Final report

Fitting the Assessment System for Rivers in Northrhine-Westphalia (Germany) using Macrophytes to the results of the completed Central-Baltic rivers' intercalibration exercise

commissioned by the Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen (LANUV NRW)

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1 Deutsche Zusammenfassung

Anpassung des Bewertungsverfahrens für Fließgewässer in Nordrhein-Westfalen anhand von Makrophyten an die Ergebnisse der abgeschlossenen Interkalibrierung für Fließgewässer der Geographischen Interkalibrierungsgruppe Mitteleuropa/Baltikum

Einleitung

Der vorliegende Bericht dokumentiert die Interkalibrierung der Klassengrenzen des Bewertungsverfahrens für Fließgewässer in Nordrhein-Westfalen anhand von Makrophyten (NRW-Verfahren) nach Vorgabe der EG-Wasserrahmenrichtlinie (WRRL).

Die Interkalibrierung erfolgte auf Grundlage des Handbuchs für Interkalibrierung für die Anpassung neuer oder aktualisierter nationaler Bewertungsverfahren an die Ergebnisse der abgeschlossenen Interkalibrierung (Birk & Willby 2011, Willby et al. 2014).

Das NRW-Verfahren ist ein neues, d. h. zuvor nicht interkalibriertes Verfahren, welches in Nordrhein-Westfalen entwickelt wurde und in weiteren Bundesländern Anwendung findet (Rheinland-Pfalz, Schleswig-Holstein, Sachsen, Sachsen-Anhalt). Im Vergleich zum bereits 2011 interkalibrierten PHYLIB-Verfahren liefert das NRW-Verfahren v. a. bei der Bewertung von *potamalen* Tieflandgewässern plausiblere Ergebnisse, weshalb für die Bewertung nach WRRL die Interkalibrierung des Verfahrens angestrebt wurde.

Im Bericht werden das Bewertungsverfahren kurz vorgestellt, die Belastungs-Wirkungs-Beziehungen aufgezeigt, die Machbarkeit der Interkalibrierung sowie die WRRL-Konformität geprüft und die Vergleichbarkeit mit den Ergebnissen der abgeschlossenen Interkalibrierung analysiert. Die durchgeführten Analysen deckten die folgenden Interkalibrierungstypen ab: Silikatische Sandbäche des Tieflandes (R-C1), silikatische Mittelgebirgsbäche (R-C3), kleine Flüsse des Tieflandes (R-C4).

Kurzbeschreibung des NRW-Verfahrens

Das NRW-Verfahren basiert auf einer modularen Bewertung von vier bis sechs Modulen je nach Gewässertyp: Gesamtdeckung, Anteil Referenzarten, Anteil Eutrophierungszeiger, Anteil Potamalisierungszeiger, Anteil Rhithralisierungszeiger, Anteil Zeiger für thermalen Stress. Zusätzlich ist der Anteil verschiedener Wuchsformentypen in einzelnen Modulen bewertungsrelevant. Für die Einstufung des ökologischen Zustands ist die Zuordnung der zu bewertenden Probestelle zu einer von zehn typspezifischen Vegetationsausprägungen auschlaggebend, welche in einer Übersichtstabelle beschrieben sind. Neben den Gewässertypen unterscheidet das NRW-Verfahren streng zwischen rhithraler und potamaler Ausprägung von Tiefland-Gewässertypen.

Belastungs-Wirkungs-Beziehung

Zur Darstellung der Belastungs-Wirkungs-Beziehungen zwischen ausgewählten anthropogenen Belastungsfaktoren und der Reaktion des NRW-Verfahrens wurden zwei statistische Untersuchungen getrennt für Tiefland- und Mittelgebirgsgewässer durchgeführt. Zum einen wurden die einzelnen Belastungsfaktoren mit dem ökologischen Qualitätsquotienten (EQR) der NRW-Methode korreliert. Zum anderen erfolgte eine multiple Regressionsanalyse der Belastungsfaktoren gegen den EQR unter Nutzung von sog. Boosted Regression Trees (BRT). Das NRW-Verfahren zeigte mäßige, aber durchweg signifikante Beziehungen zu einzelnen Belastungsfaktoren (z B. Ackerlandnutzung im Einzugsgebiet, mittlere Nährstoffkonzentrationen). Die BRT-Analysen wiesen Erklärungsanteile von bis zu 40% auf. Somit konnte ein eindeutiger Bezug des NRW-Verfahrens zu anthropogener Belastung dargestellt werden.

Machbarkeit der Interkalibrierung und WRRL-Konformität

Nach European Commission (2011) hängt die Machbarkeit der Interkalibrierung davon ab, ob das NRW-Verfahren die selben Gewässertypen und Belastungsformen berücksichtigt wie die Verfahren der abgeschlossenen Interkalibrierung. Konzeptionell dürfen keine Unterschiede zwischen den Bewertungsverfahren bestehen. Das NRW-Verfahren erfüllt alle Kriterien und bestätigt dadurch, dass die Interkalibrierung generell durchführbar ist. Allein die Berücksichtigung von Wuchsformentypen ist ein Alleinstellungsmerkmal des NRW-Verfahrens, welches sich jedoch nicht auf die numerische Vergleichbarkeit mit den anderen Bewertungsverfahren auswirkt.

Der Bericht stellt die WRRL-Konformität des NRW-Verfahrens dar und bestätigt die Einhaltung aller Konformitätskriterien.

Vergleichbarkeit mit den Ergebnissen der abgeschlossenen Interkalibrierung

Die Interkalibrierungsanalysen wurden auf Grundlage der Daten von 162 Gewässermessstellen in den Bundesländern Brandenburg, Mecklenburg-Vorpommern, Nordrhein-Westfalen, Sachsen, Sachsen-Anhalt und Schleswig-Holstein durchgeführt.

Das PHYLIB-Verfahren wurde als die „am besten korrelierte und bereits interkalibrierte nationale Klassifizierung“ (sog. BRINC *sensu* Willby et al. 2014) für die Interkalibrierungstypen R-C1 und R-C3 identifiziert. Dadurch konnte die Bezugspunkt-

Standardisierung für die Analysen entfallen. Der Vergleich der Klassengrenzen des guten ökologischen Zustands für das NRW-Verfahren mit den Ergebnissen der abgeschlossenen Interkalibrierung ergab folgende Ergebnisse für beide Interkalibrierungstypen: Die Klassengrenze gut-mäßig stimmt mit den Vorgaben der Interkalibrierung überein, d. h. eine Anpassung ist nicht notwendig. Die Klassengrenze sehr gut-gut liegt unterhalb der internationalen Vorgaben und bedarf einer Anpassung. Diese Anpassung erfolgte durch die Anhebung der Klassengrenze, so dass nur noch Bewertungsergebnisse mit EQR=1.0 zum sehr guten ökologischen Zustand gerechnet werden.

Für den Interkalibrierungstyp R-C4 konnte wegen nicht signifikanter Korrelationen mit den anderen Bewertungsverfahren keine BRINC identifiziert werden. Ursächlich dafür scheint zu sein, dass der Interkalibrierungstyp R-C4 grundsätzlich einen *rhithralen* Charakter aufweist, wogegen die meisten der bei dem Interkalibrierungsverfahren untersuchten Tieflandflüsse *potamal* (Typ 15p) geprägt waren. Die derzeit verfügbare Datenlage für *rhithral* geprägte Tieflandflüsse (Typ 15r) reicht für eine belastbare Interkalibrierung mit dem Typ R-C4 nicht aus. Es ist zu überlegen, ob die Interkalibrierung für diesen Typ nachgeholt werden soll, wenn sich die Datenlage für die rhithral geprägten Tieflandflüsse (Typ 15r) im Rahmen des Monitorings durch ständig neu hinzukommende Monitoring-Ergebnisse für die Qualitätskomponente Makrophyten zukünftig verbessert hat. Dies wird derzeit von NRW geprüft.

