ANNEX 9 – LAKES – Macrophytes & Phytobenthos - LEAFPACS

Contents

A1 Description of method

The LEAFPACS method has been designed to detect the impact of nutrient enrichment in lakes on the plants that grow there. Nutrient enrichment is not the only pressure affecting UK lakes but it is the most ubiquitous. Five indicators are used in the process, an index based on the average sensitivity to nutrients of the taxa found in the lake (LMNI)., the number of plant taxa present (NTAXA), the number of functional groups that those taxa fall within (NFG), the percentage cover of submerged plants (COV), and the proportion of that cover which is filamentous algae (ALG).

Lake macrophyte surveys are normally conducted between July and September (or June in the south of Britain) which is the period in the UK when most lake plants are well grown and are not yet dying back.

For each lake the values that would be expected for each indicator if the lake was at reference condition are calculated. These values vary with altitude, depth, area, alkalinity and Freshwater Sensitivity Class (FSC)[i]. The results for each indicator are then used to produce a set of ecological quality ratios (EQRs) which are then combined. If either of the diversity EQR values (NTAXA or NFG) are less than the LMNI EQR an equation is applied which produces a lower adjusted LMNI.

If the adjusted LMNI EQR (${}^{A}EQR_{LMNI}$) is larger than the smallest cover EQR (COV or ALG) another equation is applied which further reduces the LMNI EQR. The value of this, or the ${}^{A}EQR_{LMNI}$ if it is lower, is used as the LEAFPACS EQR which is then standardised so that the boundaries of each metric are on the same scale (0.8, 0.6, 0.4, 0.2). If there are surveys for more than 1 year the standardised EQRs are averaged.

(i) "Freshwater Sensitivity Class" describes the relative capacity of geology and soils to neutralise incoming acidity and hence limit acid loadings to fresh surface waters. There are five classes ranging from F1 (highly sensitive) to F5 (low sensitivity).The classes are derived from the Centre for Ecology and Hydrology Freshwater Sensitivity Class map; Hornung *et.al.* (1995).

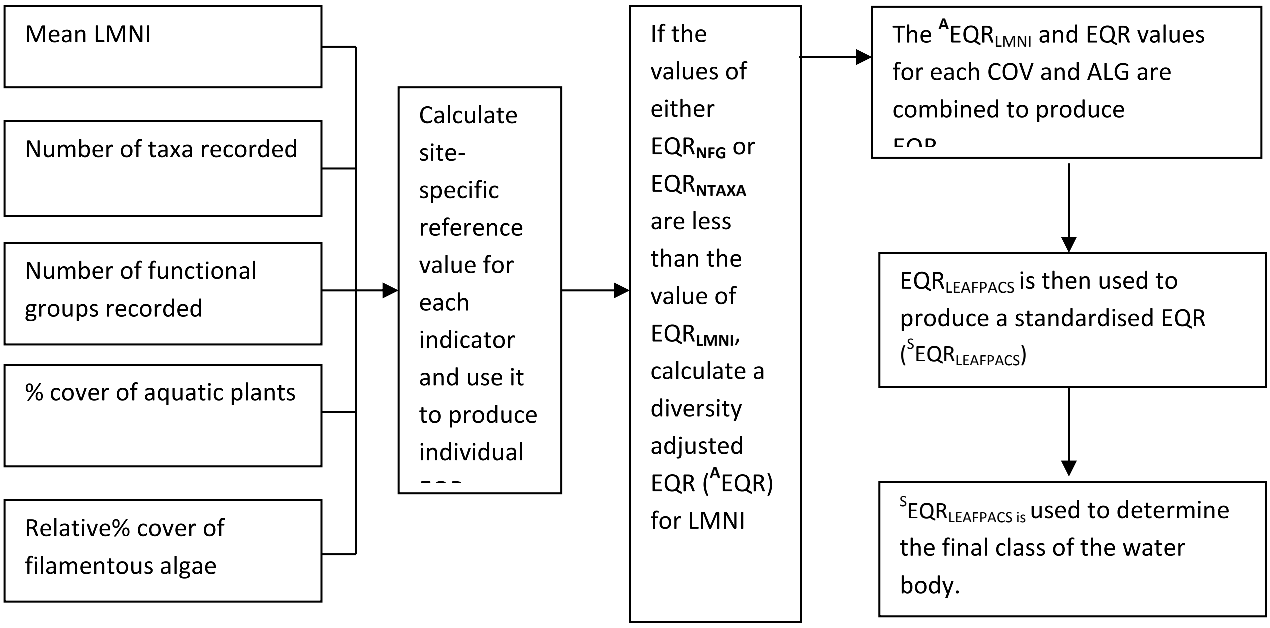

Figure 1. Flow diagram of the LEAFPACS v2 classification process

Monitoring system

A standardised approach to macrophyte surveying in lakes is taken following the one developed and trialled by the Centre for Ecology and Hydrology (CEH) during 2003-2004 (see Gunn *et al*., 2004). This approach was developed in accordance with JNCC Common Standards Monitoring (CSM) guidance (ISSN 1743-8160). It was designed for Site Condition Monitoring (SCM) of standing waters in Scotland for Habitat Directive purposes under contract to Scottish Natural Heritage (SNH). In the interests of harmonising data collection, and given that this approach has undergone extensive testing, consultation and revision, and is compliant with current CEN guidance on lake macrophyte surveys (CEN, 2003), this survey method has been adopted by SEPA (Scottish Environment Protection Agency) and the Environment Agency for use in lake macrophyte surveys for WFD purposes

Metric details

Lake Macrophyte Nutrient Index (LMNI)

In order to calculate the observed value of the parameter, LMNI, each macrophyte taxon listed in Column 1 of Table 2 and identified as being present in the lake should be assigned the corresponding lake macrophyte nutrient index score in Column 2 of that Table. The observed value of the parameter should be calculated by the equation:

$$\text{Observed value of LMNI} = \frac{\sum_{j=1}^{n} \text{LMNI}_j}{N}$$

where:

“LMNIj" is the Lake Macrophyte Nutrient Index score for taxon "j" given in Column 2 of Table 3; "j" represents a taxon listed in Column 1 of Table 3 and present in the sample. "j" has a value of 1 to "n" used to indicate which of the all the taxa (total number = "n") listed in Column 1 of Table 3 and present in the sample it represents; and “N” is the total number of macrophyte taxa listed in Column 1 of Table 3 and identified as being present in the lake.

LMNI scores are based on the unweighted average of the annual mean Total Phosphorus concentrations of lakes in which species were reported in archived data. Values were subsequently rescaled from 1 to 10 for convenience.

Number of functional groups of macrophyte taxa (NFG)

In order to calculate the observed value for the parameter, NFG, each taxon listed in Column 1 of Table 3 and identified as being present in the lake should be assigned to the corresponding functional group in Column 3 of Table 3, if a corresponding functional group is listed for that taxon in that column.

