Perspectives in Plant Ecology, Evolution and Systematics 15 (2013) 68–76

Contents lists available at SciVerse ScienceDirect

Perspectives in Plant Ecology, Evolution and Systematics

journal homepage: www.elsevier.com/locate/ppees

Review

Biological collections in an ever changing world: Herbaria as tools for biogeographical and environmental studies

Claude Lavoie*

École supérieure d'aménagement du territoire et de développement régional, Université Laval, Quebec City, Quebec G1A 0V6, Canada

ARTICLE INFO

Article history:
Received 21 April 2012
Received in revised form
17 September 2012
Accepted 14 October 2012

Keywords:
Biological invasion
Climate change
Collection computerization
Herbarium specimen
Molecular analysis
Museum
Pathogen
Pollution

ABSTRACT

Plant specimens stored in herbaria are being used as never before to document the impacts of global change on humans and nature. However, published statistics on the use of biological collections are rare, and ecologists lack quantitative data demonstrating the relevance to science of herbarium specimens. I found 382 studies with original data that used herbarium specimens to document biogeographical patterns or environmental changes. Most studies are less than 10 years old, and only 1.4% of the herbarium specimens worldwide have been used to answer biogeographical or environmental questions. The vast majority (82%) of papers dealt with vascular plants, but some studies also used bryophytes, lichens, seaweeds and fungi. The herbarium specimens were collected from all continents, but most of the studies used specimens from North America (40% of studies) or Europe (28%). Many types of researches (conservation, plant disease, plant invasion, pollution, etc.) can be conducted using herbarium specimens. Climate change, and especially phenological reconstructions, are clearly emerging research topics. By group, small herbaria (<100,000 specimens) are consulted as often as very large herbaria (>1,000,000 specimens) for biogeographical and environmental research, but in most cases, only large facilities provide specimens collected worldwide. The median number of specimens per study in papers using computerized collections (15,295) was much higher than for papers that did not include electronic data (226). The use of molecular analyses to investigate herbarium specimens is still relatively unexplored, at least from biogeographical and environmental points of view. Combined with recently developed procedures to correct biases, herbarium specimens might provide in the near future exciting additional spatio-temporal insights that are currently unimaginable.

Contents

* Tel.: +1 418 656 2131; fax: +1 418 656 2018.
E-mail address: claude.lavoie@esad.ulaval.ca

1433-8319/$ – see front matter © 2012 Elsevier GmbH. All rights reserved.
http://dx.doi.org/10.1016/j.ppees.2012.10.002

Introduction

With the decline of interest in – or resources allotted to – systematics studies (Lee, 2000; Winston, 2007; Expert Panel on Biodiversity Science, 2010; Pyke and Ehrlich, 2010), several scientists and administrators have questioned over the last two decades the relevance of preserving biological collections of plants and animals, considering space and budget limitations. This questioning is not new: in 1969, Stanwyn Shetler, one of the curators of the Smithsonian Institution, was already complaining about the growing number of people who saw biological collections "*as an economic millstone and an intellectual dinosaur in the modern scheme of science*" or as "*an expensive, latter-day white elephant, which in terms of resources demanded is a facility that drains more than it adds to a modern science program*" (pp. 716, 731). Public and institutional budget crises of the 1990s and 2000s led to the closure of some collections and to severe resource reductions of others (Dalton, 2003; Gropp, 2003). Some botanists even suggested the destruction of herbaria and their replacement by electronic or printed files (Clifford et al., 1990). Moreover, declining plant and animal collecting, especially in North America and Europe (Winker, 1996; Prather et al., 2004; Rich, 2006; Boakes et al., 2010; Lavoie et al., 2012), have slowly but surely diminished the value of collections. As stressed by Winker (1996), "*how informative is a library that stops acquiring books?*" (p. 704).

