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# New approaches to integrated quality assessment of lakeshores

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## Abstract

The EU Water Framework Directive (WFD) requires the ecological assessment of water bodies. Since the littoral zones and the lakeshores are part of lakes as water bodies as defined by the WFD, a new scheme for ecological quality assessment of lakeshores should be established. It is proposed that this scheme should go beyond the formal requirements of the WFD, as it includes aspects of nature conservancy, landscape protection, and regional planning and development. Some of these aspects are subject to other EU legislation (e.g. Habitats Directive) and some are subject to national legislation. Ten general Quality Elements (QEs) are proposed, which can be refined and reified through several levels of detail, depending on the specific aims of a study. A list of eleven topics, which should be discussed in the establishment of the lakeshore quality assessment scheme, is given. The more complex ones are the implementation of other EU legislation, the definition of lakeshore types and reference conditions, the stipulation of best aggregation procedures, and a better understanding of the significance of hydrological and morphological impacts on the biota.

**Key words:** European Water Framework Directive – WFD – European Habitats Directive – Lake Habitat Survey – hydromorphology – littoral

## Introduction

Europe is rich in lakes: it contains approximately 500,000 natural lakes of more than 0.01 km² (Kristiansen & Hansen 1994). Most of them are in the formerly glaciated areas of Northern and Eastern Europe and in the alpine landscapes and their surroundings. Germany, for example, has at least 13,076 standing water bodies that have a surface area of more than 0.01 km². The larger ones (i.e. 877 lakes > 0.50 km², out of which 400–500 are natural) are going to be included in quality assessment and management programmes, in accordance with the European Water Framework Directive (WFD) (Nixdorf et al. 2003; M. Hemm, pers. comm.). The exact length and surface area of lakeshore and littoral habitats is unknown (for a definition of the term 'lakeshore' see Appendix, p. 166). However, rough estimation shows that the total length of shorelines in Germany is in the order of magnitude of 10,000 to 100,000 km, covering some 1000 km² of lakeshore habitats (Ostendorp et al., subm.). This points to the fact that lakeshore habitats and ecosystems are of significant importance, not only because of their expanse, but also because they are ecotones between land and water, which attract many kinds of wildlife, economical, cultural and recreational uses and human settlement. In Central Europe many large lakes are situated in densely settled areas so that the interests of many parties overlap in the lakeshore zone. They interact and compete with each other for space, money and political influence. Presently, it seems that there are almost no integrated concepts for the role of lakeshores in nature conservancy, water

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protection and management, landscape ecology and regional planning, their role as a background for the prosperity or underdevelopment of a region and in supporting traditional economies and social structures. There is a poor understanding about how to assess the present ecological status of a lakeshore section, the pressures and impacts on it, and about how to protect, manage and develop lakeshore landscapes in a sustainable way. This paper concisely summarises the current methodology and concepts of lakeshore quality assessment. It focuses on larger lakes in the more densely settled areas of Central Europe.

## Lakeshores in the European Water Framework Directive (WFD)

The WFD (Directive 2000/60/EC from 22 Dec 2000) can be regarded as the most significant legislative instrument in the water field on an international basis that had ever been set up in the EU. It moves towards an integrated assessment of status, protection and management of water bodies in the EU, including lakes and their shore zones (CHAVE 2001). As a framework document, the WFD outlines principal concepts for the definition and classification of water bodies, the assessment of their ecological status, how to reach the "good" status for all natural water bodies in the EU by management plans and programmes of measures, and monitoring obligations. These concepts need further reification, which is being done in the EU by the COMMON IMPLEMENTATION STRATEGY (CIS) and by the Comité Européen des Normanisation (CEN) in co-operation with the standard organisations in the Member States. With regard to the lakeshore zone the *Horizontal Guidance Document on the Role of Wetlands in the Framework Directive* (CIS WETLANDS WG 2003) seems to be the most important document. It refers to Article I a of the WFD in which "wetlands directly depending on the aquatic ecosystems" of inland surface water bodies are explicitly mentioned. Lakeshore ecosystems on both sides of the mean water line are commonly subsumed under 'wetlands', that is as habitats which are 'developed within a hydrological gradient going from terrestrial to mainly aquatic habitats' (i.e. lakeshore ecotones) and which 'depend on a constant or periodic shallow inundation by fresh, brackish or saline water, or saturation at or near the surface of the substrate', and whose common features are 'standing or slowly moving waters, hydric soils, hydrophilous and hygrophilous vegetation and fauna' (definition from the CIS WETLANDS WG 2003 document, p. 6). However, the WFD does not set environmental objectives for wetlands (including lakeshores), and so the Water Directors of Member States during their meeting in Copenhagen, Nov. 2002 complemented that human pressures on wetlands may result in impacts on the ecological status of water bodies, so that wetlands management should be considered as a part of river basin management plans. The enhancement of wetlands may be among the tools for helping to achieve the environmental objectives of the WFD. The CIS WETLANDS WG (2003) document summarises and interprets other CIS documents and it clearly points out that lakeshores are 'associated' wetlands in the sense of the WFD, and that they are part of the lake since they are directly influencing the status of the related lake. As a consequence, many of the WFD environmental objectives and obligations to surfaces waters also apply to lakeshores (CIS WETLANDS WG 2003, p.10, 13). This broad view has not only been adopted by the CEN Technical Committee 230/WG 2 "Water Analysis", but also by Member State organisations and by some non-Member States (e.g. Switzerland). Documents on common understanding and standardization of terms and sampling and evaluation methods which are targeted at experts and stakeholders have been or are currently being developed for benthic algae, macrophyte vegetation, macroinvertebrates, fish, and the hydromorphology of lakeshores.

