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ARTICLE

Monitoring and Assessment of Wetland Condition Using Plant Morphologic and Physiologic Indicators

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Abstract We created and evaluated indices of plant performance using plant morphological and physiological attributes and assessed their potential as wetland condition indicators by studying their consistency along a stress gradient. Based on Spearman coefficients, we selected promising morphological and physiological metrics that showed consistent responses along a physico-chemical stress gradient. Metrics consistently associated with wetland condition were ranked and combined into morphological ($_{m}$PPI) or physiological Plant Performance Indices ($_{ph}$PPI). Six morphological metrics were able to discern between good and poor wetland conditions along the impact gradient and were thereafter combined into the $_{m}$PPI. The resulting $_{m}$PPI was found to be a strong indicator of stress and accurately identified degraded wetlands (r_s=−0.52; P=0.030). In contrast, most of the physiologic metrics showed lower correlations to the stress gradient. Consequently, the resulted $_{ph}$PPI had a lack of association with the stress gradient and failed to identify even heavily-impacted wetlands (r_s=−0.30; P=0.194). We conclude that the morphological characteristics of plants, the reliability of the $_{m}$PPI, and its ability to simply and easily convey habitat information makes it worthy of further refinement and validation as a tool for evaluating mitigation and restoration efforts in wetlands.

Keywords Biological assessment · Wetland evaluation · Metrics · Rapid assessment methods

Introduction

Scientists and practitioners involved in wetland construction, reclamation, and restoration need assessment techniques to evaluate the quality, performance, and relative success of their efforts. Many different types of assessment techniques based on biological indicators of wetland condition have been developed to compare altered or compensation wetlands to those in natural condition (Rader and Shiozawa 2001; Fennessy et al. 2007; Beck and Hatch 2009). Vegetation-based indices are often included in assessments because they can provide a temporally-integrated picture that represents environmental and historical differences among wetlands (Rader and Shiozawa 2001; Rothrock et al. 2008; Beck et al. 2010; Wilson et al. 2013). Vegetation Indices of Biological Integrity (vIBIs) are especially useful for regulatory objectives because they can indicate wetland condition. Plant community indicators, however, may fail to respond consistently to gradients of human perturbation when wide ranges of natural or anthropogenic variation among wetlands are included (Wilcox et al. 2002; Wray and Bayley 2006); moreover, in those circumstances, indicators may also fail to distinguish between impacted from non-impacted wetlands (Wilcox et al. 2002; Euliss and Mushet 2011).

Indices based on metrics that measure individual plant performance coupled with plant community assessments might better represent ecological conditions in wetlands (Helgen and Gernes 2001). Plant Performance Indices (PPIs) may complement and enrich plant community-based Indices of Biotic Integrity in many ways: 1) plant performance is

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better able to cover a gradient of intense human intervention even where much or most of the vegetation has been lost or replaced, 2) plant performance recovers from the impact of natural intense pulse stressors (i.e., floods, droughts) faster than is evident in vegetation stands, often soon after the pulsed stress is relieved, 3) plants are able to integrate multiple environmental and internal signals related to adverse conditions during growth regulation (Achard et al. 2006), and 4) morphological and physiological indicators may be sensitive enough to inform suboptimal conditions in cases where there is a lack of response at the population and community levels because plant tolerance mechanisms were adequate to prevent mortality or any change in reproduction due to stress. All the above-mentioned benefits encouraged us to evaluate the consistency of Plant Performance Indices (PPIs) along a stress gradient.

Laboratory and field experimental evidence supports the indicators we selected to test wetland plants morphologic and physiologic individual performance and response to a stress gradient (Pearcy et al. 1996; Maxwell and Johnson 2000; Huang 2006). In wetlands, where water is normally readily available to roots, any stress impairing water uptake by affecting either root growth or root activity can unbalance whole plant water relations and lead to water deficits (Pezeshki 2001). In this manner, root impairments are able to affect shoot morphology, as plant growth is tightly and inversely related to water deficit (Nobel 2005; Tardieu et al. 2011). In addition, as shoot growth is tightly coordinated through numerous phytohormones and growth regulators that integrate stress signals perceived at the root level (Achard et al. 2006; Wolters and Jurgens 2009), shoot morphological traits might be able to summarize diverse environmental conditions and mirror wetland condition. Alternatively, leaf gas exchange parameters and fluorescence are sensitive to stress-driven water deficits and nutritional stresses and have been widely used as performance indicators to address both naturally occurring stressful conditions or anthropogenic disturbances (Ewing et al. 1995; Mendelssohn et al. 2001; Pezeshki 2001; Meszaros et al. 2003; Cramer et al. 2009; Naidoo et al. 2010; Touchette et al. 2012). As a result of the above-mentioned characteristics, the set of techniques we selected may behave as valuable stress indicators and a source of potentially suitable metrics suitable for combination into multimetric indices of plant performance.

