Methods in Ecology and Evolution

British Ecological Society

Methods in Ecology and Evolution 2015 doi: 10.1111/2041-210X.12491

APPLICATION

The Universal Floristic Quality Assessment (FQA) Calculator: an online tool for ecological assessment and monitoring

William A. Freyman[1]*, Linda A. Masters[2] and Stephen Packard[3]

[1]University and Jepson Herbaria, University of California, Berkeley, 1001 Valley Life Sciences Building #2465, Berkeley, CA 94720-2465, USA; [2]Openlands, 25 East Washington Street Suite 1650, Chicago, IL 60602-1708, USA; and [3]Woods and Prairie Foundation, 1625 Ferndale Avenue, Northbrook, IL 60062, USA

Summary

1. Floristic Quality Assessments (FQAs) are measurements of a natural area's ecological integrity based on their plant species composition. Widely used by government agencies and conservation organizations to monitor and assess natural areas, FQA data bases have been developed for much of the United States and beyond.

2. Here, we present the Universal FQA Calculator (http://universalFQA.org), a free, open-source web-based FQA Calculator. The calculator offers 30 FQA data bases (with more being added regularly) from across the United States and Canada and has been used to calculate thousands of assessments. The Universal FQA Calculator's growing repository for site inventory and transect data is accessible via a REST API and represents a valuable resource for data on the occurrence and abundance of plant species.

3. We describe the features and implementation of the Universal FQA Calculator, provide a summary of its increasing usage and discuss the benefits of cloud-based storage of ecological assessment data.

Key-words: assessment metrics, ecological monitoring, Floristic Quality Assessments (FQAs) , software tools

Introduction

Ecosystems have a complex range of spatially and temporally variable components that make characterizing their integrity difficult. However, government agencies, conservation organizations and other land managers require quantifiable and reproducible metrics to monitor and assess a natural area's ecosystem. This need led to the development of a plant community monitoring system called the Floristic Quality Assessment (FQA), which is based on coefficients of conservatism (C values) assigned to individual plant species based on their tolerance to degradation and the degree to which the species is faithful to natural remnant habitats (Swink & Wilhelm 1994). The C values range from 0 to 10; the most highly conservative species (C values >7) are typically found associating with each other under long-unchanged conditions similar to those under which such species and communities evolved. The least conservative species (C values <3) are adapted to extreme anthropogenic or natural degradation of kinds that eliminate both high and mid conservatives. Such disturbances range from bulldozing and ice scour to toxic chemicals and overgrazing. Thus, FQA metrics generally reflect the degree to which the plot or site approximates the vegetative composition of a high-quality natural area; in this context, a natural area is a community of diverse plants and animals that have evolved together for millennia or longer. In some parts of the world, natural areas have evolved with minimal impact from humans or invading, malignant species. In others, anthropogenic fire, hunting, gathering, planting and grazing may have had major impacts, but some wild natural areas may survive with high indigenous biodiversity because the impacts have been compatible with it.

Floristic Quality Assessment metrics are used in decision-making for natural areas protection or management. High sitewise and per-plot values may indicate the desirability of preserving a site, if areas with similar composition and quality are not already adequately protected. In existing protected natural areas, metrics values that are stable or rising suggest adequate management. Falling values suggest that quality and biodiversity may be declining, and changed management deserves consideration.

The C values are assigned to all species within an ecological or geographic region. Non-native species are assigned a value of 0. The resulting list of C values (referred to here as an FQA data base) is used to calculate metrics such as mean C, Floristic Quality Index (FQI) and Adjusted FQI. Mean C is the average C value for all species within an assessment area. Since mean C

*Correspondence author. E-mail: freyman@berkeley.edu

can be similar for areas with extremely high or low species richness, FQI is calculated by weighting the mean C by species richness:

$$I = \overline{C}\sqrt{n},$$

where $\overline{C}$ is mean C, and n is species richness. Mean C and FQI are calculated either with all non-native species omitted from the calculation or assigned C values of 0. To reduce sensitivity to species richness and include the contribution of non-native species when assessing sites with high levels of human disturbance, the Adjusted FQI was developed (Miller & Wardrop 2006). It is defined as

$$I' = 100\left(\frac{\overline{C_n}}{10}\right)\left(\frac{\sqrt{n_n}}{\sqrt{n_n}}\right),$$

where $\overline{C_n}$ is native mean C, n_n is native species richness, and n_t is the total species richness.

