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Coverage and depth limit of macrophytes as tools for classification of lakes

Helle Mäemets* and Lilian Freiberg

Centre for Limnology, Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, 61101 Rannu, Tartumaa, Estonia

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Abstract. The aim of the study was to clarify the applicability of total coverage percentage of macrophytes and depth limit of submerged plants for the quality estimations of Estonian lakes. Total coverage does not seem to be correlative with lake quality. The depth limit of submerged plants appears to be a better characteristic of the state of small lakes, and is relatively well correlated with water transparency, less with chlorophyll *a* content. In large L. Peipsi the mean of macrophyte depth limit would be a better characteristic than single maximum values.

Key words: lake type, total coverage, growth depth, transparency, lake quality.

INTRODUCTION

In recent years, numerous European hydrobiologists have been involved in the elaboration of criteria for the classification of the quality of water bodies. The need for such criteria proceeds from the European Water Framework Directive (Directive 2000/60/EC) aiming to improve the state of the lakes and rivers. The fundamental idea of the reference or natural state of different types of water bodies, and of the degradation of this state caused by human impacts, serves as a basis for quality estimations. Besides abiotic characteristics, much attention has been given to different groups of biota, among them macrophytes. Attempts to develop scientific argumentation for making decisions about the "good", "moderate", or some other state of a water body may generate scepticism, due to the anthropocentric point of view, as well as numerous difficulties with the interpretation of data. Some of these, related to lakes, are:

* Corresponding author, helle.maemets@emu.ee

- Simplified typology. Variability in geological conditions, climate, lake morphometry, water balance, historical background, and other individual features complicate division of lakes of larger regions, e.g. lowland lakes of Central Europe, into a small number of types. Consequently, the limits between quality classes may be vague or, on the contrary, too rigid.
- Indicative value of species. A species may have more or less different habitat preferences in different regions. This circumstance and regional differences in the management of landscapes may lead to different expert opinions.
- Reference conditions. Absolutely natural conditions do not exist. Selection of reference lakes, based on a sparsely inhabited and weakly polluted catchment area, reflects a present situation but not events that have taken place in the past, e.g. earlier flax retting in the lake.
- Different combinations of human impacts and natural processes. Natural annual differences in the occurrence of several macrophyte taxa and their abundance, as well as in the values of other hydrobiological characteristics may exceed the limits between quality classes. Midsummer chlorophyll *a* (Chl*a*) content in surface water, as measured in the framework of the state monitoring of small Estonian lakes, serves as an example (Databases of the Centre for Limnology) (Fig. 1).

The need for simple, universal criteria contrasts with the multifaceted real world. Moreover, macrophyte databases of different countries contain heterogeneous material.

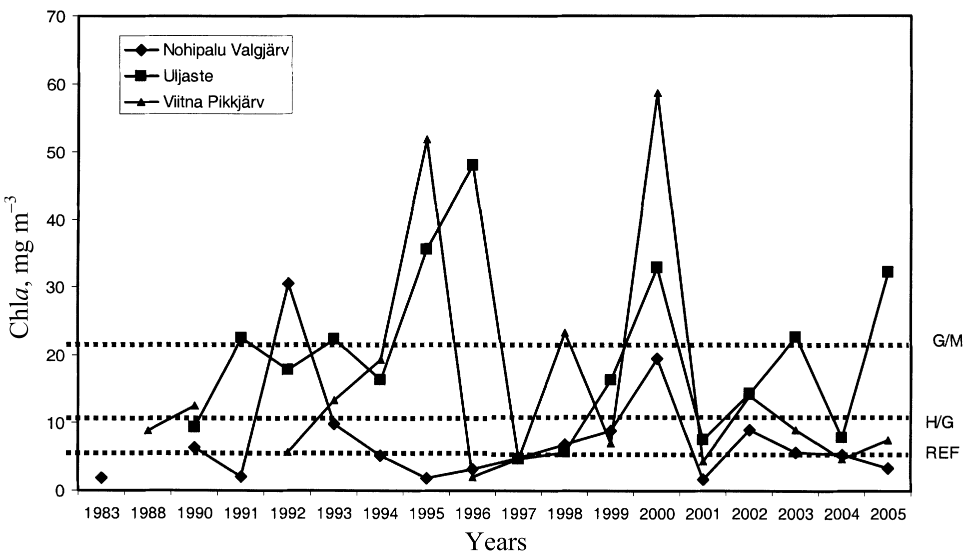

Fig. 1. Inter-annual differences of the Chl*a* content in surface water in three soft-water (LCB3) lakes in midsummer. The boundaries between lake quality classes (proposed for Estonia by I. Ott) are shown. Classes: REF – reference; H – high; G – good; M – moderate.

The aim of the present study was to clarify the applicability of two characteristics of macrophyte vegetation – total coverage percentage of macrophytes and depth limit of submerged plants (Phillips, 2006; Portelje, 2006) – for grouping and quality estimation of Estonian lakes. Considering the above-described difficulties, use of relatively homogeneous Estonian databases and a better knowledge of the situation would be the preconditions for a success in the classification of Estonian lakes. Analysis of species composition requires special research in the future. Data for large lakes can be observed as "case studies" due to specific size-dependent factors such as mechanical stress and very large size of the catchment area, which probably cause different expressions of human impact. However, some characteristics may be common for the classification of small and large lakes.

