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Application Article

Application of digital field photographs as documents for tropical plant inventory[1]

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- *Premise of the study:* We tested the credibility and significance of digital field photographs as supplements or substitutes for conventional herbarium specimens with particular relevance to exploration of the tropics.
- *Methods:* We made 113 collections in triplicate at a species-rich mountain in the Philippines while we took 1238 digital photographs of the same plants. We then identified the plants from the photographs alone, categorized the confidence of the identification and the reason for failure to identify, and compared the results to identifications based on the dried specimens.
- *Results:* We identified 72.6% of the photographic sets with high confidence and 27.4% with low confidence or only to genus. In no case was a confident identification altered by subsequent examination of the dried specimen. The failure to identify photographic sets to species was due to the lack of a key feature in 67.8% of the cases and due to a poorly understood taxonomy in 32.2%.
- *Discussion:* We conclude that digital photographs cannot replace traditional herbarium specimens as the primary elements that document tropical plant diversity. However, photographs represent a new and important artifact that aids an expedient survey of tropical plant diversity while encouraging broad public participation.

Key words: digital photographs; flora; herbarium specimens; inventory; tropics.

For more than 300 years, the pressed and dried plant specimen has been the fundamental artifact in the global survey of plant diversity. Most historians of botany credit Luca Ghini with the formal development of techniques to dry plant specimens (Egerton, 2003; Frank and Perkins, 2004). His methods worked so well that the 400-year-old herbarium of Ghini's most renowned student, Andrea Cesalpino, remains intact at the Museo di Storia Naturale di Firenze at Florence. The pressed plant specimen soon became the standard for botanical preservation, storage, and comparative study (DeWolf, 1968). Today, approximately 3400 herbaria around the world house an estimated 350,000,000 specimens (Thiers, 1998; Frank and Perkins, 2004).

Photographs have been little more than an ancillary part of traditional herbarium collections. When photographs of plants first became common in the late 19th century, botanists saw them as a form of botanical illustration rather than as a sort of herbarium specimen and so stored them in botanical libraries rather than as part of the formal herbaria (Simpson and Barnes, 2008). Such a divergent use of photographs and specimens is surprising in that there is a curious and unappreciated connection between botany and the advent of photography. One of the early inventors of photographic methods, William Henry Fox Talbot, used botanical specimens in some of his earliest plates (Gernshiem, 1986). The British botanist Anna Atkins published the first book of photographs in 1843 and titled it *Photographs of British Algae: Cyanotype Impressions* (Parr and Badger, 2004). The role of photographs as illustrations rather than scientific artifacts continued into the 20th century. For example, between 1907 and 1922, Ernest Henry Wilson carried to China a large-format Sanderson camera and a set of glass plates with which he composed more than 2400 images. These images remain at the library of the Arnold Arboretum and some are available online (Wilson, 2011). Most large herbarium libraries have similar holdings of historic photographic prints.

The advent of digital photography in the 1990s did not alter the principal role of photographs as a form of illustration rather than of documentation. Examples of floras that include online digital images include Wisflora: Wisconsin Vascular Plant Species (http://www.botany.wisc.edu/wisflora/), Michigan Flora Online (http://michiganflora.net/), and e-Flora Florida: Field Guide to Florida Plants (http://www.floridaplants.com/Eflora/cover.htm). These photographs, which number in the thousands, are not usually linked to a specimen or to a specific record of time and place and so are not treated in the same fashion as herbarium specimens. Indeed, many of the largest plant photographic collections on the Internet are not associated with herbaria at all. For example, the Gymnosperm Database (http://www.conifers.org), the International Aroid Society (www.aroid.org), and PhytoImages (http://www.phytoimages.siu.edu/) present thousands of photographs arranged by individual species. And of course, private individuals have recently filled photographic websites such as Flikr or Facebook with millions of digital photographs of plants, often rare, sometimes from isolated locations. In the mentioned examples, the photographs are

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not treated as herbarium specimens; that is, they are not stored and managed by a trusted institution and linked with full documentary information comparable to label data. There is no standard method for citing such digital images and so they are rarely mentioned in taxonomic revisions even though they often document details of morphology and habit not evident in the dried specimens.

