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Water quality — Guidance standard for the surveying of macrophytes in lakes

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ICS 13.060.70

National foreword

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Foreword

This document (EN 15460:2007) has been prepared by Technical Committee CEN/TC 230 “Water analysis”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2008, and conflicting national standards shall be withdrawn at the latest by April 2008.

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Introduction

Macrophytes are an important component of aquatic ecosystems and can be used to facilitate monitoring of ecological status. The requirement for the use of macrophytes in monitoring is inherent in numerous European and national directives, e.g. Urban Waste water Treatment Directive (91/271/EEC), and the Nitrates Directive (91/676/EEC). Macrophytes are one of four obligatory biological quality elements identified in the Water Framework Directive (Council Directive establishing a framework for a community action in the field of water policy, 2000/60/EC), and should be used in the ecological classification of all lakes.

In addition to their important ecological role, the use of macrophytes as indicators of ecological status in standing waters is based on the fact that certain species and species groups are indicators for specific standing water types and are adversely affected by anthropogenic impact. In certain situations the lack of macrophytes is also a natural characteristic of certain types of aquatic habitat. For example, in lakes with high humic content or high turbidity, macrophytes may be virtually absent due to the reduction in light penetration. Many lakes show alternating states with clear water in some years and turbid water in others associated with the dominance or absence of macrophytes but with the same anthropogenic impact.

A wide range of sampling and survey methodologies have been developed for specific applications including conservation, drainage impact, management, ecological habitat, enhancement etc. The methodology of this guidance standard is recommended specifically for the surveying of macrophytes in both natural and artificial fresh water lakes, for the purpose of monitoring ecological status or the status of the macrophyte vegetation itself. It could be used, however, as the basis for general monitoring of water quality or other applications.

According to the precise use to which this guidance standard is to be put, it is essential for specifiers and users to agree and clearly record, any necessary variations or optional procedural details prior to use.

1 Scope

This guidance standard defines a method for surveying aquatic macrophytes in lakes - primarily for the purpose of assessing ecological status, using these organisms as an element of biological quality. The information provided by this method includes the composition and abundance of the aquatic macrophyte flora.

For a complete assessment of ecological status, other elements of biological quality should also be assessed.

The general principle of the approach described in this European Standard may also form the basis for the monitoring and assessment of macrophytes in lakes, for example, for conservation purposes.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Not applicable

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
amphiphyte
plant that can grow submerged in the water up to completely above the water, typically under fluctuating water level conditions

3.2
aquatic macrophytes
larger plants of fresh water which are easily seen with the naked eye, including all aquatic vascular plants, bryophytes, stoneworts (Characeae) and macro-algal growths (see EN 14184)

NOTE For this method, this term is taken to include macrophytes growing in the water and in the wash zone, including hydrophytes, helophytes, amphiphytes, as well as supra-littoral species in the wash zone (such as *Carex*).

3.3
belt transect
band of defined width oriented at right angles to the shoreline or bank, which starts at the water line including the wash and inundation zones starting at the highest seasonal waterline and in lakes extends to the lowermost limit of the aquatic macrophyte vegetation

NOTE 1 The aquatic vegetation (species composition, abundance, cover) is analysed within this transect. The transect can be virtual or physically delineated.

NOTE 2 The lowermost limit can change over years, either the belt transect is then extended to the lowermost limit that can be expected ever, or the lowermost limit or the belt transect is left variable through the years.

3.4
ecological status
expression of the quality of the structure and functioning of aquatic ecosystems, expressed by comparing the prevailing conditions with reference conditions (see EN 14184)

NOTE As classified in accordance with Annex V of the EC Water Framework Directive (2000/60/EC).

3.5
habitat
specific environment in which a species lives (see EN 13946, EN 14407)

3.6
helophyte
plant that is normally rooted under water with emergent shoots, typically growing in marginal or marshy areas (see EN 14184)

3.7
hydrophyte
aquatic plant that is normally rooted under water with floating or submerged leaves, or totally free floating (see EN 14184)

3.8
maximum depth of the vegetation
lowermost limit of the aquatic macrophytes which are adherent to or rooted in the sediment

3.9
metric
measurable part or process of a biological system empirically shown to change in value along a gradient of human influence

3.10
monitoring site
lake, or body of water within a lake, in which aquatic macrophytes are surveyed for the assessment of ecological status and/or other purposes

3.11
reference site (RefS)
lake or body of water within a lake representing the reference conditions for a given ecological type

3.12
reference conditions
conditions reflecting a totally undisturbed state, lacking human impact, or near-natural with only minor evidence of distortion (see EN 14184)

NOTE Reference conditions can be defined using field sites or, where necessary, using expert judgement or predictive modelling techniques

3.13
sample
smallest unit of area to be sampled, typically a belt transect consists of a series of samples, continuous or discrete (with intervals), but samples may be scattered (stratified) randomly as well (non-transect methods)

3.14
supra-littoral survey location
section of shoreline and adjacent submerged areas surveyed for aquatic macrophytes

3.15
taxon (pl. taxa)
taxonomic unit, for example family, genus or species (see EN 14707)

4 Principle

This European Standard describes a methodological approach for determining the ecological status of lakes using aquatic macrophytes. The status of a lake is assessed by establishing its deviation from the natural conditions of a lake of a similar ecological type. If natural conditions in comparable lakes no longer exist to

serve as a background or a reference site (RefS), it is necessary to reconstruct this background based upon whatever records exist. This may involve using data from lakes of a similar type in other European countries.