Evidently, current debate on practical lakeshore ecology, protection, development and restoration is driven by the tight schedule EU Member States have in which to meet their obligations to the WFD. However, this view is too narrow, since other important elements of EU and national legislation (e.g. Natural Habitats and Wild Birds Directives [92/43/EEC, 79/409/EEC], Natura 2000 network, national regulations on nature conservancy, landscape protection and regional planning) should also be implemented. Furthermore, aspects of cultural heritage (e.g. remains of neolithic and bronze age pile dwellings) and aspects of traditional scenery and care and protection of monuments have to be considered. Hence, the CIS WETLANDS WG (2003) document (and other related documents) admit that the recommendations they give go beyond the legal requirements of the WFD.

## Pressures and impacts on lakeshores

Many shorelines, especially in the more densely settled areas of central Europe, are strongly influenced by diverse human activities. Indirect impacts may come from air pollution. Direct impacts come from sewage loaded inflows and from diffuse seepage, from lake level manipulation, from landside onslaught of traffic and waterside cruise ships and leisure boats, and from structural modification and constructions on both sides of the mean water line (OSTENDORP et al., subm.). Furthermore, indirect effects may arise from the selective exploitation of fish populations, and from the active introduction or

immigration of alien species as a consequence of transcatchment shipping traffic (KINZELBACH 1995; KOWARIK, 2003). An increase in human population and urban land use together with water-bound tourism facilities and road and railway lines along the shore zone complicate the migration of animal populations and may impede ground water exchange between the immediate catchment and the lake. Urbanization of lakeshore zones may lead to a rapid change in social structure and traditional economies.

Preliminary lists of human activities, pressures and impacts on the lakeshore zone have been published by BRAGG et al. (2003) and OSTENDORP et al. (subm.). However, there is no sound knowledge about the relation between certain pressures and impacts and the reaction of the biota in the lakeshore zone.

## The use and the requirements of a lakeshore quality assessment scheme

The quality assessment of landscape sections like lakeshores is a bold enterprise, since the outcome depends on many factors, including the social consensus about what is valuable, and what is not, which may vary according to political circumstances and economic pressures. Concepts that attempt to conserve the landscape at least in its present state often compete with ideas of rapid economic development in favour of welfare of residents and of interests of shareholders. The intentions of nature conservancy, the protection of the natural beauty of the landscape, the care of historical heritage, and the idea of wise use and sustainability may be more difficult to put across to the public than the imperative of water protection, since water quality and water prices are crucial factors in the private and industrial establishment's economy. The WFD promotes sustainable water use based on the long-term protection of available water resources. The concept of sustainability in the context of water management comprises the dictate that "we should leave a world for the generations to come, which allows them the realization of their requirements not less as to the same extent as it is the case for the present generation" (KAHLENBORN & KRAEMER 1999; translation by the author). One may argue that sustainability is best achieved when the water body (including its lakeshore or riparian zones) is in a more or less natural state indicated by a near-natural composition and abundance of the biota. Evidently, the WFD supports this idea.

