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# Development of a fish-based index combining data from different types of fishing gear. A case study of reservoirs in Flanders (Belgium)

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ABSTRACT. Fish assemblages in reservoirs and lakes are mainly assessed by multiple sampling gear. The challenge exists in how to combine all the data from the different types of gear to develop a fish-based index. In this paper, we describe a novel approach to this challenge in reservoirs in Flanders. The developed approach can also be used for natural lakes in the same eco-region and for any combination of fishing methods. In a first step, we defined a reference list of fish species occurring in man-made Flemish reservoirs. To compile this reference list, we adapted the reference for Dutch lakes with recent data from freshwater reservoirs in Flanders. This reference list contains guild-specific information needed to define metrics. To pre-classify the reservoirs, a habitat status for each reservoir was set using abiotic parameters (pressures). Fish gear-dependent metrics were selected according to their response to these pressures. Threshold values for metrics were determined based on the species reference list and occasionally on the calculated metric values. The ecological quality ratios derived from the index calculation were validated with an independent set of data. The developed index proved to successfully assess the ecological status of the reservoirs in Flanders.

KEY WORDS: fish reference list, fish-based index, modelling, monitoring, European Water Framework Directive.

## INTRODUCTION

The most effective way to define the ecological status of lakes and reservoirs is to assess their vegetation and fauna (Lyche-Solheim et al., 2013). Advantages of biological monitoring are well known and this is one of the reasons phytoplankton, macrophytes, benthic invertebrates and fish are suggested by the European Water Framework Directive (WFD) as biological quality elements to assess the integrity of lakes and reservoirs (EU Water Framework Directive, 2000). In Europe, fish-based indices became important bio-assessment tools since the implementation of this directive. Some researchers in Europe assessed the suitability of fish communities in lakes and reservoirs to indicate anthropogenic deterioration (e.g. Appelberg et al., 2000; Carol et al., 2006; Garcia et al., 2006). As a consequence, fish-based indices were developed to assess the ecological quality of lakes (Belpaire et al., 2000; Holmgren et al., 2007; Beck & Hatch, 2009; Wiśniewolski & Prus, 2009; Launois et al., 2011a; Argillier et al., 2013) and reservoirs (Catalan & Ventura, 2003). A fish-based index is a multimetric procedure to assess the biotic integrity of aquatic ecosystems (Karr, 1981). A metric is a variable assessing an ecological attribute of a community that is sensitive to human impact and reacts unambiguously to impact changes (Breine et al., 2010). Unfortunately, the majority of lake indices have been based on standardised procedures with stratified multi-mesh gillnet fishing only (Cen, 2005). Another difficulty with the earlier fish-based indices concerned the heterogeneity of the survey methods. Some indices were developed using different fishing techniques without considering the gear specificity (e.g. Belpaire et al., 2000; Backx et al., 2008). These indices have to be used with caution. Indeed Chow-Fraser et al. (2006) observed that, although electric fishing and fyke netting each caught 60%-75% of the species present in a wetland, particular species and dominant functional groups tended to be gear specific. Still, metric responses to stress can be developed but patterns of response to particular anthropogenic pressures are unique to gear type (Chow-Fraser et al., 2006). It is hence important to develop an index combining gear-specific metrics as it is the only effective ecological status assessment method integrating ecological, functional and structural aspects of aquatic systems.

Another crucial step in the development of a fish-based index is the realisation of a reference fish assemblage. Many lakes in Europe were identified as artificial or heavily modified water bodies (HMWB), the latter because their nature has changed fundamentally as a result of physical anthropogenic alterations. According to Article 4(3) of the WFD the principal environmental objective for HMWB and artificial water bodies, such as reservoirs, is to obtain a "good ecological potential" (GEP) instead of a "good ecological status" as required for natural systems. Similarly, the reference situation in HMWB is referred to as "maximal ecological potential" (MEP) instead of a "pristine status" (EU Water Framework Directive, 2000). According to WFD, the MEP biological conditions should reflect the biological conditions associated with the closest comparable natural water body type at reference conditions as far as possible, given the MEP's hydromorphological and associated physical and chemical conditions. For an HMWB to be classified as attaining GEP status no more than slight changes in the values of the relevant biological quality elements may be observed as compared to their values at MEP. GEP thus represents a state in which the ecological potential of a water body is falling only slightly short of the maximum it could achieve without significant adverse effects on the wider environment or on the relevant water use or uses (CWD, 2012). As a result the species list is the same for both MEP and GEP and they only differ in threshold values of the selected metrics. The biological potential can be defined once the hydromorphological, physical and chemical potentials are described.

As mentioned by Launois et al. (2011a) problems can arise in establishing a reference condition due to the lack of pristine lakes. Hence, we provide a reference condition approach that can be used for any kind of water type.

In this study we describe a new approach to develop a fish-based index combining data obtained from different types of fishing gear. As a case study we used data from reservoirs in Flanders. The proposed methodology is straightforward and can be used with any kind of data and water types.

## MATERIALS AND METHODS

### Study area

The study area comprised 26 reservoirs located in Flanders (13.521 km²) (Fig. 1). They were selected because they are incorporated into the Flemish freshwater fish-monitoring network. Only some reservoirs are connected to a river (river fed, see Table A, annex).

The surface area of the 26 reservoirs varies between 0.14 and 99 ha with an average depth ranging from 0.5 to 18.5 m (Table A, annex). According to criteria described by Lewis (1983), all reservoirs could be considered as polymictic. In addition, nine reservoirs were selected for validation purposes (Fig. 1). Pressure values were calculated as the sum of scores for industry, agriculture activity (any including ploughing activities, grassland,…) and development constructions (number of houses); the investigated adjacent area extended 100 m inland from the banks as most reservoirs have no catchment or only small brooks feeding into them. Data were recorded in the field or via Google Earth when data were missing. Industry (presence of industrial activities e.g. factories) was scored as present (1) or not (0). Thresholds for agriculture activity and development were: 1 if less than 10% of the area is used; 2= ≤30-≥10%; 3= ≤50->30%; and 4 if more than 50 % is used. We also assessed the natural state score of the banks: 1 = 100% natural, 2 = 25% or less of the bank surface is reinforced (concrete, stones etc.), 3 = between 25 and 50% is reinforced, and 4 = more than 50% is unnatural. The total pressure was obtained by summing all pressure scores and can vary between 3 and 13. A pressure class (status) was defined as follows: good or high = 3; moderate = 4; poor >4 and ≤8 and bad >9. Presence of trees was assessed as a predictor, recorded as percentage of area coverage and scored as follow: 4 (no trees); 3 = ≤ 10%; 2= > 10 ≤ 50% and 1= more than 50% of the area covered with trees.

## Fish data

All field work was performed by trained fish biologists and technicians using the protocol described in BELPAIRE et al. (2000). Surveys occurred in autumn between 1996 and 2005 (development data) and between 2006 and 2012 (independent validation data). Fish assemblage data were obtained by electric fishing from a boat with two hand-held anodes, using a 5 kW generator with an adjustable output voltage of 300 to 500 V and a pulse frequency of 480 Hz. We surveyed on average 266 m (range: 25-2100 m; average width 2.5 m) long shore transects per ha with electric gear. The variability in effort is due to the fact that no standardised method was defined before the year 2000. At least four paired-fyke nets (90 cm diameter and 22 m long) were placed per reservoir for two successive days (48h) with, on average, one paired-fyke net per hectare (Table A, annex). Fish data recorded