The observed value for the parameter, NFG, is given by the sum of the number of different functional groups of taxa identified as present in the lake.

Number of macrophyte taxa (NTAXA)

The observed value for the parameter, NTAXA, is given by the sum of the number of taxa listed in Column 1 of Table 3 that are present in the lake.

Mean percent cover of hydrophytes (COV)

The observed value for the parameter, COV, should be calculated according to the following equation:

$$\text{Observed value of COV} = \frac{\sum_{j=1}^{n} \%\mathrm{COV}_j}{\mathrm{N}}$$

where:

"%COVj" is the percentage cover of taxon "j" in the area of the lake surveyed; "j" represents a taxon listed in Column 1 of Table 3 and present in the sample. "j" has a value of 1 to "n" used to indicate which of the all the taxa (total number = "n") listed in Column 1 of Table 2 and present in the sample it represents; and “N” is the total number of macrophyte taxa listed in Column 1 of Table 3 and identified as being present in the lake.

Relative percent cover of filamentous algae (ALG)

The observed value for the parameter, ALG, should be calculated according to the following equation:

$$\text{Observed value of ALG} = \frac{\sum_{K=1}^{n} \%\mathrm{F}_k}{\sum_{j=1}^{n} \%\mathrm{COV}_j}$$

where:

“$\%F_k$” is the percentage cover of taxon "k" in the area of the lake surveyed; "k" represents a taxon listed in Column 1 of Table 3, indicated as being a filamentous algal taxon in Column 4 of that Table and present in the sample. "j" has a value of 1 to "n" used to indicate which of all the taxa (total number = "n") listed in Column 1 of Table 3 are present in the survey of that lake.

Calculation of the reference value for each parameter

Reference conditions were derived using a combination of (a) information from a network of lakes identified as being subject to no or very minor alterations likely to affect their macrophyte communities; and (b) modelling using predictive models and hindcasting methods. For the purposes of the latter, data on individual species-pressure relationships indicated by empirical analysis and historical macrophyte records were used.

Lake Macrophyte Nutrient Index (LMNI)

The expected LMNI value is related to the Morpho-Edaphic Index (MEI) where

$$MEI = \mathrm{Log}_{10}\left([(Alk + 40) \div 1000] \div D\right)$$

and where Alk is the long term mean alkalinity of the lake, expressed in ueq/L, and D is the best available estimate of average depth, expressed in metres. The model that is used to calculate expected LMNI depends on the geology of the lake catchment. This is summarised using the weighted Freshwater Sensitivity Class (wFSC)

where:

$$wFSC = F1/100 + [F2/100 \times 2] + [F3/100 \times 3] + [F4/100 \times 4] + [F5/100 \times 5];$$

"Freshwater Sensitivity Class" describes the relative capacity of geology and soils to neutralise incoming acidity and hence limit acid loadings to fresh surface waters. There are five classes ranging from F1 (highly sensitive) to F5 (low sensitivity).The classes are derived from the Centre for Ecology and Hydrology Freshwater Sensitivity Class map; Hornung *et.al.* (1995). In the above equation the terms F1 to F5 describes the % cover of the lake catchment assignable to each of the five possible sensitivity classes.

The value for the parameter, LMNI, in the reference conditions applicable to the lake should be calculated using the following equation:

If $wFSC \geq 4.0$ (i.e. well buffered catchments with soft calcareous geology):

$$\text{Reference LMNI} = 4.969 + 1.272 \times MEI + 0.193 \times MEI^2$$

If $wFSC < 4.0$ (i.e. poorly buffered catchments or those with hard calcareous geology):

Reference LMNI = 4.969 + 1.272 x MEI + 0.193 x MEI^2 - 0.55

Number of functional groups of macrophyte taxa (NFG)

The value for the parameter, NFG, in the reference conditions applicable to the lake should be calculated using the following equation:

Reference N_FG = Exponent (0.703 – [0.049 x Log_{10} H] + [0.133 x Log_{10} S] + [0.287 x Log_{10} (Alk +40)] + [0.132 (only if lake is in GB)] + [0.356 (only if wFSC<4.0)])

Number of macrophyte taxa (NTAXA)

The value for the parameter, NTAXA, in the reference conditions applicable to the lake should be calculated using the following equation:

Reference NTAXA = Exponent (1.488 – [0.098 x Log_{10} H] + [0.185 x Log_{10} S] + [0.194 x Log_{10} (Alk +40)] + [0.149 (only if lake is in GB)] + [0.287 (only if wFSC <4.0)])

where, in the above equations:

“Alk” is the annual mean reference alkalinity in μeq L^{-1};

“D” is the mean depth of the lake in metres;

"H" is the height in metres of the surface of the lake above mean sea level;

"S" is the surface area of the lake in hectares;

GB refers to those lakes not situated on the island of Ireland.

Mean percent cover of hydrophytes (COV)

The value used for the parameter, COV, in the reference conditions applicable to the lake is dependent on the method of data collection. This metric must be excluded if no formal assessment of cover or frequency has been undertaken, or if data has been collected using strand line surveys (e.g. due to the lack of a boat). Provided that data has been collected using the recommended survey method Reference COV = 8.2% should be applied in all lakes.

Relative percent cover of filamentous algae (ALG)

The value used for the parameter, ALG, in the reference conditions applicable to the lake should be 0.05

Calculation of the ecological quality ratio (EQR) for each parameter

Lake Macrophyte Nutrient Index (LMNI)

The LMNI EQR is modified depending on the calculated expected value. In sites with an expected LMNI>5 the theoretical maximum value of 10 is subtracted from both the observed and expected scores before producing the EQR. Subtracting the theoretical maximum (worst) LMNI site score ensures that sites with low LMNI scores achieve a high EQR. However this is not appropriate in sites with an expected EQR of<5 where the worst practically achievable maximum would be lower. In these sites the expected LMNI value +5 is subtracted from both the observed and expected scores before calculating the LMNI EQR. This has the effect of lowering EQR values for these sites.

If the reference value for LMNI is ≥5:

EQR_{LMNI} = (observed value of LMNI - 10) ÷ (reference value for LMNI - 10)

If the reference value for LMNI is <5:

EQR_{LMNI} = (observed value of LMNI – (reference value for LMNI + 5)) ÷

(reference value for LMNI - (reference value for LMNI + 5))

Number of functional groups of macrophyte taxa (NFG)

The ecological quality ratio (EQR) for the parameter, NFG, should be calculated using

the following equation:

EQR_{NFG} = observed value of NFG ÷ reference value for NFG

unless the observed value of NFG = 0 in which case EQR_{NFG} = 0.

Number of macrophyte taxa (NTAXA)

The ecological quality ratio (EQR) for the parameter, NTAXA, should be calculated using the following equation:

EQR_{NTAXA} = observed value of NTAXA ÷ reference value for NTAXA

unless the observed value of NTAXA = 0 in which case EQR_{NTAXA} = 0.