MATERIAL AND METHODS

In 2006 the Estonian database of small lakes (belongs to the Centre for Limnology at the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences) contained 1192 descriptions of the macrophyte composition from 472 water bodies, mainly lakes, but included also data on some isolated coastal lagoons and man-made reservoirs. About 80% of these descriptions were more or less complete, i.e., the whole lake had been circled by boat. Altogether 167 estimations of macrophyte coverage from 145 water bodies, 241 depth limit measurements for submerged plants, 170 measurements for floating-leaved plants, and 93 measurements for emergent plants from 146 water bodies were available. These numbers derive from the data of 352 lake-years (Appendix 1). Parallel measurements of depth limit and Chl*a* concentration have been made in 51 cases. Depth limits for submerged plants were measured by a plant hook supplied with a graded rope or stock. The coverage of macrophytes was calculated or estimated using bathymetric maps compiled by several investigators (mainly Riikoja, 1940; Mäemets, 1968; personal data by T. Kallejärv), vegetation schemes combined with shoreline length data, and growth depth and belt width measurements. The coverage here means the percentage of lake area occupied by macrophytes, not the percentage of the potential growth area (cf. Valta-Hulkkonen et al., 2005). Because of the frequent overlapping of the belts of different ecological groups, as well as for technical reasons, the percentage of coverage comprises all vegetation groups: emergent, floating, floating-leaved, and submerged plants. Due to varying density of stands and the absence of bathymetric data for a number of the smallest lakes, the coverage estimations are quite rough. Rare, scattered shoots were not taken into account. Composition data cover the last 100 years, but the data of coverage and growth depth cover mainly the last 50 years. Most of the macrophyte data were collected by H. Riikoja (1925–1937), H. Tuvikene (1951–1958), A. Mäemets (1961–1995), and H. Mäemets (since 1996) with the assistance of R. Laugaste, L. Freiberg, and K. Palmik.

All available data were analysed to establish a general division of small lakes on the basis of the coverage of vegetation and the growth depth limit of submerged plants. For part of the lakes only depth data are presented, for others also coverage data are provided. Types for the studied lakes are combined from the typologies for lowland lakes of Central Europe and Baltic countries (http://forum.europa.eu.int/Members/jrc/jrc/jrc_eewai/library) – LCB1–LCB3 – and Estonian typology (Mäemets, 1974; Ott & Kõiv, 1999; Nõges & Ott, 2003). They are the following: LCB1 – shallow (mean depth 3–15 m) hard-water lakes; LCB2 – very shallow (mean depth <3 m) hard-water lakes, and LCB3 – shallow (mean depth <15 m) siliceous *Lobelia* lakes. The LCB3 group here includes also several lakes that lost characteristic species during the last 70 years. "Hard water" means that HCO_3^- concentration in the surface layer water is over 80 mg L^{-1}. Owing to the high diversity of Estonian lakes, some additional types should be taken into account: soft-water mixotrophic (SMX) and dystrophic lakes (D), coastal (halotrophic) lakes (H), and alkalitrophic (HCO_3^- > 240 mg L^{-1}) lakes (A). The data for the lakes of unclear type and for reservoirs were joined into the *Varia* (X) group. As in our opinion stratification is more indicative than mean depth, LCB1 lakes were selected on the basis of stratification, which occurs mostly in deeper lakes but in some cases also in lakes with a mean depth of almost 3 m. On the other hand, in this work the LCB2 group contains also some lakes with a mean depth over 3 m but not stratified. As stratification may occur also in lakes of other types, the percentage of stratified lakes was calculated for each coverage and depth group. As a stratification process has started recently in several formerly non-stratified lakes, the situation in the period of macrophyte investigation was taken into account.

The Nordic and Baltic countries are rich in dark-water lakes, so the percentage of lakes with coloured (brownish or orange) water was calculated as well. The "coloured" group in this study is larger than it should be on the basis of the content of yellow substance, ≥7 mg L^{-1} (= light absorbance at 400 nm >4 m^{-1}), defined for dark-water lakes (Nõges & Ott, 2003), and it includes also semi-dystrophic lakes. It is known that lakes with the darkest water (dystrophic and acidotrophic lakes according to Ott & Kõiv, 1999) are naturally very poor in macrophytes, whereas slightly brownish lakes may be among the richest. The values of water characteristics were drawn from the databases of the Centre for Limnology. In all cases the data of surface water in midsummer were used even if more data were available, because the bulk of older hydrochemical data were collected only in midsummer. Estimations of high/good quality of the lakes are valid for the period of macrophyte investigation and are based on the estimations made within the framework of the *Natura 2000* project, characteristics of the catchment area, presence of sensitive species, and/or other available limnological data. The group of strongly disturbed lakes comprises water bodies with markedly changed water regime, high nutrient loading, or pollution. Both groups were selected on the basis of expert opinions.

Overviews of older macrophyte data for the large lakes of Peipsi and Võrtsjärv have been published in several papers and monographs (Mäemets & Mäemets, 2000, 2001; Mäemets, 2002; Feldmann & Mäemets, 2004). In the period 2003–2005 investigations were conducted on ten fixed transects on the Estonian coast of L. Peipsi. In 2004–2005 during Estonian–Russian joint expeditions new data from 17 stations on the Russian side of the lake were collected.