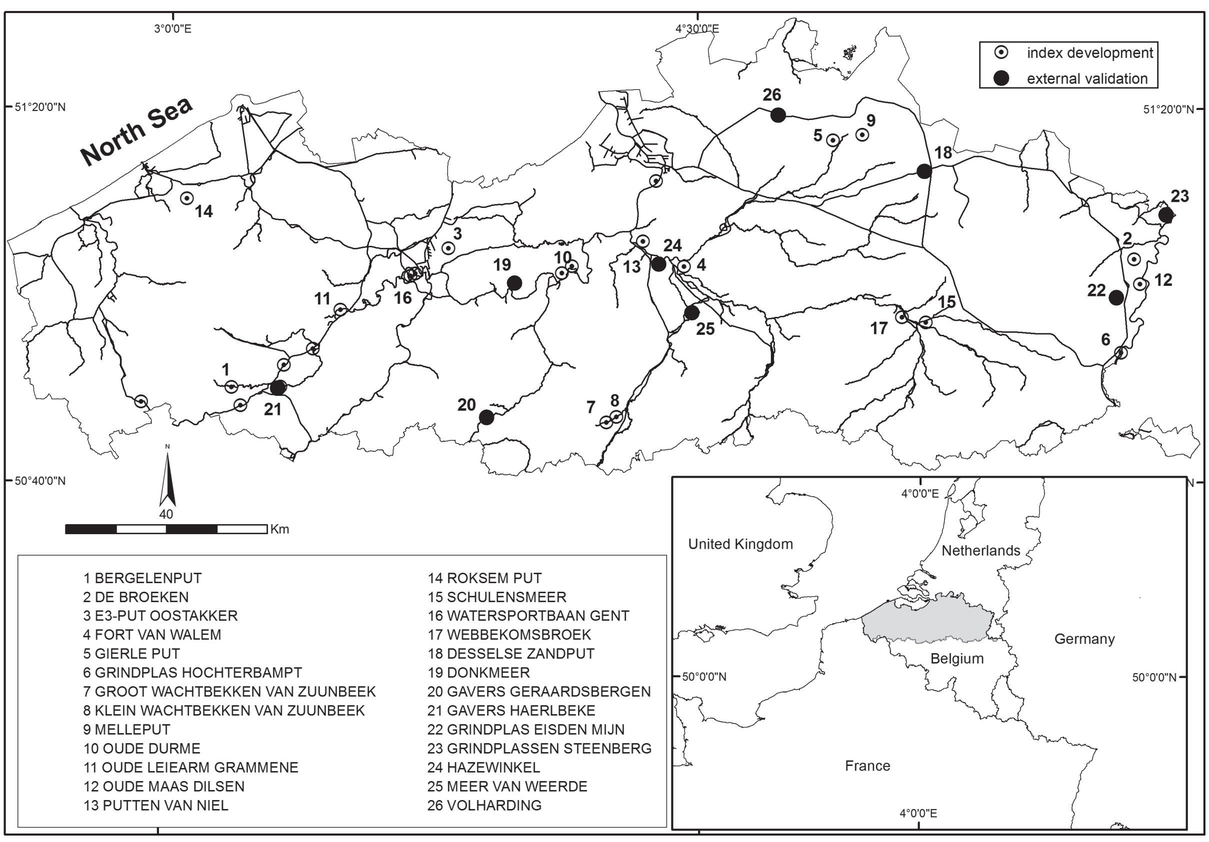


Fig. 1 – Overview of assessed reservoirs (1996-2005) and reservoirs used for the external validation (2006-2011) in Flanders, Belgium.

include species-specific fish densities, individual total lengths (TL, nearest 0.1 cm) and wet weights (nearest 0.1 g).

Data are available from the Fish Information Database (VIS databank: http://vis.milieuinfo.be).

## Species reference list

We adapted the reference species list described by Backx et al. (2008) for the Dutch lakes with Flemish data from surveys for the period 1996-2005. We omitted species from the MEP/GEP list even if they previously occurred in a particular reservoir when: 1) fish are locally or regionally extirpated or 2) a reservoir or lake is not their preferred habitat (Ramm, 1990).

Exotic species were defined according to Verreycken et al. (2007). The classification of species as 'native' and 'non-indigenous' was based on historical and archaeological records. All exotic species were omitted from the list as many authors (e.g. Karr, 1981; Belpaire et al., 2000) consider these as indicators of disturbance. Exceptions are pike-perch (*Sander lucioperca,* Linnaeus, 1758), common carp (*Cyprinus carpio*, Linnaeus, 1758) and Prussian carp (*Carassius gibelio*, Bloch, 1782) as they can be considered as naturalised. Moreover, pike-perch has a high oxygen demand (Marshall, 1977; FAO, 1984, 1989); hence, the species' presence is an indicator for good water quality.

## Index development

Fish were attributed to guilds based on a literature review (Breine et al., 2004, 2005). Species were categorised according to their tolerance for oxygen deficiency and habitat structure degradation such as shoreline bank modifications. Tolerance scores for oxygen deficiency and structural habitat modifications, from 1 (tolerant) to 5 (intolerant), were given to each species based on information from Belpaire et al. (2000) and Breine et al. (2007). Ecologically-relevant candidate metrics were selected from literature (Belpaire et al., 2000; Jeppesen et al., 2000; Mehner et al., 2004; Garcia et al., 2006; Jaarsma, 2007; Launois et al., 2011b). For each reservoir, gear-specific metric values were calculated using reference species only (Breine et al., 2010). To correct for differences in sampling effort, catch per unit effort (CPUE) was used i.e. survey data were standardised to catch results per m$^2$ (electric fishing) and catch per fyke day (number of fish per fyke per day).

## Statistical analyses

To retrieve less-skewed distribution, percentage metrics were square-root transformed and count metrics were log-transformed (logx+1) (Launois et al., 2011b). Diversity metrics were not transformed.

First the correlation among pressure scores was assessed (measure of association, p (Fisher)) to avoid co-linearity. Pearson correlation was applied to assess correlation between reservoir depth and reservoir surface (log x+1) transformed values.

The response of metrics to pressures (log transformed values to meet requirements of linear models) and predictors (depth, surface, trees) was analysed with linear mixed regression models. As some locations were sampled several times we added locality and year as random effects. We started with a full model including all pressures and predictors. We applied a stepwise backward selection until only significant terms remained. Normality assumptions were assessed with residual plots. To define the goodness-of-fit, the marginal and conditional $R^2$ values for each fitted model were calculated as described by Nakagawa & Schielzeth (2013). Only the metric response to pressures was decisive for the selection ($R^2$ conditional>35%). Redundancy of responsive metrics was analysed with a Pearson correlation. To choose among the correlated metrics (c ≥0.7; p ≤0.001), the one with the best fitted model was taken. Secondly, among the less correlated metrics (c <0.7 and ≥0.5; p ≤0.05), the one that least correlated with other metrics was selected.

The statistical software used was R.2.15.2 packages lme4, nlme and MuMIn (R Development Core Team, 2012).

Threshold value determination for the selected metrics was based on the reference list and followed Breine et al. (2010). Once the GEP was defined the other integrity classes were defined by applying trisection with GEP values.

For the relative percentage metrics (Mpi metrics) the GEP is the ratio of the number of the species included in a particular Mpi metric over the total number of species in the reference list (Breine et al, 2010).

For metrics assessing number of species 60% of the reference number was taken as the GEP status threshold value, while this was 80% for the metric tolerance value.

The average value from the highest impacted sites was used to define the minimum percentage weight of benthivorous species (BenWei) and the bream (*Abramis brama*, Linnaeus, 1758) and roach (*Rutilus rutilus*, Linnaeus, 1758) associated metric (AbrRut).

The sum of the metric scores obtained with each method gave the index of biotic integrity (IBI) score for a particular reservoir. To comply with the WFD, this score was transformed to an ecological quality ratio (EQR) calculated as a value between 0 and 1: EQR = (IBI -lowest IBI possible)/(maximum IBI possible - lowest IBI possible). The EQR for the MEP status is 1 under which four integrity classes are defined: GEP (lower threshold value 0.75), moderate (0.5), poor (0.25) and bad (<0.25). The transformation to equal interval classes was obtained using the following formula for each integrity interval (piecewise transformation):

T EQR = LV T EQR + (O EQR - LV O EQR)/(UV O EQR - LV O EQR)*0.25

O and T stand for original and transformed EQR value, UV and LV (upper and lower value of integrity class). When, during one campaign, more than one site was assessed within one reservoir, data obtained with the same method were summed and transformed to catch per unit effort (i.e. per m² or per fyke day) to calculate the final EQR for the reservoir. Selected metrics were graphically screened with boxplots to assess the response to pressure. Allowing a class difference of one unit (see Breine et al., 2007, 2010), indices were validated by comparing the integrity class obtained per reservoir with its assessed pressure status. We assessed data of reservoirs used for the index development and an independent set of data consisting of fish data from nine reservoirs not included in the index development (surveys in 2006-2012). Finally a comparison was performed between the EQR values obtained with the old (Belpaire et al., 2000) and new indices (Pearson correlation, boxplot). To allow comparison, the old EQR values for each fishing sample within one year in a particular reservoir were averaged.

## RESULTS

The selected reservoirs have different morphological characteristics and are subjected to different degrees of pressures (Table A, annex). The scores of the pressure assessment ranged between 4 and 8 (moderate and poor status). None of the assessed reservoirs seemed to have a good or high habitat-status (pressure score = 3).

In total 28 fish species were caught in reservoirs between 1996 and 2005. Eel (*Anguilla anguilla*, Linnaeus, 1758) and perch (*Perca fluviatilis,* Linnaeus, 1758) were the most frequently caught species with fyke nets and electric fishing. Perch and ruffe (*Gymnocephalus cernua*, Linnaeus, 1758) constituted the highest number of individuals caught with fyke nets, while roach and perch were most abundant during electric

TABLE 1

Candidate metrics with their predicted response to increasing disturbance.

| Candidate metrics | Abbreviation | Metric type | Category | Predicted response to disturbances |
|---|---|---|---|---|
| # benthic species | MnsBen | species (count) | species composition and richness | ↓ |
| # invertivorous species | MnsInv | species (count) | trophic composition | ↓ |
| # local species | MnsLoc | species (count) | species composition and richness | ↓ |
| # omnivorous species | MnsOmn | species (count) | trophic composition | ↑ |
| # piscivorous species | MnsPis | species (count) | trophic composition | ↓ |
| # species | MnsTot | species (count) | species composition and richness | ↑ |
| Percentage benthic individuals | MpiBen | relative percentage individuals | species composition and richness | ↓ |
| Percentage invertivorous individuals | MpiInv | relative percentage individuals | trophic composition | ↓ |
| Percentage omnivores | MpiOmn | relative percentage individuals | trophic composition | ↑ |
| Percentage piscivores | MpiPis | relative percentage individuals | trophic composition | ↓ |
| Percentage recruitment | ManRec | relative percentage individuals | age structure | ↓ |
| Percentage specialised spawners | MpiSpa | relative percentage individuals | species composition and richness | ↓ |
| Shannon-Wiener diversity index | ManSha | diversity | species composition | ↓ |
| Tolerance value | ManTol | sum of values | species composition and richness | ↓ |
| Total biomass per effort | ManBio | sum of biomass | abundance | ↓↑ |
| Percentage weight of *Abramis brama* and *Rutilus rutilus* | AbrRut | relative percentage individuals | abundance | ↑ |
| Median weight of *Abramis brama*, *Perca fluviatilis* and *Rutilus rutilus* | MedWei | median biomass | abundance | ↑ |
| Benthivore species (% weight) | BenWei | relative percentage weight | trophic composition | ↑ |
| *Sander lucioperca* (% weight) | SanLuc | relative percentage weight | abundance | ↑ |
| *Perca fluviatilis* (% weight) | PerFlu | relative percentage weight | abundance | ↓ |
| *Abramis brama* (% weight) | AbrBra | relative percentage weight | abundance | ↑ |
| Obligate species | OblSpe | species (count) | species composition and richness | ↓ |

fishing (Table B, annex). Twenty-one species were selected to occur in the reference (MEP/GEP) list, and guilds were attributed to the species included in this list (Table C, annex). A total of 22 candidate metrics were selected (Table 1).