2 Introduction

The report at hand documents the procedure to fit the *Assessment System for Rivers in Northrhine-Westphalia (Germany) using Macrophytes* (short: *NRW-method*) to the results of the completed Central-Baltic rivers' intercalibration exercise. The approach presented here closely followed the procedure of the Water Framework Directive (WFD) Intercalibration Manual (Willby et al. 2014) to fit new or updated classification methods to the results of a completed intercalibration. In this report, we show that the NRW-method is compliant with the WFD normative definitions and that its class boundaries are in line with the results of the completed intercalibration exercise.

The NRW-method represents a 'new' classification scheme with regard to its status, i.e. the method has not yet been officially intercalibrated. The method was developed for the German federal state of Northrhine-Westphalia (LUA NRW 2001, 2003, LANUV 2008) and is applied in regular river monitoring of this state since 2001. Other areas of application comprise the federal states of Rhineland-Palatinate, Schleswig-Holstein, Saxony and Saxony-Anhalt. The practical experience, especially gained from the assessment of lowland stream types, demonstrated the superior performance of the NRW-method compared to the PHYLIB-method (i.e. the German classification intercalibrated in the completed exercise for river macrophytes). This finding fostered the endeavour to intercalibrate the NRW-method, to allow for classifying the ecological river status according to the WFD using this method.

Baseline for the application of the procedure specified in the intercalibration manual are the results of the completed intercalibration exercise for river macrophytes in the Central-Baltic Geographical Intercalibration Group. These results are documented in the Milestone 6 report of the WFD Intercalibration Phase 2 (Birk & Willby 2011). Central to the fitting procedure applied in this study is the *global mean view*, i.e. the harmonised position of the high-good and good-moderate class boundary, established by the completed exercise individually for each intercalibration type. This global mean view represents the international standard to which the good status class boundaries of the NRW-method need to comply.

In the following, we present details of the NRW-method including the validation of the pressure-impact relationship, check its compliance with the WFD requirements, and demonstrate the compliance with the completed intercalibration exercise. The analyses performed cover all three intercalibration types addressed in the completed exercise, i.e. sandy lowland brooks (R-C1), siliceous mountain brooks (R-C3) and medium-sized lowland streams (R-C4).

3 The NRW-method

3.1 Short description of the assessment method

The NRW-method employs a modular assessment combining the evaluation of four to six single modules, depending on the stream type: total coverage, reference taxa, eutrophication, potamalisation, rhithralisation, thermal stress. Each module addresses a set of type-specific indicator taxa (e.g. *Ceratophyllum demersum* as an indicator of eutrophication in potamal lowland brooks) and calculates their relative abundance. In addition, the number of macrophyte growth forms is considered for selected modules. The individual module results are combined using the worst module score. Central to the classification procedure of the NRW-method is the stream type-specific look-up table containing the description of ten discrete vegetation states along a gradient of anthropogenic disturbance (similar to the biological condition gradient tiers according to US EPA 2005) (see Appendix 2). In this look-up table an EQR-score is assigned to each discrete vegetation state, and the final status classification of the sampling site is determined on the basis of the worst-case module score corresponding to one of the ten vegetation states. Tab. 1 provides a translation of the discrete EQR-scores into ecological status classes. The class boundary values used in the intercalibration analysis are 0.895 (high-good), 0.695 (good-moderate) and 0.495 (moderate-poor). Furthermore, the NRW-method distinguishes between rhithral and potamal lowland streams, emphasising the fundamental discrepancies in the reference states of these stream types due to the naturally different conditions of flow velocity.

The full method description using the WISER questionnaire is given in the Appendix.

Tab. 1: Translation of the discrete EQR-scores into ecological status classes.

EQR score	Ecological status class
1.0, 0.9	High
0.8, 0.7	Good
0.6, 0.5	Moderate
0.4, 0.3	Poor
0.2, 0.1	Bad

3.2 Pressure-impact relationship

3.2.1 Introduction, data basis and analysis

Statistical analyses were performed to investigate into the response patterns of the NRW-method to various anthropogenic stressors. Selected parameters of catchment land use and measurements of chemical water compounds (annual average values matching the years of biological sampling) were used as explanatory variables (Tab. 2).

Tab. 2: Selected statistical descriptors of the explanatory variables used to analyse the pressure-impact relationship.

Variable group	Variable	Unit	Number of samples	Minimum	Median	Maximum
Siliceous mountain streams (R-C3)						
Land use in the catchment	Urban	%	*77*	0	6	56
	Cropland	%	*77*	0	0	64
	Natural	%	*77*	0	47	100
Chemical	Total nitrogen	mg/l	*72*	0.74	2.70	5.91
	Ammonium	mg/l	*75*	0.01	0.03	1.58
	Nitrate	mg/l	*75*	0.01	0.93	4.95
	Sulphate	mg/l	*68*	5.4	14.9	91.5
	Total phosphorus	mg/l	*75*	0.008	0.037	0.263
Sandy lowland brooks (R-C1) Medium-sized lowland streams (R-C4)						
Land use in the catchment	Urban	%	*102*	0	7	53
	Cropland	%	*102*	0	65	91
	Natural	%	*102*	0	11	100
Chemical	Total nitrogen	mg/l	*93*	0.78	5.60	20.79
	Ammonium	mg/l	*91*	0.03	0.13	1.21
	Nitrate	mg/l	*91*	0.01	2.36	16.35
	Sulphate	mg/l	*90*	13.4	61.8	982.5
	Total phosphorus	mg/l	*90*	0.025	0.140	0.444

Two different analyses were conducted on the basis of the two available datasets, separating between siliceous mountain streams (R-C3; 77 surveys at 68 sites) and the two lowland stream types combined (R-C1: Sandy lowland brooks; R-C4: Medium-sized lowland streams; 102 surveys at 87 sites). First, the relationship of individual variables with the method's EQR was tested using Spearman rank correlation. Then Boosted Regression Tree (BRT) analysis[1] allowed for investigating into the combined effects of all explanatory variables on the method's EQR.

3.2.2 Results

Similar to most other national assessment methods using river macrophytes (Birk & Willby 2011) the NRW-method shows moderate, albeit significant relationships with single stressor variables (Tab. 3). For the mountain brooks, the response to physico-

[1] Boosted regression trees represent a method for fitting statistical models. BRTs combine the strengths of two algorithms: regression trees (models that relate a response to their predictors by recursive binary splits) and boosting (an adaptive method for combining many simple models to give improved predictive performance). The final BRT model can be understood as an additive regression model in which individual terms are simple trees, fitted in a forward, stagewise fashion. Boosted regression trees incorporate important advantages of tree-based methods, handling different types of predictor variables and accommodating missing data. They have no need for prior data transformation or elimination of outliers, can fit complex nonlinear relationships, and automatically handle interaction effects between predictors. Fitting multiple trees in BRT overcomes the biggest drawback of single tree models: their relatively poor predictive performance. Although BRT models are complex, they can be summarized in ways that give powerful ecological insight, and their predictive performance is superior to most traditional modelling methods (Elith et al., 2008).

chemical parameters is pronounced. The lowland-dataset features moderate correlations with selected land use parameters.

The BRT results reveal that 40% (mountains) and 24% (lowlands) of the NRW-method's EQR variance is explained by the stressor variables, respectively. Similar to the correlation analysis, physico-chemical parameters show the largest influence for the mountain brooks while land use variables are most influential at lowland streams and rivers (Tab. 4).