Although photographs were seen primarily as illustrations, they also served the critical scientific role in diversity research as documentation of type specimens. Even before the promulgation of rules for nomenclatural types at the end of the 19th century (Hitchcock, 1905; Swingle, 1913; Daston, 2004), type specimens had become the essential element to resolve the ever-expanding problems of synonymy. However, the worldwide distribution of types limited access among scientists; transport was dangerous and hand tracing was inefficient. Photographs offered a solution. The early efforts of Swingle and Swingle (1916) and others were soon expanded by botanists such as J. Francis Macbride, who traveled to Europe to photograph nomenclatural types. Macbride collected more than 40,000 photographic negatives, which are currently maintained at the Field Museum of Natural History in Chicago (Grimé and Plowman, 1986). That same era saw the use of microfiche photography to record many classic herbaria. These worthy efforts all pale in comparison to the events that followed the twin birth of digital photography and the Internet in the 1990s, whereby type specimens were quickly recorded and immediately and globally viewed (Ariño and Galicia, 2005). This worldwide effort is currently led by the JSTOR Global Plants project (https://plants.jstor.org/), which partners more than 200 herbaria and aims to index the location of more than 1.3 million type specimens. Photographic standards for type images have now been published (Häuser et al., 2005), although Vollmar et al. (2010) describe the diverse impediments to further advance. A few herbaria use these digital tools to go beyond the limits of types and have made digital images of their general collections. The New York Botanical Garden currently provides a digital image for more than 1.5 million specimens and scans an additional 100 specimens per hour (New York Botanical Garden, 2013).

In addition to images of dried specimens, some herbaria store digital images that were taken of living plants before the photographed plant was pressed and mounted. The images are then coded and stored as a linked component to the specimen. Two examples are the Missouri Botanical Garden collection of photographs of Madagascar plants available through the web portal Tropicos (http://www.tropicos.org/) and Robin Foster's extensive collection of field photographs available online through the Field Museum's Tropical Plant Guides (http://fm2.fieldmuseum.org/plantguides/color_images.asp). These exceptional examples could be more widely imitated. Baskauf and Kirchoff (2008) recommended that sets of photographs that illustrate a single plant could be treated in a way identical to a conventional herbarium specimen if the images were of high quality and with detail adequate for accurate identification. They pointed out that such digital collections could fulfill many of the roles played by traditional specimens such as to document the distribution and morphological variation of known species. However, to date, few herbaria have aggressively pursued this opportunity.

Every experienced botanist knows that digital photographs suffer limitations compared with conventional scientific specimens. The question we pose here with particular relevance to the unexplored tropics is, "Are high-quality digital photographs of living plants of sufficient scientific value that herbaria should encourage their procurement and that herbaria should conserve the images in a manner similar to ordinary specimens?"

MATERIALS AND METHODS

The study site was an accessible but poorly collected mountain in the Philippines, Mt. Kanlaon, Negros Occidental, 1200 m a.s.l. elevation, 10.477°N, 123.149°E. Between October 20 and 23, 2012, we made 15 transects separated by roughly 50 m and each roughly 100 m long and perpendicular to the main trail. We collected all fertile angiosperms that we could locate and labeled the resulting 113 specimens as *Chua 001–113*. We attempted to take only a single gathering of each species that was evidently different except where the specimens represented different floral or fruit stages. We saved material for specimens in triplicate while simultaneously taking a large number of digital photographs. The plants were photographed in the field and on a table prior to preparation as specimens. Two cameras were used: Nikon D40 SLR (Nikon Corporation, Tokyo, Japan) and Canon PowerShot G12 (Canon USA, Melville, New York, USA) with built-in macro function. Most of the photographs were taken by the junior author, a skilled photographer with limited botanical experience. To make the test a fair reflection of what an amateur botanist might do on their own, the senior author limited advice on the content of the photos to the recommendation that all plant parts be photographed with maximum magnification, that parts be dissected wherever possible, and that a scale be included. Approximately 1238 photographs were taken at a size of 2500 by 3500 pixels. They were immediately sorted, matched to collection numbers, and then copied to external storage. The specimens themselves were pressed lightly in newspaper and temporarily preserved with denatured alcohol. The specimens were sent back to the University of the Philippines, Diliman, Quezon City, where they were pressed, dried, labeled, and mounted in a conventional fashion. Specimens are stored at the Jose Vera Santos Memorial Herbarium, University of the Philippines (PUH), with one duplicate at the Philippine National Herbarium (PNH) and a third for distribution.

The senior author examined the 113 sets of photographs with the aim of matching the images to a known species and type specimen in consultation with a currently available taxonomic reference. Specialists were consulted in three cases: orchids were reviewed by W. Suarez of the Philippines; figs by L. Rodriguez, at the University of the Philippines, Diliman; and *Cyrtandra* J. R. Forst. & G. Forst. (Gesneriaceae) by G. Bradley, Royal Botanical Gardens, Kew. The level of confidence of the identification was recorded as follows: (1) confident identification to species; (2) identification to species but with low confidence, further study of the specimens is needed; (3) identification to genus only. The next category described the reasons for a failure to identify the photographs to species, that is, the reason they were placed in categories 2 and 3. These were either (1) details needed for identification not evident in the photographs, or (2) taxonomy of the genus not sufficiently known for identification. The specimens were then examined and identified in consultation with the collections of PUH and PNH.