The measure of association analyses allowed the selection of uncorrelated pressure variables to be used in the model. Only agricultural and industrial activities were correlated (V= 0.7; p= 0.003). Agricultural activities were selected as they affect water quality by the use of fertilisers and pesticides and because of their effects on soil erosion. Reservoir surface and depth were not correlated (Pearson c= 0.159; p= 0.382) and could be included in the model. The linear mixed model results are given in Table 2. For electric fishing data, seven metrics showed a significant relationship with the pressures and four with one of the descriptors. For the fyke net data, five candidate metrics showed a significant relationship with one pressure and six with one or two of the descriptors. Metrics that were not fitted by the model were omitted. Correlations between fitted metrics are given in Table 3.

To assess the ecological status with electric survey catches, two of the seven significant variables were selected (Table 4), more specifically 'relative percentage of specialised spawners' (individuals) (MpiSpa) and the 'relative percentage of invertivorous individuals' (MpiInv). For the fyke net data, four metrics were selected out of five possible candidates. These included the 'number of piscivorous species' (MnsPis), 'relative percentage of omnivorous individuals' (MpiOmn), 'relative weight percentage of benthivore species' (BenWei) and 'tolerance value' (ManTol). The response of the selected metrics to environmental pressures (pre-classification) is illustrated with boxplots showing how metric distribution changes along the pre-classification score (Fig. 2). Only one metric (MpiOmn) did not react well to increasing pressure. Compared to the other selected metrics the absolute values for its goodness-of-fit of the model ($R^2$ marginal and conditional) were smaller (Table 2).

We considered 21 species in the reference list to be attributed to the selected metrics (Table C, annex). Below we give a short description of how the MEP/GEP for the six selected metrics was defined:

- Percentage specialised spawners (MpiSpa) (electric data)

There were six species involved: pike (*Esox lucius* LINNAEUS, 1758), gudgeon (*Gobio gobio* LINNAEUS, 1758), burbot (*Lota lota* LINNAEUS, 1758), ruffe, rudd (*Scardinius erythrophthalmus* LINNAEUS, 1758) and tench (*Tinca tinca* LINNAEUS, 1758). The relative species frequency in the reference condition (all 21 reference species present) equalled 28.5% (6/21)*100) and was taken as GEP. This metric was independent from depth and surface area (Table 2).

- Percentage of invertivorous individuals (MpiInv) (electric data)

Only three species were assessed: perch (<13 cm total length, PERSSON, 1983), ruffe and gudgeon. The maximum relative species frequency was 14.2% ((3/21)*100). This value was taken as the GEP status. The metric was depth-dependent.

- Number of piscivorous species (MnsPis) (fyke data)

Five species were assessed: burbot, wels catfish (*Silurus glanis*, LINNAEUS, 1758), pike-perch, perch (≥ 13cm total length, KOTTELAT & FREYHOF, 2007) and pike. MEP status was obtained when five piscivorous species were caught. For the GEP status three of these species were needed (60%). Indeed, according to the WFD, GEP tallies with slight changes in the values of the relevant biological quality elements as compared to the values found at maximum ecological potential (EU WATER FRAMEWORK DIRECTIVE, 2000). This metric was independent from depth and surface.

TABLE 2

Reaction of metrics with uncorrelated pressures in reservoirs. The linear mixed model (lmer) assessed how far uncorrelated descriptors and pressures scores (Surlake: reservoir surface; Depth: average depth of reservoir; Dev: percentage of construction; Agr: percentage of agriculture activities; Tree: percentage of trees: Nat: percentage of natural banks) described metrics (log (L) or square root (SR) transformed (metric abbreviations are explained in Table 1).

| model <-lmer(metric ~ Lake surface + Development + Depth + Natural banks + Agriculture + Trees +(1\|reservoir) + (1\|year)) | | | | | | |
|---|---|---|---|---|---|---|
| Metrics (E) | Selected model | p value variable 1 | p value variable 2 | p value variable 3 | $R^2$ Mar | $R^2$ Cond |
| LMnsInv | 0.460-0.048Tree | 0.0154 | | | 0.244 | 0.528 |
| SRMpiSpa | 3.177+0.125Nat-0.612Tree | 0.0044 | 0.0244 | | 0.193 | 0.363 |
| SRManRec | 5.786+0.597Agr | 0.0485 | | | 0.085 | 0.136 |
| SRMpiOmn | 8.384-0.181Depth | 0.0008 | | | 0.277 | 0.404 |
| SRMpiPis | 4.576+0.193Depth-1.243Tree+0.979Nat | 0.0060 | 0.0234 | 0.0472 | 0.264 | 0.583 |
| SRMpiInv | 4.869-1.272Tree+0.144Depth+1.012Nat | 0.0101 | 0.0135 | 0.0323 | 0.209 | 0.523 |
| SRAbrRut | 0.3444-0.183Depth | 0.0155 | | | 0.212 | 0.360 |
| SRBenWei | 1.196-1.775Agr-0.741Dev | 0.0002 | 0.0181 | | 0.254 | 0.275 |
| SRSanLuc | 0.259-0.101Depth+0.426Nat | 0.0370 | 0.0940 | | 0.083 | 0.168 |
| SRPerFlu | 0.346+0.033Surlake+0.124Depth+0.659Dev | 0.0038 | 0.0041 | 0.0116 | 0.274 | 0.282 |
| LManTol | 0.622+0.005Depth | 0.0717 | | | 0.091 | 0.276 |
| Metrics (F) | Selected model | p value variable 1 | p value variable 2 | p value variable 3 | $R^2$ Mar | $R^2$ Cond |
| LMnsTot | 0.503+0.18Tree-0.016Depth | 0.0007 | 0.0042 | | 0.358 | 0.741 |
| LManBio | 2.5-0.576Tree-0.031Depth-0.006Surlake | 0.0001 | 0.0040 | 0.0060 | 0.165 | 0.310 |
| LMnsPis | 0223+0.056Nat | 0.0450 | | | 0.139 | 0.539 |
| SRMpiSpa | 1.901+0.187Tree-0.351Surlake-0.401Nat | 0.0005 | 0.0006 | 0.0020 | 0.145 | 0.579 |
| SRMpiOmn | 2.021+1.268Agr+1.352Tree | 0.0004 | 0.0024 | | 0.281 | 0.390 |
| SRMpiPis | 3.979-0.316Depth-0.116Surlake | 0.0098 | 0.0341 | | 0.296 | 0.523 |
| SRMpiInv | 6.482-1.591Tree+0.034Surlake | 0.0168 | 0.0495 | | 0.221 | 0.532 |
| SRAbrRut | -0.196+1.322Tree | 0.0090 | | | 0.257 | 0.644 |
| SRBenWei | -0.647+1.219Agr+1.288Tree | 0.0036 | 0.0184 | | 0.296 | 0.502 |
| SRSanLuc | -0.453+0.889Tree | 0.0310 | | | 0.167 | 0.468 |
| LManTol | 0.599-0.044Dev+0.068Tree | 0.0150 | 0.0220 | | 0.268 | 0.539 |

- Percentage of omnivorous individuals (MpiOmn) (fyke nets)

The omnivorous species included three-spined stickleback (*Gasterosteus aculeatus*, Linnaeus, 1758), eel, tench, bream, Prussian carp, common carp, ide (*Leuciscus idus*, Linnaeus, 1758), ninespine stickleback (*Pungitius pungitius,* Linnaeus, 1758), roach and rudd. The maximum relative species frequency was 47.6% ((10/21)*100), which was taken as the threshold between bad and poor status. A minimum weight percentage (7.9%) was defined by expert judgment whereby the MEP/GEP threshold (15.9%) was divided by two. This metric was independent from depth and surface.