RESULTS

Coverage estimations

In general, the lakes richest in macrophytes are characterized by high abundance of all groups: emergent, floating-leaved, floating, and submerged plants. Submerged plants may prevail only in some halotrophic, alkalitrophic, and other charophyte lakes. Division of the lakes into the coverage groups of 1–10%, 11–20%, 21–30%, etc. is presented in Table 1. As expected, the LCB1 lakes are characterized by the lowest coverage, but due to the presence of relatively large shallow parts in the basins of deep lakes (e.g. L. Saadjärv, L. Verevi), macrophyte beds may occupy a significantly large percentage of the lake's area in some cases. However, coverage higher than 50% is very rare. Oligotrophic soft-water lakes of LCB3 type display a high coverage in the presence of moss polsters, which reach a depth of 8 m or more. In the case of their absence, macrophyte zones are relatively small, and in the course of time moss beds have declined in

Table 1. Distribution of different groups of macrophyte coverage percentage between different lake types

Coverage %	No. of estimations	LCB1, %	LCB2, %	LCB3, %	Soft-water mixotrophic, %	Alkalitrophic, %	Coastal, %	Varia, %	Stratified, %	Coloured, %	% of measurements from lakes of good/high quality	% of measurements from strongly disturbed lakes
1–10	18	28	6	33	0	0	17	17	50	44	50	11
11–20	27	33	22	15	15	0	0	15	56	30	52	11
21–30	18	22	28	22	6	0	6	17	33	50	44	6
31–40	14	29	50	22	0	0	0	0	43	29	50	21
41–50	17	0	41	12	12	6	29	0	0	35	53	6
51–60	7	0	57	14	0	0	14	14	14	29	43	29
61–70	11	0	55	9	0	0	18	18	0	18	18	0
71–80	15	7	40	7	13	0	33	0	7	20	47	7
81–90	17	0	24	12	29	12	12	12	6	35	29	23
91–100	23	0	52	4	13	13	0	17	4	52	39	30

most of these lakes. The LCB2 lakes are represented relatively uniformly in the groups of low and high coverage as this type includes two or more Estonian types. Among them, the highest coverage is characteristic of the extremely shallow overgrowing mixotrophic lakes (L. Endla, L. Laiuse Kivijärv, L. Tõhela). Overgrowing is caused by the lowering of the water level and/or high nutrient loading. The dominating groups are charophytes and tall emergent plants; in the next stages of decline, ceratophyllids, nymphaeids, and lemnids. The LCB2 type includes also rather large (≥1 km^2) non-stratified lakes, relatively poor in plants (coverage 20–30%), with a mean depth of 3–4.5 m (L. Pühajärv, L. Ähijärv). Most of the alkalitrophic and halotrophic lakes (old coastal lagoons) belong to the groups of high coverage owing to large charophyte beds and overgrowing with reeds. However, some coastal lagoons on limestone or with a sandy bottom less than 1 m deep and with a low water exchange may be extremely poor in plants. Coloured water without morphometric characteristics does not seem to be suitable for predicting coverage: very shallow brownish lakes may be among the richest, steep-sloped lakes may be among the poorest in vegetation.

Correlation between macrophyte coverage and water transparency was weak in all cases. As 19 of the 21 estimations of the coverage ≥60% and Secchi depth ≤2.0 m (Fig. 2) belonged to the lakes where emergent or floating-leaved plants were dominating, we excluded these coverage estimations from calculations;

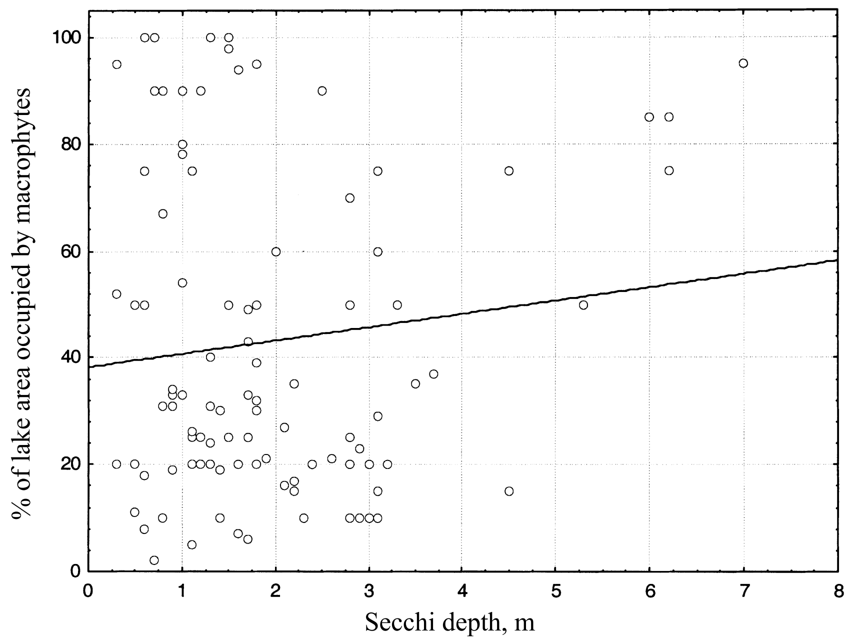

Fig. 2. Total coverage percentage of macrophytes and water transparency (103 estimations and parallel Secchi depth measurements).

however, in this case the weak positive correlation turned into a weak negative correlation. The transparency of one and the same lake of high macrophyte coverage may differ by 1 m in different periods of investigation. In L. Männikjärv, rich in floating-leaved plants and charophytes, Secchi depth was 1.3 m in 1972 and 0.3 m in 1988 at coverages of 100% and 95%, respectively.

Table 2 shows that the lakes classified as having a "high" or a "good" state are distributed quite uniformly among the coverage percentage groups. Thus the total coverage percentage does not seem to be correlative with good quality nor do coverage estimations for strongly disturbed lakes display any trend.

The macrophyte coverage of the two largest lakes, L. Peipsi and L. Võrtsjärv, remains under 20% (Mäemets & Mäemets, 2000; Feldmann & Mäemets, 2004) owing to their large pelagial area and mechanical stress. Despite this, macrophyte areas have increased in both lakes, mainly at the expense of reeds (Mäemets & Freiberg, 2004).