Prior to the development of an assessment scheme, one may ask for what purposes this scheme should be helpful and applicable. In a conflict setting of diverse stakeholder groups the scheme may subserve to some strategic targets, e.g.

- estimation of consequences from uses;
- risk prediction of accumulating burdens;
- identification of conflicting aims;
- transparence of (implicit) evaluations and assessments;
- increasing impartiality of consideration processes;
- increasing public acceptance.

There are also some more practical reasons for a detailed and sound assessment scheme, e.g.

- regulatory consolidation of different uses;
- enforcement of restrictions by convincing argument and defense against usage claims;
- optimisation of resource utilization;
- optimisation of habitat, species and object protection (including restoration);
- structuring of observation and monitoring projects.

## Quality elements of the WFD related to the lakeshore zone

The central objective of the WFD is to achieve a 'good' status for natural water bodies, for instance for lakes together with their associated lakeshore wetlands throughout all Member States, which is less than the 'high' status, but better than the 'moderate', the 'poor' and the 'bad' status. The assessment of the present status of a water body is done by comparing the measured data of a set of given quality elements (QEs) with the value these QEs have under type specific reference condition. The reference condition of a specified type of lake, is materialized in a lake (or a group of lakes) where there are (nearly) no human influences of any kind, and which is accordingly of 'high' status. This concept of ecological quality assessment of water bodies has the USEPA *Lake and Reservoir Bioassessment and Biocriteria* concept (USEPA 1998) as a precedent and prototype. Here, the methods and protocols are elaborated in full detail.

The QEs which are related, at least to some extent, to lakeshores are (WFD, Appendix V, 1.1.2):

- the structure of the lakeshore,
- hydrological regime supporting the biological elements (level, connection to ground water),
- morphological conditions supporting the biological elements (lake depth variation, quantity and structure of the substrate, structure and condition of the lakeshore zone),
- the fish fauna (species composition, abundance, age structure, presence of type-specific sensitive species),
- the benthic invertebrate fauna (taxonomic composition and abundance, ratio of disturbance sensitive to insensitive species, level of diversity), and
- the macrophytes and the phytobenthos (taxonomic composition, abundance).

Again, these general terms need further characterisation, which is being done in the CIS WETLANDS WG (2003) document, and during the standardization process in the CEN TC230/WG2.

## Quality Elements of an Integrated Lakeshore Quality Assessment (IQuALS)

The set of QEs listed in the WFD does not fit the special conditions of the lakeshore zone very well. It should be reformulated with the inclusion of more components, which, in part, are far beyond the legal requirements of the WFD. On the basis of a holistic understanding of lakeshore processes and impairment, the ten main quality elements are proposed

- QE 1: land use, settlement, traffic in the lakeshore region;
- QE 2: proportion of strictly enforced (nature) conservation areas in the lakeshore region;
- QE 3: forms and intensities of human activities in the lakeshore zone;
- QE 4: topographical transect integrity;
- QE 5: structure – dynamics – relation;
- QE 6: hydrochemical conditions (e.g. trophic status);
- QE 7: species, biocoenoses, community structures, ecosystem functions;
- QE 8: sociocultural importance;
- QE 9: character and uniqueness of the landscape;
- QE 10: criteria of equal distribution and representativity for the lake and for the landscape.

Some of these QEs are close to the requirements of the WFD, e.g. QEs 3, 4, 6 and 7, and QE 5 may also be included. These QEs may be used in an integrated way or they may be refined as it is shown for the QE 3:

- QE 3.1 interference and human disturbances;
- QE 3.2 immissions, pollution, hazardous substances;
- QE 3.3 lake hydrology;
- QE 3.4 lakeshore morphology, etc.

The QEs 3.3 and 3.4 are to a large extent congruent with quality element 'hydromorphology' in the WFD (some elements like residence time are not considered here). If necessary each of these QEs may be differentiated to greater details, like

- QE 3.4.1 shape of the shoreline;
- QE 3.4.2 cross-shore relief, from m.w.l. to the shelf break;
- QE 3.4.3 cross-shore relief, from m.w.l. up to landside border;
- QE 3.4.4 substrate quality (e.g. grain size);
- QE 3.4.5 cross-shore fixtures, below m.w.l.;
- QE 3.4.6 shore parallel fixtures below m.w.l.;
- QE 3.4.7 buildings, ground sealing of areas and other uses above m.w.l., etc.