RESULTS

We found that 72.6% of the photographic sets could be identified to species with high confidence, 8% to a species with low confidence, and 19.4% could be identified only to genus (Appendix 1). Of the species identifications made with high confidence, none were altered by subsequent examination of the specimens themselves. That may surprise some botanists, especially in so far as many of the plants might be considered exceedingly rare or poorly known from a global perspective. However, these plants were locally well known and readily identified by any botanist familiar with the Philippine flora. The genus *Saurauia* Willd. (Actinidiaceae) is species-rich and is sometimes difficult to identify; however, *Chua 002* and *Chua 104* were readily identified to the locally abundant *S. negrosensis* Elmer by comparison with the type specimen *Elmer 10139* from southern Negros (Fig. 1). Three specimens (*Chua 016*, *Chua 027*, and *Chua 041*) were identified as *Mackinlaya celebica* (Harms) Philipson (Apiaceae). This small tree, enigmatic in phylogenetic position and all but unknown in ecology, proved to be one of the most abundant small trees at Mt. Kanlaon (Fig. 2). It was confidently identified

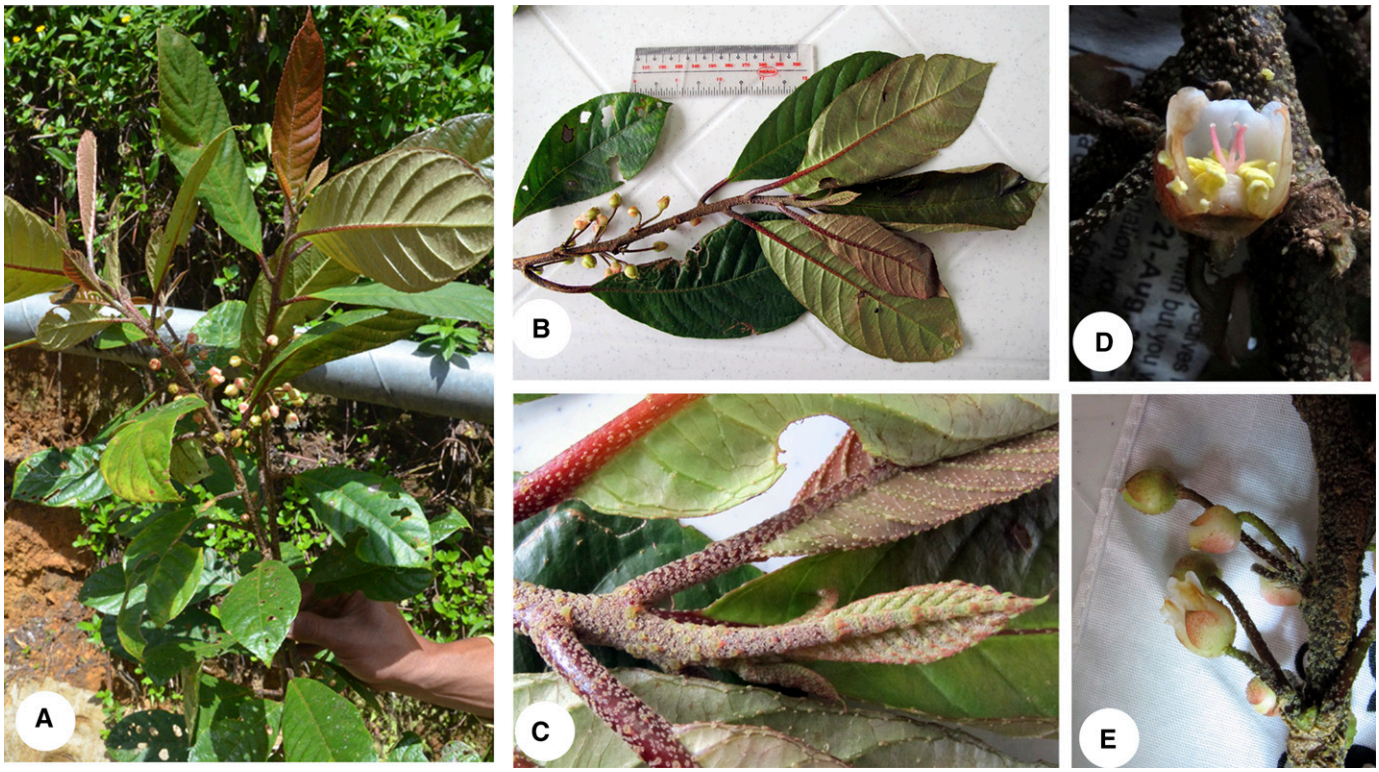

Fig. 1. Photographic set of *Saurauia negrosensis* Elmer (Actinidiaceae), specimen *Chua 002*. (A) Habit. (B) Leaves and flower position, scale. (C) Twig apex and glands. (D) Dissected flower. (E) Flower arrangement at old leaf scars.

according to the study by Philipson (1979). Specimen *Chua 024* was readily identified to the variable and widespread montane species *Arisaema polyphyllum* (Blanco) Merr. (Araceae) by comparison with the well-distributed specimen *Merrill: Species Blancoanae No. 460*. Specimen *Chua 028* was easily identified to *Aquilaria cumingiana* (Decne.) Hallier f. (Thymelaeaceae), a singular relative of the agarwood or gharu trees that is widespread and abundant in the Philippines.