Widely used by state and federal agencies as well as conservation organizations to evaluate natural areas and inform land management, FQA data bases have been developed for much of the United States (Table 1) and beyond (Italy, Landi & Chiarucci 2010; Pakistan, Malik, Shinwari & Waheed 2012; Canada, Oldham, Bakowsky & Sutherland 1995; China, Tu *et al.* 2009). However, previous FQA computer programs only calculated FQA for a single region or habitat, and for many regions, FQA had to be calculated by hand or in spreadsheet software. Furthermore, bias due to the subjective methods used to assign coefficients of conservatism was left unexplored when there was no tool to compare assessment results calculated using different FQA data bases in regions with multiple published FQA data bases. Similarly, there was no reference tool that reported the coefficients of conservatism across multiple FQA data bases for the same taxon. The Universal FQA Calculator (http://universalFQA.org) was developed to address the challenges posed by the increasing number of FQA data bases and harness responsive web application design that enables use of the calculator both on the desktop and in the field on mobile devices.

Table 1. FQA data bases available in the Universal FQA Calculator as of July 2015

Region	FQA Data base	Number of Species	% Native Species	Native Mean C
Chicago	Swink & Wilhelm (1994)	2530	64·7	7·3
Chicago	Herman, Sliwinski & Whitaker (2013)	2790	63·6	7·2
Chicago	Herman, Sliwinski & Whitaker (2014)	2768	63·4	7·2
Dakotas (excluding the Black Hills)	Northern Great Plains Floristic Quality Assessment Panel (2001)	1584	82·6	6·1
Delaware	McAvoy (2013)	2306	69·3	6·2
Illinois	Taft *et al.* (1997)	3040	68·6	6·4
Indiana	Rothrock (2004)	2812	71·9	6·0
Iowa	Drobney *et al.* (2001)	1963	75·8	6·0
Kansas	Freeman (2014)	2306	77·7	4·8
Louisiana (Coastal Prairie)	Allain *et al.* (2004)	591	86·6	4·4
Maine	Maine Natural Areas Program (2014)	2396	63·2	5·0
Michigan	Reznicek *et al.* (2014)	2872	63·0	6·5
Mid-Atlantic Allegheny Plateau (glaciated)	Mid-Atlantic Wetland Workgroup (2012)	1506	100·0	6·1
Mid-Atlantic Allegheny Plateau (non-glaciated)	Mid-Atlantic Wetland Workgroup (2012)	2135	100·0	6·2
Mid-Atlantic Coastal Plain	Mid-Atlantic Wetland Workgroup (2012)	2086	100·0	6·0
Mid-Atlantic Piedmont Region	Mid-Atlantic Wetland Workgroup (2012)	2029	100·0	6·1
Mid-Atlantic Ridge and Valley Region	Mid-Atlantic Wetland Workgroup (2012)	2048	100·0	6·2
Minnesota Wetlands	Milburn, Bourdaghs & Husveth (2007)	1266	87·5	5·9
Missouri	Ladd (1993)	2641	72·2	6·3
Missouri	Ladd & Thomas (2015)	2960	69·4	6·1
Nebraska	Rolfsmeier & Steinauer (2003)	2071	75·9	5·2
New Jersey	Bowman's Hill Wildflower Preserve (2006)	3435	62·7	6·4
Pennsylvania Piedmont	Bowman's Hill Wildflower Preserve (2006)	3419	46·0	4·6
Southern Ontario	Oldham, Bakowsky & Sutherland (1995)	2333	69·3	6·9
Washington State (Eastern: Columbia Basin)	Rocchio & Crawford (2013)	2734	76·2	5·3
Washington State (Eastern: mountains)	Rocchio & Crawford (2013)	2734	76·2	5·3
Washington State (Western)	Rocchio & Crawford (2013)	2218	68·6	5·1
West Virginia	West Virginia Natural Heritage Program (2015)	2827	74·2	6·1
Wisconsin (Midwest region)	Parker *et al.* (2014)	2594	65·7	6·4
Wisconsin (Northcentral–Northeast region)	Parker *et al.* (2014)	2594	65·7	6·4

Methods

IMPLEMENTATION

The Universal FQA Calculator was implemented on the open-source LAMP (Linux/Apache/MySQL/PHP) software stack using the model–view–controller (MVC) software architectural pattern. The calculator uses the open-source JavaScript libraries jQuery (http://jquery.com) and Bootstrap (http://getbootstrap.com) for a fluid, responsive user interface design that is effective both on desktop computers and mobile devices. The code for the Universal FQA Calculator is licensed under the open-source GNU General Public License (Free Software Foundation 2007) and can be accessed freely in a Git version control repository (Hamano & Torvalds 2005) at https://github.com/wf8/universalFQA.

