Online Databases Track Plant Phenology With Digital Images From Citizen Scientists

By Wendy Anthony for Eric Higgs, UVic ES 490 Directed Studies, 2 November 2014

Tracking the flowering phases of plant phenology over time can be a useful bio-indicator tool, and also a temperature proxy for climate change (MacGillivray, Hudson, & Lowe, 2010; Menzel, 2002; Primack, Miller-Rushing, Primack, & Mukunda, 2007), as the timing of spring plant growth stages is very responsive to changes in temperature (Intergovernmental Panel on Climate Change, 2007; Koch, et.al. 2011; Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004). A growing number of people interested in the natural world now have access to new digital technology, enabling them to engage with nature and contribute as citizen scientists by taking digital photos of native plants, and uploading them to an online database, which can then be analyzed by research scientist as they monitor species distribution. Phenological databases, documenting plant flowering stages with the use of citizen science and digital photography, need to use common methodologies and terms in order for data to be shared between communities, scientists, and other databases, to help understand the patterns of species biodiversity in changing environments (National Biodiversity Network, 2011; National Ecological Observatory Network, 2014; Rosemartin & Crimmins, 2012).

Phenology

Phenology studies the timing of the seasonal patterns of plants and animals, including their relationships to the environment and weather, and can be useful in biological surveys, to observe species distribution and monitor biodiversity (Denny, et.al., 2014; MacGillivray, Hudson, & Lowe, 2010; Nature's Notebook, 2014). Even back in 1893, Clarke notes that each group of plant species has a relationship between their flowering time and the seasons, and uses the most favorable time to bloom (Clarke, 1893). Phenology is also “a driver of dynamic ecological processes” (MacGillivray, Hudson, & Lowe, 2010, p. 426). Successful plants synchronize the timing of when they leaf and flower with the local environment, responding to changing cues. If the synchronicity is disrupted between pollinators and plants, or between seed dispersers and seed producers, the future productivity and distribution of the plant, as well as associated species, can be affected (Primack, Miller-Rushing, Primack, & Mukunda, 2007).

Plant cycles are so predictable that they can also be used to approximate the timing of other events. Nancy Turner notes that Pacific NW Indigenous peoples used “phenological indicators” to schedule their seasonal round of travel and harvest activities (Turner, 2014, p. 15). According to John-Bradley Williams, the WSÁNEĆ First Nation people continue to use the flowering stages of the Ocean Spray shrub to plan the timing of both salmon fishing and deer hunting (personal communication, August 19, 2014).

Though very little research has been done on the flowering stages of plants, most has focused on spring flowering, and its direct connection to average spring temperature changes in the four months before and during flowering (Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004; Menzel, 2002). Species differ in their response rate (Haggerty, Hove, and Mazer, n.d.), and genetic variation in individual plants may result in a variation in timing and duration of flowering, to ensure species survival in years of differing patterns (MacGillivray, Hudson, & Lowe, 2010). Studies have documented “a progressively earlier spring by about 2.3 to 5.2 days/decade in the last 30 years in response to recent climate warming” (Intergovernmental Panel on Climate Change, 2007), which may make flower phenology a useful indicator tool for tracking plant responses to climate change (Benton, 2009; Park, 2012; Weltzin, 2012). Local warming may result in urban plants tending to have earlier blooming times compared to rural plants, due to the heat island effect of city pavement and buildings (Alberta Plant Watch, 2012; Beubien & Hamann, 2012; Menzel, 2002; Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004).

To research the effects of changing climate on plants, data needs to be collected. With few available long-term data records, both herbarium specimens and photo image collections, which include date and location, could be used as alternative sources of reliable data, to help determine if phonological event timings are changing. Herbarium collections document the peak flowering phase, and since 2004 have been suggested for use as an historic baseline to approximate the date of field plant flowering (Haggerty, Hove, and Mazer, n.d; Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004; Primack, Miller-Rushing, Primack, & Mukunda, 2007; MacGillivray, Hudson, & Lowe, 2010). Small herbariums are slowly starting to digitize label data, and contribute to other databases, though, due to budget restrictions, very few are using photography to digitize the specimens (Dr. Gerry Allen, personal communication, August 22, 2014).