- Benthivore species (BenWei, % relative weight) (fyke nets)

The benthivorous species considered were bream, white bream (*Blicca bjoerkna*, Linnaeus, 1758), common carp, ruffe and tench. The average value for all surveys (n=197) was 18.1% and the average value for sites in a poor status was 42.0% representing the threshold between bad and poor. A minimum weight percentage (7%) was defined as a minimum of benthivores that should be present, whereby the MEP/GEP threshold (14%) was divided by two. This metric was independent from depth and surface.

- Tolerance value (ManTol) (fyke nets)

If all reference species are present in one reservoir, then the maximal tolerance value of 50 was obtained, which is the sum of all tolerance values. The GEP status was obtained when 17 species were present (80%). The tolerance value of the 17 most frequently caught species was 40. This value was taken as the lower threshold for the GEP status. This metric was independent from depth and surface.

- Index scoring: EQR

Within one reservoir, data from different surveys within one year were grouped per method, giving one index value for each method. The sum of the metric scores obtained with each method gave the IBI score for a particular site. The maximum sum of the IBI scores is 5.2 as only two metrics have a MEP threshold value. The minimum possible sum of the IBI scores is 1.2 (6*0.2). This score was transformed to an EQR calculated as a value between 0 and 1. The appreciation of the status was defined by the EQR value (see Table 4).

Internal validation was performed using data of 17 reservoirs. We calculated the final EQR

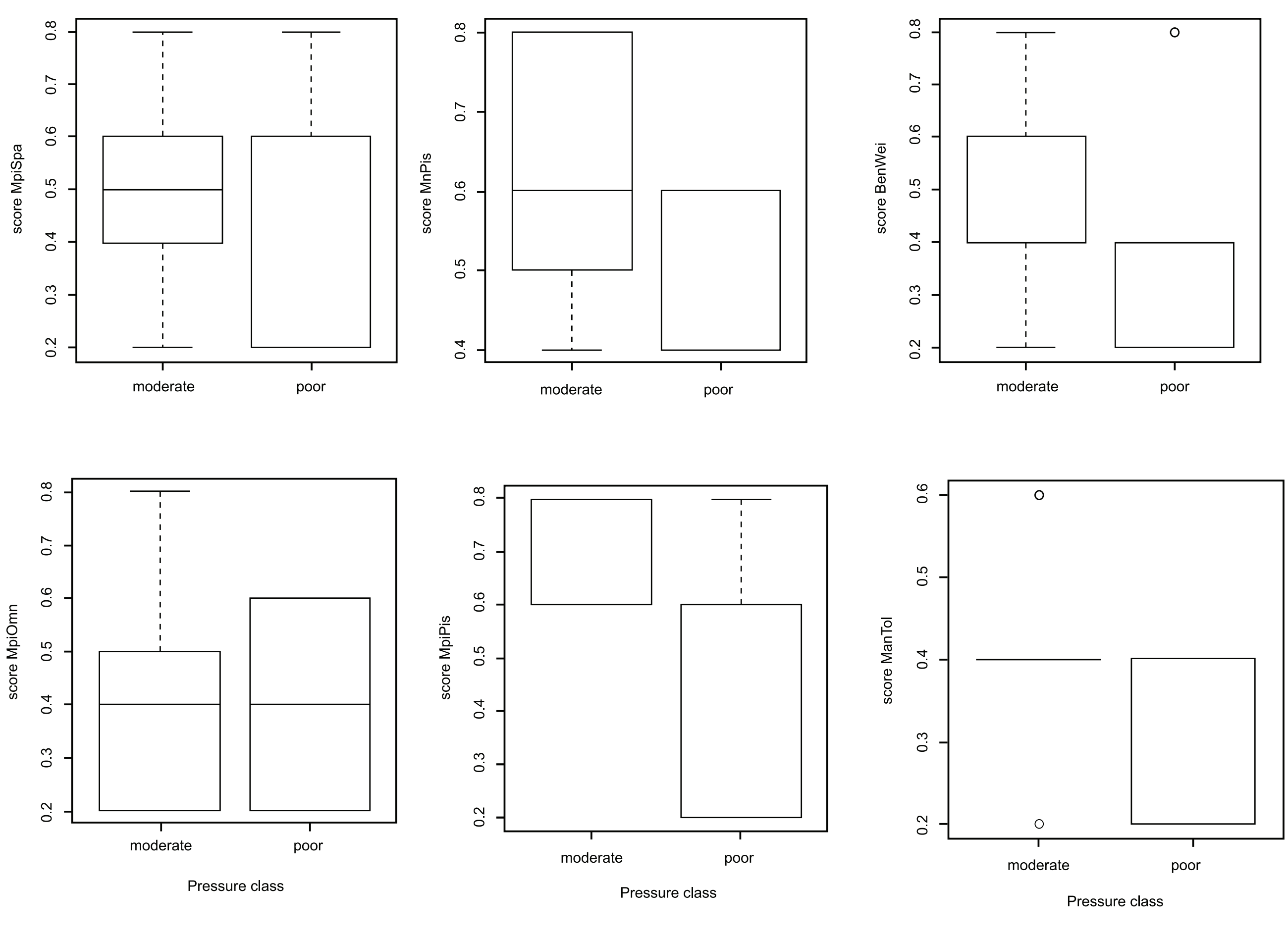


Fig. 2 – Graphical screening of the scores of selected metrics as a function of the pre-classification of the reservoirs (Pressure class) by boxplots (for abbreviation of the metrics, see Table 1); bolt line = median, hinges = 25th and 75th percentiles, whiskers = range.

TABLE 3

Pearson coefficient (c) and significance (**p ≤0.001; * p≤0.05) for correlation analysis of model fitted metrics with electric and fyke data (abbreviations, see Table 1).

| Electric | MnsInv | MpiSpa | ManRec | MpiOmn | MpiPis | MpiInv | AbrRut | BenWei | PerFlu | SanLuc |
|---|---|---|---|---|---|---|---|---|---|---|
| MpiSpa | 0.0481 | 1 | | | | | | | | |
| ManRec | 0.0965 | 0.2788* | 1 | | | | | | | |
| MpiOmn | -0.1699 | 0.0205* | -0.1964* | 1 | | | | | | |
| MpiPis | 0.2766* | 0.2166* | 0.1864* | -0.7123** | 1 | | | | | |
| MpiInv | 0.3700** | 0.1153 | 0.2349* | -0.7051** | 0.9266** | 1 | | | | |
| AbrRut | 0.0334 | -0.2274* | 0.2003* | 0.2955* | -0.1937* | -0.0756 | 1 | | | |
| BenWei | 0.1654 | 0.2111 | 0.1412 | 0.0456 | -0.1139 | -0.0401 | 0.018 | 1 | | |
| PerFlu | 0.1182 | -0.0756 | 0.2642* | -0.5314** | 0.6938** | 0.6993** | 0.0561 | -0.2327* | 1 | |
| SanLuc | 0.1363 | -0.0243 | -0.1897* | 0.0976 | -0.0158 | -0.0602 | -0.0003 | -0.0673 | -0.2387* | 1 |
| ManTol | 0.1330 | 0.4280* | -0.0267 | -0.0716 | 0.1904* | 0.0941 | -0.2247* | 0.0290 | 0.03782 | -0.3105* |
| **Fykes** | **MnsTot** | **ManBio** | **MnsPis** | **MpiSpa** | **MpiOmn** | **MpiPis** | **MpiInv** | **AbrRut** | **BenWei** | **SanLuc** |
| ManBio | 0.8138** | 1 | | | | | | | | |
| MnsPis | 0.5750** | 0.4796** | 1 | | | | | | | |
| MpiSpa | 0.2657** | 0.1303* | -0.0404 | 1 | | | | | | |
| MpiOmn | 0.4891** | 0.6088** | 0.1635 | 0.2625** | 1 | | | | | |
| MpiPis | -0.2866** | -0.2991** | 0.5132** | -0.3236** | -0.5729** | 1 | | | | |
| MpiInv | 0.0878 | 0.0391 | 0.3967** | -0.1591* | -0.2003* | 0.5904** | 1 | | | |
| AbrRut | 0.5928** | 0.3390* | 0.2711** | 0.0900 | 0.3486** | -0.1780* | -0.0672 | 1 | | |
| BenWei | 0.5391** | 0.4457** | 0.1795 | 0.1892* | 0.4060** | -0.3292** | -0.1071 | 0.4883** | 1 | |
| SanLuc | 0.2201** | 0.1935* | 0.3908** | -0.1974* | -0.0400 | 0.2814** | -0.2182* | 0.1029 | 0.0575 | 1 |
| ManTol | 0.3506** | 0.4505** | 0.3795** | 0.2322* | 0.4002** | 0.1821* | 0.5469** | 0.0405 | 0.1603 | -0.1484* |

and compared its appreciation (i.e. integrity class) with the pressure status. One reservoir reached the GEP status, one had a bad status, six obtained a poor status, and nine had a moderate status (Table 5). Thirteen reservoirs had the same EQR appreciation as the pressure status (pressure class). Three reservoirs scored too high, i.e. the EQR was higher than the pressure status (one class difference). One reservoir scored too low two class differences).

For the external validation of the EQR of nine reservoirs (independent data), a high correspondence was found between the EQR appreciation and the attributed pressure status. Only one reservoir scored differently.