In the Beaver Hills region of central Alberta, Canada, most of the wetlands outside protected areas have been impacted by anthropogenic perturbations, primarily through landscape deforestation and fragmentation (Young et al. 2006), but also through pollution from agricultural practices or industrial sources (North Saskatchewan Watershed Alliance 2005). The Beaver Hills region is of critical conservation importance because it supports a great diversity of vegetation, waterfowl, birds, and mammals in an area under increasing anthropogenic pressure for land and freshwater (Strong and Leggat 1992; North Saskatchewan Watershed Alliance 2005). The lack of earlier environmental assessments on wetland vegetation in the region prompted government agencies to look for reliable and cost-effective indicators for monitoring purposes (North Saskatchewan Watershed Alliance 2005; Wray and Bayley 2006).

Our overall research objective was to develop multimetric indices of plant performance and assess their potential to serve as wetland condition indicators by evaluating their consistency along a gradient of human impact. Specific objectives were: 1) to test reliability of individual plant performance metrics along a gradient of anthropogenic impact, 2) to score and combine consistent metrics into Plant Performance Indices (PPIs) and, 3) to test the reliability of responses of PPIs along the stress gradient. Two indices were evaluated: one constructed using morphologic traits and another using plant physiological attributes.

Materials and Methods

Study Site

This study was conducted in wetlands situated in the Beaver Hills sub-watershed of the North Saskatchewan River (centered approximately 53° 25′44″ N, 112° 53′37″ W, Appendix A). The Beaver Hills sub-watershed area includes a portion of the Low Boreal Mixedwood sub-region located within the Aspen Parkland region of central Alberta (Strong and Leggat 1992; North Saskatchewan Watershed Alliance 2005). The sub-watershed encompasses 400,544 ha, 10 % of which is covered by wetlands (North Saskatchewan Watershed Alliance 2005).

The climate of the region is cool-continental (mean annual temperatures 1.9 °C, 15.5 °C in August), (Environment Canada 2012) and receives 373–505 mm of annual precipitation, approximately two thirds of which falls as rain. The terrain is hummocky knob and kettle terrain of deposited moraine materials following glacial retreat. The dominant tree species are *Populus tremuloides* Michx., *P. balsamifera* L., *Betula papyrifera* Marshall, *Picea mariana* (Mill.) Britton, Sterns & Poggenb., and *P. glauca* (Moench) Voss (Strong and Leggat 1992; Young et al. 2006). There is a wide diversity of natural wetlands, ranging from shallow saline and freshwater marshes to peat-accumulating wetlands: swamps, fens, and bogs (Nicholson and Vitt 1994). Natural wetlands in the Beaver Hills region are protected in one national park (Elk Island National Park) and several provincial parks (Cooking Lake-Blackfoot and Miquelon Lake). Wetlands in those parks were included as natural reference sites (Appendix A).