NOTE Even within similar lake types there can be significant biogeographical variation in the naturally occurring species.

The presence of aquatic macrophyte taxa in the individual lakes is recorded. Macrophyte abundance, measured in terms of the spatial extension of taxa or macrophyte beds, and/or macrophyte abundance estimates or biomass, is assessed by different methods adapted to the scale and purpose of the study.

Numerical derivatives or metrics of the macrophyte composition and abundance in a lake survey can be used to identify the divergence from type-specific, natural conditions.

5 Equipment: the following equipment list is suggested.

5.1 Equipment common to all surveys

5.1.1 High resolution maps of survey area, preferably laminated.

5.1.2 Range of plastic bags and hard plastic containers, for retaining specimens or the temporary storage of macrophytes requiring laboratory identification.

NOTE Mosquito netting or lace bags are easier to use than plastic bags in water.

5.1.3 Waterproof labels

5.1.4 Pencils or pens, with indelible ink.

5.1.5 Field data recording system, using either waterproof sheets, a small cassette recorder or water-resistant portable computer;

5.1.6 Floras, relevant field keys and identification guides, and iconographs (illustrations), appropriate to the habitats under consideration;

5.1.7 Records from any previous macrophyte surveys of the lakeunder survey

5.1.8 Personal protective clothing

5.1.9 First aid kit

5.1.10 Notebook, preferable with hard back and water repellent paper.

NOTE A pre-prepared *pro forma* is helpful in the field. This can be a *pro forma* count sheet with a list of taxon names and space beside each on which the abundance estimates can be made, or a notebook organised in such a way that taxon identities and numbers can be clearly recorded, or a computer program with facilities for direct entry of data. It is recommendable that design of the recording sheets or programs takes into account the requirements of any Quality Assurance programmes that are in place. Alternatively, field notes can be dictated into a small cassette recorder or digital dictaphone with flash memory.

5.2 Additional equipment for diving surveys

5.2.1 Wet-suit, snorkelling or SCUBA equipment;

5.2.2 Sinkable measuring tape, with concrete weight (or leaded line graduated along its length at appropriate points e.g. 5 m distances) to mark survey transects.

5.2.3 Dive (Alpha) flag, to attach to boat or buoy.

5.3 Additional equipment for boat surveys

5.3.1 Boat suitable for local conditions, with appropriate safety equipment. Where a boat is used, a means of communication from the boat to designated shore-based staff, with access to rescue services.

NOTE The use of an experienced boat handler familiar with local conditions or as a minimum detailed bathymetric maps for the survey area is recommended for safe surveying.

Accurate bathymetric data are crucial in delineating littoral zones, bed slopes etc. Where the data are not available, it should be an integral part of any vegetation survey. At a practical level, the use of transducer depth finders is recommended, which will operate to depths of up to approximately 73 m.

5.3.2 Double-sided rake grapnel and/or multi-point grapnel, attached to a suitable length of rope.

NOTE 1 The double-sided rake grapnel is preferable on relatively smooth, uniform substrates. On stony terrain with large interstices, the multi-point grapnel will tend to be more effective as it can slip into areas that a double rake cannot access. However, grapnels and rakes are inefficient for sampling smaller aquatic macrophyte species, a grab and netting techniques can be more effective.

NOTE 2 Double rake grapnels can be fabricated from two 32 cm garden rakes with 6 cm prongs at 2 cm intervals welded back to back with an attachment point for a rope. Rakes with longer prongs at smaller intervals can be preferred as they can be more efficient in sampling some situations. So called ‘grass rakes’ with 10 cm prongs transversely mounted are more suitable than ordinary garden rakes, especially for smaller specimen on soft sediments.

NOTE 3 The efficiency of rakes can be increased by folding fine maze wire netting around the rake teeth; in very soft sediments and with only very tiny plants a grab and handnet can be used as effective alternatives.

The rope should be of sufficient length to allow the deployment and recovery of the rake/grapnel. It should be of a sufficiently heavy gauge to allow pressure to be applied when the grapnel is snagged but not of excessive thickness that will lead to problems with deployment and recovery. Hemp ropes are less prone to kinking. Alternatively, extendable handles can be used that are effective to depths of approximately 3,5 m [3].

5.3.3 Rake, with rigid extendable handle.

5.3.4 Graduated floating line and weighted mooring buoy

5.4 Additional equipment

5.4.1 Geographical Positioning System (GPS)

5.4.2 Polarising sunglasses

5.4.3 Underwater viewing aid/bathyscope, viewing tube, bucket or box with clear Perspex base.

5.4.4 Camera with polarising lens

5.4.5 Underwater ‘drop’ camera, waterproof camera mounted to a cable or pole, that can lowered into the water.

5.4.6 Sanitised wipes

5.4.7 Binoculars

5.4.8 Hand lens, ×10 and ×20 magnification.

5.4.9 White plastic trays

5.4.10 Equipment to measure water depth, e.g. rod marked with intervals of 1 cm to 2 cm; or for deep, less vegetated areas, a hand-held echo-sounder.