Mean percent cover of hydrophytes (COV)

The ecological quality ratio (EQR) for the parameter, COV, should be calculated using the following equation:

EQR_{COV} = √ observed value of COV ÷ √ reference value for COV

Relative percent cover of filamentous algae (ALG)

If the observed value of ALG is > 0.05, the ecological quality ratio for the parameter should be calculated using the following equation:

$$EQR_{\mathbf{ALG}} = [\text{observed value of ALG} - 1] \div [0.05 - 1]$$

If the observed value of ALG is ≤ 0.05, the ecological quality ratio for the parameter

should be given the value "1".

Combining the ecological quality ratios for the different parameters

The ecological quality ratio for the combined parameters ($EQR_{\mathbf{LEAFPACS}}$) should be determined as follows:

If the values of either $EQR_{\mathbf{NFG}}$ or $EQR_{\mathbf{NTAXA}}$ are less than the value of $EQR_{\mathbf{LMNI}}$, a diversity adjusted EQR (^{A}EQR) for the parameter, LMNI, should be calculated as follows:

$^{A}EQR_{LMNI}$ = [EQR_{LMNI} + ($^{A}EQR_{NFG}$ or $^{A}EQR_{NTAXA}$, whichever is the smaller x 0.5)] ÷ 1.5

If EQR_{LMNI} is less than the values of either EQR_{NFG} or EQR_{NTAXA} the value of EQR_{LMNI} is unchanged (i.e. $EQR_{LMNI} = {}^{A}EQR_{LMNI}$).

If the value of $^{A}EQR_{LMNI}$ is larger than whichever is the smaller of the values for EQR_{COV} and EQR_{ALG}, $EQR_{LEAFPACS}$ should be calculated using the following equation:

$EQR_{LEAFPACS}$ = [$^{A}EQR_{LMNI}$ + (0.25 × {EQR_{COV} or EQR_{ALG}, whichever is the smaller})] ÷ 1.25

If the value of $^{A}EQR_{LMNI}$ is smaller than or the same as whichever is the smaller of the values for EQR_{COV} and EQR_{ALG}, $EQR_{LEAFPACS}$ should be assigned the same value as $^{A}EQR_{LMNI}$

Application of the method for the purposes of classification

When using the method for the purposes of classifying the ecological status of a water body:

The classification boundaries for the $EQR_{LEAFPACS}$ are given in Table 1

Table 1 UK Lake Macrophyte EQR boundaries agreed for use in classification

$^{S}EQR_{LEAFPACS}$	**Status**
0.80 - 1.0	High
0.66 - 0.799	Good
0.51 - 0.659	Moderate
0.35 - 0.509	Poor
0 - 0.349	Bad

However, to enable the confidence of the classification to be calculated

(a) a standardised ecological quality ratio (^{S}EQR) should be calculated for

$EQR_{LEAFPACS}$ as follows:

If the value of $EQR_{LEAFPACS}$ is < 0.20, $^{S}EQR_{LEAFPACS}$ should be assigned a value of "0". If the value of $EQR_{LEAFPACS}$ is > 1.05, $^{S}EQR_{LEAFPACS}$ should be assigned a value of "1". Otherwise, $^{S}EQR_{LEAFPACS}$ should be calculated using the following equations:

If $EQR_{LEAFPACS} \geq 0.8$:

$$^{S}EQR_{LEAFPACS} = ([EQRLEAFPACS - 0.8] \div [1.05 - 0.8]) \times 0.2 + 0.8,$$

If EQRLEAFPACS ≥ 0.66:

$$^{S}EQR_{LEAFPACS} = ([EQRLEAFPACS – 0.66] \div [0.8 - 0.66]) \times 0.2 + 0.6$$

If EQRLEAFPACS ≥ 0.51:

$$^{S}EQR_{LEAFPACS} = ([EQRLEAFPACS – 0.51] \div [0.66 - 0.51]) \times 0.2 + 0.4$$

If EQRLEAFPACS ≥ 0.35:

$$^{S}EQR_{LEAFPACS} = ([EQRLEAFPACS – 0.35] \div [0.51 - 0.35]) \times 0.2 + 0.2$$

If EQRLEAFPACS < 0.35:

$$^{S}EQR_{LEAFPACS} = ([EQRLEAFPACS – 0.20] \div [0.35 - 0.20]) \times 0.2$$

and

(b) the value of $^{S}EQR_{LEAFPACS}$ for surveys carried out between July and September should be used. If surveys have been carried out in more than one year the mean value of $^{S}EQR_{LEAFPACS}$ should be used.

The value of $^{S}EQR_{LEAFPACS}$ should then be assigned to an ecological status class according to Table 2.

Table 2 Standardised UK Lake Macrophyte EQR boundaries

$^{S}EQR_{LEAFPACS}$	Status
0.80 - 1.0	High
0.60 - 0.79	Good
0.40 - 0.59	Moderate
0.20 - 0.39	Poor
0 - 0.20	Bad

Table 3: List of lake macrophyte taxa and associated information for the calculation of the values for the parameters

Column 1	Column 2	Column 3	Column 4
Macrophyte taxa	**Lake macrophyte nutrient index score**	**Number of functional group**	**Taxa indicated as filamentous algal taxa ("F")**
Alisma gramineum	7.65	13	
Apium inundatum	4.32	7	
Aponogeton distachyos	8.88	16	
Azolla filiculoides	7.25	1	
Baldellia ranunculoides	3.97	13	
Batrachospermum sp.	1.56		
Butomus umbellatus	7.97	13	
Callitriche brutia var. brutia	2.26	6	

Callitriche brutia var. hamulata	4.08	6	
Callitriche hermaphroditica	8.08	5	
Callitriche obtusangula	9.34	6	
Callitriche platycarpa	9.50	6	
Callitriche sp.	7.11	6	
Callitriche stagnalis	6.38	6	
Callitriche truncata	8.28	6	
Ceratophyllum demersum	7.99	5	
Ceratophyllum submersum	6.78	5	
Chara aculeolata	3.49	2	
Chara aspera	4.19	2	
Chara baltica	5.83	2	
Chara canescens	4.73	2	
Chara connivens	5.60	2	
Chara contraria var. contraria	5.06	2	
Chara contraria var. hispidula	6.41	2	
Chara curta	4.14	2	
Chara globularis	6.86	2	
Chara hispida	3.95	2	
Chara intermedia	5.04	2	
Chara rudis	3.93	2	
Chara sp.	5.57	2	
Chara virgata	4.29	2	
Chara virgata var. annulata	4.07	2	
Chara vulgaris	5.56	2	
Crassula helmsii	5.57	5	
Damasonium alisma	6.19	13	
Elatine hexandra	3.81	11	
Elatine hydropiper	5.34	11	
Eleocharis acicularis	8.68	4	