Again, the QEs on this level can be refined e.g. in the following way

- QC 3.4.7.1 uses without buildings and ground sealing;
- QC 3.4.7.2 ground sealing of areas without buildings;
- QC 3.4.7.3 constructions, $< 20 \times 20$ m (footprint) ;
- QC 3.4.7.4 constructions, $> 20 \times 20$ m (footprint), etc.

The basic ideas of this design of lakeshore quality assessment are

- encompassing a wider range of 'qualities' from different stakeholder viewpoints than it is required by the WFD,
- high flexibility along a hierarchy of target orientated levels of detail from a very broad view (for a general report on large areas) to a very detailed view (for very specific objectives),
- reflectance of significant pressures in the list of QEs in completion to the pure empirical data,
- downward compatibility over several levels of detail, and upward compatibility during the process of aggregation of single assessment scores toward a condensed and integrated assessment.

## Elements of a desktop design of an assessment scheme

Meanwhile, a lot of knowledge has been accumulated about how to design an assessment scheme on the desktop, so that new und extensive practical experiences about how to do this, and how to operate the scheme later on in the field are not necessary in this first stage. A large part of this knowledge comes from the multimetric approach for the assessment of rivers and lakes, used by the U.S. Environmental Protection Agency (e.g. USEPA 1998), and by several Federal State Environment Agencies and from experiences of scientists, consultants and practical experts who put these schemes to the test. In Europe it also comes from national approaches to hydromorphology of rivers (e.g. FRIEDRICH & LACOMBE 1992; BOBBE et al. 1993; ZUMBROICH et al. 1998; LUA 1998; LAWA 1999a, 1999b in Germany; WERTH 1987 in Austria, and BUWAL 1998a; 1998b in Switzerland, and RAVEN et al. 2000, WRIGHT et al. 2000, ENVIRONMENT AGENCY 2003 in the UK). Many of these national approaches were collected and concisely summarized by the CEN TC230/WG2.

A desktop design of an assessment scheme and protocol should consider at least the following points

- Implementation of other EU legislation and flexibility towards national legislation: the WFD postulates in Annex IV that other EU legislation must be implemented, out of which the Natural Habitats Directive (92/43/EEC) with the Natura 2000 network may be of highest importance for the lakeshore zone. The system should be downwards compatible with the (implicite) assessment schemes of these Directives, but also flexible enough to allow implementation of legislation and practice in Member States.
- Completeness, flexibility and compatibility: the full list of quality descriptors should reflect all relevant pressures and impacts in great detail. Some descriptors may be treated as obligatory in all cases, and others may be facultative depending on lakeshore type, special task, available resources and reasonable effort. In practice it should be possible to select those descriptors which are relevant to an individual case. However, the system of descriptors should be organised in such way that rough and general views are compatible with a very detailed view, which considers only a limited array of descriptors.
- Lakeshore types: since *type specific* reference conditions are needed according to the WFD different types of lakes generally bring about different types of lakeshores in terms of cross-shore profile, substrate and vegetation. A given lake normally has more than one type of lakeshore, but a given type of lakeshore may be present in different lake types.
- Description of reference conditions: the reference conditions may be based empirically on whole lakes or selected type specific lakeshore sections at which the absence of human impact can clearly be seen, or may be based on models. In the case of lakeshores historical descriptions, paintings and photos may help in the development of such conceptual models. It has to be decided whether the whole range of quality descriptors must be in the reference condition or whether it is sufficient to look at single descriptors out of which some are in the reference condition, and others are not. For instance, can a lakeshore section with a completely unaffected profile and substrate serve as a reference site, even if it is situated in a heavily eutrophied lake?
- Measures of significance of impacts: impacts on biota in the lakeshore zone can be regarded using two aspects: the specific impact, i.e. the impact per unit (e.g. the impact of 1 km of artificial shore embankment), and the abundance, frequency or extension of such impacts (e.g. the total length of such shore embankments). It may be difficult to quantify the specific impact, but experts may be able to rank lists of impacts according to their significance for the biota.
- Relevance of hydromorphological descriptors for the biota: in contrast to the significance of some hydrochemical descriptors on the biota in the lakeshore zone we have a very poor understanding of the effects of hydrological changes and morphological modification of the shore on the biota.
- Aggregation procedure (many descriptors, one shore section): if a broad array of descriptors are used in quality assessment it is necessary to aggregate single assessment scores to scores on a higher level so that finally only one score is yielded for a given lakeshore section. It is clear that the final result – and it is this *final* result in which stakeholders are often most interested – clearly depends on the procedure and algorithm used. In principle there are three basic types, (i) univariate methods which use means and standard deviation or similar central and dispersion values (see e.g. USEPA 1998), (ii) multivariate methods often using some kind of factor analysis methods, which consider the mutual dependence and partial correlation among descriptors, (iii) algorithms which rely to a large degree on collected expert knowledge about the specific significance and ranking of single impacts (e.g. LAWA 1999a; 1999b; Brüggemann et al. 2001; 2004).
- Survey units and aggregation of scores along survey units: survey units along the total shore line of a water body may be arranged in different ways. The total shoreline is intersected in sections of a given length (e.g. 100 m, 1 km), and (i) all sections, or (ii) a set of selected sections are surveyed. This selection process may be random (each section has the same chance to be selected) or stratified (e.g. every fifth section is selected) or made by a stratified random procedure (e.g. each lakeshore type is presented by a given number of randomly selected sections). The scores of individual shore sections must be aggregated to give finally a single score for one water body as required by the WFD.
- Initiation of the intercalibration process: the WFD requires an intercalibration (Annex V, 1.4.1) to assure that the results of ecological assessment of water bodies (including lakeshores) are comparable among Member States. The focus is on the boundaries between the 'high'/'good' and the 'good'/'moderate' status. The *Guidance on Establishment of the Intercalibration Network and on the Process of the Intercalibration Exercise* (CIS WG2.5 2002) describes how this can be done. The essentials of this guidance should be applied to the lakeshore quality assessment.
- Initiating supplementary research: with regard to the present knowledge it is likely that many questions remain open, especially the relation between a given hydrological or morphological impact of a given magnitude and the reaction of the biota. Here, further research is required in order to achieve meaningful re-