These threats to the existence of biological collections are paradoxical, since plant and animal specimens are being used more than ever before to document the impacts of global change on humans and nature (Pyke and Ehrlich, 2010). Several scientists have recently reviewed the possible uses of these collections, such as the reconstruction of distribution ranges, habitat uses, morphological changes, pollution trends or population sizes, or the identification of pests and diseases threatening human health or agricultural activities (Shaffer et al., 1998; Suarez and Tsutsui, 2004; Rainbow, 2008; Newbold, 2010; Pyke and Ehrlich, 2010). These reviews are informative, but they have essentially focussed on animal collections. Herbaria are also important sources of information, with more than 350 million specimens stored worldwide (New York Botanical Garden, 2012).

Published statistics on the use of biological collections are rare, and ecologists lack quantitative data demonstrating the relevance to science of plant specimens. To remedy this problem, I reviewed all studies, published from 1933 up to February 2012, which used herbarium specimens as information sources for documenting biogeographical patterns or environmental changes. I collected statistics on the research topics, the study sites, the types of herbaria consulted, and the number of specimens used. I also investigated the impact of computerization on the use of herbaria. I answered the following questions: (1) to what extent are herbaria used for biogeographical and environmental studies; (2) what are the trending research topics associated with herbarium specimens; (3) are small and medium sized herbaria consulted as frequently as large facilities for biogeographical and environmental studies; (4) has the computerization of collections facilitated the use of specimens for documenting environmental changes; and (5) are biogeographers and ecologists studying herbarium specimens using molecular techniques.

Materials and methods

The literature review focussed exclusively on peer-reviewed journals. Other information sources (reports, online databases, etc.) can also provide important insights regarding the use of herbarium specimens. However, considering their sometimes limited distribution (especially of reports), it would have been impractical to conduct an international review within a reasonable time-frame. I first examined all papers found by the Web of Science[SM] search engine (Thomson Reuters, 2012), with the keywords "collection" or "museum" or "herbarium" ("herbaria") in the headings "topic" or "title". Each paper identified was screened for its content: only papers presenting original data and explicitly using herbarium specimens for documenting biogeographical patterns or environmental changes were retained. Papers focussing exclusively on systematics, or using herbarium specimens only for mapping the distribution range of a plant without further spatial or temporal analysis were discarded. Although these papers reflect an extremely important use of herbaria, our focus was on studies presenting innovative or non-traditional uses of herbarium specimens. Additional papers (about 50% of the total) were subsequently found by reading the articles and screening the literature cited. The author of this paper can read English, French, Italian and Spanish, and collaborators provided papers in other languages (especially Chinese), but it is likely that several papers, especially those published in Russian, were missed.

Each paper was categorized according to the topics covered; papers could have more than one topic: (1) biases associated with the use of herbarium specimens (bias assessment or correction methods); (2) biogeographical patterns (plant distribution analyses); (3) conservation priorities (site selection for natural reserves); (4) historical floristic assessments (comparisons of floras over time); (5) impacts of climate change on plant distribution; (6) plant diseases; (7) plant invasions; (8) plant phenology (historical reconstructions or spatio-temporal distributions); (9) pollution trends (including carbon dioxide as a pollutant); (10) rare or declining plant species (population trends or spatial distributions); and (11) other topics (chemical ecology, insect outbreaks, pollination, etc.).

The following data were collected for each paper: (1) first author affiliation; (2) publication year; (3) journal name; (4) number of pages; (5) study site (country); (6) organisms studied (vascular plants, bryophytes, lichens, fungi, seaweeds); (7) number of herbarium specimens used; (8) herbarium/herbaria consulted; (9) whether or not a computerized database was used; and (10) whether or not molecular analyses were conducted on specimens. Additional data were collected for herbaria, i.e. (1) location (country) and (2) number of specimens stored (from New York Botanical Garden, 2012).

Results

Number of studies and spatial distribution of study sites

I found 382 studies with original data that used herbarium specimens to document biogeographical patterns or environmental changes (Appendix 1). These papers total 4620 pages and were