5.5 Equipment for collecting additional data

5.5.1 Conductitivity meter

5.5.2 Depth meter

5.5.3 pH meter

5.5.4 Secchi disc

NOTE A secchi-disc to indicate the depth of light penetration, and equipment to measure the depth and level of the water can be useful in interpreting the resulting data. A hand-held conductivity and pH meter can also be useful, especially if surveying lakes with different water chemistry.

6 Survey planning

6.1 General

Survey planning is very much dependent on the purpose of the study and the procedure described here is primarily for the purpose of assessing ecological status.

At the beginning of a survey the geographic region(s), the hydromorphological lake typology and the expected reference conditions characteristic for the type of lake under investigation should be defined.

6.2 Establishing reference conditions

Ecological reference conditions for each hydromorphological lake type need to be established before the ecological status of a monitoring site can be assessed. This can be achieved either by surveying reference sites (RefS) within a specific type or, where suitable RefS cannot be found, by modelling or expert opinion. Historical data from unimpacted sites may also be invaluable.

Reference sites (lakes, or bodies of water within a lake), should be as close as possible to natural conditions with respect to their species composition and the abundance of each species, physical and chemical variables and hydromorphological background. Hazardous substances should either be totally absent or close to the limit of detection. Nutrient concentrations and the levels of acidification should be close to background levels taking into account the influences of the local geology and geographical location. Catchment pressures from, for example, agriculture and forestry should be low and significant point-discharges should be absent.

The selection of reference sites (RefS) should be based on information from regional or national surveys that have data on the species composition, distribution and diversity of the aquatic vegetation.

6.3 Monitoring sites

The ecological status of a lake or body of water within a lake (a monitoring site) is measured in terms of the deviation of the aquatic macrophyte flora from the reference conditions for the same lake type. For most practical purposes the lake is the waterbody unit and not the individual areas surveyed for macrophytes.

Where the concentration of lakes is high, as for example in Scandinavia, it is impractical and unnecessary to survey macrophytes in all lakes. In these circumstances a representative subset of monitoring sites can be surveyed to reflect the range of lake types represented and the extent to which these are influenced by specific human pressures. When selecting representative lakes from lake clusters use similar criteria to those listed in Clause 6.2.

6.4 Survey protocols

In the case of heavily modified or artificial water bodies the survey procedure may differ from that described in this guidance standard, depending on the extent of the hydromorphological changes or differences, but only when certain elements of the procedure cannot be implemented because of the hydromorphological deviation from the reference conditions. For instance: if banks of the lake have been modified, through embankment, consolidation or other means, the littoral zone, the wash zone and the inundation zone might be absent or reduced too much to serve as a relevant element in the quality assessment.

Lake macrophyte surveys can be undertaken at different levels of sophistication and intensity. This can involve the surveying of:

i) several discrete transects, or short lengths of shoreline in lakes with shallow littoral zones, which are regarded as representative of the visible and littoral flora of the study lake (quick survey) involving the identification of species present and a crude estimate of abundance;

ii) multipoint transects, or longer lengths of shoreline as a means of defining the best positioning for survey locations under approach (i); or

iii) contiguous transects or stretches of shoreline; or

iv) complete surveys of the lake (or body of water within a lake) to produce species inventories and in the selection of representative transects.

The survey protocol may vary between these different approaches depending on the purpose of the survey. For example, less intensive data collection may be appropriate for preliminary (quick) surveys designed to locate representative survey locations.

The first two approaches require relatively little time and may be useful for the routine assessment of ecological status. They allow only representative survey locations to be described, but they can be useful for spatial and temporal monitoring. A longer stretch of a shoreline is surveyed first, using the second approach to demonstrate the “evenness” of a) physical and b) biological variables. Representative survey locations are then selected within those stretches, and surveyed using the first approach.

Contiguous survey stretches cover the full length of the shoreline, but are labour intensive and so may not be suitable for routine use.

The last approach fulfils more specialist needs. For example, this can be part of the procedure to find reference sites (RefS) for different ecological lake types such as those with acute inclines into deep water but also those with shallower littoral areas. It is a labour-intensive approach not to be applied for routine surveys. It is for use in special cases, e.g. long-term monitoring and for detailed background information for ecological classification.

The procedure described in this guidance standard relates to the first approach, using belt transects.

If using alternative approaches, such as shoreline (walk-around) surveys, care should be taken to demonstrate that the resulting data are as representative as possible of the flora and conditions present.

6.5 Transect surveys

The most widely used method for surveying macrophytes in lakes is based on belt transects (3.3). This approach allows mapping of the distribution of individual species and abundance of aquatic macrophytes, it provides robust data sets that can be used to generate indices and metrics, and it is a cost effective means of data collection.

The number and positioning of survey locations at which belt transects are surveyed should allow a representative flora and the extent of colonisation to be recorded, reflecting the extent of human impact on the lake. These decisions should be made, as far as is possible, before the initiation of fieldwork.

NOTE 1 A quick survey is recommended to investigate variability across and between the lakes and to determine which lakes are representative

It is strongly recommended that the important and/or representative sections of the shoreline are walked prior to survey. This allows the opportunity for pilot surveys of several short transects in order to obtain a general impression of the vegetation and to identify likely safety hazards. Preliminary walks will also provide information on seasonal variation of the aquatic vegetation. Where this is not possible due to the extent of the helophyte reed growths this may be undertaken from a boat or using aerial photographs.