A confident identification did not imply the absence of taxonomic controversy. For example, collection *Chua 057* was readily identified within the species-rich genus *Medinilla* Gaudich. (Melastomataceae) to the species *M. monantha* Merr. It is characterized by a single flower per inflorescence and matches Merrill's (1908) description and the type collection of *Clemens 1136.* However, contrary to Merrill's (1908) segregation, Regalado (1995) combined this with the regionally widespread and morphologically variable species *Medinilla myrtiformis* (Naudin) Triana. The situation in *Piper* L. (Piperaceae) offered a contrary example. Quisumbing (1930) recognized 92 species of *Piper* in the Philippines; almost all were national endemics and many from single locations. Photographs were inadequate to identify species according to his treatment because it required careful microscopic study of the flowers. However, Gardner (2006) reduced these 92 species to 20, of which only one is endemic. Gardner's treatment allowed most of our photographic sets to be identified within his broad regional species.

Failure to identify specimens from photographs was due to inadequate photographs in 20 cases, or 64.5% of the 31 collections not confidently identified to species. We should emphasize that "inadequate photographs" did not imply that they were technically poor with regard to focus or magnification, rather the photograph did not show a key part, for example, the floral details of orchids. Species of the genus *Ardisia* Sw. (Primulaceae) were more easily identified by the dry rather than fresh leaves, while the genus *Lasianthus* Jack (Rubiaceae), despite its recent revision for the Philippines (Zhu et al., 2012), required details of the flower not seen in some of our photographs. We might also emphasize our finding that single photographs were rarely adequate for a sound determination. A combination of photographs taken of the different plant parts at different scales was required. The current poverty of the relevant taxonomy was important in 11 out of 31 cases (35.5%). The photographs appeared to be of sufficient detail to allow a sound identification if more was known about the genus. An example was the genus *Cyrtandra*, which is characterized by a large number of species that are very narrowly distributed; many species remain undescribed. A recent review of *Cyrtandra* in Palawan Island, Philippines (Atkins and Cronk, 2001), found 12 species present of which 10 were island endemics, five species were already described, a further three species and one variety were described as new, and the remaining four taxa were likely new but required better collections. In Mt. Kanlaon, we found five species of *Cyrtandra* in flower or fruit, of which only one could be assigned to a species. For another three species, we were reasonably confident that they are new species and have sent the duplicate specimens to Kew for incorporation in the ongoing regional revision.

DISCUSSION

Had the senior author not gone to Mt. Kanlaon and had received nothing but the photographic sets, our herbarium would

Fig. 2. Photographic set of *Mackinlaya celebica* (Harms) Philipson (Apiaceae), specimens *Chua 016* and *Chua 041*. (A) Fruit. (B) Dissected fruit. (C) Inflorescence. (D) Flower. (E) Upper side of leaf. (F) Lower surface of leaf.

still have reliable documentation for the presence of more than 70 species at a previously unexplored site. We would also have a wealth of new morphological data on phenology, ecology, and floral and fruit color. Even photographs that cannot be identified to species proved valuable. For example, the three species of *Cyrtandra* that were not identified were nonetheless of sufficient quality to allow a confident assertion that they are likely new species. This occurrence is not unusual. During a recent national review of the genus *Dillenia* L. (Dilleniaceae), we noted on the Internet a set of high-quality photographs of a species with yellow flowers from a poorly collected part of Luzon and readily determined this to be a species that could not be accommodated in the last regional revision of the genus (Hoogland, 1952). The exact location is known and efforts are now underway to make a formal collection and so provide the species with a name.

The obvious question many might ask is "Why take a set of photographs and not make a voucher collection?" There are several instances where conventional specimens cannot or should not be made. First of all, under Philippine law, specifically Republic Act 9147, the collection of plant specimens for any reason by any person requires acquisition of a set of permits and letters of prior informed consent before permission is granted. A second set of permits is required to transport the specimens within the country. This process, which applies to Philippine citizens as well as international visitors, is compulsory and is always followed in the case of well-planned expeditions. Such demands, however, preclude collections by individuals who travel and explore on the spur of the moment; in such circumstances, it is easier to simply take photographs.

Secondly, we must note the case of rare and endangered species such as *Lilium philippinense* Baker (Liliaceae), which is overexploited by ornamental plant enthusiasts and for which new collections are unwarranted. Photographs of this completely unmistakable lily would add to the extensive geographic survey of the remaining populations by Balangcod et al. (2011). A related case would be the ecologically critical task of documenting the distribution of noxious weeds. It is financially impractical for a poorly funded tropical herbarium to fill its shelves with weeds such as *Eichhornia crassipes* (Mart.) Solms (Pontederiaceae). A single photograph with date, location, and observer would be adequate to build a national record of distribution. In the United States, such a digital program is already underway in the Early Detection & Distribution Mapping System at the Center for Invasive Species and Ecosystem Health at the University of Georgia (Rawlins et al., 2011).