Wetlands Selection and Stress Gradient Construction

This study was restricted to permanent or semi-permanent marshes and shallow open water wetlands. Most of the chosen wetlands had permanent open water. However, one wetland with intermittent open water was also incorporated (Ag43; Appendix A); measurements were done during a wet period (i.e. open water) in that wetland. The study included eight natural reference sites and seven natural sites located in agricultural lands, as well as 16 urban wetlands in the Cities of Edmonton and Sherwood Park (Appendix A); urban wetlands included seven naturalized constructed wetlands and nine stormwater-management ponds. Wetlands in the countryside were categorized as either agricultural when surrounded by less than 50 % of undisturbed forest within a 500 m radius or as natural sites with more than 50 % undisturbed forest within a 500 m radius. All natural sites were situated within protected areas. The amount of anthropogenic stress experienced by each wetland was quantified using stress scores for each wetland, which were calculated in a broader study that identified metrics associated with biotic communities as indicators of wetland health (Wilson and Bayley 2012). The current study shares 28 wetlands from a total of 81 wetlands sampled by Wilson and Bayley (2012) in 2010. The stress gradient that is used here was developed for that study and included 41 environmental variables. The 41 environmental variables were grouped into three abiotic categories (physical variables, water chemistry, and sediment chemistry) and calculated following the approach by Rooney and Bayley (2010) to construct each wetland's stress score. Firstly, a Principal Components Analysis (PCA) was used to determine inclusion into the stress gradient. Then, eight variables, the most-correlated with the first two ordination axes, were incorporated into the final stress gradient (Wilson and Bayley 2012). The important variables were shoreline slope, water clarity as represented by proportion of Secchi depth; $NO_{2+}NO_3$ concentration, Total Nitrogen (TN) concentration, and conductivity in the open water zone; and % Nitrogen (N), Total Phosphorus (TP), and % water content in the sediment (Wilson and Bayley 2012). Finally, variables were standardized and scores were combined and rescaled to produce stress scores that ranged from 0 to 10 along a gradient from minimally to heavily impacted wetlands (Wilson and Bayley 2012). Three wetlands (Elsinore, Ozerna, and Ag22; Appendix A) were not included in Wilson and Bayley (2012), sampling in 2010 but their scores were indirectly calculated through linear regressions from data taken during the 2008–2009 sampling seasons in a broader set of wetlands. Natural reference and agricultural wetlands tended to be the least stressed wetlands, with scores ranging between 0 and 4. Constructed wetlands and stormwater ponds were ranked as the most stressed wetlands, with scores ranging from 5 to 10; these two types of constructed wetlands were combined and classified as urban wetlands.

Plant Species Selection and Measurements

Species selection was based on plant distribution characteristics, suitable features, and a gradient of relative stress tolerance: 1) Cattail (*Typha latifolia* L.) is a ubiquitous plant species found across the entire stress gradient, 2) Mint (*Mentha arvensis* L.) is consistently found across different wetlands types, 3) Marsh skullcap (*Scutellaria galericulata* L.) is an easily identified species that is likely sensitive to stress as it is found less frequently in constructed and urban wetlands, 4) Field sowthistle (*Sonchus arvensis* L.) is an exotic invasive species commonly found on highly impacted wetlands, and 5) Northwest Territory sedge (NWT sedge, *Carex utriculata* Boott) is a fairly common native species representative of the rich and ecologically important genus *Carex* (Bernard et al. 1988).

Seven individuals of each species were chosen for the morpho-physiological measurements in each wetland and measurements were averaged across the seven individuals. Morphological measurements included shoot height (*i.e.* the height of reproductive shoots taken from the rooted sediment level to the apex); leaf length and width were measured in fully expanded leaves. A total of 17 metrics were derived from the morphological measurements (Table 1, Fig. 1). Morphological measurements were carried out during July and August 2010. Physiological measurements were carried out during July and August 2010 (Cattail, NWT sedge) and July 2011 (Mint, Field sowthistle, Marsh skullcap). Physiological measurements were taken near midday on clear days. Plant physiology was assessed using light equipment. Gas exchange rates (net CO_2 exchange) and stomatal conductance were measured in mature, fully-exposed leaves in a similar position on all plants using an infrared gas analyzer (LCi, ADC Bioscientific Ltd., Herts, UK). Gas exchange parameters were measured when photosynthetic photon flux density (PPFD) was above 1,400 μmol m^{-2} s^{-1}. Leaf fluorescence was simultaneously measured. Chlorophyll *a* fluorescence transients were studied in dark-adapted leaves on ten shoots per species per wetland with a Hansatech Pocket PEA (Hansatech Instruments Ltd., King's Lynn, Norfolk, UK). Measured leaves were dark-adapted with leaf clips for 20 min. The transients were induced by a light pulse of 3,500 μmol m^{-2} s^{-1} with a peak wavelength of 627 nm provided by a high intensity LED. The fast polyphasic fluorescence rise (OJIP rise) until F_M was recorded from 10 μs