Eleocharis multicaulis	3.03	4	
Eleogiton fluitans	2.03	15	
Elodea callitrichoides	7.64	5	
Elodea canadensis	7.45	5	
Elodea nuttallii	6.19	5	
Eriocaulon aquaticum	1.47	4	
Filamentous algae	6.70		F
Fontinalis antipyretica	4.19	3	
Fontinalis squamosa	3.09	3	
Groenlandia densa	5.35	5	
Hippuris vulgaris	5.23	7	
Hottonia palustris	6.29	7	
Hydrocharis morsus-ranae	6.51	8	
Hydrodictyon reticulatum	8.42		F
Hypericum elodes	3.56	11	
Isoetes echinospora	2.47	4	
Isoetes lacustris	2.22	4	
Isoetes sp.	2.22	4	
Juncus bulbosus	2.42	4	
Lagarosiphon major	3.51	5	
Lemna gibba	7.66	1	
Lemna minor	8.52	1	
Lemna minuta	10.00	1	
Lemna trisulca	7.96	1	
Leptodyction riparium	8.71	3	
Limosella aquatica	3.80	11	
Littorella uniflora	3.73	4	
Lobelia dortmanna	2.16	4	
Ludwigia palustris	3.82	11	
Luronium natans	3.52	13	

Lythrum portula	4.31	11	
Menyanthes trifoliata	5.17	10	
Myriophyllum alterniflorum	2.66	7	
Myriophyllum aquaticum	6.87	7	
Myriophyllum spicatum	6.23	7	
Myriophyllum verticillatum	5.32	7	
Najas flexilis	2.89	14	
Najas marina	5.24	14	
Nitella confervacea	3.28	2	
Nitella flexilis agg.	5.19	2	
Nitella gracilis	3.56	2	
Nitella mucronata	5.67	2	
Nitella opaca	2.36	2	
Nitella sp.	4.66	2	
Nitella translucens	2.73	2	
Nitellopsis obtusa	5.23	2	
Nuphar lutea	7.47	12	
Nuphar pumila	4.82	12	
Nuphar x spenneriana	3.65	12	
Nymphaea alba	6.84	12	
Nymphoides peltata	6.75	10	
Persicaria amphibia	8.25	10	
Pilularia globulifera	3.59	4	
Potamogeton alpinus	4.48	16	
Potamogeton berchtoldii	6.58	14	
Potamogeton coloratus	3.46	16	
Potamogeton compressus	5.18	14	
Potamogeton crispus	7.50	17	
Potamogeton epihydrus	1.00	16	
Potamogeton filiformis	3.68	15	

Potamogeton friesii	4.71	14	
Potamogeton gramineus	2.85	16	
Potamogeton lucens	4.37	17	
Potamogeton natans	4.71	16	
Potamogeton obtusifolius	6.97	14	
Potamogeton pectinatus	7.19	15	
Potamogeton perfoliatus	4.42	17	
Potamogeton polygonifolius	2.39	16	
Potamogeton praelongus	3.92	17	
Potamogeton pusillus	7.54	14	
Potamogeton rutilus	5.49	14	
Potamogeton trichoides	5.79	14	
Potamogeton x cooperi	4.93	17	
Potamogeton x griffithii	2.57	16	
Potamogeton x lintonii	7.21	14	
Potamogeton x nitens	3.48	17	
Potamogeton x salicifolius	5.89	17	
Potamogeton x sparganifolius	3.71	16	
Potamogeton x suecicus	4.62	15	
Potamogeton x zizii	4.04	16	
Ranunculus (sub sect. Batrachian) sp.	5.31	18	
Ranunculus aquatilis agg.	6.30	18	
Ranunculus aquatilis var diffusus	4.20	18	
Ranunculus aquatilis var. aquatilis.	5.81	18	
Ranunculus circinatus	8.70	5	
Ranunculus fluitans	5.65	18	
Ranunculus hederaceus	8.33	11	
Ranunculus lingua	6.79	10	
Ranunculus omiophyllus	5.51	11	

Ranunculus peltatus subsp. baudotii	6.48	18	
Ranunculus peltatus subsp. peltatus	6.49	18	
Ranunculus penicillatus subsp. penicillatus	4.21	18	
Ranunculus penicillatus subsp. pseudofluitans	6.68	18	
Riccia fluitans	6.35	1	
Ricciocarpus natans	5.32	1	
Ruppia cirrhosa	7.03	15	
Ruppia maritima	7.85	15	
Ruppia sp.	8.08	15	
Sagittaria sagittifolia	6.01	12	
Sparganium angustifolium	2.52	13	
Sparganium emersum	6.06	13	
Sparganium natans	2.79	13	
Sphagnum (aquatic indet.)	2.74	3	
Spirodela polyrhiza	9.62	1	
Stratiotes aloides	6.20	8	
Subularia aquatica	1.80	4	
Tolypella glomerata	5.32	2	
Ulva (Enteromorpha) flexuosa	9.05		F
Utricularia australis	2.87	9	
Utricularia intermedia sens.lat.	1.61	9	
Utricularia minor	2.36	9	
Utricularia ochroleuca	1.04	9	
Utricularia sp.	3.34	9	
Utricularia stygia	1.30	9	
Utricularia vulgaris	4.24	9	
Zannichellia palustris	8.69	15	

Worked example

The following data were obtained from a GB lake survey.

The values below represent the cover determined from a single survey covering a minimum of four sectors of a lake.

Taxon present in the lake	% cover in sampled area	Lake macrophyte nutrient index score	Number of functional group
Chara aspera	10	4.19	2
Elodea canadensis	1	7.45	5
Hippuris vulgaris	5	5.23	7
Nitellopsis obtusa	2	5.23	2
Nymphaea alba	10	6.84	12
Potamogeton obtusifolius	5	6.97	14

In addition, the following environmental data were obtained:

Variable	Value
Lake altitude (H)	15 metres
Mean depth (D)	2.7 metres
Area (S)	3.1 hectares
Reference alkalinity (Alk)	1700 µeq L^{-1}
weighted Freshwater Sensitivity Class (wFSC)	4.1

LMNI

The observed value of LMNI is calculated as follows:

1. Sum LMNI scores for all taxa = 35.91

2. Divide this value by the number of taxa present (6) = 5.99

The reference value is calculated using the equation in section 3.2. This results in a reference value for LMNI of 4.73.

$EQR_{\mathbf{LMNI}}$ = (5.99 – (4.73 + 5)) / (4.73 – (4.73 + 5)) = 0.75.

Functional diversity (NFG)

The observed number of functional groups (NFG) for this lake is 5 (*Chara aspera* and *Nitellopsis obtusa* are in group 2, *Potamogeton obtusifolius* group 14, *Nymphaea alba* group 12, *Hippuris vulgaris* group 7 and *Elodea canadensis* group 5).

The reference value is calculated using the equation in section 3.2. This results in a reference value for NFG of 5.89.

EQR_{NFG} = observed NFG / reference NFG = 0.85

Number of taxa (NTAXA)

The observed number of taxa (NTAXA) is 6.