Survey locations should include the principal habitats and components of bathymetry of the lake – including inlet and outlet points (although only where no perceptible flow), embayments, exposed areas, islands etc. – and represent the various land-use types in the immediate catchment. Where possible, the natural conditions of substrate, water depth, bank-side shading etc. should be similar to those at survey locations at the reference site(s), if included in the study, so that differences in the flora due to anthropogenic impact can be distinguished more easily from differences due to natural hydromorphological conditions.

The number of survey locations/transects can be derived empirically [3] or from mathematical considerations [4]. The objectives of the survey, the requirements and constraints of the subsequent data analysis (one transect equates to one sample for multivariate analysis), the degree of confidence required from the data, and the resources and expertise available commensurate with achieving that confidence, should all be taken into account. In all cases, sufficient transects will need to be surveyed to generate representative data, particularly with respect to identifying the maximum number and abundance of species, but also to ensure that changes in the macrophyte assemblage due to anthropogenic factors such as land-use can be distinguished from changes due to natural factors, such as differences in geology, altitude, or exposure. Surveyors should be aware that the number of species recorded will increase with increasing number of transects surveyed. Sufficient transects should be surveyed in order to determine the Species Saturation Number (SSN – when the number of species recorded does not increase with an additional transect).

NOTE 2 Example of a survey strategy [3]: A minimum of 4 transects are surveyed for each land-use type around the lake. Additional transects within each land-use type are surveyed if – when surveying the 4th transect – the SSN has not been reached for that land-use type, or if there is a marked variation in abundance of one or more species. If the land-use type occurs in other areas around the lake, then only one transect is required at each of these additional areas, provided the SSN is still met (otherwise the basic requirement of a minimum of 4 transects applies).

Transects can be of varying widths and lengths (usually 1 m to 5 m in width) but this should be standardised as far as possible, particularly when comparing lakes that are defined as having the same or very similar hydromorphological characteristics. It is recommended that each transect surveyed is the same in terms of its width as for the corresponding reference site. However, as with river aquatic macrophyte surveying (see EN 14184), much of the data can be compared directly by mathematical scaling.

The start point for a transect is at the shoreline from the highest water level (as demarcated by the litter line, which can be several metres from the water's edge) and from here the transect runs perpendicular to the shore. GPS or a compass can be used to fix the direction of the transect. In smaller lakes visual landmarks can be helpful in fixing the transect direction.

Each transect should be surveyed to the depth at which no further plant growth occurs, where possible, confirming this by the use of divers or drop cameras. In very shallow lakes (< 3 m mean depth) there may not be a defined end to the aquatic macrophyte colonisation area. Alternative strategies that may be considered include setting a maximum length to the belt transect, surveying across the entire width of the lake (suitable for smaller lakes) or applying the principle of stopping observations when no new taxa are identified. The latter approach will not establish the depth limit of plant colonisation or the extent of the macrophyte beds to be determined, which are important parameters.

6.6 Timing of initial and subsequent surveys

As far as possible, macrophyte surveys of lakes should be undertaken between late Spring and early Autumn (normally May to late September, but this is dependent on local climatic conditions), when macrophyte growths will be optimal.

NOTE 1 The growing period will be considerably longer in southern Europe than in Scandinavia, for example, and the timing of aquatic macrophyte surveys will need specifically to address local conditions. In shallow lakes the growing season can be considerably shorter.

NOTE 2 This recommended time period is not necessarily the optimum growth period for macroscopic benthic algae and other elements of the phytobenthos, which can be surveyed separately.

The field survey should preferably follow periods of low rainfall when water clarity is maximised and lake levels are reasonably close to normal, thereby enhancing visibility and allowing a better judgement of which plants are true aquatics and which are helophytes and amphibious species. In addition, if water clarity is impaired the observation and collection of smaller species and the recording of abundance may be inaccurate, which reduces the reliability of the data. Information regarding the timing of vegetation cutting is essential prior to surveying, where this is known to be usual management practice.

Aquatic macrophyte species grow and reach sexual maturity at different times over the summer period. For this reason surveys of sites in similar lake types should be undertaken in quite close chronological succession where comparative data are required.

Due to differential growth rates between macrophyte species, which can result in different data patterns between early and late summer surveys, it is recommended that where possible surveys are undertaken on two separate occasions during each survey year, if resources allow. Preferably the first survey will be early (e.g. around May/June) in the survey period. The second survey should be several months later (e.g. August or September). Timings will differ in the northern and southern parts of Europe to take into account local climatic influences. This is particularly important for reference sites where complete species lists are important as a means of detecting subtle changes over time.

Comparative surveys in subsequent years should be undertaken at the same time of the year as before. This will ensure that changes resulting from differential seasonal growth patterns are minimised. The development of macrophyte growth in Spring can vary between years as it is highly dependent on water depth, physical disturbance/ modification, solar radiation (photosynthetically active radiation, PAR) and water temperature. All of these factors can vary significantly between years. For these reasons pilot visits to survey sites are necessary to assess the state of development. Where a lake is regulated, with large fluctuations in lake level, the comparability of lake level with previous years should also be taken into account when timing the survey. In lowland regulated lakes the extent of fluctuation may be less but may have an important influence on the macrophyte flora.