Tab. 3: Results of the Spearman rank correlation analysis. Only parameters yielding coefficients of r >|0.2| are presented.

Parameter	Correlation coefficient	p
Siliceous mountain streams (R-C3)		
Ammonium	-0.28	<0.05
Nitrate	-0.40	<0.001
Sulphate	-0.48	<0.001
Total nitrogen	-0.36	<0.001
Total phosphorus	-0.47	<0.001
Sandy lowland brooks (R-C1) ***Medium-sized lowland streams (R-C4)***		
Cropland	-0.23	<0.05
Natural land use	0.30	<0.01

Tab. 4: Results of the BRT analysis, specifying the explained deviance and the relative influence of individual explanatory variables

Siliceous mountain streams (R-C3)	
% Deviance explained[1]	40%
Relative influence of individual explanatory variables	
Total phosphorus	38 %
Sulphate	23 %
Nitrate	13 %
Total nitrogen	12 %
Ammonium	5 %
Urban land use	4 %
Natural land use	3 %
Cropland	2 %
Sandy lowland brooks (R-C1) ***Medium-sized lowland streams (R-C4)***	
% Deviance explained[2]	24 %
Relative influence of individual explanatory variables	
Natural land use	23 %
Cropland	22 %
Total phosphorus	16 %
Ammonium	10 %
Sulphate	10 %
Urban land use	8 %
Total Nitrogen	7 %
Nitrate	6 %

[1] number of trees: 1600; [2] number of trees: 1650

3.3 Intercalibration feasibility check

The intercalibration feasibility check evaluates whether the NRW-method considers the same common intercalibration types and pressures as addressed in the completed intercalibration exercise. Furthermore, the check scrutinises if the assessment concept of the NRW-method is similar to the concept of the methods intercalibrated in the completed exercise.

With regard to the stream types addressed by the NRW-method, these fully match the relevant common intercalibration types. This is confirmed by Birk & Böhmer (2007) that translated the intercalibration types relevant for Germany into national stream types. Table 4.1 (*Pressure-impact-relationships of national methods and selected pressure variables*) of the Milestone 6 report of the WFD Intercalibration Phase 2 (Birk & Willby 2011) lists parameters of catchment land use and eutrophication being the relevant stressors to which the intercalibrated assessment methods respond. This is in line with the results of the pressure-impact analysis of the NRW-method provided in Chapter 3.2.

The assessment concept of the NRW-method is very similar to those of the intercalibrated methods. All classifications are based on indicator species responding to anthropogenic stress, esp. eutrophication. Specific features of the NRW-method comprise the assessment on the basis of distinct vegetation states summarised in a look-up table, the differentiation between rhithral and potamal stream types, and the additional focus on hydrological stress expressed through indicators of man-made flow velocity increase (rhithralisation) or decrease (potamalisation). The consideration of growth form numbers represents another particular characteristic of the method. Nevertheless, these features still allow for a high correlation with other methods already intercalibrated, as demonstrated below. Merely for stream type R-C4, these conceptual discrepancies seem to cause a lacking correspondence with the intercalibrated methods (see Chapter 4.4).

3.4 Checking of compliance with the WFD requirements

According to European Commission (2011) only methods meeting the requirements of the WFD can be intercalibrated. An important step in the intercalibration procedure is the checking of the NRW-method considering various WFD compliance criteria. The WFD compliance criteria are specified in the reporting template for milestone reports (Annex VI of European Commission 2011). We used this template to document the compliance of the NRW-method (Tab. 5). All compliance criteria are met for the NRW-method.

Tab. 5: Compliance criteria and compliance checking conclusions

Compliance criteria	Compliance checking conclusions
Ecological status is classified by one of five classes (high, good, moderate, poor and bad).	The NRW-method classifies the ecological status by one of five classes (high, good, moderate, poor, bad).
High, good and moderate ecological status are set in line with the WFD's normative definitions (Boundary setting procedure).	Following the WFD's normative definitions for macrophytes, *high ecological status* is defined by a taxonomic composition that corresponds totally or nearly totally to undisturbed conditions, including no detectable changes in the average macrophytic abundance. *Good status* exhibits slight changes in the composition and abundance of macrophytic taxa, but without indication of accelerated plant growth. At *moderate status*, taxonomic composition and abundance differ moderately from the type-specific community. Following these normative definitions, the NRW-method has established detailed macrophyte community descriptions reflecting the vegetative features corresponding to these status classes (see Appendix 2 as an example).
All relevant parameters indicative of the biological quality element are covered (see Table 1 in the IC Guidance). A combination rule to combine parameter assessment into BQE assessment has to be defined. If parameters are missing, Member States need to demonstrate that the method is sufficiently indicative of the status of the QE as a whole.	"Macrophytes" is one of two components of the Biological Quality Element "Macrophytes and Phytobenthos". Within the macrophyte methods all relevant parameters of the Biological Quality Element (i.e. composition and abundance) are covered. See also Annex 2 of Birk & Willby (2011) for further explanation.
Assessment is adapted to intercalibration common types that are defined in line with the typological requirements of the WFD Annex II and approved by WG ECOSTAT.	Yes, but for this criterion, see also Chapter 3.3.
The water body is assessed against type-specific near-natural reference conditions.	The assessment of the NRW-method operates on the basis of type-specific near-natural reference conditions, each of which is based on a detailed macrophyte community description (see Appendix 2 as an example).
Assessment results are expressed as EQRs.	Yes
Sampling procedure allows for representative information about water body quality/ ecological status in space and time.	Yes, the sampling procedure follows the European Standard DIN EN 14184:2012 and allows for representative information about water body quality/ ecological status in space and time.
All data relevant for assessing the biological parameters specified in the WFD's normative definitions are covered by the sampling procedure.	The biological parameters of the WFD's normative definitions (i.e. composition and abundance) are covered by the sampling procedure.
Selected taxonomic level achieves adequate confidence and precision in classification.	Yes, the species-level used by the NRW-method guarantees adequate confidence and precision in classification.

4 Demonstrating the compliance with the completed intercalibration exercise

4.1 Introduction

The completed river macrophyte intercalibration exercise corresponded with *Case B2: IC Option 3 using continuous benchmarking* (Willby et al. 2014). This means that a common biological metric was not used in the completed exercise (but a so-called 'pseudo-common metric'), and reference or alternative benchmark sites were not commonly available at a national level. Key to successful intercalibration is thus to identify a *BRINC*, i.e. the best-related and intercalibrated national classification method. However, as described in the following sections, the requirement for benchmark standardisation was not necessary. The BRINC used in this exercise was the German PHYLIB-method that was developed and is applied in the same biogeographical region as the NRW-method, and acquires the survey data using the same sampling protocol.

All biological data used in this intercalibration exercise (Fig. 1) were sampled in the years 2006 to 2009 on the basis of a survey protocol in line with the requirements of the European Standard DIN EN 14184:2012 (LANUV 2008). Representative river stretches were visually inspected during the growing season (June to September) by wading, diving or boating, using rake, grapnel or aqua-scope where necessary. Representative sites spanned about 100 m of river length. Selected parameters of catchment land use and measurements of chemical water compounds (annual average values matching the years of biological sampling) were acquired from the CORINE-database[2] and chemical monitoring programmes, respectively. The macrophyte survey data were collected following the same procedure as the intercalibrated German PHYLIB-method (Schaumburg et al. 2012), based on the standardised list of aquatic taxa in Germany (BLfW 2003). Therefore, the dataset used in this study complies with the data acceptance criteria of Birk & Willby (2011) and is thus suitable for performing the necessary boundary calculations.