Table 1 Spearman correlation coefficients and significance of morphologic and physiologic metrics not included in plant performance indices

Morphologic metric	N	r_s	p	Physiologic metric	N	r_s	p
Cattail							
Culm height	17	−0.42	**0.045**	Photosynthesis	21	0.42	**0.029**
Leaf length	17	0.15	0.237	Stomatal cond.	21	−0.03	0.442
Green/tot. leaves	17	−0.24	0.170				
Mint							
Leaf width	14	−0.48	**0.032**	Photosynthesis	22	0.01	0.471
				Stomatal cond.	22	−0.10	0.324
				Fv/Fm	21	−0.15	0.256
				Perform. Index	21	0.10	0.327
Field sowthistle							
Leaf width	14	−0.60	**0.021**	Photosynthesis	16	−0.28	0.141
				Fv/Fm	14	0.18	0.244
				Perform. Index	14	0.40	0.054
Skullcap							
Shoot height	12	−0.21	0.498	Fv/Fm	12	0.32	0.139
Leaf length	12	0.21	0.504	Perform. Index	12	0.22	0.232
Leaf width	12	0.25	0.213				
Northwest Territory sedge							
Culm height	14	−0.08	0.388	Photosynthesis	14	−0.28	0.141
Leaf length	14	−0.11	0.351	Stomatal cond.	14	0.33	0.243
Leaf width	14	0.47	0.089	Fv/Fm	14	−0.38	0.163

Statistically significant coefficients ($p<0.05$) are in bold font

to 1 s. Plant performance was measured in plants established in the saturated zone, as near as possible to the open water, to offset performance differences associated with the moisture gradient. Different clumps or well-spaced shoots were selected whenever possible to reduce the likelihood of measuring the same genet more than once.

Performance Tests of Candidate Metrics and Construction of Plant Performance Indices

Candidate metrics were examined graphically against stress scores following the same procedures used by Miller et al. (2006), Rothrock et al. (2008) and Wilson and Bayley (2012) for vegetation metrics. Each attribute was measured for each site and plotted against stress scores to determine whether or not to include it as a metric. Relations between metrics and stress scores were analyzed using non-parametric Spearman's Rank correlation coefficients to avoid transformation of metrics that violated assumptions of normality (Miller et al. 2006). Metrics with Spearman correlation coefficients (r_s) greater than 0.50 (absolute value) and significant P values were included in the PPIs. In order to avoid redundancy, only the metric with higher r_s was included in the PPI when metrics were obviously correlated due to allometric relations (e.g.: Field Sowthistle leaf length and width). Metric scoring followed the discrete scaling system proposed by Karr (1981). Ranges of response to stress scores of each of the six morphologic or physiologic metrics were trisected. The first level (0–33.3 % response) received a score of 1, the second level (33.4–66.6 % response level) received a score of 3, and the highest level (66.7–100 % response level) received a score of 5. Since wetland maximum scores were different due to the absence of some species in some of the wetlands, the PPIs per wetland were obtained by summing the scores from the metrics and then dividing the results by the maximum score possible per wetland. At least four metrics out of the six were used per PPI. Relations between PPIs and stress scores were analyzed by Spearman's Rank correlation coefficients (Rothrock et al. 2008).

Results

Responses of Candidate Metrics Along the Stress Gradient

All of the significant morphological metrics had an inverse relationship with stress scores (Fig. 1, Table 1). Six