FEATURES

The Universal FQA Calculator calculates site inventory and transect FQAs, allowing the user to select from any existing FQA data base. Inventory assessments report species richness, mean *C*, FQI and Adjusted FQI, reporting values both for all species and for natives only. Some FQA data base authors have included coefficients of wetness, duration and physiognomic data for each taxon, so assessments calculated using those data bases also contain summary metrics for those values. Transect assessments differ from inventory assessments by permitting the user to enter quadrat data including species abundance as either per cent cover or using the Braun–Blanquet scale (1932). Transect assessments report the same metrics as inventory assessments both at the quadrat level and transect level, and additionally report relative frequency, relative coverage and relative importance value of all species observed. Furthermore, transect assessments report cover-weighted FQI, which is defined as

$$I_\gamma = \overline{C_\gamma}\sqrt{n},$$

where $\overline{C_\gamma}$ is cover-weighted mean C. Given $\overline{\gamma_i}$ as the mean per cent cover for the *i*th species out of *n* total species, cover-weighted mean *C* is defined as

$$\overline{C_r} = \frac{\sum_{i=1}^{n} C_i\overline{\gamma_i}}{\sum_{i=1}^{n}\overline{\gamma_i}}$$

Users may store as many inventory and transect assessments as they wish in their online account, and results of all assessments are downloadable as.csv spreadsheet files. Users can also import Assessment Strings, the special file format used to export data from the original FQA software developed by the Conservation Design Forum (Wilhelm & Masters 1995).

A number of features were developed to give users substantial flexibility when working with FQA data bases. Users can view and download all FQA data bases, and as new FQA data bases are published, the data base's authors or other users can upload them to the site. Users can quickly recalculate an existing assessment with a different FQA data base and compare the results, and taxon names will be automatically translated to the accepted names used in the new FQA data base if the data base's authors included a list of synonyms. Users may also customize data bases for their own purposes (e.g. modifying taxon names or coefficients) without altering the publically available published version of the data base. Lastly, there is a function to generate a list of all entries for a given genus or species found in any of the FQA data bases that allows for easy comparison of coefficient values across different regions and data bases.

The Universal FQA Calculator's data are accessible programmatically through a web application programming interface (API). Researchers can use the API to query and retrieve all FQA data bases and public inventory and transect assessments. The API uses the Representational State Transfer (REST; Fielding 2000) architectural style and returns JavaScript Object Notation (JSON)-formatted data. Details on using the API are available through the Universal FQA Calculator's online help section.

Results and Discussion

The Universal FQA Calculator went live in September 2013 with a single FQA data base (Chicago region, Swink & Wilhelm 1994) and as of July 2015, the site offers 30 FQA data bases from across the United States and Canada (Table 1). The 588 registered users have saved data from 2138 inventory assessments and 857 transect assessments. Traffic to the site continues to steadily increase, growing from 114 user sessions in February 2014 to 1312 sessions in July 2015 (Fig. 1). The average session duration was 10 min 17 s.

The Universal FQA Calculator makes ecological assessments accessible, easy to use and free. By providing a convenient web interface, FQA practitioners can easily compare assessment results and coefficients across multiple FQA data bases. This functionality could aid future authors as they create new FQA data bases and use empirical data driven methods that refine assigned C values by revealing imprecision and unintentional bias (Cohen, Carstenn & Lane 2004; Matthews, Spyreas & Long 2015). Moreover, there are benefits to the cloud-based storage of ecological assessment data. Since the Universal FQA Calculator keeps all assessment data in a centralized data base repository, the assessments can easily be recalculated as new regional and possibly nationwide FQA data bases are developed (Medley & Scozzafava 2009).

The Universal FQA Calculator's growing online repository for site inventory and transect data is also a valuable resource

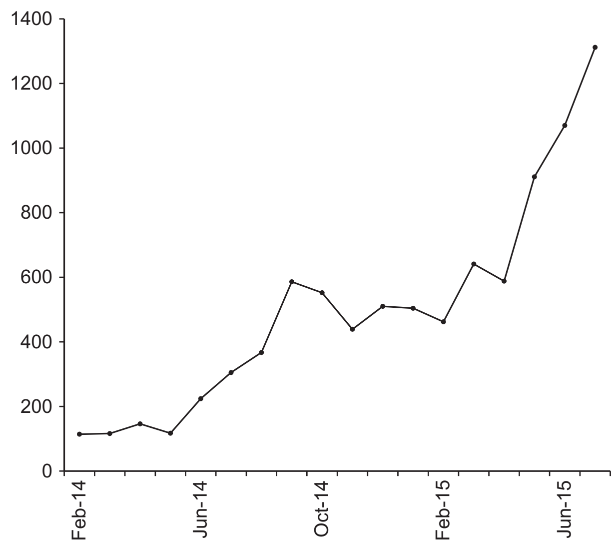

Fig. 1. Number of Universal FQA Calculator user sessions per month from February 2014 to July 2015. The average session duration was 10 minutes 17 seconds.