[2] European Environmental Agency; http://www.eea.europa.eu/publications/COR0-landcover

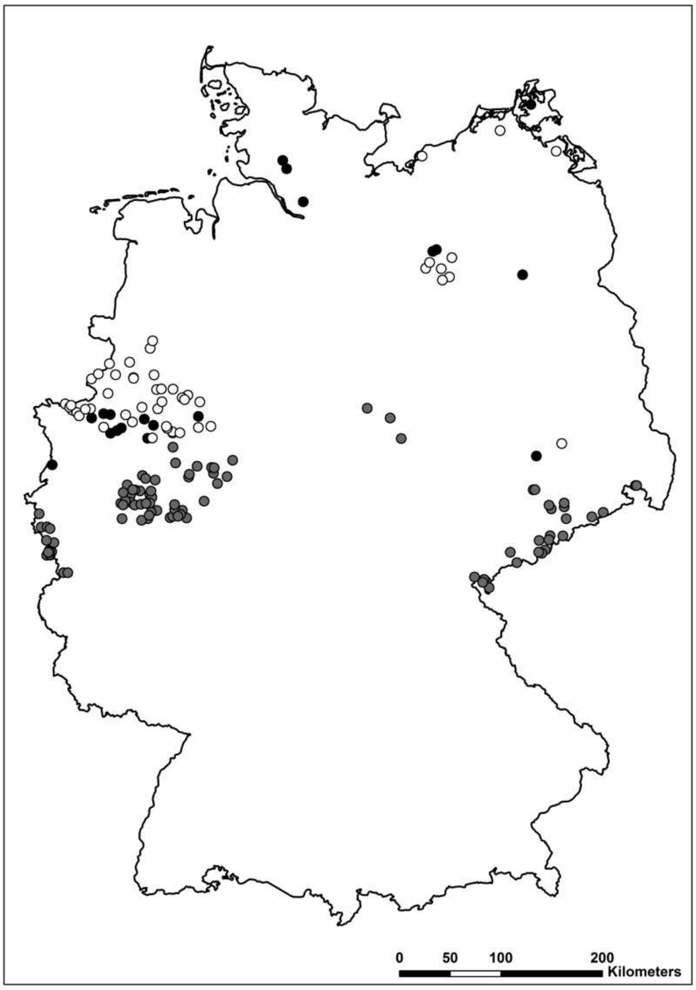

Fig. 1: Location of the 162 sampling sites used in the intercalibration analysis. Black dots: Sandy lowland brooks; grey dots: Siliceous mountain brooks; white dots: medium-sized lowland streams.

4.2 Sandy lowland brooks (R-C1)

4.2.1 Data basis

The data used in the analysis of the sandy lowland brooks covered 32 macrophyte surveys taken at small sand-dominated lowland rivers of rhithral character (German stream type 14r, corresponding to the PHYLIB stream type TRk) in the federal states of Brandenburg, Mecklenburg-Western Pomerania, Northrhine-Westphalia, Saxony and Schleswig-Holstein (see Fig. 1). Due to twelve surveys not meeting the specific data criteria of the PHYLIB-method, only 20 surveys were used in the analysis involving this method.

4.2.2 Identification of the BRINC

Tab. 6 shows the results of the correlation analysis of the NRW-method with the different classification methods intercalibrated for the sandy lowland brooks (R-C1). The NRW-method is best correlated with the German PHYLIB-method. Therefore, this method is selected as the BRINC.

Tab. 6: Results of the correlation analysis of the NRW-method with the different national classification methods intercalibrated for the sandy lowland brooks (R-C1). R – correlation coefficient, N – number of surveys, n.s. – not significant.

National classification method	Pearson's R	N
Germany (PHYLIB – Type TR)	0.841	20
Italy (IBMR)	0.440	32
Poland (MIR)	0.252	32
Great Britain (LEAFPACS)	n.s.	32
Flanders (Type KKB)	0.429	32
Flanders (Type GKB)	0.288	32
Flanders (Type KB)	0.303	32
Flanders (Type GB)	0.398	32
Flanders (Type KR)	0.341	32

4.2.3 Benchmark standardisation

No benchmark standardisation is necessary, since the German PHYLIB-method was developed and is applied in the same biogeographical region as the NRW-method, and acquires the survey data using the same sampling protocol.

4.2.4 Global mean view translated into BRINC

To translate the global mean view of the completed intercalibration exercise into the units of the BRINC (i.e. the PHYLIB-method), we referred to the values of the PHYLIB boundary positions and the boundary-specific class biases documented in Table 8.1 (*National class boundaries and boundary bias*) of the Milestone 6 report (Birk & Willby 2011). We reconstructed the global mean view in BRINC units according to the formula:

High-good boundary

$0.745^{a} - [(0.745^{a} - 0.495^{b}) * 0.12^{c}] = \mathbf{\underline{0.715}}^{d}$

[a] high-good boundary of the PHYLIB-method,

[b] good-moderate boundary of the PHYLIB-method,

[c] boundary bias of the high-good boundary,

[d] position of the high-good global mean view in units of the PHYLIB-method.

<u>Good-moderate boundary</u>

0.495[a] – [(0.495[a] – 0.245[b]) * 0.24[c]] = **<u>0.435</u>**[d]

[a] good-moderate boundary of the PHYLIB-method,

[b] moderate-poor boundary of the PHYLIB-method,

[c] boundary bias of the high-good boundary,

[d] position of the good-moderate global mean view in units of the PHYLIB-method.

4.2.5 Predicting the position of NRW-method's class boundaries on the BRINC scale

Fig. 2 shows the scatterplot of the NRW-method regressed against the BRINC. Tab. 7 lists the reference and boundary positions of the NRW method translated into BRINC units.

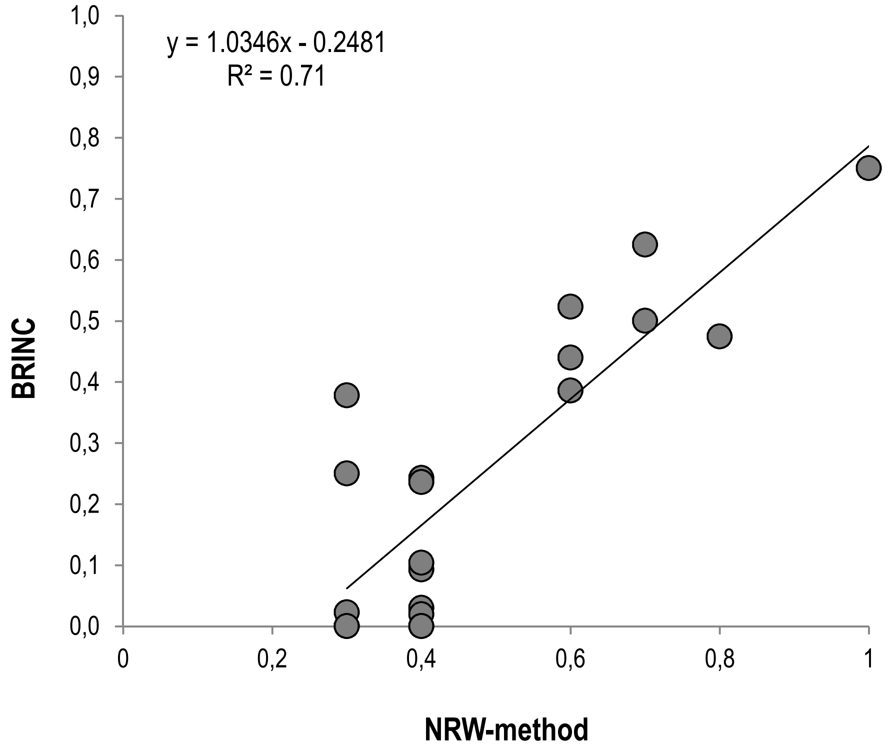

Fig. 2: Regression plot of the NRW-method against the BRINC for the sandy lowland brooks, specifying the regression equation and the coefficient of determination (number of samples: n=20).