The Pearson correlation between the averaged EQR values (n=26) obtained with the initial index from Belpaire et al. (2000) and the new EQR values did not show a significant correlation (c= 0.108; p= 0.598). With the old index, 14 reservoirs obtained an ecological status that diverged one class from the pressure status, and one reservoir diverged two classes (Table 5). The new index assessed the same reservoirs more accurately: only five showed a difference of one class. The new index also seemed to better separate the different pressure classes (Fig. 3).

## DISCUSSION

### Reference list

Species in the reference list are similar to those described for the Netherlands (Backx et al., 2008). However, we did not include the European weatherfish (*Misgurnus fossilis* Linnaeus, 1758) and spined loach (*Cobitis*

TABLE 4

Selected metrics for reservoirs and their threshold values for the metric and EQR-scores (abbreviations, see Table 1).

| | MEP | GEP | Moderate | Poor | Bad |
|---|---|---|---|---|---|
| Electric data | | | | | |
| metric - score | 1 | 0.8 | 0.6 | 0.4 | 0.2 |
| MpiSpa (%) | | < 28.5 ≥ 21.4 | ≥28.5 & < 21.4≥ 14.2 | < 14.2 ≥ 7.1 | < 7.1 |
| MpiInv (%) | | < 28.9 ≥ 14.2 | ≥ 28.9 & < 14.2 ≥ 9.4 | < 9.4 ≥ 4.7 | < 4.7 |
| Fyke net data | | | | | |
| metric - score | 1 | 0.8 | 0.6 | 0.4 | 0.2 |
| MpiOmn (%) | | < 15.9 ≥7.9 | < 31.7 ≥ 15.9 & <7.9 | < 47.6 ≥ 31.7 | ≥ 47.6 |
| MnsPis (#) | 5 | <5 ≥ 3 | 2 | 1 | 0 |
| BenWei (% weight) | | < 14 ≥ 7 | < 28.0 ≥ 14.0 & <7 | < 42.0 ≥ 28.0 | ≥ 42.0 |
| ManTol | 50 | <50 ≥40 | <40 ≥27 | <27 ≥13 | <13 |
| EQR | 1 | < 1 ≥ 0.75 | < 0.75 ≥ 0.50 | < 0.50 ≥ 0.25 | < 0.25 |
| Appreciation | MEP | GEP | Moderate | Poor | Bad |

*taenia* LINNAEUS, 1758) as these do not (or rarely) occur in our reservoirs. Rheophilic species were omitted as they do not occur naturally in standing waters. We did not include alien species in our list. Unlike the observations by VANDEKERKHOVE et al. (2013), their presence was not always an indication of malfunctioning of the ecosystem as some of our alien species have relative high quality demands. In addition, some alien species only reside for a short time; e.g. the brown bullhead (*Ameiurus nebulosus* LESUEUR, 1819) is disappearing from Flemish reservoirs (Schulensmeer, authors' observations between 1998-2011). Other species remaining for decades in our waters, e.g. pike-perch, are considered as naturalised. Only species occurring in the reference list were considered to assess the ecological quality of the reservoir. This approach is similar to the one used in BREINE et al. (2010).

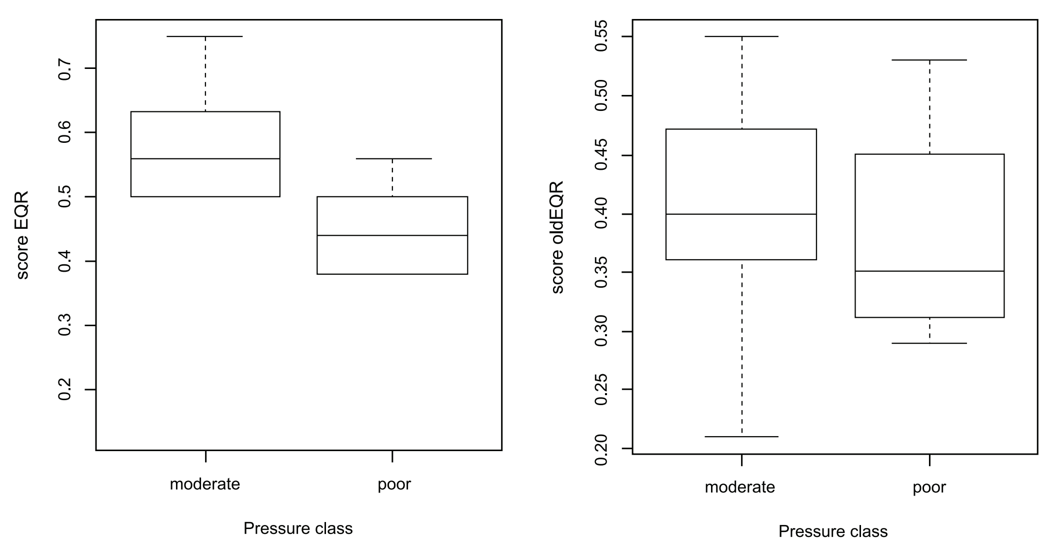


Fig. 3 – Boxplots showing the EQR value variation of the new and old index in the different pressure classes; bolt line = median, hinges = 25th and 75th percentiles, whiskers = range.

TABLE 5

Validation for reservoirs with internal data (1997-2005) and external independent data (2006-2011); for each reservoir metric scores, EQR and old EQR values (Belpaire et al., 2000), integrity and pressure class and class difference are given (abbreviations, see Table 1).

| Reservoir (internal) | Year | MpiSpa | MpiPis | MnsPis | MpiOmn | BenWei | ManTol | EQR | Integrity class | Pressure class | Class difference | old EQR | Integrity class (old) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bergelenput | 2001 | 0.6 | 0.6 | 0.4 | 0.8 | 0.6 | 0.2 | 0.63 | moderate | moderate | 0 | 0.36 | poor |
| De Broeken | 2004 | 0.4 | 0.6 | 0.6 | 0.2 | 0.6 | 0.4 | 0.50 | moderate | moderate | 0 | 0.47 | poor |
| E3-put Oostakker | 2003 | 0.2 | 0.6 | 0.4 | 0.4 | 0.8 | 0.2 | 0.44 | poor | poor | 0 | 0.48 | poor |
| Fort van Wallem | 2003 | 0.2 | 0.6 | 0.4 | 0.6 | 0.4 | 0.2 | 0.38 | poor | poor | 0 | 0.43 | poor |
| Gierle put | 2001 | 0.6 | 0.6 | 0.6 | 0.4 | 0.2 | 0.2 | 0.44 | poor | poor | 0 | 0.45 | poor |
| Grindplas Hochterbampt | 2005 | 0.6 | 0.6 | 0.8 | 0.2 | 0.6 | 0.4 | 0.63 | moderate | moderate | 0 | 0.43 | poor |
| Groot wachtbekken van Zuunbeek | 2002 | 0.2 | 0.2 | 0.4 | 0.2 | 0.2 | 0.4 | 0.13 | bad | poor | -1 | 0.45 | poor |
| Klein wachtbekken Zuunbeek | 2002 | 0.8 | 0.2 | 0.6 | 0.2 | 0.2 | 0.4 | 0.38 | poor | poor | 0 | 0.31 | poor |
| Melleput | 2003 | 0.6 | 0.6 | 0.6 | 0.6 | 0.2 | 0.4 | 0.56 | moderate | poor | 1 | 0.33 | poor |
| Oude Durme | 2005 | 0.4 | 0.8 | 0.6 | 0.2 | 0.8 | 0.6 | 0.69 | moderate | moderate | 0 | 0.41 | poor |
| Oude Leiearm Grammene | 2005 | 0.6 | 0.6 | 0.6 | 0.4 | 0.2 | 0.4 | 0.50 | moderate | moderate | 0 | 0.54 | moderate |
| Oude Maas Dilsen | 2002 | 0.4 | 0.8 | 0.8 | 0.6 | 0.6 | 0.4 | 0.75 | GEP | moderate | 1 | 0.55 | moderate |
| Putten van Niel | 1997 | 0.4 | 0.8 | 0.6 | 0.6 | 0.2 | 0.4 | 0.56 | moderate | poor | 1 | 0.53 | moderate |
| Roksem put | 2003 | 0.2 | 0.2 | 0.6 | 0.6 | 0.8 | 0.2 | 0.44 | poor | poor | 0 | 0.29 | poor |
| Schulensmeer | 1998 | 0.2 | 0.6 | 0.8 | 0.4 | 0.6 | 0.4 | 0.56 | moderate | moderate | 0 | 0.54 | moderate |
| Watersportbaan Gent | 2002 | 0.2 | 0.8 | 0.6 | 0.2 | 0.2 | 0.4 | 0.38 | poor | poor | 0 | 0.34 | poor |
| Webbekomsbroek | 1997 | 0.8 | 0.8 | 0.4 | 0.4 | 0.2 | 0.4 | 0.56 | moderate | moderate | 0 | 0.35 | poor |
| **Reservoir (external)** | **Year** | **MpiSpa** | **MpiPis** | **MnsPis** | **MpiOmn** | **BenWei** | **ManTol** | **EQR** | **Integrity class** | **Pressure class** | **Class difference** | **old EQR** | **Integrity class (old)** |
| Desselse Zandput | 2011 | 0.2 | 0.4 | 0.6 | 0.6 | 0.2 | 0.4 | 0.38 | poor | poor | 0 | 0.36 | poor |
| Donkmeer | 2008 | 0.4 | 0.6 | 0.8 | 0.4 | 0.2 | 0.6 | 0.56 | moderate | moderate | 0 | 0.39 | poor |
| Gavers Geraardsbergen | 2006 | 0.4 | 0.6 | 0.8 | 0.6 | 0.2 | 0.4 | 0.56 | moderate | poor | 1 | 0.3 | poor |
| Gavers Harelbeke | 2009 | 0.8 | 0.6 | 0.4 | 0.6 | 0.2 | 0.2 | 0.50 | moderate | moderate | 0 | 0.33 | poor |
| Grindplas Eisden Mijn | 2012 | 0.6 | 0.6 | 0.6 | 0.8 | 0.2 | 0.2 | 0.56 | moderate | moderate | 0 | 0.21 | bad |
| Grindplassen Steenberg | 2012 | 0.2 | 0.6 | 0.8 | 0.4 | 0.8 | 0.4 | 0.63 | moderate | moderate | 0 | 0.37 | poor |
| Hazewinkel | 2007 | 0.8 | 0.6 | 0.6 | 0.2 | 0.2 | 0.4 | 0.50 | moderate | moderate | 0 | 0.46 | poor |
| Meer van Weerde | 2008 | 0.2 | 0.6 | 0.6 | 0.6 | 0.6 | 0.4 | 0.56 | moderate | moderate | 0 | 0.39 | poor |
| Volharding | 2011 | 0.6 | 0.2 | 0.6 | 0.2 | 0.8 | 0.2 | 0.44 | poor | poor | 0 | 0.31 | poor |