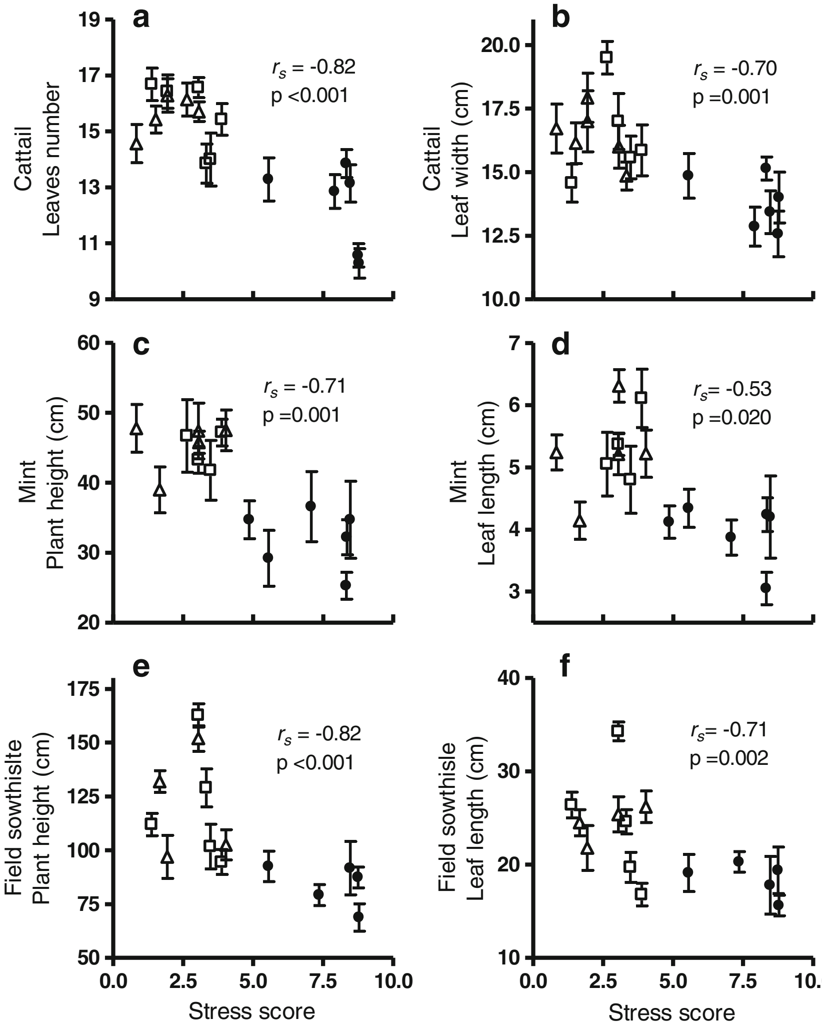

Fig. 1 Scatter graphs between plant morphology vs. stress scores with a $P \leq 0.001$. Spearman correlation coefficients (r_s) and their significance are shown. **a** Cattail leaves number and **b** Cattail leaf width, **c** Mint plant height, **d** Mint leaf length, **e** Field sowthistle plant height and **f** Field sowthistle leaf length. Different wetland types are shown: natural wetland (*open triangles*), agricultural wetlands (*open squares*), and urban wetlands (*closed circles*). Each data point shows the mean ± SE of seven replicates per wetland

out of 17 morphological metrics were incorporated into the $_m$PPI as they showed Spearman correlation coefficients (r_s) (absolute values) greater than 0.50 and significant P values (Fig. 1, Table 1). Morphological metrics selected for the $_m$PPI were cattail leaf number and width, as well as shoot height and leaf length for Mint and Field sowthistle (Fig. 1).

Physiological metrics, in general, had a weaker association with the stress gradient than did morphological metrics (Fig. 2, Table 1). Six out of 20 physiological metrics showed r_s values greater than 0.50 (absolute values) and significant P values; these were included in the $_{ph}$PPI (Fig. 2, Table 1). Physiological variables selected for the $_{ph}$PPI were: photochemistry efficiency (Fv/Fm) and fluorescence Performance Index (hereafter $_f$PI) for Cattail, stomatal conductance for Field sowthistle, $_f$PI for NWT sedge, as well as stomatal conductance along with net photosynthetic rate for Skullcap (Fig. 2).

Evaluation of Plant Performance Indices along the Stress Gradient

The $_m$PPI had significant yet lower Spearman correlation coefficient than each of the six individual metrics included in the index (r_s=−0.52; P=0.030; Fig. 3a). In addition, the $_m$PPI showed reasonably good consistency along the stress gradient and was successful in discriminating between lightly and heavily impacted wetlands (Fig. 3a). On the other hand, the $_{ph}$PPI had a non-significant association with the stress gradient (r_s=−0.30; P=0.194; Fig. 3b) and failed to clearly rank wetlands according to their impact status (Fig. 3b).