Citizen Science

One way to create large photographic collections of flowering plant sample data would be to engage the assistance of amateur naturalists, and other citizen scientists who are interested in photo-documenting their observations of the natural world around them, and the places they are familiar with. As flowers are beautifully appealing, and attract attention from both people and pollinators, they are also more likely to be photographed. These recorded observations allow volunteer observers to participate in scientific projects by creating data that can contribute to further scientific research. A person is also more likely to care about something they know and experience (Parks Canada, 2003), and may develop a greater awareness for noticing any changes in their environment.

Though citizen science is not new, the inaccuracies and inconsistencies of paper recording forms can be improved by using photos to document observations. Many people now have access to digital cameras, or GPS-enabled smart phones and tablets, creating a readily available tool to take photos. Dated and geolocated photo collections can create a potentially valuable data resource (MacGillivray, Hudson, & Lowe, 2010), as they are more abundant than scientific field observations, and can supplement and broaden the "geographic and temporal scale" (Havens-Young & Henderson, 2012, p. 034; Primack, Miller-Rushing, Primack, & Mukunda, 2007). Photos can act as evidence to document data for phonological plant phases and to verify observations. They can also be compared to the long-term historical species records found in local herbariums, and archived "to answer future questions" (Crimmins & Crimmins, 2008, p. 950; MacGillivray, Hudson, & Lowe, 2010; Plant Tracker, 2012).

To help engage volunteers and increase data quality, training materials should be provided, including video tutorials, field identification guides with phenophase examples, sampling and recording techniques, equipment advice, tips for recognizing & recording habitat, advice for time of day, season and weather conditions, and conduct codes for handling specimens (Barnett, 2012; Haggerty, Hove, and Mazer, n.d.).

Choosing only a few indicator species and locations will simplify options for volunteers, and create more manageable databases (MacGillivray, Hudson, & Lowe, 2010; Menzel, 2002). Observing only native plant species, which are uniquely adapted to their local environment, will minimize any adaptive effects caused by hybridization (Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004; USA-NPN, 2012). Collecting data from specific locations will help show “local variation in natural responses to climate change” (Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004; p. 1263), though, any anomalies created by the urban heat island effect need to be accounted for when comparing species from different locales.

Repeat observations of plant phonological events, including “leaf unfolding, flowering, fruit ripening, leaf colouring, [and] leaf fall” (Intergovernmental Panel on Climate Change, 2007), “have been shown to be important indicators of global change” (Crimmins & Crimmins, 2008, p. 949). Peak events, such as full flowering (a minimum of 50% of the flowers blooming), should be chosen for observation, as first events tend to be outliers, and can lead to biased conclusions (Haggerty, Hove, and Mazer, n.d.). Determining the date of full flower may still be off 3-5 days, even if the peak flowering date and duration of flowering of specific plants are observed weekly by the same people, due to the length of the time gap between observations (Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004). Including data from many collectors may help to avoid collector bias due to collection fluctuations and gaps (Haggerty, Hove, and Mazer, n.d.). Trends can be obscured by errors in collection times, location data, or species identification, as well as variations in site or genetics, environment changes, losses of habitat, changes caused by human use, multiple views of same plant on the same day, locations on well-travelled paths or edges, and urban heat effects (MacGillivray, Hudson, & Lowe, 2010; Primack, Imbres, Primack, Miller-Rushing, & Del Tredici, 2004).

Differences in volunteer observation skills can affect data accuracy, though the quality can be improved by using consistent, standard protocols, and methodologies similar to other phenology projects (Rosemartin & Crimmins, 2012). Ensuring the use of the same categories and terminology, will allow collected data to be shared, or exported to other databases (National Biodiversity Network, 2011).