to any ecological researcher who needs data on the occurrence, distribution and abundance of plant species. Though all of the site's users may choose to keep their data private, they also have the option to make their assessments public and thereby share their data with researchers that may be developing new ecological indicators or involved in other ecological research that utilizes occurrence or abundance data. This data can be accessed and queried through the Calculator's web API, enabling researchers to rapidly and programmatically collect data in a reproducible way and integrate it with data from other sources (Poisot *et al.* 2015). As novel ecological indicators such as further enhancements to FQI or even phylogenetic metrics (Faith 1992) are developed, they can be integrated into the Universal FQA Calculator's assessment reports and automatically calculated for all existing assessment data, keeping FQA practitioners abreast of the latest developments and best practices in ecological assessment research.

Acknowledgements

The authors would like to thank all the authors of the FQA data bases available on the Universal FQA Calculator (Table 1) for sharing their hard work and making it publically accessible. We also thank two anonymous reviewers and the Associate Editor for their comments that helped improve the manuscript. The Universal FQA Calculator was developed with funds from Openlands. WAF was supported by the National Science Foundation Graduate Research Fellowship under Grant DGE 1106400.

Data accessibility

This manuscript does not include any data.

References

Allain, L., Smith, L., Allen, C., Vidrine, M.F. & Grace, J.B. (2004) A Floristic Quality Assessment System for the Coastal Prairie of Louisiana. *Proceedings of the 19th North American Prairie Conference*. Paper 62. August 2004, Madison, Wisconsin, USA.

Bowman's Hill Wildflower Preserve (2006) *Bowman's Hill Wildflower Preserve Plant Stewardship Index*. Bowman's Hill Wildflower Preserve, New Hope, Pennsylvania, USA.

Braun-Blanquet, J. (1932) *Plant Sociology*. Translated by Fuller, G.D. & Conrad, H.S. McGraw-Hill, New York, USA.

Cohen, M.J., Carstenn, S. & Lane, C.R. (2004) Floristic quality indices for biotic assessment of depressional marsh condition in Florida. *Ecological Applications*, **14**, 784–794.

Drobney, P.D., Wilhelm, G.S., Horton, D., Leoschke, M., Lewis, D., Pearson, J., Roosa, D. & Smith, D. (2001) *Floristic Quality Assessment for the State of Iowa*. Neal Smith National Wildlife Refuge and Ada Hayden Herbarium, Iowa State University, Ames, Iowa, USA.

Faith, D.P. (1992) Conservation evaluation and phylogenetic diversity. *Biological Conservation*, **61**, 1–10.

Fielding, R.T. (2000) *Architectural styles and the design of network-based software architectures*. Doctoral dissertation, University of California, Irvine.

Free Software Foundation (2007) GNU General Public License. http://www.gnu.org/licenses/gpl.html

Freeman, C.C. (2014) *Coefficients of Conservatism for Kansas Vascular Plants and Selected Life History Attributed*. Kansas Biological Survey and R.L. McGregor Herbarium, University of Kansas, Lawrence, Kansas, USA.

Hamano, J. & Torvalds, L. (2005) Git-fast version control system. http://git-scm.com/

Herman, B., Sliwinski, R. & Whitaker, S. (2013) *Chicago Region FQA (Floristic Quality Assessment) Calculator Beta Version*. U.S. Army Corps of Engineers, Chicago, Illinois, USA.

Herman, B., Sliwinski, R. & Whitaker, S. (2014) *Chicago Region FQA (Floristic Quality Assessment) Calculator Version 1.16.14*. U.S. Army Corps of Engineers, Chicago, Illinois, USA.

Ladd, D.M. (1993) *Coefficients of Conservatism for Missouri Vascular Flora*. The Nature Conservancy, St. Louis, Michigan, USA.

Ladd, D. & Thomas, J.R. (2015) Ecological Checklist of the Missouri Flora for Floristic Quality Assessment. *Phytoneuron*, **2015–12**, 1–274.

Landi, S. & Chiarucci, A. (2010) Is floristic quality assessment reliable in human-managed ecosystems? *Systematics and Biodiversity*, **8**, 269–280.

Maine Natural Areas Program (2014) *CoC Scores for Maine*. Maine Natural Areas Program, Augusta, Maine, USA.