7 Survey procedure

7.1 Survey preparation

Prior to survey site locations should be selected and marked as an appropriate number of survey locations on the lake map(s). Data collected from pilot surveying informs the process of selecting a representative number of transects. This should include the range of local conditions principally present in the lake including embayments, exposed areas, islands, land-use variations, bathymetry (where it is known), inlet and outlet points, etc.

It is important to be able to locate the survey transects precisely during subsequent surveys. It may be appropriate to use markers or permanent landmarks such as field boundaries, trees etc. The marking of survey locations should be geo-referenced (preferably by GPS), which also facilitates easy processing in Geographic Information Systems (GIS). This makes data transfer, central data acquisition and the production of quality status maps much simpler, especially with respect to long-term trend monitoring. Greater accuracy and reproducibility of transect site location can be achieved using a Global Positioning system of appropriate accuracy.

To assist this process and the subsequent selection of representative survey locations, relevant background information on the lake(s) to be surveyed should be gathered. The area should be inspected on foot, detailed maps examined, aerial photographs and any other sources of relevant information investigated such as water quality data sets is highly recommended. Potential point-sources of pollution such as waste water treatment

plants, fish farms, centres of high population density etc. should be identified. Land-use within the lake catchment/sub-catchment to be surveyed, should be investigated. Changes in catchment usage and potentially water quality in terms of nutrient loadings are likely to occur should be established. Geomorphological criteria including solid and drift geology etc. should be established. Locate any physical barriers and physical obstructions that may influence aquatic macrophyte communities.

NOTE 1 Detailed interrogation of water quality databases can be important in this context. When they are not available, chemical survey can be undertaken at the time of macrophyte survey, but more detailed data sets are of greater value. Chemical measurements made in Summer can give values that are not typical of the background levels for a specific lake, primarily as a result of biological processes.

NOTE 2 It is recommended that the background information collected is mapped in order to facilitate the ready identification of suitable survey sites. Reports on quality status monitoring can require a geo-reference and GIS background in many cases, especially with respect to national central organisations and/or at European Union level.

It is recommended that a risk assessment is undertaken for each lake before it is surveyed for the first time. This includes factors such as parking, access to the lake, launch of the boat, nature of the ground at the access point (quaking bog, marsh, fen, etc.), other hazards associated with the adjacent land-use, and hazards posed by other lake users (e.g. boats, windsurfers, water skiers). All sailing clubs, launching facilities etc. are then be informed of the dates and locations of diver presence. Lone working is not recommended, on the grounds of safety. *Pro formas* for each sampling location/lake to be surveyed is to be prepared, detailing the lake name, individual survey site identification number, map location, National Grid References, the transect number and location and any other relevant information. Mark the positions of the survey transect on appropriate maps of each lake. Where possible use a checklist of aquatic macrophyte species likely to be encountered to facilitate recording in the field. These checklists are based on national surveys, differing for each ecological type of lake in the European countries.

Assemble the necessary equipment dependent on the survey method to be used.

7.2 Transect surveying

7.2.1 General considerations

A transect survey comprises:

i) survey along the transect conducted by either diving or by boat (both requiring suitably trained personnel); and

ii) survey of the shallow littoral and wash zone by wading along the shoreline to either side of the transect.

Survey techniques to establish the ecological status of lakes using the aquatic vegetation as a quality element are usually semi-quantitative, based on a descriptor scale, with visual estimates of species composition and abundance. This approach is especially recommended for short- and long-term monitoring of ecological status, as it permits the efficient use of resources.

Sufficient time should be spent at each survey location to ensure the necessary accuracy/precision. Methods suitable for monitoring regimes should be efficient and cost effective. However, although time spent collecting field data should be kept to a minimum, it is essential that sufficient time is allowed to record accurate, reproducible data with minimal inter-surveyor variation (see Clauses 8 and 11). Adverse weather conditions should be avoided as these might impair the ability of surveyors to work accurately and safely. Windy weather can stir shallow water resulting in increased turbidity, and can lead to difficulties in maintaining position and in keeping cables vertical. In these circumstances, diving surveys are the preferred methodology (7.2.2.)

Accurately locate the position of the survey transect using the relevant map or where available GPS of suitable accuracy. Ensure that there are no obvious hazards that might affect boat operation along the survey transect which runs at right angles to the shoreline. In the event of perceived hazards re-position the survey location as necessary. A detailed knowledge of the local bathymetry and the use of a boatman with local experience are strongly recommended to ensure safe operations.

7.2.2 Transect surveying using divers

Direct observation and collection of plant material *in situ* is the most accurate and reproducible means of surveying transects and, where suitably trained personnel are available, this approach is recommended [3]. This survey method can be resource-demanding as several trained personnel are required on site during diving operations in order to ensure safe operator safety. Only trained and qualified SCUBA divers should be used in this type of survey.

The survey transect is best marked with a sinkable measuring tape from the outermost (deepest) extent of macrophyte colonisation through to the shoreline , secured in deep water by a concrete weight (a graduated lead-weighted line can be used as an alternative, although this may reduce visibility for up to 30 min after being installed). Belt transects between 2 m and 5 m can be effectively surveyed by a single diver in one run taking into account national safety practices. When plant stands are non-uniform or mosaic-like, several such belts should be surveyed to ensure a record of all species and abundance levels present. Starting from the shore the diver moves along the transect line identifying and estimating the abundance of individual species. When wider belts are used (e.g. 20 m wide) the diver should zig-zag over the whole width of the transect.