sults, since the focus of the WFD ecological assessment scheme is on the biota.

- Quality assurance, basic and continued training of experts, circulation of ideas, scientific results and data: quality assurance is a challenge on several levels. First, it must be assured that the same impact in the field is assessed in the same way by different persons in different Member States. Second, the aggregation procedures must be checked for bias and for robustness against errors arising during fieldwork or errors that come from the exclusion/inclusion of single descriptors. A training network may be helpful to achieve a common understanding of this matter among experts. Guidelines with verbal descriptions, examples and simply a collection of drawings and pictures of impacts of different kinds and of graded significance will elucidate the way in which an assessment should be done (e.g. BUWAL 1998b; LUA 1998). An internet network (website, mailing lists) may be established to collect and distribute new scientific results and new experiences in this field.

## Synthesis

The current discussion about lakeshore quality assessment and the adverse impacts that certain human pressures may have on the integrity of lakeshore ecosystems is dominated by the EU Water Framework Directive (WFD). The WFD and the CIS Horizontal Guidance documents do not specifically deal with the special conditions in the lakeshore zone as a transitional complex of habitats which is directly influenced by man, and in which many stakeholder interests and conflicts overlap.

Hence, it is proposed that a lakeshore quality assessment scheme should focus also on aspects like nature conservancy and regional planning and development. Ten general Quality Elements (QEs) are given. These can be refined and reified through several levels of detail, depending on the specific aims of a study. However, current understanding concerning what many of these QEs mean to the lakeshore biota is poor. On the other hand, ecological quality assessment of water bodies according to the WFD focus on the biota, and not on the abiotic, hydrological and morphological characteristics.

Lakeshore quality assessment is a fairly new field in which not so much experience exists in the EU Member States. But we have good knowledge from other bioassessment and habitat assessment fields about how to structure a lakeshore quality assessment scheme, and where some of the pitfalls lie. A list of eleven topics is presented in this paper, which should be discussed in the establishment of the lakeshore quality assessment scheme. The more complex ones are the implementation of other EU legislation (e.g. Habitats Directive), the definition of lakeshore types and reference conditions, the stipulation of best aggregation procedures, and a better understanding of the significance of hydrological and morphological impacts on the biota. It may not be adequate to judge from a human point of view what 'pure nature' on the lakeshore should look like, without a sound understanding of how several taxonomic groups respond to deviations from the reference conditions. This calls for a new initiative for supplementary research.