Tab. 7: Translation of the reference and boundary positions on the basis of the regression equation specified in the figure above.

	NRW-method	BRINC
Reference	1.000	0.787
High-good	0.895	0.678
Good-moderate	0.695	0.471
Moderate-poor	0.495	0.264

4.2.6 Calculating the high-good class boundary bias of the NRW-method

With the global mean view of the high-good boundary at 0.715 BRINC EQR-units and the NRW-method's high-good boundary translated into BRINC EQR-units at 0.678, the NRW-method's high-good boundary is positioned below the global mean view. This means, that the boundary bias needs to be calculated against the class width of the NRW-method's high status class. The boundary bias is computed according to the following formula:

$(0.678^{a} – 0.715^{b}) / (0.787^{c} – 0.678^{a}) = -\underline{\mathbf{0.34}}^{d}$

[a] NRW-method's high-good boundary translated into BRINC EQR-units,

[b] global mean view of the high-good boundary,

[c] NRW-method's reference value translated into BRINC EQR-units,

[d] high-good class boundary bias of the NRW-method.

The high-good class boundary bias of the NRW-method falls below the threshold of -0.25 and thus requires adjustment.

4.2.7 Adjustment of the high-good class boundary

Adjusting the high-good boundary of the discrete classification of the NRW-method requires to raise the boundary position by 0.1 EQR-units from 0.89 to 0.99 (Fig. 3). Translated into BRINC-units, this corresponds to a value of 0.781. Therefore, the NRW-method's adjusted high-good boundary is now positioned above the global mean view. This means, that the new boundary bias needs to be calculated against the class width of the NRW-method's good status class. The bias of the adjusted boundary is computed as follows:

$(0.781^{a} – 0.715^{b}) / (0.781^{a} – 0.471^{c}) = +\underline{\mathbf{0.21}}^{d}$

[a] NRW-method's adjusted high-good boundary translated into BRINC EQR-units,

[b] global mean view of the high-good boundary,

[c] NRW-method's good-moderate boundary translated into BRINC EQR-units,

[d] high-good class boundary bias of the NRW-method.

After the adjustment the high-good class boundary bias of the NRW-method complies with the required standard of intercalibration.

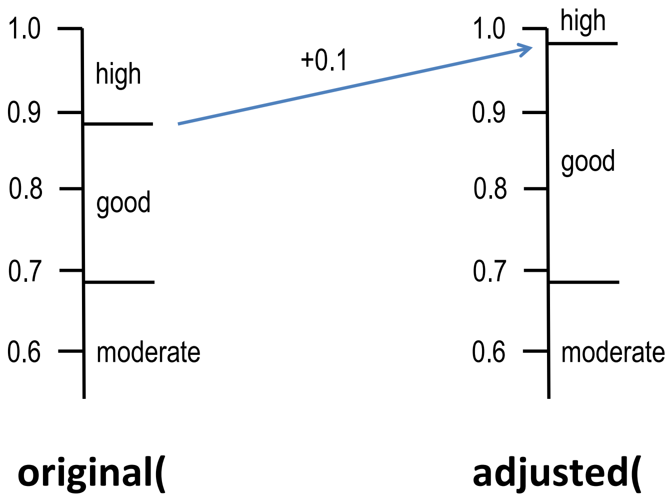

Fig. 3: Scheme on adjusting the high-good boundary position of the NRW-method

4.2.8 Calculating the good-moderate class boundary bias of the NRW-method

With the global mean view of the good-moderate boundary at 0.435 BRINC EQR-units and the NRW-method's good-moderate boundary translated into BRINC EQR-units at 0.471, the NRW-method's good-moderate boundary is positioned above the global mean view. This means, that the boundary bias needs to be calculated against the class width of the NRW-method's moderate status class. The boundary bias is computed according to the following formula:

(0.471[a] – 0.435[b]) / (0.471[a] – 0.264[c]) = +**<u>0.17</u>**[d]
[a] NRW-method's good-moderate boundary translated into BRINC EQR-units,
[b] global mean view of the good-moderate boundary,
[c] NRW-method's moderate-poor boundary translated into BRINC EQR-units,
[d] good-moderate class boundary bias of the NRW-method.

The good-moderate class boundary bias of the NRW-method complies with the required standard of intercalibration.

4.3 Siliceous mountain brooks (R-C3)

4.3.1 Data basis

The data used in the analysis of the siliceous mountain brooks covered 105 macrophyte surveys taken at small coarse substrate dominated siliceous highland rivers (German stream type 5, corresponding to the PHYLIB stream type MRS) in the federal states of Northrhine-Westphalia, Saxony and Saxony-Anhalt (see Fig. 1).

4.3.2 Identification of the BRINC

Tab. 8 shows the results of the correlation analysis of the NRW-method with the different classification methods intercalibrated for the siliceous mountain brooks (R-C3). The NRW-method is best correlated with the German PHYLIB-method. Therefore, this method is selected as the BRINC.

Tab. 8: Results of the correlation analysis of the NRW-method with the different national classification methods intercalibrated for the siliceous mountain brooks (R-C3). R – correlation coefficient, N – number of surveys.

National classification method	Pearson's R	N
Germany (PHYLIB – Type MRS)	0.785	105
Austria (AIM)	0.711	105
France (IBMR)	0.672	105
Poland (MIR)	0.659	105
Great Britain (LEAFPACS)	0.725	105

4.3.3 Benchmark standardisation

No benchmark standardisation is necessary, since the German PHYLIB-method was developed and is applied in the same biogeographical region as the NRW-method, and acquires the survey data using the same sampling protocol.

4.3.4 Global mean view translated into BRINC

To translate the global mean view of the completed intercalibration exercise into the units of the BRINC (i.e. the PHYLIB-method), we referred to the values of the PHYLIB boundary positions and the boundary-specific class biases documented in Table 8.1 (*National class boundaries and boundary bias*) of the Milestone 6 report (Birk & Willby 2011). We reconstructed the global mean view in BRINC units according to the formula:

High-good boundary

$0.745^{a} - [(1.000^{b} - 0.745^{a}) * -0.41^{c}] = \mathbf{0.850}^{d}$

[a] high-good boundary of the PHYLIB-method,

[b] reference values of the PHYLIB-method,

[c] boundary bias of the high-good boundary (*note that we used the pre-harmonisation bias-value*),

[d] position of the high-good global mean view in units of the PHYLIB-method.

Good-moderate boundary

$0.545^{a} - [(0.745^{b} - 0.545^{a}) * -0.32^{c}] = \mathbf{0.609}^{d}$

[a] good-moderate boundary of the PHYLIB-method,

[b] high-good boundary of the PHYLIB-method,

[c] boundary bias of the high-good boundary (*note that we used the pre-harmonisation bias-value*),

[d] position of the good-moderate global mean view in units of the PHYLIB-method.

4.3.5 Predicting the position of NRW-method's class boundaries on the BRINC scale

Fig. 4 shows the scatterplot of the NRW-method regressed against the BRINC. Tab. 7 lists the reference and boundary positions of the NRW method translated into BRINC units.