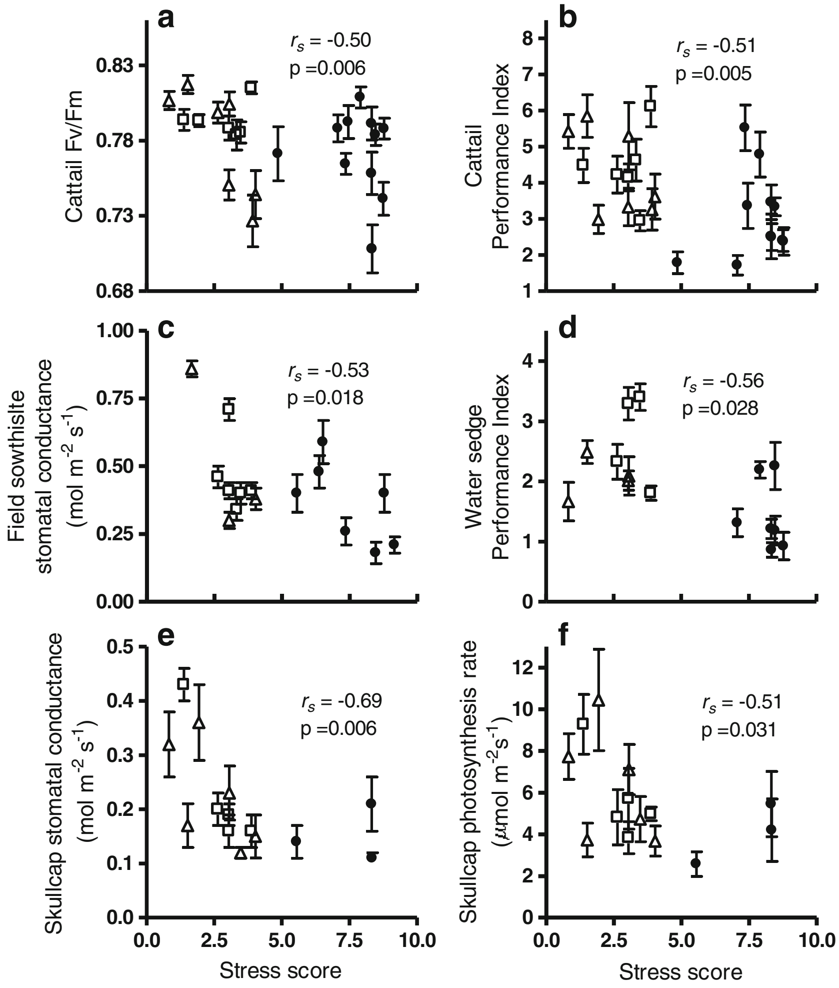

Fig. 2 Scatter graph of plant physiological performance vs. stress scores with a $P \leq 0.001$. Spearman correlation coefficients and their significance are shown. **a** Cattail photochemistry efficiency (Fv/Fm), **b** Cattail fluorescence Performance Index, **c** Water sedge photochemistry efficiency (Fv/Fm), **d** Water sedge fluorescence Performance Index, **e** Marsh skullcap stomatal conductance and **f** Marsh skullcap net photosynthesis rate. Different wetland types are shown: natural wetland (*open triangles*), agricultural wetlands (*open squares*), and urban wetlands (*closed circles*). Each data point shows the mean ± SE of seven replicates per wetland

Discussion

Plant shoot and leaf dimensions are recognized to be especially sensitive to water deficits, salinity, and site fertility (Nilsen and Orcutt 1996; Huang 2006; Wolters and Jurgens 2009), variables that were included in our stress gradient as a way to reflect wetland condition. We found that nine out of 17 plant morphological metrics were consistently and strongly associated with wetland condition (Fig. 1; Table 1). In effect, Cattail leaf numbers as well as shoot and leaf dimensions for Cattail, Mint, and Field sowthistle were clearly reduced in those urban wetlands diagnosed as