Digital Images & Online Databases

People with different knowledge levels can be encouraged "to map where and when species occur" (iNaturalist, 2014), and to contribute their native plant photos to online databases (Denny, 2012; Haggerty, Hove, and Mazer, n.d.). Data generated by volunteer citizen scientist is created with the intent to be shared, and if the data is accessible and distributed through public websites, it can become a "platform for biodiversity research" by land managers and research scientists (iNaturalist, 2014).

Access to the new technology of GPS enabled smart phones, and mobile devices, creates an opportunity to generate high quality image observation data, in quantities never before possible, though expert species verification of any photos should be performed before adding to the database.

A user-friendly interface to easily upload photos and field data, from either mobile devices using free, customized web apps, or from conventional webpages, using geo-located photos stored in computer files, will assist the process for contributing photos, and provide opportunities for greater public participation. Photos may also need to be resized due to storage capacity considerations. Drop-down lists for species name, locations, and phonological phases, will ensure the use of standard terminology, and assist with the correct categorization needed for searching and data sharing, as will field guides for users to verify the species, along with help menus, and tutorials. (iNaturalist, Android app, 2014; Plant Tracker, 2012). Using photos on a public website will require agreements, such as Creative Commons Licenses with photographer attribution, to cover terms of use, distribution, and publication (Boyer, Webb & Turner, 2010; National Biodiversity Network, 2011; Nature's Notebook, Android app, 2014).

Photo records can be stored in an online database, and be accessed from a web server hosting a public website. Drupal, a free, open-source, searchable content-management database software, is increasingly being used for websites hosting citizen science data from the biodiversity community (National Biodiversity Network, 2011).

After an extensive search, I found four examples of websites using digital photos collected by citizen scientists: E-Flora, Nature's Notebook, Plant Tracker, and iNaturalist. **E-Flora**, a project of University of British Columbia's Geography Department, uses citizen science photo location data to interactively map and document any changes in the range and distribution of native, naturalized, and invasive species (Klinkenberg, 2013). After photos are uploaded, experts verify the species identification, and though the photos represent species found in BC they do not need to be shot locally in BC. **Plant Tracker**, a project of the UK's Environment Agency, University of Bristol, and the Centre for Ecology and Hydrology, tracks location data for the distribution of non-native invasive species to help prevent their spread. They store the data in a hosting warehouse, to create a "national recording scheme for vascular plants" of the British Isles (Plant Tracker, 2012). **iNaturalist** "is an online social network of people sharing biodiversity information, to help each other learn about" and connect with nature. Species are recorded and identified through crowdsourcing, and generate "scientifically valuable biodiversity data from these personal encounters" (iNaturalist, 2014). For private projects, iNaturalist also offers the opportunity to use the app in the field, as did the Kootenay Camas Project in BC's Interior (Dr. Brenda Beckwith, personal communication, July 2014). **Nature's Notebook**, a California-based project of the USA National Phenologic Network, monitors the status and abundance of chosen species (Weltzin, 2012), with a 5-year plan "to increase science, phenology and climate literacy, and improve the quality of the data" (Barnett, 2012, p. 100). Observational data is collected from across the USA, and is aggregated and summarized using visualization tools, with maps and time sliders, showing trends and averages. Phenology walks and trails have also been established to link plant observation points, and to encourage community engagement and education.

Conclusions

Crowd-sourced digital photos from citizen scientists can be used to document the phonological phases of native plant species. When common methods and terminology are used, the resulting information can be hosted in online databases, and shared with others who are also interested in observing the biodiversity around them. This accumulated data can supplement scientific field studies, and may prove to be useful to scientists, as they monitor biodiversity, and research biological indicators of environmental change. By documenting the peak flowering phase, and tracking these phases over time, phenology may become a useful climate change indicator tool.

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