A comparison of the merits and deficiencies of specimens vs. photographic sets is most easily compiled as a simple table (Box 1). A few points bear further comment. The first and perhaps most obvious question lies in the relative cost efficiency of photographs vs. collections. A formal comparison is not easily made. Modern cameras make good photography astonishingly easy, and yet the time needed to take an entire set of high-quality photographs will depend on the experience of the photographer, the number of macro photographs required, and also conditions such as rain or darkness. In some circumstances, to simply collect a specimen is faster. On the other hand, collections in duplicates of 10 or more also requires drying, printing labels, sorting, and distributing, which can be time consuming. Despite our inability to quantify costs and benefits, one aspect of relative efficiency merits a note. Almost all of the present specimens in the Philippine herbaria were made by people employed for that task, either as professional collectors or as scientists

Photographs	Herbarium specimens
Disadvantages	**Advantages**
Not subject to novel or more detailed scrutiny.	Subject to reinvestigation with novel microscopic and chemical methods, even molecular-based identification.
Scale must be included; even with a scale, distortion of size and shape is possible.	Scale is always clear.
Cannot be a type of a new species.	The required basis for describing new species.
Living plants are often not amenable to existing keys and descriptions—linking fresh and dried characters requires vouchering specimens.	Most descriptions and keys in the tropics are based on dried specimens; many characters critical for initial identification are evident only on drying (e.g., dry leaf color).
Advantages	**Disadvantages**
All parts of the plant can be recorded—habit, bark, wood, twigs, nodes, reproductive parts.	Typical specimens include only a fragment of the living plant.
Long-lasting, can be duplicated without limit.	Unique, subject to decay or destruction.
Preserves color and complex shape.	Shape and color are greatly modified or lost upon drying.
Storage and curation is of modest cost.	Storage and curation are costly in space and time.
Immediately available.	Months, sometimes years or decades before the international community can evaluate the specimen.
Available to everyone with Internet access. Even if Internet access is not available, CD-ROMs or flash drives make collections accessible.	Restricted to individuals with access to herbaria.
In general, permits are not required for photographs.	In many countries, permits are required to make specimens.
A photographer living nearby has repeated opportunities to make a photographic record.	The episodic and infrequent flowering of tropical plants means that conventional expeditions can only gather a small portion of the local flora.
More than ever before, good photographs can be taken by anyone with a camera and minimal training.	Good-quality specimens are usually prepared only by a professional botanist or plant collector.

Box 1. Comparison of the merits and deficiencies of photographs and traditional plant specimens.

who collected as a part of their work. Photographs could be contributed by hundreds of volunteers at their own expense.

A second point of comparison of photographs and specimens is the sometimes-unappreciated fact that much of the taxonomic literature of the past two centuries is largely based on the herbarium study of dried specimens rather than upon the living plants. Even such a renowned field botanist as E. D. Merrill would sometimes compose a monograph, such as his study of *Microtropis* Wall. ex Meisn. (Celastraceae), and confess that he had never encountered a living plant of that genus (Merrill and Freeman, 1940). Consequently, many of the characters employed in plant recognition and identification are restricted to dried material. Leaf color and texture are especially notable in this regard. In a contrasting way, Basset et al. (2000) and Thomas et al. (2007) found that in working with field informants in ethnobotany, color photographs were much more likely to be identified than were dried specimens.

A third point of comparison is the wealth of morphological detail that is evident in photographs and lost in dried specimens. Photographs can record three-dimensional branching patterns of an inflorescence, the shape and color of fragile floral parts, and the presence and color of exudate. This is perhaps generally true for plants but is an especially common problem in monocotyledons of the tropics, most notably the Zingiberales, Araceae, Orchidaceae, and Arecaceae.

A fourth important point of contrast between photographs and specimens lies in the rapidity with which new findings can be distributed to the scientific community. It is not uncommon for years or even decades to pass before a herbarium specimen is distributed and studied by an expert. Of the four classic 19th-century collections from the Philippines, only those of Hugh Cumings have had a significant impact on our knowledge of local plants. The collections of the Malaspina Expedition include the specimens of Thaddäus Haenke, which are chiefly in Prague and have had a mostly European distribution and only a modest study by Presl (1830), while the estimated 10,000 collections of Luis Née are presumably still in Madrid and have had almost no distribution or study. Sebastian Vidal's 14,000 collections from the 1880s are in Madrid (Calabrese and Velayos, 2009), and many are still being studied with important effect. A recent review of Vidal's collections of Fabaceae found that these century-old specimens included five species not previously documented for the country (de la Estrella et al., 2007).