Maximum growth depth of submerged macrophytes

The records of depth limits for different taxa are presented in Table 2. Note that most measurements were made in the 1950s. Distribution of growth depth limits among different lake types is summarized in Table 3, and a general overview is given in Fig. 3. Generally, depth limits are not registered for coastal lagoons owing to their extremely shallow water. As expected, LCB2 lakes are only represented in the depth groups up to 4 m, as their mean depth is generally smaller. In the groups with the largest growth limits, stratified LCB3 lakes are the sole representatives (group >8 m). However, like in the coverage groups, the LCB3 lakes are characterized by the lowest and the highest values also for macrophyte growth depth, which depends mainly on the presence of a moss polster,

Table 2. Records of depth limits for different taxa (Database of the Centre for Limnology)

Taxon	Maximum growth depth, m	Lake, year
Ceratophyllum demersum L.	6.0	Koorküla Valgjärv, 1952
Myriophyllum spicatum L.	6.0	Koorküla Valgjärv, 1952
Potamogeton compressus L	6.0	Koorküla Valgjärv, 1952
Potamogeton lucens L.	5.5	Konsu, 1953; Räätsma, 1954
Potamogeton perfoliatus L.	5.0	Peipsi, 1962
Elodea canadensis Michx.	7.0	Piigandi, 1998
Utricularia vulgaris L.	6.0	Räätsma, 1954
Fontinalis antipyretica Hedw.	8.5	Koorküla Valgjärv, 1955
Rhynchostegium riparioides (Hedw.) Card.	12.0	Nohipalu Valgjärv, 1960
Charophyta, undetermined	6.0	Koorküla Valgjärv, 1952, 1955

Table 3. Distribution of different groups of macrophyte growth depth limits among lake types (percentages of A and H lakes not shown)

Depth limit, m	No. of measurements	LCB1, %	LCB2, %	LCB3, %	Soft-water mixotrophic, %	Varia, %	Stratified, %	Coloured, %	% of measurements from lakes of good/high quality	% of measurements from strongly disturbed lakes
0.0–1.0	11	18	36	9	27	9	18	45	27	63
1.1–1.5	25	20	28	20	16	12	24	24	32	28
1.6–2.0	37	30	41	11	16	3	35	30	41	27
2.1–2.5	24	50	29	13	4	0	63	33	46	33
2.6–3.0	37	32	41	8	5	11	35	8	38	14
3.1–3.5	28	46	32	21	0	0	50	0	46	7
3.6–4.0	30	70	20	13	0	0	70	3	43	20*
4.1–5.0	19	36	0	47	0	11	52	11	63	0
5.1–6.0	14	57	0	36	0	7	86	0	57	0
6.1–8.0	12	17	0	83	0	0	92	8	58	0
>8.0	9	0	0	100	0	0	100	0	67	0

* Lake Verevi after the lowering of the water level.

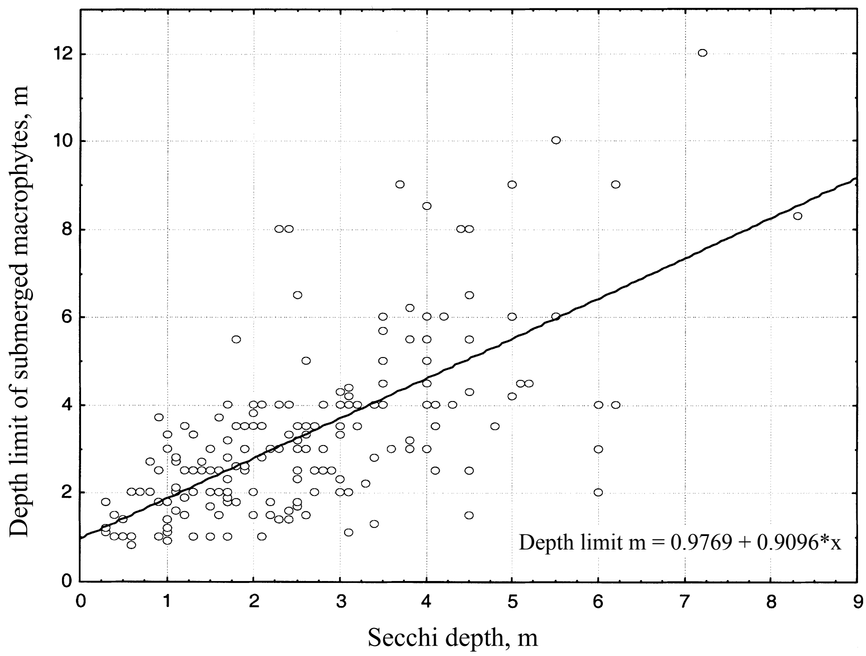

Fig. 3. Water transparency and maximum growth depth of submerged plants in small lakes (202 parallel measurements).

because in Estonian lakes the growth limit is mostly 2 m for *Isoëtes* and 1 m for *Lobelia*. Lakes with coloured water are rare in the groups of depth limit ≥2.6 m. Lakes of good or high status are quite uniformly distributed among the growth depth limit groups, their frequency being somewhat higher in the groups of larger values. Two estimations in the group 3.1–3.5 m (7%) can be ascribed to the eutrophied soft-water lakes of Paidra and Inni while other lakes in this group are not disturbed. Excluding the measurements for L. Verevi from the period after the manipulation of its water level (Table 3), it is evident that significantly disturbed lakes are absent from the depth groups ≥3.6 m. Correlation of growth depth with simultaneously measured Secchi depth is relatively good, 0.68 ($p < 0.001$) (Fig. 4). If two extraordinarily high Chl*a* measurements (hundreds of micrograms per litre) are excluded for the 1.2 m depth limit of submerged plants, the correlation of depth limit with Chl*a* is –0.3276 ($p = 0.017$) (Fig. 4).