### Pre-classification

Similar to the approach explained by BREINE et al. (2007, 2010) and QUATAERT et al. (2011), the pre-classification is a device to rank reservoirs in a reasonable way with respect to anthropogenic pressures enabling the construction of a biotic index. The thresholds for the pre-classification attribution were based on expert judgement. However, the main point was not to have an absolute expression of the quality, but to have a good ranking with respect to human impact. The pre-classification of reservoirs based on abiotic variables is an important issue. It was used to make a first selection among the candidate metrics and for the external validation. The combination of scores expressing the pressures classified the reservoirs. Land cover percentages were also used by DRAKE & PEREIRA (2002). One of the largest factors contributing to impairment, namely non-point source pollution, is commonly associated with land-use modification (e.g., agriculture, urbanization) leading to eutrophication of surface waters (WANG et al., 2001; DODDS et al., 2009). As we focused on direct impacts from the neighbourhood, a zone of 100 m surrounding the reservoir was appropriate. Pre-classifying the reservoirs with presence absence data only (0 or 1) reduced the ranking efficiency as all reservoirs got the same score. Modelling with raw pressure values (log transformed) did not provide better results. Only for electric data, two metrics produced significant results: the metric ‘relative percentage weight of perch’ (PerFlu~0,7563+0,0314Surlake+0,1182Depth+0,0459Dev, $R^2$conditional=0.253) and ‘the relative percentage weight of pike-perch’ (SanLuc~1,9371+0,064Agr, $R^2$=0.294). Fyke data did not produce significant results.

We acknowledge that some important parameters were missing in our assessment, e.g. total phosphorus and total nitrogen (LAUNOIS et al., 2011b). Total phosphorus is an important parameter to assess the eutrophication of lakes and reservoirs (WETZEL, 1983). Nitrogen increases with human activities but is too variable to be a robust parameter (MOSS et al., 2003). We used agricultural activity as a proxy for these parameters as measurements were only made in some reservoirs. The selected pressure parameters are known to have a negative impact on fish assemblages (DRAKE & PEREIRA, 2002; BACKX et al., 2008; LAUNOIS et al., 2011b, ARGILLIER et al., 2013).

### Fishing methods

A single method underestimates the species richness (JACKSON & HARVEY, 1997). For lakes and reservoirs no single type of fishing gear is sufficient to survey all habitat types or to sample all fish species (WHITTIER, 1999; BONAR et al., 2009; KUBEČKA et al., 2009). The need to use multiple types of gear is a result of habitat heterogeneity, and the differences in habitat use of the associated species in lakes and reservoirs (FISCHER, 2012). In lakes and reservoirs fish can be pelagic, demersal or benthic. Therefore, adapted techniques should be used to assess the presence of the fish occurring in the water column or dwelling near the bottom. In deep reservoirs or lakes, electric fishing cannot be used nor can fykes easily be placed in vegetated habitats. As a consequence, data collected with multiple methods allows greater reliability in interpretations using information on lentic fish assemblages. By using different methods, we can retrieve a more accurate picture of the fish assemblage and therefore the ecological status of a reservoir (or lake) can be more precisely assessed. Multi-mesh gillnets are not used in Flanders as this method results in high fish mortality. Electric fishing in the littoral zone and fyke nets on the bottom are effective for sampling in lakes (JENNINGS et al., 1999). The sampling effort for each method should be such that adding an additional unit effort should not substantially increase species number or change proportional abundances. The fish protocol currently used in reservoirs in Flanders (1 fyke/ha overnight for two successive days with a minimum of 4 and a maximum of 20 per reservoir combined with electric fishing along 250 m long shore transects per ha) has proven to fulfil this requirement (see also Belpaire et al., 2000).

### Metric selection

The list of candidate metrics was based on literature. These metrics were chosen for their known reaction to human induced pressures and because they assess complementary aspects of the ecological functioning of the lakes. No explicit metric assessing alien species was included. The rationale is that if there is a significant pressure by alien species, this will be detected by other metrics.

The modelling approach allowed a first selection of metrics based on their sensitivity for one or more pressures. Only species occurring in the reference lists were considered for the calculation of the metric value. If only one fishing method had been used, the index would have consisted of less metrics. As a consequence, some effects of human disturbance would not have been assessed. Here, electric data metrics were sensitive to changes of the banks, while fyke net metrics also assessed impacts from agriculture and development. Our models showed that habitat quality (natural state of bank) and agricultural activities were major pressures explaining changes in fish assemblages. This corresponds with observations by Launois et al. (2011b) where habitat alterations and eutrophication in lakes seem to have a prominent effect on fish assemblages. European fish-based indices for lakes assess primarily eutrophication (Ritterbusch et al., 2011). To avoid over-fitting, a Pearson correlation was applied for examining redundancy among metrics. This method has also been applied by other authors (e.g. Minns et al., 1994; McCormick et al., 2001). Graphical screening of the selected metrics as a function of the pre-classification of the reservoirs by boxplots also showed that for nearly all metrics a clear gradient was seen (Fig. 2). The metric 'percentage of omnivores' was retained, though it did not seem to separate the pressure classes well. We considered that a less optimal metric can sometimes give invaluable information in combination with other metrics (Breine et al., 2007).

### Rejected metrics fitted by the model

For electric fishing, the metrics assessing the 'invertivorous species' (MnsInv), 'percentage of omnivores' (MpiOmn), the 'relative combined weight of bream and roach' (AbrRut) and the 'tolerance values' (ManTol) were rejected as they only reacted to descriptors (deforestation or depth, Table 2). $R^2$ for the metric 'percentage of species that recruit' (ManRec) was small and its reaction to pressure was opposite to what was expected. Metrics assessing the 'relative percentage weight of perch' (PerFlu), 'benthivore species' (BenWei) and 'percentage weight of pike-perch' (SanLuc) were fitted but did not show the expected response.

For metrics assessing fyke net data, we rejected all metrics reacting to descriptors only. These included 'total number of species' (MnsTot), 'total biomass' (ManBio), 'percentage of piscivores' (MpiPis) and 'invertivores' (MpiInv), the 'relative combined weight of bream' (AbrRut) and the 'percentage weight of pike-perch' (SanLuc). The metric 'specialised spawners' (MpiSpa) was not selected as it decreased with increasing habitat quality, which was rather unexpected.

### Properties of the selected metrics

- Percentage specialised spawners (MpiSpa) (electric data)

This metric was previously proposed by Didier (1997) and Breine et al. (2004). It includes species having specific demands for spawning, and nest builders. As such, it assesses degradation of the spawning habitat. Due to degradation, fish will not spawn successfully and this will be reflected by the absence of one or more year classes or eventually lead to the extinction of one or more species (Nicola et al., 1996; Gassner et al., 2003). Extremely high values indicate a disturbance (moderate status). In our study this metric reacted to the natural state of the banks. This metric scored 61.1% of the reservoirs in agreement with the pre-classification (Fig. 2).

- Percentage of invertivorous individuals (MpiInv) (electric data)

This metric is often integrated in an IBI (Hughes & Oberdorff, 1999). The invertivorous level decreases with degradation (Belpaire et al., 2000). In French lakes, this metric did not show a response with pressure because the assessed species were overall tolerant to degraded lake conditions (Launois et al. ,2011b). Here, we did not consider overall tolerant species, i.e. perch (<13 cm), ruffe and gudgeon. In our study this metric reacted to the natural state of the banks. Here, 83.3% of the reservoirs were correctly scored (Fig. 2).