NOTE 1 The use of wider transects can reveal more statistical non-detectable scatter than a series of narrower belt transects. The time spent on surveying a set of narrower transects requires less effort than surveying broader transects and the former also gives better statistical accuracy in the recording of macrophyte species and their abundance.

Lakes where the depth does not exceed 2 m can be surveyed using a wet suit, mask and snorkel, if the lake bed is clearly visible. In deeper lakes SCUBA equipment is necessary and should be used only by trained personnel. Plant records can be made on submersible note pads, which limits the need to re-surface. Where positive identification cannot be made *in situ*, samples should be taken for subsequent detailed examination.

NOTE 2 For safety reasons, a dive (Alpha) flag, either flown from the boat or on a surface marker buoy, is showing whilst any diver is in the water. Where possible, there is also a surface cover provided by a boat (on small lakes with no recreational craft, this may not be necessary).

Where a boat is used, the boat handler should be familiar with operating a dive boat (i.e. the recovery of divers from the water) and there should be an air-horn on the boat to warn other users of the presence of divers in the water.

7.2.3 Transect surveying using a boat with rakes or grapnels

Take the boat slowly into the shoreline taking care that there are no submerged obstructions along the transect to be surveyed. Ensure that there is sufficient water depth at the closest point to shore that allows effective boat operation.

Macrophyte material is obtained by either dropping the double-headed rake grapnel or multi-point grapnel with an attached rope or using a rake with an extendable handle in water depths up to 3,5 m.

The boat is stopped at a known distance along the transect. The double headed rake or grapnel is dragged across the lake bottom for a few metres to collect samples. The rake should be deployed until no new taxa are obtained.

The material is removed from the rake and identified. If necessary specimens are retained for subsequent identification in individually labelled plastic bags. Where local water conditions allow, the extent of macrophyte colonisation should be observed directly using a viewing tube (bathyscope). In deeper waters a drop camera can be used with a surface recorder to locate and identify submerged hydrophytes and the extent of their colonisation.

This process should be repeated every few metres along the transect and the species collected and their abundance recorded (see below). This sampling is repeated until no plants are recovered from the transect, this marking the end of the zone at which plants will grow at the survey location. The depth of this zone will vary between lakes. For example, it may be less than 2 m in humic waters, but as deep as 6 m in limestone lakes [5] or considerably deeper in lakes of other regions and character (e.g. Alpine and Northern lakes). Note the distance from shore at which there is no evidence of macrophyte colonisation. This information may be useful in establishing temporal variations in any subsequent surveys and/or mapping exercises, which might give an indication of deterioration or improvement in the ecological status of a lake.

Alternatively, use a floating line calibrated at, for example, 5 m intervals, moored to a weighted buoy. This has the benefit that estimates of aquatic macrophyte colonisation can be made reproducibly within discrete survey units along the belt transect. For example, if the transect band-width is 5 m and individual 5 m lengths are surveyed along the belt transect then if an individual species cover is 1 m^2 the percentage coverage within the 25 m^2 unit is 4 %. Accurate GPS location of a virtual transect offers a further practical approach and is particularly useful for long transects.

A drop camera can be used to confirm the extent and abundance of the submerged macrophyte growths along each transect as well as establishing the effectiveness of the grapnel collections, paying particular attention to the presence of smaller species, which may have been overlooked. These cameras should also be used to locate the depth boundaries beyond which no macrophyte colonisation occurs and provide long-term photographic evidence of the assemblages recorded.

Certain species of macrophytes are very difficult to sample with a grapnel (e.g. *Elatine* spp., *Sparganium natans,* etc.) and so where these species are known to be present, extra effort to sample adequately may be required. Grapnel sampling should not be used where rare and/or legally protected species are known to be present, as it is a destructive sampling method.

7.2.4 Shoreline and littoral surveying

In order to identify the maximum number of aquatic macrophyte species, a search along the shoreline and shallow littoral areas should be undertaken for each transect. Typically some bryophytes are restricted to these areas as they are adapted to periodic inundation. This surveying may be particularly important where the slope of the lake is very gradual and where level fluctuations may affect large areas of lakes enhancing colonisation by amphibious species (amphiphytes – species distributed almost equally in the water and on the shore).

NOTE Where applicable and expertise is available, it can also be useful to record the larger species of aquatic lichens, as these can be good indicators of past changes in lake level.

From the shoreline, locate the point at which the boat transect meets the high water line on the lake shore. Survey submerged macrophytes in the littoral zone to at least either side of the transect. Record the relative abundance of each species (7.3). Where it is not possible to identify the species present these should be committed to pre-labelled plastic bags or hard plastic pots for identification later. Similarly, species growing in the wash zone should also be recorded and the extent of their colonisation estimated. Fragments on the strand line but not growing *in situ* should not be recorded as they may have originated elsewhere in the lake (although it can be useful to record these separately if a total species list is required for the lake).

With pilot surveys where a boat is not used, it is beneficial to survey the macrophytes present beyond the wadable limit using either a long-handled rake or grapnel. A viewing tube (bathyscope) is also helpful in assessing colonisation in the shallower littoral areas, particularly where the waters are either turbid or subject to peat stain.

7.3 Recording and quantification scales for macrophytes

Record the date of the survey, the name of the surveyor and any other relevant information that will assist the execution of future surveys.