According to monitoring data, in L. Peipsi the mean growth limits may differ for different years and lake parts. Figure 5 presents the mean values from the Estonian side of L. Peipsi between Raigla and Tammispää ($n = 7$, the same stations) in 2004 and 2005 and those from the Russian side between Kunest-Bratukhnovo and Sityag ($n = 7$) in 2005. Some results of parallel measurements ($n = 14$) of water transparency in the littoral zone of L. Peipsi and of depth limits of *Potamogeton perfoliatus* L. are presented in Fig. 6. The correlation between these

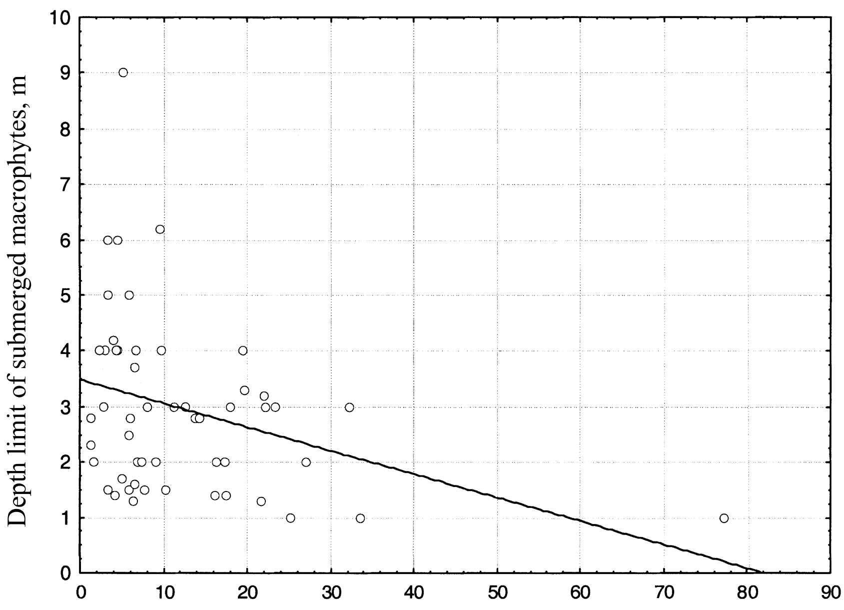

Fig. 4. Chl*a* content of surface water in midsummer and maximum growth depth of submerged plants in small lakes (51 parallel measurements).

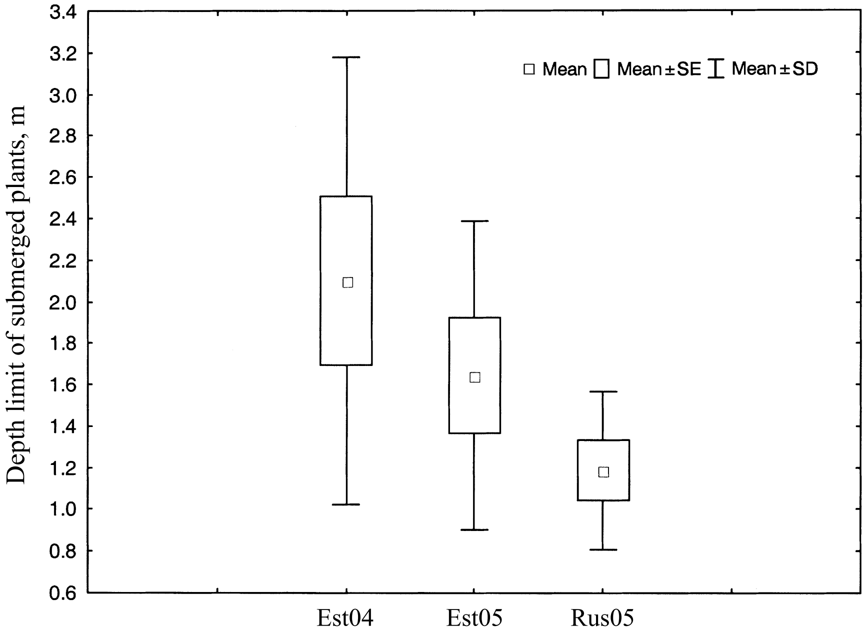

Fig. 5. Mean depth limit of submerged plants (*Potamogeton perfoliatus* L.) in L. Peipsi in different years and different lake parts: Est04 and Est05 – for seven stations at the Estonian coast in 2004 and 2005; Rus05 – for seven stations at the Russian coast in 2005.