Finally, we should emphasize that the inclusion of a broad base of plant photographers has a social consequence far beyond the scientific value of their documentation. The Philippine herbaria were built by professional botanists, with little or no role played by the general public. If photographs were treated as specimens then a larger sector of the population could contribute to the national program of inventory and enumeration and thereby promote a greater appreciation of plant diversity. A recent example of this social movement is found in Co's Digital Flora of the Philippines (http://www.philippineplants.org/), where more than 5000 members share photographs on a daily basis (Barcelona et al., 2013). The best of these photographs are stored and displayed at the website PhytoImages hosted at Southern Illinois University (http://www.phytoimages.siu.edu/).

This study does not suggest that professional botanists no longer make specimens. To make specimens and to study them in a herbarium is still the only road to a deep appreciation of plant diversity. Furthermore, new species require a specimen as the type, and new observations often require microscopic study of specimens or careful quantitative measurements. We might emphasize again that individual snapshots taken in tropical forests are almost always inadequate for sound documentation. What can be taken away from this study is that sets of good-quality photographs by amateur botanists yield significant social and scientific value and that they merit conservation by tropical herbaria.

LITERATURE CITED

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* 161: 105–121.

Ariño, A. H., and D. Galicia. 2005. Taxonomic-grade images. *In* C. L. Häuser, A. Steiner, J. Holstine, and M. J. Scoble [eds.], Digital imaging of biological type specimens: A manual of best practice, 41–55. European Network for Biodiversity Information, Stuttgart, Germany.

Atkins, H., and Q. C. B. Cronk. 2001. The genus *Cyrtandra* (Gesneriaceae) in Palawan, Philippines. *Edinburgh Journal of Botany* 58: 443–458.

Balangcod, T. D., V. C. Cuevas, I. E. Buot, and A. K. Balangcod. 2011. Geographic distribution of *Lilium philippinense* Baker (Liliaceae) in the Cordillera Central Range, Luzon Island, Philippines. *Taiwania* 56: 186–194.

Barcelona, J. F., D. L. Nickrent, J. V. LaFrankie, J. C. Callado, and P. B. Pelser. 2013. Co's Digital Flora of the Philippines: Plant identification and conservation through cybertaxonomy. *Philippine Journal of Science* 142: 57–67.

Baskauf, S. J., and B. K. Kirchoff. 2008. Digital plant images as specimens: Toward standards for photographing living plants. *Vulpia* 7: 16–30.

Basset, Y., V. Novotny, S. E. Miller, and R. Pyle. 2000. Quantifying biodiversity: Experience with parataxonomists and digital photography in Papua New Guinea and Guyana. *Bioscience* 50: 899–908.

Calabrese, G. M., and M. Velayos. 2009. Type specimens in the Vidal Herbarium at the Real Jardín Botánico, Madrid. *Botanical Journal of the Linnean Society* 159: 292–299.

Daston, L. 2004. Type specimens and scientific memory. *Critical Inquiry* 31: 153–182.

de la Estrella, M., G. M. Calabrese, B. Camara, and M. Velayos. 2007. Leguminosae of Philippines in the Vidal herbarium at Real Jardín Botánico, Madrid. *Nordic Journal of Botany* 25: 41–52.

Dewolf, G. P. 1968. Notes on making a herbarium. *Arnoldia* 28: 8–9.

Egerton, F. N. 2003. A history of the ecological sciences, part 10: Botany during the Italian Renaissance and beginnings of the scientific revolution. *Bulletin of the Ecological Society of America* 84: 130–137.

Frank, M. S., and K. D. Perkins. 2004. Herbaria and herbarium specimens. University of Florida Herbarium. Website http://www.flmnh.ufl.edu/herbarium/herbariaandspecimens.htm [accessed 19 February 2013].

Gardner, R. O. 2006. *Piper* (Piperaceae) in the Philippine Islands: The climbing species. *Blumea* 51: 569–586.

Gernshiem, H. 1986. A concise history of photography, 3rd ed. Dover Publications, Mineola, New York, USA.

Grimé, W. E., and T. Plowman. 1986. Type photographs at Field Museum of Natural History. *Taxon* 35: 932–934.

Häuser, C. L., A. Steiner, J. Holstein, and M. J. Scoble. 2005. Digital imaging of biological type specimens. A manual of best practice. European Network for Biodiversity Information, Stuttgart, Germany.

Hitchcock, A. S. 1905. Nomenclatorial type specimens of plant species. *Science* 21: 828–832.

Hoogland, R. D. 1952. A revision of the genus *Dillenia. Blumea* 7: 1–145.

Merrill, E. D. 1908. New Philippine plants from the collections of Mary Strong Clemens, I. *Philippine Journal of Science* 3: 129–165.

Merrill, E. D., and F. L. Freeman. 1940. The old world species of the Celastraceous genus *Microtropis* Wallich. *Proceedings of the American Academy of Arts and Sciences* 73: 271–307, 309–310.

New York Botanical Garden. 2013. The C.V. Starr virtual herbarium picks up momentum: Digitization at The New York Botanical Garden. Website http://www.nybg.org/science/new_20120926.php [accessed 27 February 2015].

Parr, M., and G. Badger. 2004. The photobook: A history, Vol. 1. Phaidon, London, United Kingdom.