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## References

Bobbe, Th., Buschmann, M., Fleischhacker, Th., Kern, K., Pauschert, P. & Rast, G. (1997): Entwicklung eines Kartier- und Bewertungsverfahrens für Gewässerlandschaften mittlerer Fließgewässer und Anwendung als Planungsinstrument am Beispiel der Mulde. DVWK Materialien 3/1997 , Vol. 1, 211 pp.

Bragg, O.M., Duck, R.W., Rowan, J.S. & Black, A.R. (2003): Review of methods of assessing the hydromorphology of lakes. Report for the Scotland and Northern Ireland Forum for Environmental Research, Geography Dept., Univ. Dundee, UK, 138 pp., www.sniffer.org.uk

Brüggemann, R., Halfon, E., Welzl, G., Voigt, K. & Steinberg, C.E.W. (2001): Applying the concept of partially ordered sets on the ranking of near-shore sediments by a battery of tests. J. Chem. Inf. Comput. Sci. **41**: 918-925.

Brüggemann, R., Walz, N., Brauns, M. & Ostendorp, W. (2004): Seeufer, ein vergessenes Ökoton. (3) Gedanken zum Schutzziel 'Artengemeinschaften'. UWSF – Z. Umweltchem. Ökotox. **16**: 48–56.

Bundesamt für Umwelt, Wald und Landschaft (BUWAL) (1998a): Methoden zur Untersuchung und Beurteilung der Fliessgewässer: Modul-Stufen-Konzept. Mitt. Gewässerschutz **26**, 41 pp, Berne (CH).

Bundesamt für Umwelt, Wald und Landschaft (BUWAL) (1998 b): Methoden zur Untersuchung und Beurteilung der Fliessgewässer: Ökomorphologie Stufe F (flächendeckend). Mitt. Gewässerschutz **27**, 37 pp. + appendix, Berne (CH).

Carter, R.W.G. (1988): Coastal environments – An introduction to the physical, ecological and cultural systems of coastlines. Academic Press, London, 617 pp.

Chave, P. (2001): The EU Water Framework Directive – An introduction. IWA Publ., London, 208 pp.

CIS Wetlands Working Group (2003): Horizontal guidance document on the role of wetlands in the Framework Directive (final version agreed on the meeting of Water

Directors on 24/25 Nov 2003 in Rome), 63 pp., http://forum.europa.eu.int/Public/irc/env/wfd/

CIS (2003): Identification of water bodies – Horizontal guidance document on the application of the term "water body" in the context of the Water Framework Directive (final version agreed on the meeting of the Water Directors on 21/22 November 2002 in Copenhagen). 21 pp., http://forum.europa.eu.int/Public/irc/env/wfd/

CIS WORKING GROUP 2.5 (2002): Towards a guidance on establishment of the intercalibration network and on the process of the intercalibration exercise. 50 pp., http://forum.europa.eu.int/Public/irc/env/wfd/

ENVIRONMENTAL AGENCY (2003): River habitat survey in Britain and Ireland. Field Survey Guidance Manual.

FRIEDRICH, G. & LACOMBE, J. (eds.) (1992): Ökologische Bewertung von Fließgewässern. Limnologie aktuell, Vol. 3. Stuttgart.

HANSOM, J.D. (1988): Coasts. Cambridge University Press, Cambridge, 96 pp.

KAHLENBORN, W. & KRAEMER, R.A. (1999): Nachhaltige Wasserwirtschaft in Deutschland. Berlin, Springer, XXII + 244 pp.

KINZELBACH, R. (1995): Neozoans in European waters – exemplifying the worldwide process of invasion and species mixing. Experientia **51**: 521–526.

KOWARIK, I. (2003): Biologische Invasionen: Neophyten und Neozoen in Mitteleuropa. Eugen Ulmer, Stuttgart, 380 pp.

KRISTIANSEN, P. & HANSEN, H.O. (eds.) (1994): European rivers and lakes: assessment of their environmental state. EEA Environmental Monographs 1, European Environment Agency, Silkeborg, Denmark.

LÄNDERARBEITSGEMEINSCHAFT WASSER (LAWA) (ed.) (1999a): Gewässerstrukturgütekartierung in der Bundesrepublik Deutschland – Übersichtsverfahren. Report, 30 pp.

