommnung der quantitativen Phytoplankton-Methodik. Mitt. Int. Verein. Limnol. **9**: 1–38.