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

Correction(s) for this article

Erratum
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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 u Calculator's growir a a REST API and represents a valuable resource for data on the occurrence and abundance of plant species.

storage of ecological assessment data.

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 assig as an FQA data base) is used to d Adjusted FQI. Mean C is the average C value for all species within an assessment area. Since mean C can be

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

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
Chicago	[illegible]
Chicago	Herman, Sliwinski & Whitaker (2013)

Chicago	Herman, Sliwinski & Whitaker (2014)
Dakotas (excluding the Black Hills)	Northern Great Plains Floristic Quality Assessment Pane
Delaware	McAvoy (2013)
Illinois	Taft *et al*. (1997)
Indiana	Rothrock (2004)
Iowa	Drobney *et al*. (2001)
Kansas	Freeman (2014)
Louisiana (Coastal Prairie)	Allain *et al*. (2004)

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 Adjuste … only. Some FQA data base autho … nomic data for each taxon, so as … mary 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 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 secti

Results and Discussion

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.

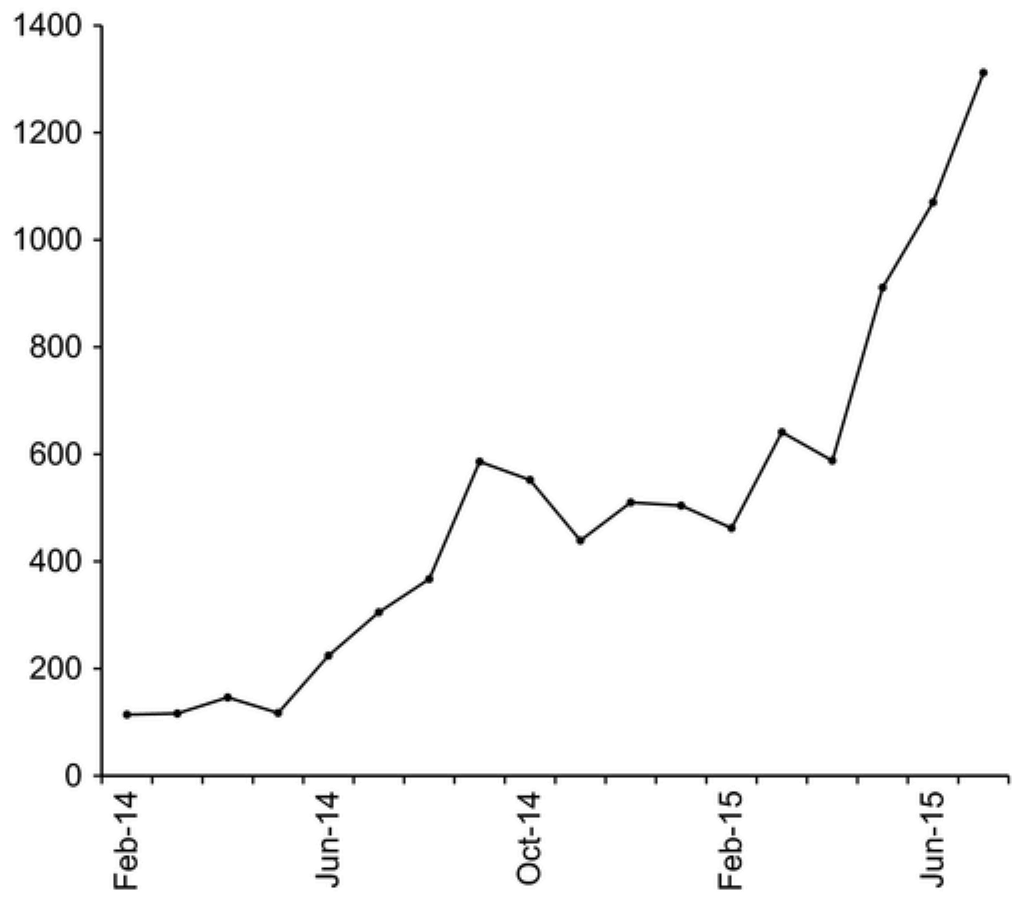

Figure 1

Open in figure viewer | PowerPoint

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

The Universal FQA Calculator makes ecological assessments accessible, easy to use and free. By providing a conve … sessment results and coefficients … ure authors as they create new FQ … efine assigned C values by revealing imprecision and unintentional bias (Cohen, Carstenn & Lane 2004;

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 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.

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Data accessibility

This manuscript does not include any data.

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