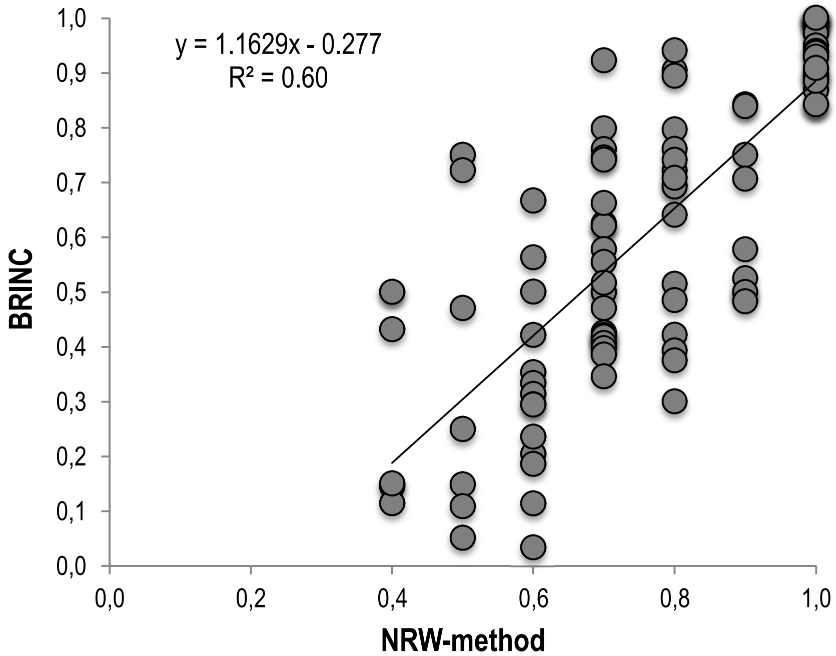

Fig. 4: Regression plot of the NRW-method against the BRINC for the siliceous mountain brooks, specifying the regression equation and the coefficient of determination (number of samples: n=105).

Tab. 9: Translation of the reference and boundary positions on the basis of the regression equation specified in the figure above.

	NRW-method	BRINC
Reference	1.000	0.886
High-good	0.895	0.764
Good-moderate	0.695	0.531
Moderate-poor	0.495	0.299

4.3.6 Calculating the high-good class boundary bias of the NRW-method

With the global mean view of the high-good boundary at 0.850 BRINC EQR-units and the NRW-method's high-good boundary translated into BRINC EQR-units at 0.764, the NRW-method's high-good boundary is positioned below the global mean view. This means, that the boundary bias needs to be calculated against the class width of the NRW-method's high status class. The boundary bias is computed according to the following formula:

$(0.764^{a} – 0.850^{b}) / (0.886^{c} – 0.764^{a}) = -\underline{\mathbf{0.71}}^{d}$

[a] NRW-method's high-good boundary translated into BRINC EQR-units,

[b] global mean view of the high-good boundary,

[c] NRW-method's reference value translated into BRINC EQR-units,

[d] high-good class boundary bias of the NRW-method.

The high-good class boundary bias of the NRW-method falls below the threshold of -0.25 and thus requires adjustment.

4.3.7 Adjustment of the high-good class boundary

Adjusting the high-good boundary of the discrete classification of the NRW-method requires to raise the boundary position by 0.1 EQR-units from 0.89 to 0.99 (see Fig. 3). Translated into BRINC-units, this corresponds to a value of 0.880. Therefore, the NRW-method's adjusted high-good boundary is now positioned above the global mean view. This means, that the new boundary bias needs to be calculated against the class width of the NRW-method's good status class. The bias of the adjusted boundary is computed as follows:

$(0.880^{a} – 0.850^{b}) / (0.880^{a} – 0.531^{c}) = +\underline{\mathbf{0.09}}^{d}$

[a] NRW-method's adjusted high-good boundary translated into BRINC EQR-units,

[b] global mean view of the high-good boundary,

[c] NRW-method's good-moderate boundary translated into BRINC EQR-units,

[d] high-good class boundary bias of the NRW-method.

After the adjustment the high-good class boundary bias of the NRW-method complies with the required standard of intercalibration.

4.3.8 Calculating the good-moderate class boundary bias of the NRW-method

With the global mean view of the good-moderate boundary at 0.609 BRINC EQR-units and the NRW-method's good-moderate boundary translated into BRINC EQR-units at 0.531, the NRW-method's good-moderate boundary is positioned below the global mean view. This means, that the boundary bias needs to be calculated against the class width of the NRW-method's good status class. The boundary bias is computed according to the following formula:

$(0.531^{a} - 0.609^{b}) / (0.880^{c} - 0.531^{a}) = -\underline{\mathbf{0.22}}^{d}$

[a] NRW-method's good-moderate boundary translated into BRINC EQR-units,

[b] global mean view of the good-moderate boundary,

[c] NRW-method's high-good boundary translated into BRINC EQR-units,

[d] good-moderate class boundary bias of the NRW-method.

The good-moderate class boundary bias of the NRW-method complies with the required standard of intercalibration.

4.4 Medium-sized lowland streams (R-C4)

4.4.1 Data basis

The data used in the analysis of the medium-sized lowland streams covered 59 macrophyte surveys taken at mid-sized and large sand and loam-dominated lowland rivers of potamal character (German stream type 15p, corresponding to the PHYLIB stream type TNm) in the federal states of Brandenburg, Mecklenburg-Western Pomerania, Northrhine-Westphalia and Saxony (see Fig. 1). Due to the strict data quality criteria of the PHYLIB-method only 46 surveys were used in the analysis involving this method.

4.4.2 Identification of the BRINC

Tab. 10 shows the results of the correlation analysis of the NRW-method with the different classification methods intercalibrated for the medium-sized lowland streams (R-C4). None of the correlations are significant. Therefore, a BRINC cannot be identified.

Tab. 10: Results of the correlation analysis of the NRW-method with the different national classification methods intercalibrated for the medium-sized lowland streams (R-C4). R – correlation coefficient, N – number of surveys, n.s. – not significant.

National classification method	Pearson's R	N
Germany (PHYLIB – Type TN)	n.s.	46
France and Italy (IBMR)	n.s.	59
Poland (MIR)	n.s.	59
Great Britain (LEAFPACS)	n.s.	59

4.4.3 Conclusions on R-C4 intercalibration

None of the national assessment methods reveals significant correlations with the NRW-method. This finding is similar to the case of the Flemish assessment method documented by Birk & Willby (2011): The Flemish method had to be excluded from the analysis for stream type R-C4 due to its low correlation with the 'pseudo-common metric'. Testing the relationship of the NRW-method with the Flemish classification revealed a noticeable correlation of r=0.458.

Analysing the definitions of the intercalibration type R-C4 discloses a typological issue: Birk & Willby (2010) conclude their description of the reference macrophyte community for the medium-sized lowland streams: "This is an assemblage of medium-sized, active, moderate to fast-flowing, shallow lowland rivers on neutral to base-rich geology with clear, mesotrophic to eutrophic water." And according to Birk & Willby (2011), the type characteristics of R-C4 describe the channel substrate of this intercalibration type as gravel and sand. This points at a reference state featuring moderate to high flow velocities. Contrary to this, the NRW-method to be intercalibrated for R-C4 rivers is adapted to streams of potamal character, i.e. predominantly slow flowing watercourses. The intercalibration typology does not match this potamal type assessed by the NRW-method, thus intercalibration according to the manual prescriptions (Willby et al. 2014) cannot be performed for this stream type.

5 Summary

In this report we documented the fitting procedure of the *Assessment System for Rivers in Northrhine-Westphalia (Germany) using Macrophytes* (short: *NRW-method*) to the results of the completed Central-Baltic rivers' intercalibration exercise. The NRW-method revealed significant pressure-impact relationships and successfully passed the tests of intercalibration feasibility and WFD compliance.