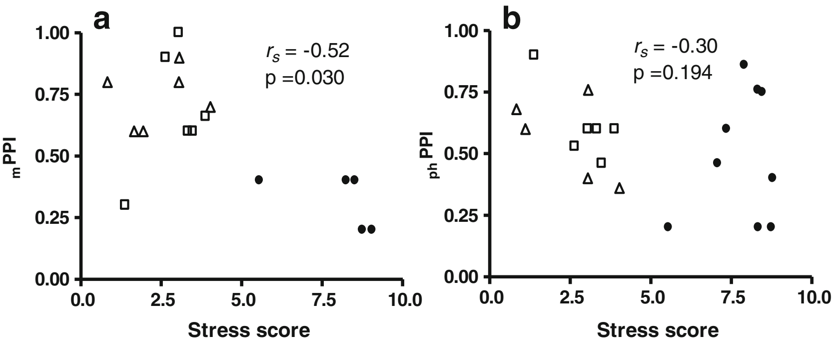

Fig. 3 Evaluation of Plant Performance Indices (PPIs) along a stress gradient **a** morphologic based PPI and **b** physiologic based PPI. Different wetland types are shown: natural wetland (*open triangles*), agricultural wetlands (*open squares*), and urban wetlands (*closed circles*)

having a low habitat quality (Fig. 1; Table 1). On the other hand, pristine wetlands in central Alberta are meso to eutrophic while impacted natural wetlands are hypereutrophic (Bayley and Prather 2003). Shoot dimensions, as highly sensitive stress indicators, should be able to reflect the nutrient differences expected to occur in eutrophic vs. hypereutrophic wetlands. Indeed, some of the morphological features such as Mint leaf length and Field sowthistle plant height (Fig. 1d, e) showed smaller sizes in the lower stress score values of the most pristine than in the more impacted natural wetlands. In spite of this lack of accuracy in the less-stressed reference wetlands, nine morphological indicators robustly detected anthropogenic change even with a background of high natural variability.

All of the effective morphological metrics were drawn from low-cost and easily measurable plant features, belong to species able to thrive in a wide range of wetland conditions, and had a highly sensitive and foreseeable response to the stress gradient. All these advantages of individual plant morphological metrics, which are in line with desired ecological indicators features (Dale and Beyeler 2001; Niemi and McDonald 2004), suggested that they could successfully be included into a Plant Performance Index for wetland health assessment. The constructed $_{\mathrm{m}}$PPI showed a strong relationship to the impact gradient ($r_s = -0.52$; $P = 0.030$) and was effective in clearly identifying the highly impacted conditions of urban wetlands. In this manner, the $_{\mathrm{m}}$PPI was sensitive and effective in diagnosing wetland health, and as it inherited morphological indicators properties, it is cost-effective as well as easy and rapid to measure. Moreover, as the $_{\mathrm{m}}$PPI was based on annual growth-related traits, it presumably integrated the stress factors and conditions present in each of the wetlands during the sampling year (Achard et al. 2006; Keurentjes et al. 2011). In consequence, the mentioned features of the $_{\mathrm{m}}$PPI fulfilled many of the essential requirements of a good environmental indicator and rapid assessment technique (Herricks and Schaeffer 1985; Dale and Beyeler 2001; Rader and Shiozawa 2001; Fennessy et al. 2007).

Seven out of 20 physiological metrics measured at the leaf level were significantly associated with wetland condition (Fig. 2; Table 1). Despite these promising results, a closer inspection of performance-to-stress gradient relationships showed that some wetlands, having similar stress scores, presented highly dissimilar plant physiologic performances (Fig. 2). Plant physiological rates and processes measured at the leaf level do not necessarily integrate plants' historical conditions in an easily discernible manner (Duda et al. 2004; Damour et al. 2010) but, on the contrary, their sensitivity to stress can depend on the individual plant's antecedent growth conditions and other intrinsic plant and even organ characteristics such as age and developmental stage (Chiarello and Gulmon 1991). The low strength of the physiological metric-stress gradient relationships suggested that the inclusion of physiological indicators into an assessment index may result in a poorly performing wetland health indicator. Accordingly, the resulting $_{\mathrm{ph}}$PPI lacked sensitivity and was uncorrelated with the physico-chemical stress gradient (Fig. 3b). Moreover, it failed to identify heavily-impacted urban wetlands. As a result, the $_{\mathrm{ph}}$PPI cannot be used as a wetland health indicator as it did not reflect habitat quality, the most basic requirement of a good environmental indicator (Dale and Beyeler 2001; Niemi and McDonald 2004).