LÄNDERARBEITSGEMEINSCHAFT WASSER (LAWA) (ed.) (1999b): Gewässerstrukturgütekartierung in der Bundesrepublik Deutschland – Verfahren für kleine und mittelgroße Fließgewässer. Report, 147 pp. + App.

LANDESUMWELTAMT NRW (LUA) (1998): Gewässerstrukturgüte in Nordrhein-Westfalen – Kartieranleitung. LUA Merkblätter Nr. **14**, 159 pp.

NIXDORF, B., HEMM, M., HOFFMANN, A. & RICHTER, P. (2003): Zustand und Entwicklung der wichtigsten Seen Deutschlands. UBA Texte 05/04, 43 pp., CD-ROM, UBA Berlin.

OSTENDORP, W., SCHMIEDER, K & JÖHNK, K. (subm.): Assessment of human pressures and hydromorphological impacts on lakeshores in Europe. Ecohydrology and Hydrobiology.

RAVEN, P.J., HOLMES, N.T.H., NAURA, M. & DAWSON, F.H. (2000): Using river habitat survey for environmental assessment and catchment planning in the UK. Hydrobiologia **422**: 359–367.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA) (Ed.) (1998): Lake and reservoir bioassessment and biocriteria. Doc. No. EPA 841-B-98-007, www.epa.gov/owov/monitoring/tech/lakes.html

WERTH, W. (1987): Ökomorphologische Gewässerbewertungen in Oberösterreich (Gewässerzustandskartierungen). Österr. Wasserwirtschaft **39**: 122–128.

WETZEL, R.G. (2001): Limnology – Lake and river ecosystems. 3rd ed., Academic Press, San Diego, 1006 pp.

WRIGHT, J.F., SUTCLIFFE, D.W. & FURSE, M.T. (eds.) (2000): Assessing the biological quality of fresh waters. Freshwater Biological Association, Ambleside, Cumbria.

ZUMBROICH, T., MÜLLER, A. & FRIEDRICH, G. (eds.) (1998): Strukturgüte von Fließgewässern – Grundlagen und Kartierung. Springer, Berlin, X, 238 pp.

## Appendix

A definition of 'lakeshore' is given in CIS WETLANDS WG (2003) p. 21, as "that part of land (*sic!*) immediately adjacent to a lake, the structure of which significantly influences the value attained by other hydro-morphological quality elements, the biological quality elements or the physical elements, and which may in turn be influenced by lake flooding or wave action". This definition, which refers more to the landside border than to the lakeside border, implies that there is another zone in which the phytobenthos, the submerged macrophytes etc. live (i.e. the littoral zone, see e.g. WETZEL, 2001, p. 528). However, in other paragraphs of the CIS WETLANDS WG (2003) document the term 'lakeshore' is also applied to the littoral zone (which is regarded as specific type of wetland), but the term 'littoral' is mentioned only two times in context with natural lakes. Since a strict separation of a landside *lakeshore* zone and a lakeside *littoral* zone does not reflect the modern understanding of lakeshore+littoral zone as an ecotone, and a common word that comprises both habitats seems to be lacking, it is proposed to take the term 'lakeshore' for both the more or less dry land, and the more or less submerged zone. Then, the landside border is congruent with the definition of the CIS WETLANDS WG (2003) document, and comprises the littoral zone, the shoreline and the riparian zone (BRAGG et al. 2003). The lakeside border may be defined according to slope morphology (i.e. the zone where the cross shore differential of slope gradient reaches its maximum, i.e. the shelf-break), according to wave action (i.e. the zone where the deep water waves change to shallow water waves, indicated by shoaling and refraction [see e.g. CARTER 1988, p. 43 ff.]), or according to the production biology of substrate bound macrophytes [e.g. Characeae] (i.e. the maximum depth of closed macrophyte beds due to the transparency of the lake water). In this paper the term 'lakeshore zone' comprises both zones as mentioned above. It is also proposed to use the term 'lakeshore region' for the more landside areas from which significant pressures like recreation activities, urbanization, ground sealing, noise pollution arise. Since many relevant data sets are bound to certain administrative districts, the lakeshore region may extend hundreds of metres or even more than a kilometre landward. These definitions are in line with the definition of the coastal zone as a "space in which terrestrial environments influence marine (or lacustrine) environments and vice versa, and in which "the coastal zone may be characterized according to physical, biological or cultural criteria" (CARTER 1988, p. 1) (see also HANSOM 1988, Fig. 2.11).