Philipson, W. R. 1979. Flora Malesiana: series 1. Spermatophyta. Flowering plants: vol. 9, part 1. Revisions. Araliaceae 1: 1–105. Foundation Flora Malesiana, Leiden, The Netherlands.

Presl, C. B. 1830. Reliquiae Haenkeanae. J. G. Calve, Prague.

Quisumbing, E. 1930. Philippine Piperaceae. *Philippine Journal of Science* 43: 1–246.

Rawlins, K. A., J. E. Griffin, D. J. Moorhead, C. T. Bargeron, and C. W. Evans. 2011. EDDMapS: Invasive plant mapping handbook. Center for Invasive Species and Ecosystem Health, University of Georgia, Tifton, Georgia, USA.

Regalado, J. C. 1995. Revision of Philippine *Medinilla* (Melastomataceae). *Blumea* 40: 113–193.

Simpson, N., and P. G. Barnes. 2008. Photography and contemporary botanical illustration. *Curtis's Botanical Magazine* 25: 258–280.

Swingle, W. T. 1913. Types of species in botanical taxonomy. *Science* 37: 864–865.

Swingle, W. T., and M. K. Swingle. 1916. The utilization of photographic methods in library research work, with special reference to the natural sciences. *Bulletin of the American Library Association* 10: 194–199.

Thiers, B. M. 1998 onward (continuously updated). Index Herbariorum. New York Botanical Garden. Website http://sweetgum.nybg.org/ih/ [accessed 3 July 2012].

Thomas, E., I. Vandebroek, and P. van Damme. 2007. What works in the field? A comparison of different interviewing methods in ethnobotany with special reference to the use of photographs. *Economic Botany* 61: 376–384.

Vollmar, A., J. A. Macklin, and L. Ford. 2010. Natural history specimen digitization: Challenges and concerns. *Biodiversity Informatics* 7: 93–112.

Wilson, E. H. 2011. Magnificent trees: 100 of Ernest Henry Wilson's finest images of trees. Website http://arboretum.harvard.edu/library/image-collection/botanical-and-cultural-images-of-eastern-asia/magnificent-trees/ [accessed 23 February 2015].

Zhu, H., M. C. Roos, and C. E. Ridsdale. 2012. A taxonomic revision of the Malesian species of *Lasianthus* (Rubiaceae). *Blumea* 57: 1–102.

Appendix 1. List of collections from Mt. Kanlaon; the identifications were from examination of the photographic sets and were only confirmed and not altered with subsequent study of the dry specimens.