- Number of piscivorous species (MnsPis) (fyke data)

The top of the food chain is represented by predators. This constitutes the piscivorous level, which also is sensitive to degradation (Shields et al., 1995; Miller et al., 1988; Steedman, 1988). The presence of trophic specialists is very sensitive to increasing pressure and is often integrated in an IBI (Hughes & Oberdorff, 1999). This metric decreases in value as human impact increases (Backx et al., 2008; Belpaire et al., 2000; Launois et al., 2011a). With our data this metric was sensitive to changes in habitat. A total of 55.5% of reservoirs were scored correctly using this metric.

- Benthivore species (BenWei, % weight) (fyke nets)

High values of the metric indicate unspecific degradation including eutrophication (Ritterbusch et al., 2011). It measures the abundance of littoral and some pelagic species. Benthivore species are also used in the assessment systems of Germany, Lithuania, The Netherlands and Poland (Ritterbusch et al., 2011). In our study, the metric reacted to agricultural activities and scored 83.3% of the reservoirs correctly.

- Percentage of omnivorous individuals (MpiOmn) (fyke nets)

Increasing abundances of omnivores are observed in eutrophic, constructionally-modified lakes; and with increasing pressures (Hickman & McDonough 1996; Whittier 1999; Drake & Pereira, 2002). As eutrophication increases, the consequent higher primary production will lead to a higher total fish biomass (Belpaire et al., 2000). The absence of chemical pollution in Flemish reservoirs can explain why, in our study the metric is not bi-directional. The metric reacted to agricultural activities. Only 44.4% of the reservoirs were correctly classified.

- Tolerance value (ManTol) (fyke nets)

It is a good indication of human impact as lower values correspond with higher habitat degradation. The metric was selected as it reacts to construction. Using this metric 61.1% of the reservoirs were scored correctly. The mean tolerance value was also used in Belpaire et al. (2000) to assess the quality of standing waters in Flanders. It has also been used to assess ecosystem conditions in the US (Novotny et al., 2005; Meador & Carlise, 2007).

## Metric scoring

Four metrics contain species that were rarely (crucian Carp (*Carassius carassius* Linnaeus, 1758), gudgeon, ide and ninespine stickleback) or never (burbot and wels catfish) caught. These species were still included as they are not extirpated, and because lakes or reservoirs are their preferred habitat. Including these species in the assessment did not affect the attribution of thresholds for the metric scores because 60%, for metrics assessing number of species, was taken as GEP. To compensate for gear specificity, the threshold values for metric ‘tolerance value’ were defined using the 17 most frequently caught species (80%). For the ‘number of piscivorous species’, three out of five species was scored as ‘good’. Thresholds for the ‘relative percentage of specialised spawners’ and ‘piscivores’ were based on the reference list independently from the catch results. Boxplots showed that, although overlaps exists, these metrics efficiently separated the different pressure classes. No adjustment for surface or depth was needed for the selected metrics (Table 2). Only MpiInv (electric fishing, Table 2) seemed to be influenced by depth, but in the model it had a small coefficient and scores were therefore attributed independently of the depth. Several methodologies were applied to determine metric scoring criteria whereby reference sites play a major role (BECK & HATCH, 2009). In the absence of reference conditions, minimally disturbed sites are sometimes used to select optimal metric scores and score classes are determined by dividing the total metric range into three or five equal portions (assuming a linear behaviour of the metrics) (BREINE et al., 2010). The Dutch fish-based index for lakes also uses the developed reference as a benchmark for the metric scoring (BACKX et al., 2008). Other member states use type-specific near reference sites to score the selected metrics (e.g. BELPAIRE et al, 2000; GASSNER et al., 2003; LAUNOIS et al., 2011a). Adapting this species list was the best option as the reservoirs in this study are impacted (moderate in the best case). Dividing the metric values into equal parts is a widely applied approach for indices (GOFFAUX et al., 2001). Due to data limitation, no other approach (linear regression or modelling) could be applied here to define metric thresholds. Only on two occasions was expert judgment used to define threshold values between the poor and bad status. For the 'percentage of omnivorous individuals' (MpiOmn) expert judgement (dividing MEP/GEP threshold) was used only to define the minimum weight. A similar approach indicated the minimum weight for the metric assessing the 'benthivore species' (BenWei, % relative weight). The importance of this threshold is much less than the boundary between good and moderate. Indeed, according to the WFD, no actions have to be undertaken when a good status is reached. In a lower status (moderate, poor and bad) however, actions to improve the ecological status are needed.

### The index score

In our study, data from different methodologies was assessed with different metrics as suggested by JENNINGS et al. (1999) and BECK & HATCH (2009). The index score was obtained by the sum of the individual gear-specific metrics. This value was then transformed to an EQR and an appreciation was attributed. Integrity classes have equal distance intervals. To define tendencies, of under- or over-estimation, we allowed a one-class difference between the habitat status (pre-classification) and the EQR as was done by GOFFAUX et al. (2001) and BREINE et al. (2004, 2011). Our validation showed that the newly-developed index was able to distinguish between different degrees of degradation within the pre-classified reservoirs. We consider the new index as an improvement as the EQR corresponded generally better with the attributed pressure status compared to the old index (Fig. 3). The first index for standing waters in Flanders (BELPAIRE et al., 2000) assessed reservoirs by combining fish results obtained from different fishing strategies without considering the gear specificity of these methods. In addition, the approach used now seems to be more robust as less expert judgement was used.

## CONCLUSIONS

We developed a multi-metric index for reservoirs taking into consideration the different standardised sampling methodologies. The main aim was to present an approach that could be applied with any given set of data. The selected metrics are relevant allowing for an appropriate assessment of anthropogenic impacts on the fish communities. We also ensured that the metrics assess different aspects of the ecological functions of reservoirs for fishes, and that they are not redundant. The reference list provides a realistic goal i.e. presence of reference species corresponds to a good ecological potential. Finally the index is a clear communication tool for environmental managers, politicians and other target groups.

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TABLE A

Overview of surveys in reservoirs (1996-2005). Surface area, average depth, River fed with indication of stream system (IJ: IJzer; S: Schelde; M: Maas) and origin. The lower the scores for the pressure the better. Total number of fish caught with electric fishing (MnsTotE) and fyke nets (MnsTotF). The number of individuals (MniInd) and biomass (ManBio) expressed per m² for electric fishing (E) or per fyke day for fyke net catches (F) (i.e. the number of fykes multiplied by the days) *: Oude Leiearm Wevelgem consists of two reservoirs and Putten van Niel is a combination of five pits. Blanks= no data.

| Reservoirs (year of survey) | Surface area (ha) | Average depth (m) | River fed | Origin | Pressure value | Electric surveys | Fyke days | MnsTot E | MnsTot F | MniInd E (/m²) | MniInd F (/fyke day) | ManBio E (g/m2) | ManBio F (g/fyke day) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bergelenput (2001) | 8.0 | 5.0 | N | sand extraction | 4 | 1 | 14 | 9 | 5 | 0.23 | 371.36 | 26.57 | 3422.7 |
| Blaarmeersen (2004) | 17.0 | 13.5 | N | man made | 5 | | 30 | | 2 | | 0.5 | | 45.02 |
| De Broeken (2004) | 1.7 | 1.5 | N | peat extraction | 4 | 1 | 12 | 6 | 6 | 0.17 | 14.08 | 17.99 | 4071.0 |
| E3-put Oostakker (2003) | 2.5 | 2.8 | Y (S) | sand extraction | 6 | 4 | 10 | 10 | 7 | 0.42 | 39.3 | 29.94 | 909.1 |
| Fort van Wallem (2003) | 3.0 | 2.1 | N | man made | 6 | 5 | 16 | 11 | 9 | 0.31 | 13.56 | 24.07 | 1381.18 |
| Galgenweel (2005) | 47.2 | 6.0 | Y (S) | dyke breach | 5 | | 40 | | 10 | | 32.55 | | 2383.67 |
| Gavers Harelbeke (2005) | 53.0 | 10.0 | Y (S) | sand extraction | 5 | | 36 | | 5 | | 24.22 | | 1573.36 |
| Gierle put (2001) | 7.5 | 10.0 | N | sand extraction | 6 | 1 | 2 | 4 | 4 | 0.11 | 42.5 | 1.59 | 608.1 |
| Grindplas Hochterbampt (2005) | 14.0 | 18.5 | N | gravel extraction | 4 | 8 | 28 | 13 | 11 | 0.15 | 55.36 | 11.22 | 7789.69 |
| Groot wachtbekken van Zuunbeek (1996 & 2002) | 4.0 | 0.6 | Y (S) | man made | 8 | 1 | 24 | 12 | 12 | 31.46 | 16.59 | 98.88 | 9935.44 |
| Grote Roggeman (1999) | 4.3 | 0.5 | N | bank creation | 8 | 1 | | 10 | | 16.07 | | 233.63 | |
| Klein wachtbekken Zuunbeek (1996 & 2002) | 2.0 | 0.6 | Y (S) | man made | 8 | 1 | 14 | 9 | 9 | 0.34 | 25.64 | 31.67 | 6134.08 |
| Meer van Weerde (1998) | 14.0 | 3.5 | N | sand extraction | 5 | 2 | 12 | 14 | 9 | 0.28 | 34.6 | 12.42 | 1064.0 |
| Melleput (1996 & 2003) | 25.0 | 11.0 | N | sand extraction | 5 | 9 | 90 | 10 | 8 | 0.08 | 2.59 | 0.72 | 202.8 |
| Oude Durme (2005) | 16.0 | 1.8 | Y (S) | dyke creation | 4 | 20 | 30 | 18 | 16 | 0.18 | 32.37 | 12.03 | 2424.15 |
| Oude Leie Bavikhove (1998) | 3.6 | 3.5 | N | dyke creation | 5 | 3 | | 10 | | 0.62 | | 15.66 | |
| Oude Leiearm Grammene (2005) | 18.4 | 2.5 | N | dyke creation | 4 | 11 | 16 | 19 | 12 | 0.19 | 47.81 | 19.48 | 1553.43 |
| Oude Leiearm Wevelgem* (1997) | 3.2 | 2.0 | N | dyke creation | 5 | 5 | | 11 | | 0.26 | | 18.56 | |
| Oude Maas Dilsen (2002) | 8.4 | 1.5 | Y (M) | dyke creation | 4 | 2 | 26 | 14 | 11 | 0.18 | 52.5 | 8.08 | 1989.59 |
| Palingbeek (1999) | 3.0 | 2.0 | Y (IJ) | man made | 5 | 3 | | 10 | | 0.28 | | 57.15 | |
| Putten van Niel* (1997) | 7.94 | 10.0 | Y (S) | clay extraction | 5 | 10 | 20 | 11 | 10 | 0.3 | 20.35 | 15.26 | 962.16 |
| Roksem put (2003) | 40.0 | 7.0 | N | sand extraction | 5 | 4 | 40 | 3 | 5 | 0.02 | 6.4 | 3.47 | 630.3 |
| Schulensmeer (1998) | 89.0 | 4.2 | Y (S) | sand extraction | 4 | 13 | 16 | 17 | 13 | 1.2 | 69.56 | 24.34 | 4605.75 |
| Sisput (2001) | 0.14 | 3.0 | Y (S) | dyke creation | 5 | 2 | | 6 | | 0.15 | | 7.96 | |
| Watersportbaan Gent (2002) | 22.0 | 2.5 | Y (S) | man made | 8 | 10 | 20 | 9 | 11 | 0.05 | 36.9 | 3.18 | 6692.0 |
| Webbekomsbroek (1997 & 2004) | 2.0 | 1.0 | Y (S) | man made | 4 | 4 | 24 | 16 | 10 | 1.19 | 56.71 | 26.18 | 1839.09 |