Record any observations relevant to the survey transect, such as depth, water turbidity, sediment type, adjacent land-use, water uses, shading and evidence of recent changes in the water level.

NOTE 1 The recording of any relevant information such as land-use, the extent of afforestation, evidence of pollution pressure and any other facets of the immediate catchment is to be encouraged. Such information can assist in the explanation of anomalies in the biological data. Where appropriate, contemporary sampling of water and sediments can be undertaken for subsequent chemical analysis, using CEN or ISO standards where these are available. A Secchi disc can be used to indicate the depth of light penetration. Measurement of water level (height above sea-level or other national datum system) is to be encouraged.

Record all macrophyte species present in each transect on the survey data sheet. Collect samples of plants for later verification for Bryophyta, algae, *Ranunculus* species*, Callitriche* species*,* narrow leaved *Potamogeton* species and Charales and any other uncertain taxa (however, see Clause 8 on protection of rare species). Samples should be kept in voucher collections. Where necessary, specimens should be retained in national collections following verification of species which are rare or difficult to identify.

Surveys should take into account particular growth forms (submerged helophytes, emergent hydrophytes, etc.). The growth form of the species present should be noted irrespective of its growth form elsewhere. In the case of species that are distributed almost equally in the water and on the shore, the use of the term amphiphyte may be appropriate. Absence or presence of species known to be reliable indicators of particular ecological conditions is especially useful.

Helophyte species can be recorded separately for biotope or conservation purposes however, it is advisable to record the data independently as these can influence subsequent assessments of ecological status.

For each transect, estimate and record the area/cover or three-dimensional development/volume/amount of each species, for example as Plant Mass Estimates (PME) [3] or using an abundance scale such as Table 1. Where species are identified that are not present on the checklist, record these in an appropriate section of the recording sheet.

For each sample unit in a transect a descriptor scale or percentage classes can be used to record estimates of species-related parameters such as abundance, scales with about 3 or 5 levels are in most cases sufficient to allow adequate reproducibility and to discriminate between different macrophyte assemblages. Scales with a greater number of levels may artificially appear to be more accurate but may be less reproducible. Useful quality assurance measures, particularly if more than 5 levels are used, are to (i) organise inter-calibrations between surveyors and (ii) give visual examples of quantitative estimations.

An example of a 5-level scale used to assess abundance is given in Table 1. Other scales can be used such as a 10-level scale (+, 1 to 9).

Table 1 — Example of a macrophyte abundance scale (DAFOR)

Scale	Abundance Descriptor[a]	Percentage Cover
1	**R**are	< 1 %
2	**O**ccasional	1 to 10
3	**F**requent	10 to 25
4	**A**bundant	25 to 75
5	**D**ominant (very abundant)	> 75 %
[a] Abundance of Species X on DAFOR scale (see [8].		

Presence and absence scales can be used to calculate percentage occurrence or frequency occurrence for individual species. For example, if a species is recorded in 10 of the 20 sampling points it has a 50 % frequency of occurrence.

Total cover of the vegetation should be estimated. Depending on the needs for the assessment method this should be estimated in every unit or sample in the transect. It is strongly recommended that separate estimates are made for different growth forms. Total cover should be estimated as a percentage as accurately as possible.

8 Aquatic macrophyte identification

Suitably trained and experienced personnel should be able to identify most macrophytes and macroalgae to species level in the field using the appropriate keys and guides for specific member states. Where the identity of a species cannot be established with confidence, samples should be returned to the laboratory for confirmation. Collect only sufficient material to allow positive identification. Transport in pre-labelled plastic bags or other appropriate sealed containers.

If necessary, confirmation by an independent national/regional expert should be sought particularly for difficult groups.

Permits have to be applied for in case rare and endangered species that are protected under National or European legislation can be expected or if the water body is part of a nature reserve. Surveyors should be fully conversant with the provisions of such legislation and the identification of these species.

Voucher collections should be maintained as either pressed or preserved specimens to allow quality assurance of plant identification. Photographic records of species present under field conditions in the reference and monitoring sites are recommended. Photographs of the shoreline, taken on repeated surveys from designated positions and showing emergent and floating-leaved vegetation, can also provide a useful archive record.

Care should be taken for transitory parts of some plant species that contain key properties for identification. For instance: Flowers of *Ranunculus* species, Batrachium section, should be collected and dried separately and the colour pattern of the petiols should be noted before drying; Characeae with gametangia growing in mucus (i.e. *Nitella capillaris*) should be dried with extra care: protect the gametangia with mucus between small pieces of plastic foil to prevent the mucus to be absorbed by the paper. The mucus also disappears in alcohol.

9 Fixation and preservation

The accurate identification of aquatic macrophytes is central to the ecological assessment of lakes and while appropriate training will largely prevent such inaccuracies occurring, there is still the potential for misidentification, particularly with difficult groups such as *Potamogeton* spp. and their hybrids.

The collection and retention of voucher collections is recommended. These specimens are best preserved between sheets of newspaper or blotting paper (as a herbarium), or in ethyl alcohol. The latter is preferred for fine-leaved, small species as macrophytes can become brittle when dried.

WARNING — National safety guidance should be followed when handling any chemicals.

Care should be taken to maintain herbaria, to avoid infestation/infection of the dried plant material by other organisms.