The intercalibration analyses against the global mean view of the completed exercise showed the requirement to adjust the high-good status boundary of the NRW-method (Tab. 11) for the intercalibration types of sandy lowland brooks (R-C1) and siliceous mountain brooks (R-C3). The NRW-method could not be intercalibrated for the medium-sized lowland streams (R-C4) as this type does not match this potamal type assessed by the NRW-method.

Tab. 11: Results of the NRW-method's intercalibration exercise for the intercalibration types R-C1 and R-C3, assigning the discrete EQR scores to the ecological status classes and specifying the ecological status class boundaries.

Ecological status class	EQR score	Ecological status boundary
High	1.0	High-good: 0.995
Good	0.9, 0.8, 0.7	Good-moderate: 0.695
Moderate	0.6, 0.5	Moderate-poor: 0.495
Poor	0.4, 0.3	Poor-bad: 0.295
Bad	0.2, 0.1	-

6 References

Birk, S., & Willby, N. (2010). Towards harmonization of ecological quality classification: establishing common grounds in European macrophyte assessment for rivers. Hydrobiologia, 652, 149-163.

Birk, S. & Willby, N. (2011) CBrivGIG Intercalibration Exercise "Macrophytes" – WFD Intercalibration Phase 2: Milestone 6 Report. Joint Research Institute, Ispra (IT): 41 pp.

Birk, S., & Böhmer, J. (2007). Die Interkalibrierung nach EG-Wasserrahmenrichtlinie – Grundlagen und Verfahren. Wasserwirtschaft, 9, 10-14.

Birk, S., Willby, N., Kelly, M., Bonne, W., Borja, A., Poikane, S., van de Bund, W. (2013). Intercalibrating classifications of ecological status: Europe's quest for common management objectives for aquatic ecosystems. Science of the Total Environment, 454-455, 490-499.

BLfW (2003). Taxaliste der Gewässerorganismen Deutschlands zur Kodierung biologischer Befunde. Bayerisches Landesamt für Wasserwirtschaft, München: 367 pp.

DIN EN 14184:2012 Wasserbeschaffenheit - Anleitung für die Untersuchung aquatischer Makrophyten in Fließgewässern.

Elith, J., Leathwick, J. R., & Hastie, T. (2008). A working guide to boosted regression trees. The Journal of Animal Ecology, 77(4), 802-813.

European Commission (2011). Guidance document on the intercalibration process 2008-2011. CIS-Guidance Document No. 14: 102 pp.

LANUV (2008). Fortschreibung des Bewertungsverfahrens für Makrophyten in Fließgewässern in Nordrhein-Westfalen gemäß den Vorgaben der EG-Wasser-Rahmen-Richtlinie. LANUV-Arbeitsblatt 3. Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen, Recklinghausen: 78 pp.

LUA NRW (2001). Vegetationskundliche Leitbilder und Referenzgewässer für die Ufer- und Auenvegetation der Fließgewässer von Nordrhein-Westfalen. LUA-Merkblätter Nr. 32. Landesumweltamt Nordrhein-Westfalen, Essen: 83 pp.

LUA NRW (2003). Kartieranleitung zur Erfassung und Bewertung der aquatischen Makrophyten der Fließgewässer in NRW gemäß den Vorgaben der EU-Wasser-Rahmen-Richtlinie. LUA-Merkblätter Nr. 39. Landesumweltamt Nordrhein-Westfalen, Essen: 61 pp.

Schaumburg, J., Schranz, C., Stelzer, D., Vogel, A., & Gutowski, A. (2012). Verfahrensanleitung für die ökologische Bewertung von Fließgewässern zur Umsetzung der EG- Wasserrahmenrichtlinie: Makrophyten und Phytobenthos (PHYLIB). Bayerisches Landesamt für Umwelt, Wielenbach: 195 pp.

US EPA (2005). Use of Biological Information to Better Define Designated Aquatic Life Uses: Tiered Aquatic Life Uses. U.S. Environmental Protection Agency, Washington DC: 196 pp.

Willby, N., Birk, S., Poikane, S., & Van de Bund, W. (2014). Water Framework Directive Intercalibration Manual. Procedure to fit new or updated classification methods to the results of a completed intercalibration. Joint Research Institute, Ispra (IT): 33 pp.

Appendix 1: Questionnaire on biological assessment methods used in national WFD monitoring programmes: The NRW-method

A - General information

A-01 Name of person completing this questionnaire
Klaus van de Weyer

A-02 Email address of person completing this questionnaire
klaus.vdweyer@lanaplan.de

A-03 Institution of person completing this questionnaire
lanaplan, Lobbericher Str. 5, 41334 Nettetal, Germany

A-04 Name of assessment method (original full name)
Fortschreibung des Bewertungsverfahrens für Makrophyten in Fließgewässern in Nordrhein-Westfalen gemäß den Vorgaben der EG-Wasser-Rahmen-Richtlinie

A-05 Name of assessment method (translated into English)
Assessment system for rivers in Northrhine-Westphalia (Germany) using macrophytes

A-06 Abbreviation of assessment method
NRW-method

A-07 EU Member State
Germany

A-08 Water Category
Rivers

A-09 If *Transitional Waters*, please specify
- not applicable -

A-10 Biological Quality Element
Macrophytes

A-11 If *Angiosperms*, please specify
- not applicable -

A-12 Scope of detected pressures
Catchment land use
Eutrophication
Flow modification
General degradation (unspecific pressures)
Hydromorphological degradation
Thermal pollution

A-13 Has the pressure-impact relationship of the assessment method been tested?
Yes, with quantitative data (e.g. against range of sites reflecting continuous gradient).

If yes, please specify pressure and impact metrics, the amount of used, statistical significance of pressure.
see Chapter 3.2

A-14 Is the assessment method applied to water bodies in the whole country?
No
If no, please specify region of application: *German federal states of Northrhine-Westphalia, Rhineland-Palatinate, Schleswig-Holstein, Saxony, Saxony-Anhalt*

A-15 If the method has been/is intercalibrated, please specify the relevant Geographical Intercalibration Group(s) and common intercalibration type(s).
Central Baltic GIG (rivers and lakes)
Common intercalibration type(s): *R-C1, R-C3, R-C4*

A-16 Status of assessment method: Method (will be) used for …
Second RBMP (2015)

A-17 Web page describing national method
http://www.lanuv.nrw.de/veroeffentlichungen/arbeitsblatt/arbla3/arbla3start.htm

A-18 Name of responsible person having developed the assessment method
Klaus van de Weyer

A-19 Email address of responsible person having developed the assessment method
klaus.vdweyer@lanaplan.de

A-20 Institution of responsible person having developed the assessment method
lanaplan, Lobbericher Str. 5, 41334 Nettetal, Germany

A-21 Pertinent literature of mandatory character (e.g. official note, national standard)
LANUV Arbeitsblatt 3
http://www.lanuv.nrw.de/veroeffentlichungen/arbeitsblatt/arbla3/arbla3start.htm

A-22 Scientific literature (preferably quote references written in English)
none

A-23 Comments
none

B - Data acquisition

B-01 Which guidelines are followed for the sampling/surveying and sample processing?
DIN EN 14184: 2012

B-02 Sampling/survey device
Macrophytes
Rake
Grapnel
Aqua-scope

B-03 Please specify sampling/survey device
-

B-04 Minimum size of organisms sampled and processed
Macrophytes: visible with the naked eye

B-05 Sampled/surveyed habitat
All available habitats per site (Multi-habitat)

B-06 If *Single habitat(s)* are sampled/surveyed, please specify habitat(s)
- not applicable -

B-07 Which zone is sampled/surveyed in areas with tidal influence (only coastal and transitional waters)?
- not applicable -

B-08 How many sampling/survey occasions (in time) are required to allow for ecological quality classification of sampling/survey site or area?
One occasion per season

B-09 Sampling/survey month(s)
June to September

B-10 Which method is used to select the sampling/survey site or area?
-

B-11 How many spatial replicates per sampling/survey occasion are required to allow for ecological quality classification of sampling/survey site or area?
- not applicable -

B-12 Total sampled area or volume, or total surveyed area, or total sampling duration on which ecological quality classification of sampling/survey site or area is based
River stretch of 50 to 100m length

B-13 Short description of field sampling/survey procedure
Representative river stretches are visually inspected during the growing season (June to September) by wading, diving or boating, using rake, grapnel or aqua-scope where necessary. Representative sites span about 50 to 100m of river length.