TABLE B

Recent fish data for reservoirs in Flanders (autumn 1996-2005). # is the number of catches per species grouped over all surveys. Frequency is the catch frequency in the reservoirs (#/campaigns). # ind. gives the number of individuals caught in the reservoirs. Last column indicates if the species is a MEP/GEP species. Fyke days equals the number of fykes multiplied by the days they were standing; n gives the number of electric surveys.

| **Scientific name** | **Fykes (520 fyke days)** | | **Electric fishing (n=112)** | | |
|---|---|---|---|---|---|
| | **frequency** | **# ind.** | **frequency** | **# ind.** | **MEP/ GEP** |
| *Abramis brama* (LINNAEUS, 1758) | 32.47 | 1918 | 36.60 | 116 | X |
| *Alburnus alburnus* (LINNAEUS, 1758) | 0.43 | 1 | 1.31 | 2 | |
| *Ameiurus nebulosus* (LESUEUR, 1819) | 6.93 | 487 | 5.88 | 343 | |
| *Anguilla anguilla* (LINNAEUS, 1758) | 80.95 | 2193 | 86.27 | 3649 | X |
| *Blicca bjoerkna* (LINNAEUS, 1758) | 29.44 | 802 | 28.1 | 477 | X |
| *Carassius carassius* (LINNAEUS, 1758) | 0.43 | 1 | 3.92 | 8 | X |
| *Carassius gibelio* (BLOCH, 1782) | 12.12 | 304 | 35.29 | 1154 | X |
| *Cobitis taenia* (LINNAEUS, 1758) | 0.00 | 0 | 4.58 | 36 | |
| *Cyprinus carpio carpio* (LINNAEUS, 1758) | 15.15 | 225 | 21.57 | 392 | X |
| *Esox lucius* (LINNAEUS, 1758) | 5.19 | 16 | 49.67 | 563 | X |
| *Gasterosteus aculeatus* (LINNAEUS, 1758) | 0.00 | 0 | 6.54 | 399 | X |
| *Gobio gobio* (LINNAEUS, 1758) | 0.00 | 0 | 5.88 | 39 | X |
| *Gymnocephalus cernua* (LINNAEUS, 1758) | 38.10 | 2776 | 35.95 | 455 | X |
| *Lepomis gibbosus* (LINNAEUS, 1758) | 15.15 | 874 | 33.99 | 2238 | |
| *Leucaspius delineatus* (HECKEL, 1843) | 0.87 | 3 | 11.11 | 195 | X |
| *Leuciscus idus* (LINNAEUS, 1758) | 2.16 | 5 | 15.03 | 45 | X |
| *Liza ramada* (RISSO, 1827) | 0.43 | 2 | 0.00 | 0 | |
| *Lota lota* (LINNAEUS, 1758) | 0.0 | 0 | 0.00 | 0 | X |
| *Perca fluviatilis* (LINNAEUS, 1758) | 60.17 | 6408 | 91.50 | 7577 | X |
| *Platichthys flesus* (LINNAEUS, 1758) | 6.06 | 21 | 3.27 | 9 | |
| *Pseudorasbora parva* (TEMMINCK & SCHLEGEL, 1846) | 6.93 | 96 | 9.80 | 431 | |
| *Pungitius pungitius* (LINNAEUS, 1758) | 0.00 | 0 | 2.61 | 10 | X |
| *Rhodeus sericeus* (PALLAS, 1776) | 6.06 | 160 | 18.95 | 1069 | X |
| *Rutilus rutilus* (LINNAEUS, 1758) | 38.96 | 2700 | 79.08 | 8879 | X |
| *Salmo trutta* (LINNAEUS, 1758) | 0.43 | 1 | 0.65 | 4 | |
| *Sander lucioperca* (LINNAEUS, 1758) | 33.33 | 1836 | 15.69 | 65 | X |
| *Scardinius erythrophthalmus* (LINNAEUS, 1758) | 13.85 | 303 | 58.17 | 1666 | X |
| *Silurus glanis* (LINNAEUS, 1758) | 0.00 | 0 | 0.00 | 0 | X |
| *Squalius cephalus* (LINNAEUS, 1758) | 0.00 | 0 | 1.31 | 2 | |
| *Tinca tinca* (LINNAEUS, 1758) | 15.58 | 59 | 43.14 | 541 | X |

TABLE C

Reference fish species occurring in reservoirs in Flanders and their guild attribution. * *Perca fluviatilis*: ≥ 13 cm piscivorous; ** not caught in reservoirs yet.

| **Scientific name** | **Omnivore** | **Benthic** | **Invertivore** | **Piscivore** | **Tolerance value** | **Specialised spawner** | **Obligatory species** |
|---|---|---|---|---|---|---|---|
| *Abramis brama* (LINNAEUS, 1758) | x | | | | 1 | | x |
| *Anguilla anguilla* (LINNAEUS, 1758) | x | x | | | 2 | | |
| *Blicca bjoerkna* (LINNAEUS, 1758) | | | | | 2 | | x |
| *Carassius carassius* (LINNAEUS, 1758) | | | | | 3 | | |
| *Carassius gibelio* (BLOCH, 1782) | x | | | | 0 | | |
| *Cyprinus carpio carpio* (LINNAEUS, 1758) | x | | | | 2 | | |
| *Esox lucius* (LINNAEUS, 1758) | | | | x | 4 | x | x |
| *Gasterosteus aculeatus* (LINNAEUS, 1758) | x | | | | 1 | | |
| *Gobio gobio* (LINNAEUS, 1758) | | | x | | 3 | x | |
| *Gymnocephalus cernua* (LINNAEUS, 1758) | | x | x | | 2 | | x |
| *Leucaspius delineatus* (HECKEL, 1843) | | | | | 4 | | |
| *Leuciscus idus* (LINNAEUS, 1758) | x | | | | 4 | | |
| *Lota lota* (LINNAEUS, 1758)** | | x | | x | 4 | x | |
| *Perca fluviatilis* (LINNAEUS, 1758) | | | x | x* | 2 | | x |
| *Pungitius pungitius* (LINNAEUS, 1758) | x | | | | 1 | | |
| *Rhodeus sericeus* (PALLAS, 1776) | | | | | 3 | x | |
| *Rutilus rutilus* (LINNAEUS, 1758) | x | | | | 1 | | x |
| *Sander lucioperca* (LINNAEUS, 1758) | | | | x | 3 | | |
| *Scardinius erythrophthalmus* (LINNAEUS, 1758) | x | | | | 3 | x | x |
| *Silurus glanis* (LINNAEUS, 1758)** | | x | | x | 2 | | |
| *Tinca tinca* (LINNAEUS, 1758) | x | x | | | 3 | x | |