NOTE Aquatic plant specimens can also be permanently preserved in vessels containing Strasburger's mixture (1:1:1 water:glycerol:96 % ethanol), sealing the vessels with screw caps or other air-tight lids.

Where inaccurate identifications are made the collection and preservation of voucher specimens allows archive data to be checked independently and if necessary for historical data to be corrected. In addition, the availability of voucher material will assist with training and allow accurate identification of rare specimens.

10 Data collation and classification

10.1 Data storage

Data should be stored in its original form. Changing data for compatibility with the software to be used should always be made after storage. If changes are needed, this should be considered as a flaw of the software used. Software can be improved, data reduction can never be restored. It is recommended that data should be transferred to electronic storage at the earliest possible opportunity to minimise the risk of loss. Alternatively photocopies or digital scans can be made of written records.

Where possible, all data entries should be independently checked to ensure the accuracy of the data transfer prior to the application of subsequent statistical and data collation (see EN 14996).

10.2 Comparison with reference conditions

Comparisons between aquatic macrophyte records should only be made between lakes of similar ecological type (ecoregion, elevation above sea level, etc.), which share similar hydromorphological characteristics. Even within lakes, no attempt should be made to compare macrophyte records from individual transects or groups of transects which are very obviously different in terms of their physical structure. Do not compare the flora of exposed hard, shallow littoral zones with deep, sheltered embayments as the physical conditions, irrespective of human influences, are very different in terms of the plant species that they will support.

While it is possible to undertake analysis of the data obtained from individual transects/survey locations, the degree of deviation from reference conditions should be based on data either from groups of transects or the whole site (lake, or body of water within the lake) – not by comparing individual transects. In each case, ensure that the units used in both monitoring and reference sites are similar in terms of their natural, physical characteristics.

Comparisons between data sets can be made either in the form of multivariate statistical methods or based on a series of metrics [5], [9]. Recommended metrics include dominance, species number, estimates of plant masses, presence of rare species amongst others [3], [9] that may have regional importance. Appropriate use can also be made of locally relevant trophic scoring systems [8]. Metrics for monitoring and reference sites can be compared to produce Ecological Quality Ratios [10].

It is possible to analyse the transects individually, but these analyses should only be undertaken to investigate variability within a lake. Methods used for clustering of data from individual transects or samples depend on the assessment method applied.

NOTE Trophy is still an important feature to be assessed in lakes in order to improve their nutrient-impaired condition in some European regions; however, it is not specifically addressed within the EC Water Framework Directive. It is element of the EU intercalibration exercise for the Water Framework Directive and part of future European management strategies for eutrophication [1]. It is not a primary indicator of the ecological status.

10.3 Macrophyte mapping

The mapping of the distribution and abundance of aquatic macrophyte species and groups of species is particularly useful for presenting the data collected from field surveys. It is also particularly important for detecting and visualising changes over time.

At a simple level the distribution of species and groups of species can be mapped directly using data extrapolated from a series of transects or more completely from whole lake surveys. The use of aerial photography can be invaluable for mapping purposes. Near infra-red or true colour images of aquatic macrophyte distribution calibrated with subsequent ground-truth data is a permanent record that can form a baseline condition for individual lakes.

NOTE 1 The presence and distribution of smaller species can be obscured by larger mainly floating species such as the nymphaeids in aerial photographic images.

Direct mapping of macrophyte beds can be undertaken in the field using GPS of sufficient accuracy to define their boundary limits. This can be coupled with aerial photographs to give valuable information relating to macrophyte dynamics over time.

NOTE 2 Modern instruments like DGPS and echo-sounding allow a rapid and cheap survey of wide-spread occurrences of emerse and submerse macrophytes. The basis of such a survey is an exact survey of the long-term mean-water shore zone of a lake.

From a boat and by means of echo-sounding, macrophytes and the littoral zones are surveyed systematically and simultaneously. Identification of species, delimitation of homogeneous vegetation zones and further vegetation surveys, for example transect plottings, follow complementary.

11 Quality assurance

The validity of ecological assessments based on aquatic macrophytes depends on the accuracy and precision of all activities involved in the collection and analysis of data. For this reason, assessments should be subject to quality assurance procedures. For more details, reference should be made to standards being developed by CEN/TC 230/WG 2 in this area, e.g. EN 14996.

The design of *pro forma* sheets or programmes for recording macrophyte data should take into account the requirements of any quality assurance systems that are in place.

The facility for verifying the identity of difficult specimens is important. This can take several forms: drawings, high quality photomicrographs or captured video images may suffice. The retention of voucher specimens for difficult taxa from individual lakes is strongly recommended.

Surveyors should have demonstrated their competence. They should have received appropriate training in the identification of aquatic macrophytes specifically in a lake context. The levels of taxonomic skills should be continually reviewed and additional training provided as necessary.

Standardization of abundance estimates between surveyors is a key element of survey quality assurance.

A reference collection of all taxa recorded should be mandatory for individual surveyors and the additional storage of voucher specimens of difficult taxa is strongly recommended, see Clause 9.

Participation in regular training courses and ring tests is also strongly recommended.

All data records relating to a specific survey should be individually identifiable and retained for a period not usually less than 5 years. Data transcription into electronic formats should, where possible, be independently checked to ensure that errors are corrected before further data treatment and manipulation.

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