The reference value is calculated using the equation in section 3.2. This results in a reference value for NTAXA of 9.41.

EQR_{NTAXA} = observed value of NTAXA / reference value for NTAXA = 0.64

Mean percent cover (COV)

The observed value for COV is calculated as follows:

1. Sum % cover values for all taxa = 33

2. Divide this value by the number of taxa present (6) = 5.5

A reference value for COV of 8.2 applies to those lakes where data is collected by the recommended method.

$EQR_{COV} = \sqrt{5.5} \div \sqrt{8.2} = 0.82$

Relative cover of algae (ALG)

As the relative cover of filamentous algae is < 0.05, $EQR_{\mathbf{ALG}}$ = 1.00

Combining metrics

The complete results for this lake are, therefore, as follows:

Parameter	Observed value	Reference value	EQR
LMNI	5.99	4.73	0.75
NFG	5.00	5.89	0.85
NTAXA	6.00	9.41	0.64
COV	5.50	8.20	0.82
ALG	0.00	0.05	1.00

$EQR_{\mathbf{LMNI}}$ is larger than the lowest of $EQR_{\mathbf{NFG}}$ and $EQR_{\mathbf{NTAXA}}$ (0.64) so the diversity adjusted ecological quality ratio for LMNI is given by:

$$^{A}EQR_{\mathbf{LMNI}} = [(0.75 + (0.64 \text{ x } 0.5)] \div 1.5 = 0.71$$

The value of $^{A}EQR_{\mathbf{LMNI}}$ (0.71) is less than the values of $EQR_{\mathbf{COV}}$ (0.82) and $EQR_{\mathbf{ALG}}$

(1.00) and is therefore taken as the value for $EQR_{\mathbf{LEAFPACS}}$. This value is then standardised according to the formula in Section 3.5 such that:

$$^{S}EQR_{\mathbf{LEAFPACS}} = ([0.71 – 0.66] \div [0.8 – 0.66]) \text{ x } 0.2 + 0.6 = 0.67$$

$^{S}EQR_{\mathbf{LEAFPACS}}$ values in the range 0.6 to 0.8 are assigned to Good Ecological status (Table 2). Therefore the status of this water body based on its macrophyte assemblage would be Good.

A2 Summary of changes between 1st RBMP and 2nd RBMP

A number of changes were made to LEAFPACS during intercalibration:

1. New nutrient index scores have been assigned to species. 31 species now have higher scores than they did in the previous version. Although the majority of species have reduced scores the species that have higher scores are typically very nutrient tolerant and are also normally found in higher alkalinities. The overall effect of these changes therefore tends to lower EQR in high alkalinity lakes. Nine taxa have been removed from the list as they have not been recorded in WFD lakes.

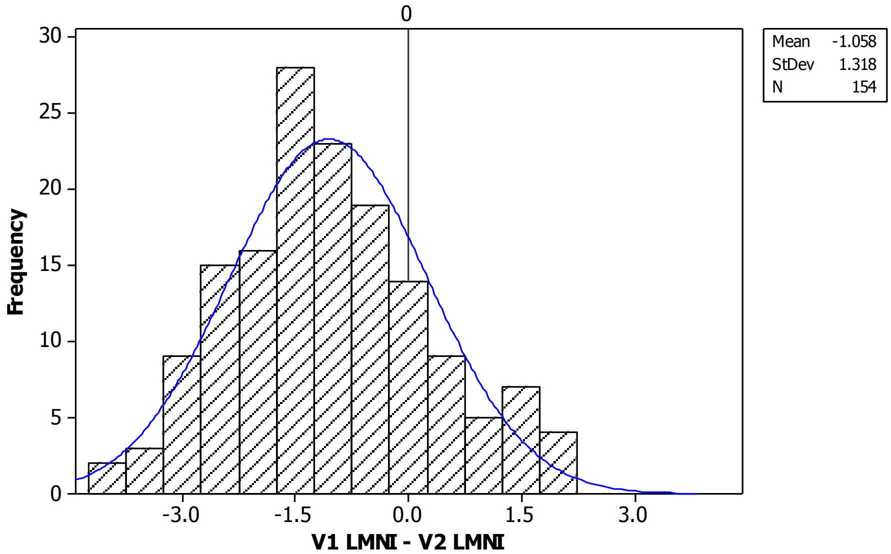

Figure 2. Histogram of change in LMNI score for species

2. Reference LMNI value calculations have been adjusted to overcome difficulties in intercalibrating high alkalinity lakes. Freshwater Sensitivity Classes are now combined to produce a weighted FSC (wFSC) value which is used to determine whether the lake catchment is well or poorly buffered and the appropriate reference equation is then applied.

3. Reference NFG and NTAXA values have revised calculations

4. The LMNI EQR is modified depending on the calculated expected value. In sites with an expected LMNI>5 the theoretical maximum value of 10 is subtracted from both the observed and expected scores before producing the EQR. Subtracting the theoretical maximum (worst) LMNI site score ensures that sites with low LMNI scores achieve a high EQR. However this is not appropriate in sites with an expected EQR of<5 where the worst practically achievable maximum would be lower. In these sites the expected LMNI value +5 is subtracted from both the observed and expected scores before calculating the LMNI EQR. This has the effect of lowering EQR values for these sites.

5. Adjusted EQRs have been reduced in number, their calculations changed and rules for their application set out

6. Rules for combining the adjusted EQRs to produce an $EQR_{LEAFPACS}$ have changed

7. The standardised $EQR_{LEAFPACS}$ is now calculated differently when using the method to classify a waterbody. There are standard values of 0 for $EQR_{LEAFPACS}$ < 0.2 and 1 for values above 1.05, the remaining values are split into 5 categories and different equations applied to them

A3 Consequences of changes

England

Table 4. Comparison of classifications of ecological status determined by original and revised versions of the lake macrophyte tool, LEAFPACS.