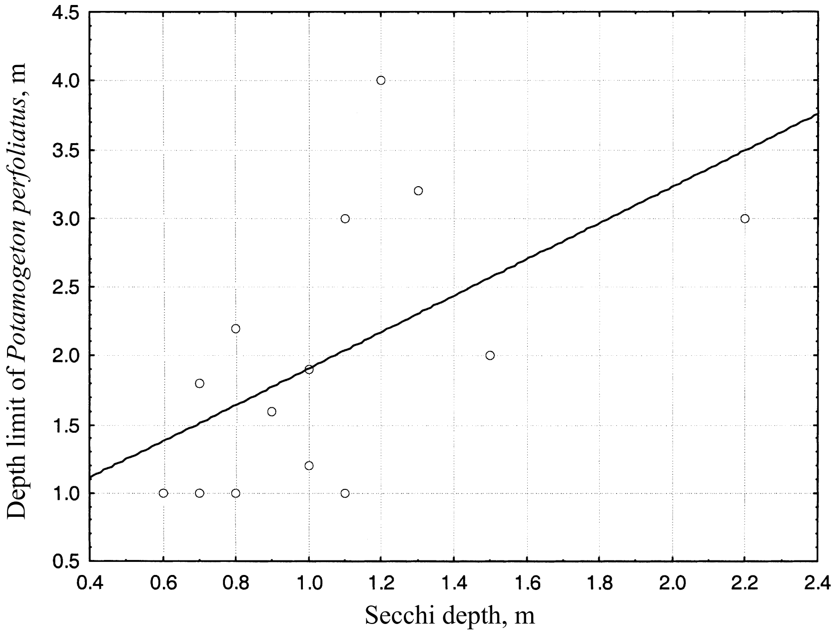

Fig. 6. Water transparency and maximum depth limit of *Potamogeton perfoliatus* L. in different stations of L. Peipsi.

characteristics was weaker than in small lakes, 0.5604 ($p = 0.037$). The contrast between the average of limit values of L. Peipsi and single maximum values of the growth depth is remarkable. Data on L. Peipsi suggest that for large lakes the mean value of growth limit may be more suitable for the classification than single records.

DISCUSSION

The differences between the coverage estimations in our dataset (total coverage %) and the abundance data used by Portelje (2006) (abundance of submerged plants) make the results not well comparable. Our results suggest a low indicative value of the coverage percentage for the estimation of the status of the lakes. For the LCB1 lakes this characteristic has definite limits, 1–40% (Table 1). Division of the heterogeneous group of LCB2 lakes into coverage groups does not support quality classification. For the LCB3 lakes, low coverage may indicate a decline in mosses and a disturbed state for deeper lakes; however, some larger shallow LCB3 lakes seem to be naturally poor in mosses (L. Tänavjärv). It is very likely that the reason is the sensitivity of mosses to mechanical stress. The irrelevance of coverage in distinguishing lakes according to status is also related to a too general understanding of the good status, defined mainly by low density of human population and prevalence of natural areas in the catchment. However, a 100 years ago water lowering or flax retting may have taken place, determining the whole further development of some "reference" lakes. Water lowering increases total macrophyte coverage in most lakes, while nutrient loading has a similar effect mainly on hard-water lakes. In the case of submerged plants, especially charophytes, also the nutrient loading should be interpreted more exactly than is presently done. Although the correlation between an increase in charophyte stands and a good state of very shallow hard-water lakes has been studied intensively and verified (Scheffer, 1998; Berg, 1999), the problem of how indicative charophytes are for the non-impacted state is not solved in all aspects. The sensitivity of charophytes to phosphorus-rich water is well known (Forsberg, 1964, 1965; Krause, 1981, 1997; Schmieder, 1998; Berg, 1999; Sviridenko, 2000). Less is known about their relationship with nitrogen content. Being close to green algae in systematics, charophytes may be favoured by nitrogen (Krause, 1997; Lee, 1999). For example, in two LCB2 lakes of Päidla, located near cattle-breeding farms, charophytes are spreading rapidly and have suppressed such rare species as *Najas flexilis* (Willd.) Rostk. et W. L. E. Schmidt. Moreover, in water bodies of high alkalinity, phosphorus may be retained in a complex with Ca compounds. These lakes are clear and charophyte-rich at high nitrogen loading (e.g. alkalitrophic lakes of Pandivere).

The depth limit of submerged plants appears to be a better characteristic of the lake's state than total coverage percentage and it is relatively well correlated with transparency, less with Chl*a* content. The relationship between Chl*a* and transparency can be modified by turbidity caused by humic substances and detritus (discussed also by Phillips, 2006). Besides, different groups of phytoplankton are responsible for differences in transparency at the same Chl*a* level (R. Laugaste, pers. comm.). It is highly probable that macrophytes depend more on the environmental conditions in the previous summer or at the beginning of the vegetation period (Rooney & Kalff, 2000; Mäemets et al., 2006) than on water conditions at the time of measurement. Algal blooms and transparency of water are relatively variable during the vegetation period. The data on L. Peipsi seem to support this supposition, displaying different depth limits at low water transparency during the midsummer investigation period (Fig. 6).

The growth depth limit ≥3.6 m coincides with the boundary of the high/good status for LCB1 lakes, proposed by Phillips (2006), and may be suitable for the classification of stratified hard-water lakes of high status. High growth depth values for hypertrophic strongly stratified L. Verevi after a short-term water lowering and the following restoration suggest that all other characteristics as well as background data should be taken into account in classification. Yet, aeration and mineralization of lake sediments did improve the state of L. Verevi for some years (Mäemets & Freiberg, 2005). The boundary of the good/moderate status, 2.8 m for submerged plants in LCB1 lakes and 2.0 m in LCB2 lakes according to Phillips (2006), may not require setting different values for different types. Generally, strongly disturbed hard-water lakes with a growth depth limit of 3 m are very rare; moreover, for some formerly fertilized LCB2 lakes macrophytes may reach a depth of 2.8 m (L. Köstrejärv in 2005). The classification based on growth depth limits should take into account the species growing at the maximum depth. *Ceratophyllum demersum*, abundantly present in nitrogen-rich lakes (Schmieder, 1998), may reach considerable depths in both LCB1 and LCB2 lakes. For LCB3 lakes, rich in moss, the growth depth limit for the boundary of good/moderate status may be at 6 m, and for the high/good boundary at 8 m, as suggested by the data on L. Nohipalu Valgjärv and L. Kurtna Valgejärv over decades (database of the Centre for Limnology). The problem of the natural inter-annual variability of growth depth limits should be solved for a more exact setting of class limits. For small lakes only a few relevant data are available. Monitored stations of L. Peipsi displayed differences in depth limits between the years. Thus variability may influence the estimation of lake quality.