B-14 Sample processing
Organisms of the complete sample are identified.

B-15 If *Sub-sampling* is performed, please describe procedure
- not applicable -

B-16 Record of biological data: Level of taxonomical identification
Species/species groups level

B-17 If level of taxonomical identification differs (multiple answers on B-16), please specify what groups are mainly identified to which level.
- not applicable -

B-18 Record of biological data: How is the biota's abundance within the sample/survey measured?
Percent coverage
Abundance classes (ordinal scale)

B-19 Record of biological data: Abundance is related to …
Area

B-20 Please specify unit in which the biota's abundance is expressed
Estimated cover percentage

B-21 If biomass is measured, please specify how it is quantified.
- not applicable -

B-22 Other records of biological data (e.g. organism length, plant growth form, shoot density)
- not applicable -

B-23 Special cases, exceptions, additions
- not applicable -

B-24 Comments
none

C - Data evaluation

C-01 Complete list of biological metric(s) used in assessment
Relative abundance of indicator taxa for different indicative modules (type-specific reference taxa, eutrophication module, rhithralisation module, potamalisation module, thermal pollution module), number of growth forms

C-02 Data basis for metric calculation: From which biological data are the metrics calculated?
Data from single sampling/survey occasion in time (see B-08)

C-03 Does the selection of metrics differ between types of water bodies (e.g. different metrics to assess lowland brooks compared to mountain streams)?
Yes

C-04 Combination rule for multi-metrics
Worst metric score

C-05 Scope of reference conditions
Surface water type-specific

C-06 Key source(s) to derive reference conditions
Existing near-natural reference sites
Expert knowledge
Historical data

C-07 Number of sites used to derive reference conditions
*see LUA NRW (1999), LUA NRW (2001) and LANUV (2008)**

C-08 Geographical coverage of sites used to derive reference conditions
Various stream types of Northrhine-Westphalia

C-09 Location of sites used to derive reference conditions
*see LUA NRW (1999), LUA NRW (2001) and LANUV (2008)**

C-10 Time period (months + years) of data of sites used to derive reference conditions
-

C-11 Reference community description
see LUA NRW (1999), LUA NRW (2001) and LANUV (2008), as well as Appendix 2 for an example*

C-12 Reference sites' criteria
*see LUA NRW (1999), LUA NRW (2001) and LANUV (2008)**

C-13 Are the assessment results expressed as Ecological Quality Ratios (EQR)?
Yes

C-14 Setting of ecological status boundaries
Equidistant division of the EQR gradient (e.g. boundary setting at 0.8, 0.6, 0.4, 0.2).

C-15 Please describe the boundary setting procedure in relation to the pressure
Boundary setting was performed on the basis of the shifts observable in the macrophyte community due to human influence (physico-chemical and hydromorphological degradation). The relative abundance of indicators (species or growth form types) addressing these pressures denotes characteristic vegetation states translated into ecological status.

C-16 Good status community description
see LANUV (2008), as well as Appendix 2 for an example*

C-17 Has the uncertainty of the method been quantified and is it regarded in the assessment?
No

C-18 If the uncertainty has been quantified and regarded, please specify how this is done.
- not applicable -

C-19 Comments

** LUA NRW (1999). Referenzgewässer der Fließgewässertypen Nordrhein-Westfalens. Teil 1: Kleine bis mittelgroße Fließgewässer. LUA Merkblätter Nr. 16. Landesumweltamt NRW, Essen: 245 pp.*

LUA NRW (2001). Vegetationskundliche Leitbilder und Referenzgewässer für die Ufer- und Auenvegetation der Fließgewässer von Nordrhein-Westfalen. LUA-Merkblätter Nr. 32. Landesumweltamt NRW, Essen: 83 pp.

LANUV (2008). Fortschreibung des Bewertungsverfahrens für Makrophyten in Fließgewässern in Nordrhein-Westfalen gemäß den Vorgaben der EG-Wasser-Rahmen-Richtlinie. LANUV-Arbeitsblatt 3. Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein-Westfalen, Recklinghausen: 78 pp.

Appendix 2: Exemplary description of the macrophyte community of siliceous mountain brooks (R-C3) at high and good ecological status according to the NRW-method

Assessment module		Status class	high		good	
		EQR	**1**	**0.9**	**0.8**	**0.7**
Total Coverage			in case of complete shading and absence of structural and physico-chemical pressure	-	-	-
	Total Coverage	**Percent**	<2	-	-	-
Reference taxa	**Type-specific reference taxa** *Apium nodiflorum, Berula erecta, Nasturtium officinale agg., Scapania undulata, Fontinalis squamosa, Chiloscyphus polyanthos, Amblystegium fluviatile, Jungermannia exsertifolia, Racomitrium aciculare, Schistidium rivulare, Marsupella emarginata, Lemanea spp., Platyhypnidium riparioides, Fontinalis antipyretica, Hygrohypnum ochraceum f. ochraceum, Ranunculus fluitans, R. peltatus, R. penicillatus, Myriophyllum spicatum, Myriophyllum alterniflorum, Nitella flexilis, Potamogeton polygonifolius, Callitriche brutia var hamulata, C. cophocarpa, C. platycarpa, C. stagnalis, Montia fontana*	**Relative dominance compared to single abundances**	dominant	dominant	dominant	dominant
Eutrophication*	**Eutrophication indicators** *Potamogeton pectinatus, P. crispus, P. pusillus, P. berchtoldii, P. trichoides, Zannichellia palustris, Crassula helmsii, Elodea canadensis, Elodea nuttallii, Egeria densa, Ceratophyllum demersum, C. submersum, Lagarosiphon major, Leptodictyum riparium, Hygrohypnum ochraceum f. obtusifolia, Octodiceras fontanum, Cladophora spp.* (> 0,5 m Länge), *Oedogonium spec.* (> 0.5 m length), *Rhizoclonium spec.* (> 0.5 m length), *Spirogyra spec.* (> 0.5 m length), *Enteromorpha intestinalis*	**Relative abundance**	0	<0.1	0.1- <0.2	0.2- <0.3
Potamalisation 1*	**Potamalisation indicators 1** *Sparganium emersum* [aquatic], *S. erectum* [aquatic], *Sagittaria sagittifolia* [aquatic], *Nuphar lutea*, *Nymphaea alba*, *Potamogeton natans*, *P. nodosus*, *Butomus umbellatus* [aquatic], *Persicaria amphibia* [aquatic], *Vallisneria spiralis*, *Lemna minor*, *L. gibba*, *L. minuta*, *L. turionifera*, *Spirodela polyrhiza*, *Salvinia natans*	**Relative abundance**	0	<0.1	0.1- <0.2	0.2- <0.3
Potamalisation 2*	**Potamalisation indicators 2** all helophytes	**Relative abundance**	<0.4	<0.4	<0,4	<0.4

* Note that number of growth forms become relevant for assessing the moderate and poor ecological status.