Malik, R.N., Shinwari, Z.K. & Waheed, H. (2012) Linkages between spatial variations in riparian vegetation and floristic quality to the environmental heterogeneity a case study of River Soan and its associated streams, Pakistan. *Pakistan Journal of Botany*, **44**, 187–197.

Matthews, J.W., Spyreas, G. & Long, C.M. (2015) A null model test of Floristic Quality Assessment: are plant species' Coefficients of Conservatism valid? *Ecological Indicators*, **52**, 1–7.

McAvoy, W.A. (2013) *The Flora of Delaware Online Database*. Delaware Division of Fish and Wildlife, Species Conservation and Research Program, Smyrna, Delaware, USA.

Medley, L. & Scozzafava, M. (2009) Moving toward a national floristic quality assessment: considerations for the EPA National Wetland Condition Assessment. *National Wetlands Newsletter*, **31**, 6–9.

Mid-Atlantic Wetland Workgroup (MAWWG) (2012) *Floristic Quality Assessment Index (FQAI) Calculator*. Pennsylvania State University Cooperative Wetland Center, University Park, Pennsylvania, USA.

Milburn, S.A., Bourdaghs, M. & Husveth, J.J. (2007) *Floristic Quality Assessment for Minnesota Wetlands*. Minnesota Pollution Control Agency, St. Paul, Michigan, USA.

Miller, S.J. & Wardrop, D.H. (2006) Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. *Ecological Indicators*, **6**, 313–326.

Northern Great Plains Floristic Quality Assessment Panel. (2001) Coefficients of conservatism for the vascular flora of the Dakotas and adjacent grasslands. U.S. Geological Survey, Biological Resources Division, Information and Technology Report USGS/BRD/ITR-2001-0001, 32.

Oldham, M.J., Bakowsky, W.D. & Sutherland, D.A. (1995) *Floristic Quality Assessment System for Southern Ontario*. Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Peterborough, ON, Canada.

Parker, E.C., Curran, M., Waechter, Z.S. & Grosskopf, E.A. (2014) Wisconsin FQA (Floristic Quality Assessment) Databases for Midwest and Northcentral-Northeast Regions for Universal FQA Calculator.

Poisot, T., Gravel, D., Leroux, S., Wood, S.A., Fortin, M.J., Baiser, B. & Stouffer, D.B. (2015) Synthetic datasets and community tools for the rapid testing of ecological hypotheses. *bioRxiv*, 021402.

Reznicek, A.A., Penskar, M.R., Walters, B.S. & Slaughter, B.S. (2014) *Michigan Floristic Quality Assessment Database*. Herbarium, University of Michigan, Ann Arbor, Michigan and Michigan Natural Features Inventory, Michigan State University, Lansing, Michigan, USA.

Rocchio, F.J. & Crawford, R.C. (2013) *Floristic Quality Assessment for Washington Vegetation*. Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia, Washington, USA.

Rolfsmeier, S. & Steinauer, G. (2003) Vascular Plants of Nebraska (Version I - July 2003). Nebraska Natural Heritage Program, Nebraska Game and Parks Commission. Lincoln, Nebraska, USA.

Rothrock, P.E. (2004) Floristic quality assessment in Indiana: The concept, use, and development of coefficients of conservatism. Final Report for ARN A305-4-53, EPA Wetland Program Development Grant CD975586-01.

Swink, F. & Wilhelm, G. (1994) *Plants of the Chicago Region*, 4th edn. Indiana Academy of Science, Indianapolis, USA.

Taft, J.B., Wilhelm, G.S., Ladd, D.M. & Masters, L.A. (1997) *Floristic Quality Assessment for Vegetation in Illinois, a Method for Assessing Vegetation Integrity*. Illinois Native Plant Society, Westville, Illinois, USA.

Tu, W.G., Gao, X.F., Wu, N. & Liu, S.H. (2009) A novel method for floristic quality assessment using the vegetation of the Jiuding Mountain, Sichuan, China as an example. *Nordic Journal of Botany*, **27**, 61–68.

West Virginia Natural Heritage Program (2015) *Coefficients of Conservatism for the Vascular Flora of West Virginia*. Wildlife Diversity Unit, West Virginia Division of Natural Resources, Elkins, Wes Virginia, USA.

Wilhelm, G.S. & Masters, L.A. (1995) *Floristic Quality Assessment in the Chicago Region and Application Computer Programs*. Morton Arboretum, Lisle, Illinois, USA.

Received 21 August 2015; accepted 23 September 2015
Handling Editor: Timothée Poisot