Definition of the potential area of colonization depends on the value of depth limit considered as characteristic (expected) for the lake in question. The definition of this area using the depth limit in the observation period (Valta-Hulkkonen et al., 2005) is questionable. In larger lakes where strong mechanical stress on macrophytes causes much lesser colonization (Feldmann & Mäemets, 2004) or at strong anthropogenic disturbances the deviation of the depth limit from the average, characteristic for this lake type, may be great. It seems to be most reasonable to define potential colonization area considering the average depth limit for the lake type and plant group (emergent, floating-leaved, and submerged) in undisturbed lakes. Our results reveal that in LCB1 lakes the expected colonization area may be restricted with 40%.

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Appendix 1. Investigated water bodies and the number of observation years. Types of water bodies: A – alkalitrophic; H – halotrophic; LCB1 – hard-water lakes, mean depth >3 m; LCB2 – hard-water lakes, mean depth <3 m; LCB3 – soft-water lakes; SMX – soft-water mixotrophic lakes; D – dystrophic lakes; X – reservoirs and lakes of unknown type

Lake name	Lake type	Years
Ainja Sinejärv	A	1
Äntu Linaleojärv	A	1
Äntu Roheline	A	1
Äntu Sinijärv	A	2
Äntu Valgejärv	A	1
Käomardi	H	1
Kellamäe Mustjärv	D	1
Kiissalaht	H	1
Kiljatu	H	1
Koigi	H	1
Kooru	H	1
Laialepa	H	1
Linnulaht	H	1
Nonni	H	1
Põldealune	H	1
Sarapiku	H	1
Sutlepa	H	1
Suurlaht	H	1
Tammelais	H	1
Veskilais	H	1
Viinistu Maalaht	H	1
Vöölameri	H	1
Agali	LCB1	2
Holstre	LCB1	1
Jäneda Kalijärv	LCB1	2
Jänukjärv	LCB1	1
Jõksi	LCB1	4
Kaasjärv	LCB1	1
Kahrila	LCB1	1
Karijärv	LCB1	3
Karula	LCB1	1
Kaussjärv	LCB1	1
Kiruvere	LCB1	2
Konsu	LCB1	1
Kooraste Kõverjärv	LCB1	2
Kooraste Suurjärv	LCB1	1
Kriimani	LCB1	1
Kuningvere	LCB1	1
Kuremaa	LCB1	2
Lasva Kalijärv	LCB1	2
Liivakraavi	LCB1	1
Lõõdla	LCB1	1
Mäetilga	LCB1	1
Majori järv	LCB1	1
Neeruti Tagajärv	LCB1	2
Nõuni	LCB1	4
Otepää Pikajärv	LCB1	1
Päidla Kõverjärv	LCB1	1
Pangodi	LCB1	2
Pappjärv	LCB1	4
Pindi Kärnjärv	LCB1	1
Räätsma	LCB1	2
Riiska	LCB1	1
Rõika	LCB1	2
Rõuge Suurjärv	LCB1	7
Rõuge Valgjärv	LCB1	2

Appendix 1. *Continued*

Lake name	Lake type	Years	Lake name	Lake type	Years
Ruusmäe	LCB1	1	Köstrejärv	LCB2	3
Saadjärv	LCB1	5	Kurtna Nõmmejärv	LCB2	1
Tillijärv	LCB1	1	Kurtna Suurjärv	LCB2	1
Tornijärv	LCB1	1	Küünimõtsa	LCB2	1
Tõugjärv	LCB1	1	Laiuse Kivijärv	LCB2	1
Tuuljärv	LCB1	1	Leegu	LCB2	1
Tündre	LCB1	4	Lepaauk	LCB2	1
Uhtjärv	LCB1	1	Maardu	LCB2	1
Uiakatsi	LCB1	2	Mäeküla	LCB2	1
Vagula	LCB1	2	Männikjärv	LCB2	2
Väinjärv	LCB1	1	Misso Palujärv	LCB2	1
Vasula	LCB1	1	Mõrtsuka	LCB2	1
Verevi	LCB1	8	Murati	LCB2	1
Verijärv	LCB1	3	Muti	LCB2	1
Viisjaagu	LCB1	2	Neeruti Eesjärv	LCB2	2
Viljandi	LCB1	1	Neeruti Orajärv	LCB2	1
Aheru	LCB2	2	Neitsijärv	LCB2	1
Ähijärv	LCB2	1	Noodasjärv	LCB2	1
Allikajärv, Kurtna	LCB2	1	Nõo Karujärv	LCB2	2
Aravuse	LCB2	1	Nõva Allikajärv	LCB2	2
Arbi	LCB2	1	Nüpli	LCB2	2
Elistvere	LCB2	1	Õisu	LCB2	1
Endla	LCB2	2	Ojajärv	LCB2	1
Harku	LCB2	4	Otepää Valgjärv	LCB2	1
Haugjärv	LCB2	1	Päästjärv	LCB2	1
Illi Suur	LCB2	2	Päidla Mõisajärv	LCB2	1
Illi Väike	LCB2	2	Päidla Suurjärv	LCB2	3
Ilmjärv	LCB2	1	Pautsjärv	LCB2	1
Jaanuse	LCB2	1	Peen-Kirjakjärv	LCB2	1
Jõemõisa (& Papijärv)	LCB2	1	Peresi Umbjärv	LCB2	1
Jussi Veinjärv	LCB2	1	Pühajärv	LCB2	3
Kaarepere Pikkjärv	LCB2	1	Pupastvere Umbjärv	LCB2	2
Kääriku	LCB2	1	Puustusjärv	LCB2	1
Kaarna	LCB2	3	Raadi	LCB2	1
Kaiavere	LCB2	1	Rääkjärv	LCB2	1
Kaisma	LCB2	1	Räbijärv	LCB2	1
Kaiu	LCB2	1	Raigastvere	LCB2	1
Kalli	LCB2	1	Rebasejärv	LCB2	1
Kastjärv	LCB2	1	Ruhijärv	LCB2	2
Keeri	LCB2	2	Saare	LCB2	1
Kodijärv	LCB2	1	Soitsjärv	LCB2	1
Köödre	LCB2	1	Tamula	LCB2	2