		Revised					Grand Total
		High	Good	Moderate	Poor	Bad	
Current	**High**	6	1	2			**9**
	Good	3	18	25	3		**49**
	Moderate	1	1	32	20	3	**57**
	Poor			3	8	3	**14**
	Bad			1	1	2	**4**
Grand Total		**10**	**20**	**63**	**32**	**8**	**133**

Table 5. Percentage of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Class	Current Method	Revised Method
High	6.8%	7.5%
Good	36.8%	15.0%
Moderate	42.9%	47.4%
Poor	10.5%	24.1%
Bad	3.0%	6.0%

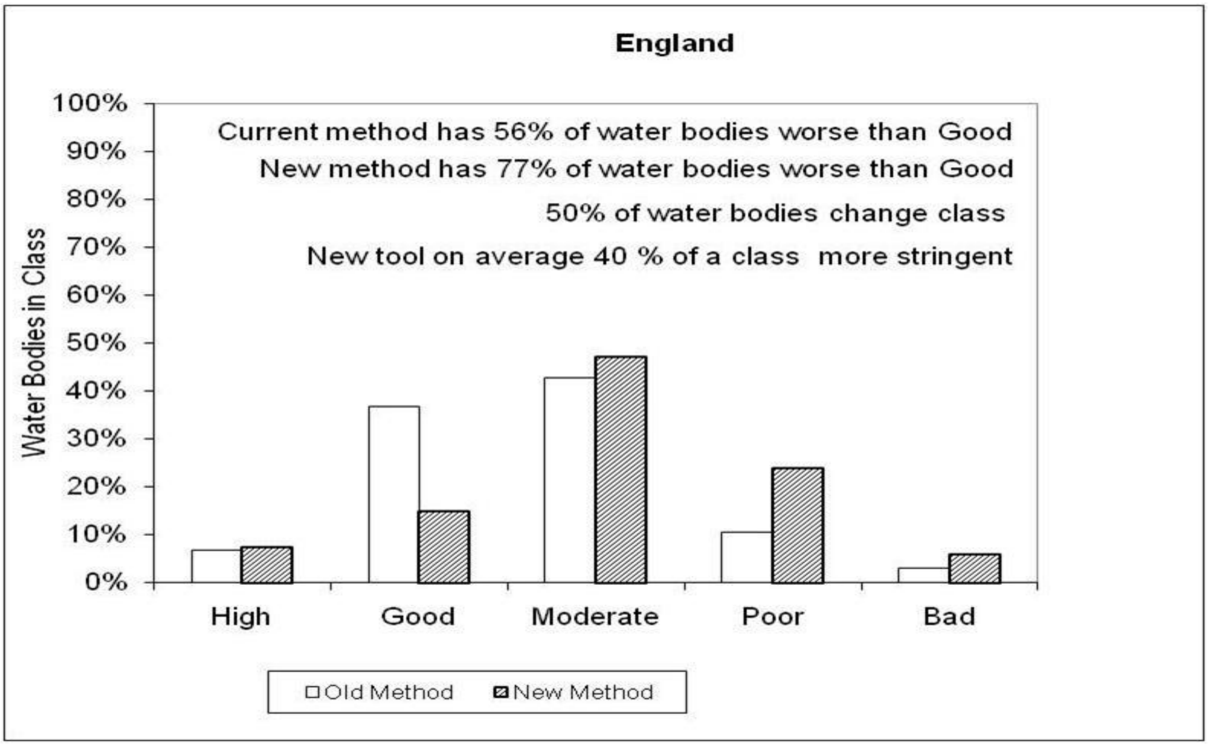

Figure 3. Percentage of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Table 6. Number and percentage of water bodies that change class when using the revised version of the lake macrophyte tool, LEAFPACS.

	Number	Percentage
Current 4 class worse	0	0.0%
Current 3 class worse	0	0.0%
Current 2 class worse	2	1.5%
Current 1 class worse	8	6.0%
Same class	66	49.6%
Revised 1 class worse	49	36.8%
Revised 2 class worse	8	6.0%
Revised 3 class worse	0	0.0%
Revised 4 class worse	0	0.0%

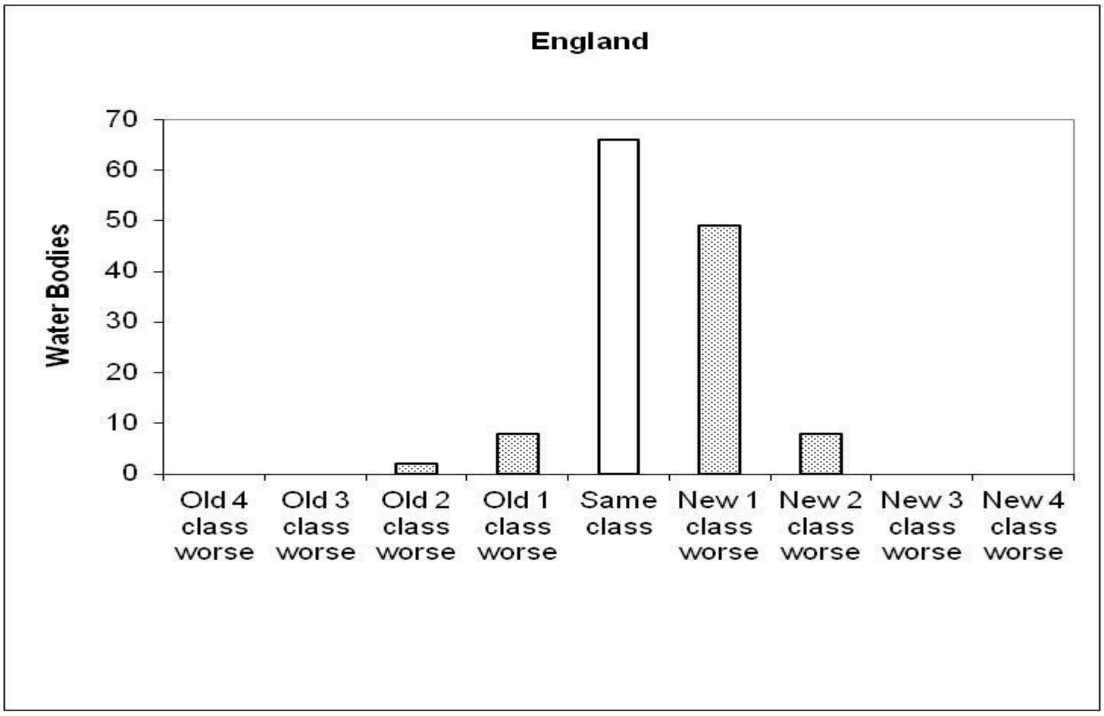

Figure 4. Number of water bodies that change class when using the revised version of the lake macrophyte tool

Wales

Table 7. Comparison of classifications of ecological status determined by original and revised versions of the lake macrophyte tool, LEAFPACS.