$_{\mathrm{m}}$PPIs may convey important information about habitat degradation. Results clearly indicated that Cattail, Mint, and Field sowthistle responded to the stress gradient through significant morphological impairment. Poor habitat condition is an issue in urban wetlands, as water quality is affected by various types of pollution (North Saskatchewan Watershed Alliance 2005) as well as nutrient pulses of unpredictable timing and magnitude. Physical degradation is also noticeable in urban stormwater ponds where the emergent and wet meadow sediments are often covered with cobbles, and slopes are steep, creating isolated patches of stunted vegetation. Changes in urban temperature with respect to the countryside could also cause phenological (Zhang et al. 2004) and possibly morphological modifications. As a result, there are many different environmental changes that could have caused the morphological differences shown in Cattail, Mint, and Field sowthistle plants. Regardless of the multidimensional physico-chemical complexity of urban wetlands conditions, the $_{\mathrm{m}}$PPI has consistently responded to the multiple stress factors summarized in the stress gradient.

IBI assessment protocols look for sensitivity while controlling redundant information. The addition of morphological metrics or a multi-metric index into assessment techniques may improve their robustness without including further redundancy. Nonetheless, validation across different wetland types or regions, as well as refinement of the index is still required and potential weaknesses need to be accounted for before including $_{\mathrm{m}}$PPI into rapid assessment methods. Still, the strength of the morphological metrics and $_{\mathrm{m}}$PPI's make them worthy of further research into their potential as possible tools to assess wetland conservation and reclamation.

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Appendix A

Table 2 Characteristics and coordinates of urban, agricultural, and natural wetlands in where plant performance measurements were done

Wetland	Type	Location	Latitude (N)	Longitude (W)
Bearspaw	Urban	Edmonton	53°26′38″	113°30′14″
Brintnell	Urban	Edmonton	53°36′	113°24′13″
Callingwood	Urban	Edmonton	53°29′23″	113°39′19″
Canossa	Urban	Edmonton	53°38′02″	113°31′31″
Clarkdale	Urban	Sherwood Park	53°33′02″	113°15′21″
Cloverbar	Urban	Sherwood Park	53°33′16″	113°16′47″
Elsinore	Urban	Edmonton	53°38′17″	113°30′06″
Hamptons	Urban	Edmonton	53°29′39″	113°40′30″
Hudson	Urban	Edmonton	53°36′18″	113°32′48″
Larkspur Lake	Urban	Edmonton	53°28′54″	113°23′27″
Meadowbrook	Urban	Edmonton	53°28′19″	113°23′31″
Oxford Lake	Urban	Edmonton	53°37′17″	113°32′58″
Ozerna	Urban	Edmonton	53°37′35″	113°27′06″
Summerside	Urban	Edmonton	53°25′25″	113°28′20″
Terwillegar	Urban	Edmonton	53°26′52″	113°35′54″
Valencia	Urban	Edmonton	53°38′20″	113°28′58″
Ag 18	Agricultural	Strathcona County	53°39′33″	113°05′30″
Ag 22	Agricultural	Strathcona County	53°32′24″	113°02′01″
Ag 23	Agricultural	Strathcona County	53°22′04″	112°54′59″
Ag 27	Agricultural	Strathcona County	53°27′14″	113°10′32″
Ag 28	Agricultural	Leduc County	53°17′14″	113°14′35″
Ag 34	Agricultural	Lamont County	53°34′19″	112°42′22″
Ag 43	Agricultural	Lamont County	53°33′50″	112°42′20″
Nat0	Natural	Elk Island NP	53°42′27″	112°48′41″
Nat02	Natural	Elk Island NP	53°39′29″	112°49′43″
Nat03	Natural	Cooking L. AP	53°29′49″	112° 56′40″
Nat07	Natural	Cooking L. AP	53°28′33″	112°46′50″
Nat08	Natural	Cooking L. AP	53°29′19″	112°48′51″
Nat12	Natural	Elk Island NP	53°38′28″	112°51′21″
Nat46	Natural	Elk Island NP	53°34′30″	112°51′07″
Nat47	Natural	Elk Island NP	53°35′24″	112°56′40′

Cooking L. AP Cooking-Lake Blackfoot Provincial Recreational Area (Alberta Parks), *Elk Island NP*=Elk Island National Park (Parks Canada)

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