Appendix 1. *Continued*

Lake name	Lake type	Years	Lake name	Lake type	Years
Tõhela	LCB2	2	Holstre Linajärv	S	1
Uuri	LCB2	1	Inni	S	3
Vahejärv	LCB2	1	Kogrejärv Kaika	S	1
Väimela Alajärv	LCB2	1	Kooraste Linajärv	S	1
Väimela Mäejärv	LCB2	1	Mäha järv	S	1
Vasavere Mustjärv	LCB2	1	Partsi Kõrtsijärv	S	2
Veisjärv	LCB2	3	Suur Pehmejärv	S	1
Viss	LCB2	1	Hindaste	SMX	1
Aegviidu Ahvenajärv	LCB3	1	Kahala	SMX	2
Aegviidu Sisalikujärv	LCB3	1	Käsmu	SMX	1
Aegviidu Vahejärv	LCB3	1	Listaku Soojärv	SMX	1
Ahnejärv	LCB3	2	Metsküla	SMX	1
Ännijärv	LCB3	1	Orava Mustjärv	SMX	1
Hino	LCB3	2	Parika	SMX	2
Ihamaru Palojärv	LCB3	1	Põldaluse	SMX	1
Jussi Linajärv	LCB3	2	Puhatu	SMX	1
Kavadi Mäejärv	LCB3	1	Pumbuta	SMX	1
Kirikumäe	LCB3	1	Tihu Keskmine	SMX	1
Kise	LCB3	1	Tihu Kolmas	SMX	2
Koorküla Valgjärv	LCB3	4	Turvaste Mustjärv	SMX	1
Kurtna Liivjärv	LCB3	2	Ubajärv	SMX	1
Kurtna Suur Linajärv	LCB3	1	Valguta Mustjärv	SMX	1
Kurtna Väike Linajärv	LCB3	1	Alevi	X	1
Kurtna Valgejärv	LCB3	2	Järva-Jaani reservoir	X	1
Lohja	LCB3	1	Karksi reservoir	X	3
Mähuste järv	LCB3	3	Karujärv, Saaremaa	X	3
Martiska järv	LCB3	2	Kaunissaare reservoir	X	1
Metstoa Ümerikjärv	LCB3	2	Kogrejärv, Ähijärve	X	1
Nikerjärv	LCB3	1	Linnajärv	X	1
Nohipalu Valgjärv	LCB3	10	Peräjärv	X	1
Pabra järv	LCB3	1	Pikane	X	1
Paidra	LCB3	1	Põlva reservoir	X	1
Paukjärv	LCB3	2	Pormeistri	X	1
Piigandi järv	LCB3	5	Raudjärv	X	1
Põrste	LCB3	1	Rõõsa	X	2
Tänavjärv	LCB3	1	Rummu	X	1
Udsu	LCB3	2	Ruskavere Nõmmejärv	X	1
Uljaste	LCB3	2			
Väike Palkna	LCB3	5	Sillamäe reservoir	X	1
Vaskna	LCB3	3	Soodla reservoir	X	1
Veskijärv	LCB3	1	Tammelehe	X	1
Viitna Pikkjärv	LCB3	6	Väike-Virna (2.)	X	1

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Suurtaimestiku katvus ja sügavuspiir järvede klassifitseerimise vahenditena

Helle Mäemets ja Lilian Freiberg

Suurtaimestiku kõigi rühmade poolt hõivatud järveosa (%) ja veesiseste taimede sügavuspiiri põhjal on jagatud klassidesse 146 erinevat tüüpi väikejärve, et selgitada kahe nimetatud näitaja seost järvetüübi ja kvaliteediga (seisundiga). Kalgiveelistes kihistunud järvedes on katvus kuni 40%, mis ei seostu aga vee läbipaistvusega. Suur katvus võib olla omane nii heas seisundis kui ka tugevasti mõjutatud järvedele. Selgem on veesiseste taimede levikupiiri korrelatsioon järvetüübiga, kalgiveeliste väikejärvede seisundiga ja vee läbipaistvusega, vähem vee klorofüllisisaldusega. Peipsi iga-aastased andmed järve eri osadest näitavad maksimaalse kasvusügavuse muutlikkust ajas ja ruumis, samuti selle väiksemat korreleeruvust vee läbipaistvusega. Veesiseste taimede sügavuspiiri väärtus 3,6 m sobib kihistunud kalgiveeliste järvede hea ja väga hea seisundi piiriks, kõigi kalgiveeliste järvede hea ja kesise seisundi piir võiks olla 2,8–3 m. Sügavamad pehmeveelised vähetoitelised järved jagunevad nii taimestiku katvuse kui ka sügavuspiiri järgi sõltuvalt sammalde olemasolust või hävimisest ja sammalde esinemise puhul võiksid nimetatud näitajad klassifitseerimist toetada.