		Revised					Grand Total
		High	Good	Moderate	Poor	Bad	
Current	High	1		1			2
	Good	9	12	5	1		27
	Moderate		1	7	5		13
	Poor				4		4
	Bad					1	1
Grand Total		10	13	13	10	1	47

Table 8. Percentage of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Class	Current Method	Revised Method
High	4.3%	21.3%
Good	57.4%	27.7%
Moderate	27.7%	27.7%
Poor	8.5%	21.3%
Bad	2.1%	2.1%

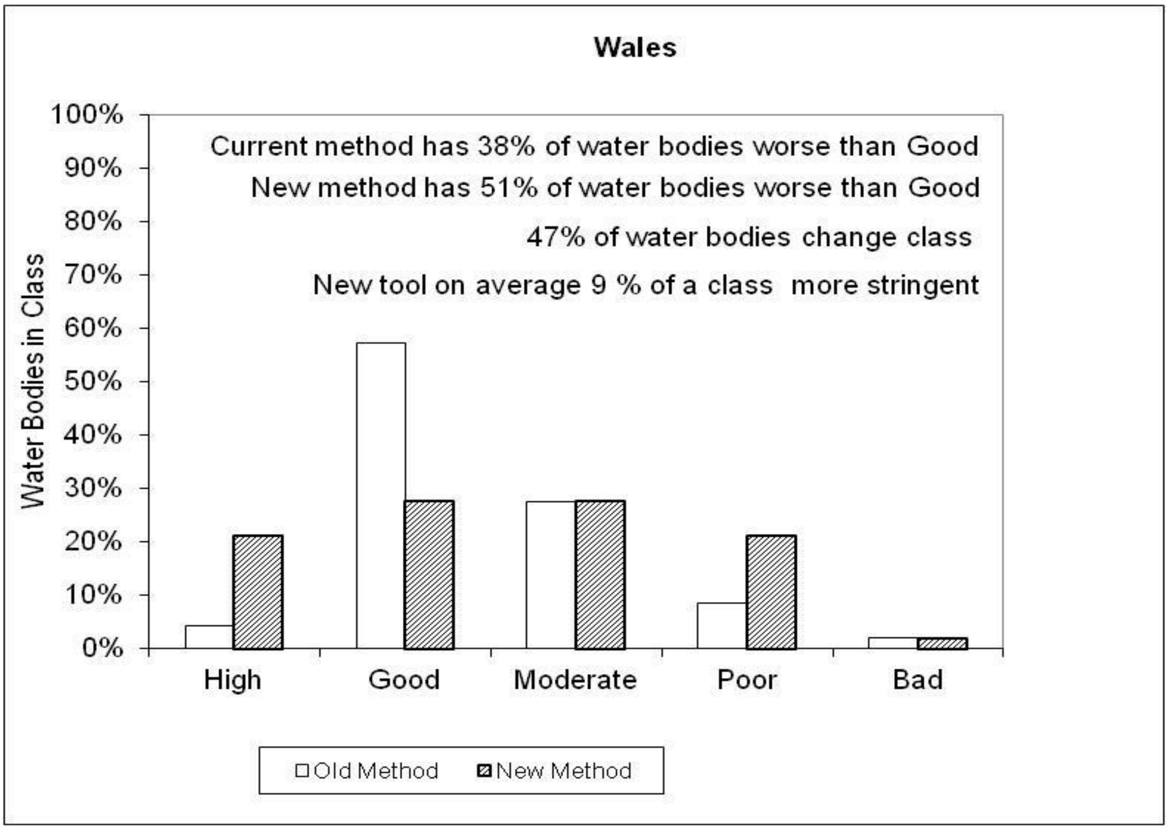

Figure 5. Percentage of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Table 9. Number and percentage of water bodies that change class when using the revised version of the lake macrophyte tool, LEAFPACS.

	Number	Percentage
Current 4 class worse	0	0.0%
Current 3 class worse	0	0.0%
Current 2 class worse	0	0.0%
Current 1 class worse	10	21.3%
Same class	25	53.2%
Revised 1 class worse	10	21.3%
Revised 2 class worse	2	4.3%
Revised 3 class worse	0	0.0%
Revised 4 class worse	0	0.0%

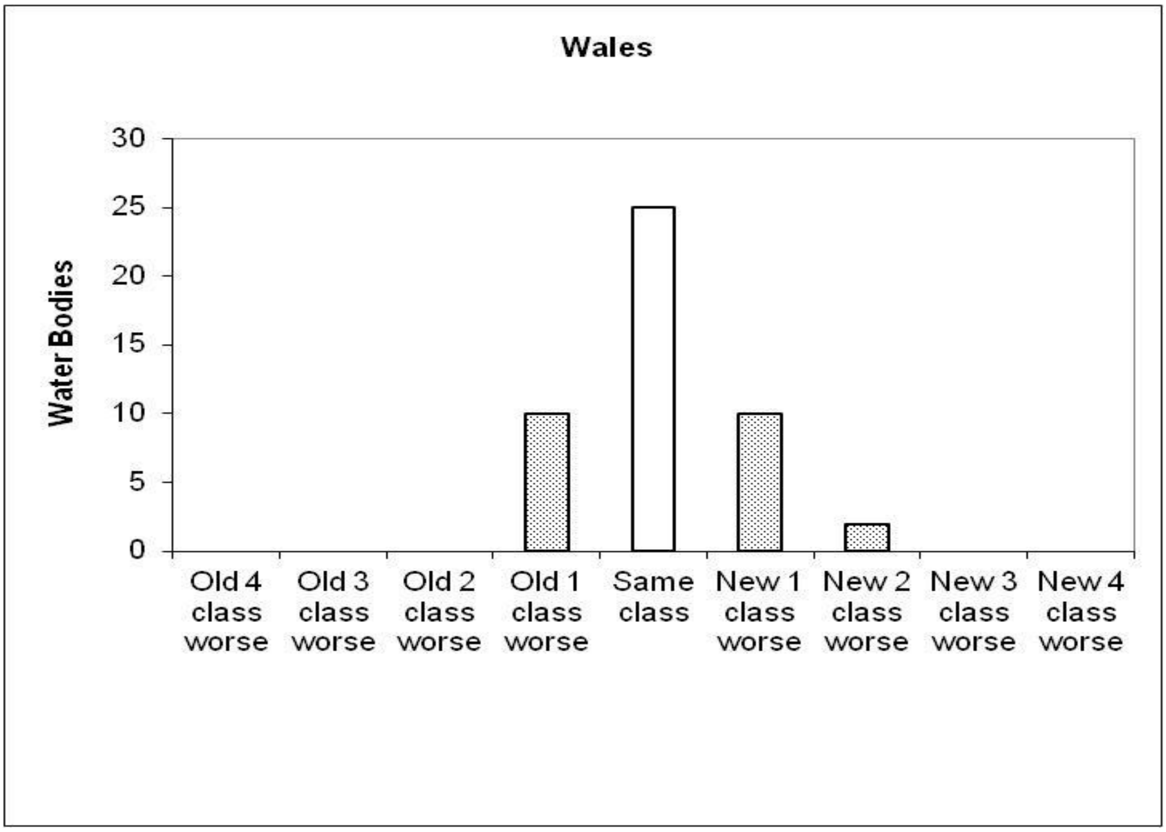

Figure 6. Number of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Scotland

Table 10. Comparison of classifications of ecological status determined by original and revised versions of the lake macrophyte tool, LEAFPACS.

		Revised					Grand Total
		High	Good	Moderate	Poor	Bad	
Current	High	3	2				**5**
	Good	4	21	10			**35**
	Moderate		6	7	1		**14**
	Poor			1	1		**2**
	Bad						
Grand Total		**7**	**29**	**18**	**2**		**56**

Table 11. Percentage of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Class	Current Method	Revised Method
High	8.9%	12.5%
Good	62.5%	51.8%
Moderate	25.0%	32.1%
Poor	3.6%	3.6%
Bad	0.0%	0.0%

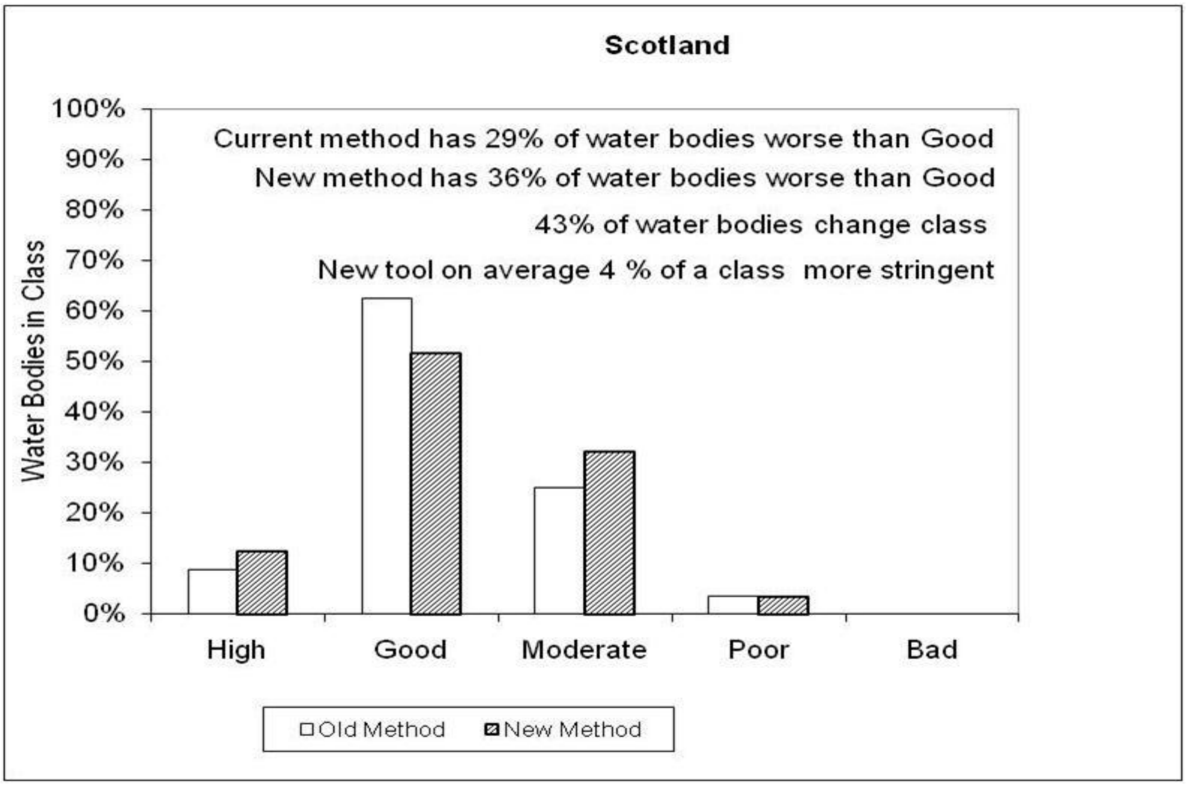

Figure 7. Percentage of water bodies in each class, determined using original and revised versions of the lake macrophyte tool, LEAFPACS.

Table 12. Number and percentage of water bodies that change class when using the revised version of the lake macrophyte tool, LEAFPACS.

	Number	Percentage
Current 4 class worse	0	0.0%
Current 3 class worse	0	0.0%
Current 2 class worse	0	0.0%
Current 1 class worse	11	19.6%
Same class	32	57.1%
Revised 1 class worse	13	23.2%
Revised 2 class worse	0	0.0%
Revised 3 class worse	0	0.0%
Revised 4 class worse	0	0.0%

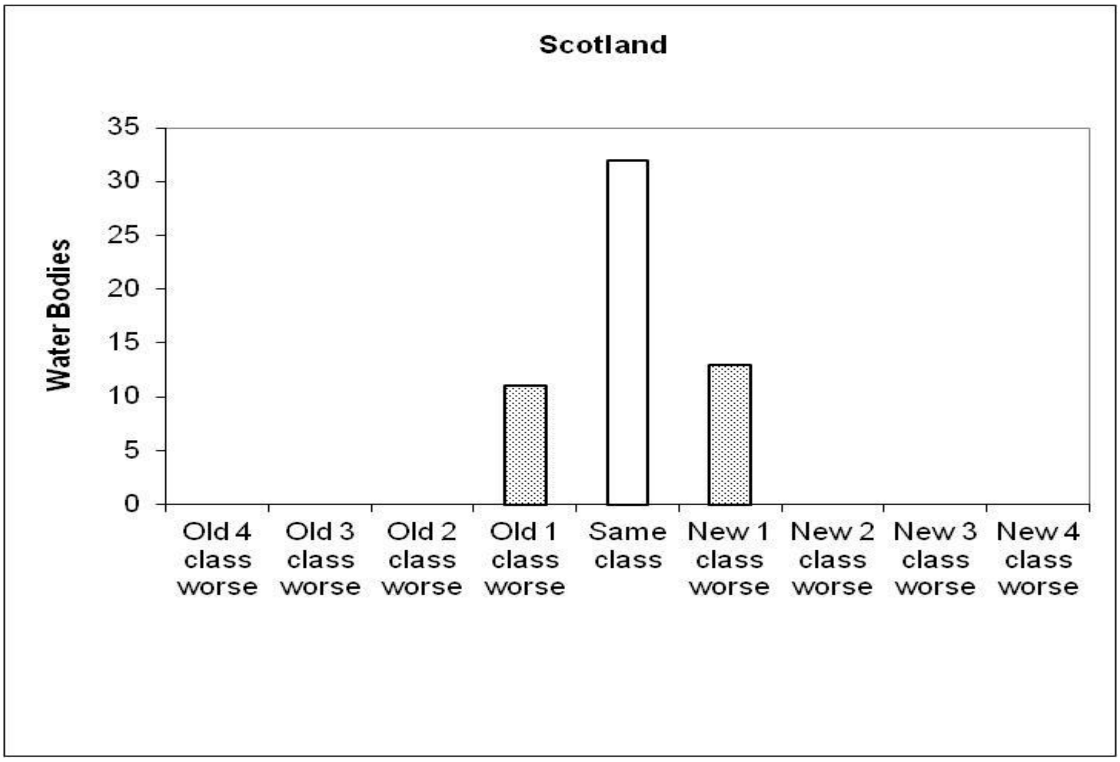

Figure 8. Number of water bodies in Scotland that change class when using the revised version of the lake macrophyte tool

A4 Key documents

LEAFPACS method statement	detailed description of method used for 1st RBMP (survey method unchanged, some adjustments to calculations for 2nd RBMP)
Free Index method statement	detailed description of method