Collection	Identification[a]	Family[b]	ID quality[c]	Reason for failure[d]
Chua 001	*Ophiorrhiza oblongifolia* DC.	Rubiaceae	1	
Chua 002	*Saurauia negrosensis* Elmer	Actinidiaceae	1	
Chua 003	*Saurauia trichophora* Quisumb.	Actinidiaceae	1	
Chua 004	*Curculigo capitulata* (Lour.) Kuntze	Hypoxidaceae	1	
Chua 005	*Spathoglottis plicata* Blume	Orchidaceae	1	
Chua 007	*Calliandra calothyrsus* Meisn.	Fabaceae	1	
Chua 008	*Litsea quercoides* Elmer	Lauraceae	1	
Chua 009	*Sambucus javanica* Reinw. ex Blume	Adoxaceae	1	
Chua 010	*Medinilla involucrata* Merr.	Melastomataceae	1	
Chua 011	*Elatostema whitfordii* Merr.	Urticaceae	1	
Chua 012	*Elatostema spinulosum* Elmer	Urticaceae	1	
Chua 015	*Syzygium panayense* (Merr.) Merr.	Myrtaceae	1	
Chua 016	*Mackinlaya celebica* (Harms) Philipson	Apiaceae	1	
Chua 017	*Aglaia elliptica* Blume	Meliaceae	1	
Chua 021	*Piper decumanum* L.	Piperaceae	1	
Chua 022	*Piper abbreviatum* Opiz	Piperaceae	1	
Chua 023	*Glochidion merrillii* C. B. Rob.	Phyllanthaceae	1	
Chua 024	*Arisaema polyphyllum* (Blanco) Merr.	Araceae	1	
Chua 026	*Mycetia javanica* (Blume) Korth.	Rubiaceae	1	
Chua 027	*Mackinlaya celebica* (Harms) Philipson	Apiaceae	1	
Chua 028	*Aquilaria cumingiana* (Decne.) Ridl.	Thymelaeceae	1	
Chua 029	*Clerodendrum minahassae* Teijsm. & Binn.	Lamiaceae	1	
Chua 030	*Alpinia haenkei* C. Presl	Zingiberaceae	1	
Chua 034	*Solanum lasiocarpum* Dunal	Solanaceae	1	
Chua 037	*Codiaeum luzonicum* Merr.	Euphorbiaceae	1	
Chua 038	*Alyxia sibuyanensis* Elmer	Apocynaceae	1	
Chua 040	*Goodyera rubicunda* (Blume) Lindl.	Orchidaceae	1	
Chua 041	*Mackinlaya celebica* (Harms) Philipson	Apiaceae	1	
Chua 043	*Ophiorrhiza oblongifolia* DC.	Rubiaceae	1	
Chua 044	*Lycianthes banahaensis* (Elmer) Bitter	Solanaceae	1	
Chua 047	*Elatostema whitfordii* Merr.	Urticaceae	1	
Chua 050	*Pipturus arborescens* (Link) C. B. Rob.	Urticaceae	1	
Chua 051	*Pipturus arborescens* (Link) C. B. Rob.	Urticaceae	1	
Chua 052	*Desmodium gangeticum* (L.) DC.	Fabaceae	1	
Chua 053	*Dichroa philippinensis* Schltr.	Hydrangeaceae	1	
Chua 056	*Villebrunea trinervis* Wedd.	Urticaceae	1	
Chua 057	*Medinilla monantha* Merr.	Melastomataceae	1	
Chua 058	*Crassocephalum crepidioides* (Benth.) S. Moore	Asteraceae	1	
Chua 059	*Ficus cuneiformis* C. C. Berg	Moraceae	1	
Chua 060	*Macaranga tanarius* (L.) Müll. Arg.	Euphorbiaceae	1	
Chua 062	*Pollia thyrsiflora* (Blume) Steud.	Commelinaceae	1	
Chua 063	*Garcinia venulosa* (Blanco) Choisy	Clusiaceae	1	
Chua 064	*Garcinia venulosa* (Blanco) Choisy	Clusiaceae	1	
Chua 065	*Piper abbreviatum* Opiz	Piperaceae	1	
Chua 066	*Piper abbreviatum* Opiz	Piperaceae	1	
Chua 067	*Schefflera insularum* (Seem.) Harms	Araliaceae	1	
Chua 068	*Piper caninum* Blume	Piperaceae	1	
Chua 069	*Clethra canescens* Reinw. ex Blume	Clethraceae	1	
Chua 071	*Costus speciosus* (J. Koenig) Sm.	Costaceae	1	
Chua 074	*Mycetia javanica* (Blume) Korth.	Rubiaceae	1	
Chua 075	*Sarcandra glabra* (Thunb.) Nakai	Chloranthaceae	1	
Chua 076	*Magnolia liliifera* (L.) Baill.	Magnoliaceae	1	
Chua 077	*Tetracera fagifolia* Blume	Dilleniaceae	1	
Chua 078	*Omalanthus populneus* (Geisel.) Pax	Euphorbiaceae	1	
Chua 080	*Chloranthus elatior* Link	Chloranthaceae	1	
Chua 081	*Tabernaemontana pandacaqui* Poir.	Apocynaceae	1	
Chua 082	*Lasianthus attenuatus* Jack	Rubiaceae	1	
Chua 083	*Aglaia luzoniensis* (S. Vidal) Merr. & Rolfe	Meliaceae	1	
Chua 084	*Alocasia heterophylla* (C. Presl) Merr.	Araceae	1	
Chua 085	*Aglaonema densinervium* Engl.	Araceae	1	
Chua 086	*Schismatoglottis plurivenia* Alderw.	Araceae	1	
Chua 087	*Aglaonema densinervium* Engl.	Araceae	1	
Chua 089	*Magnolia liliifera* (L.) Baill.	Magnoliaceae	1	
Chua 090	*Dillenia reifferscheidia* Fern.-Vill.	Dilleniaceae	1	
Chua 091	*Schefflera insularum* (Seem.) Harms	Araliaceae	1	
Chua 092	*Elatostema spinulosum* Elmer	Urticaceae	1	
Chua 093	*Gomphostemma javanicum* (Blume) Benth.	Lamiaceae	1	
Chua 094	*Cinnamomum mercadoi* S. Vidal	Lauraceae	1	

Appendix 1. Continued.

Collection	Identification[a]	Family[b]	ID quality[c]	Reason for failure[d]
Chua 096	*Coffea arabica* L.	Rubiaceae	1	
Chua 097	*Magnolia philippinensis* P. Parm.	Magnoliaceae	1	
Chua 098	*Medinilla involucrata* Merr.	Melastomataceae	1	
Chua 100	*Leucosyke capitellata* (Poir.) Wedd.	Urticaceae	1	
Chua 102	*Calanthe mcgregorii* Ames	Orchidaceae	1	
Chua 104	*Saurauia negrosensis* Elmer	Actinidiaceae	1	
Chua 105	*Ficus bataanensis* Merr.	Moraceae	1	
Chua 106	*Ficus cuneiformis* C. C. Berg	Moraceae	1	
Chua 107	*Acer laurinum* Hassk.	Sapindaceae	1	
Chua 108	*Acer laurinum* Hassk.	Sapindaceae	1	
Chua 110	*Ficus ruficaulis* Merr.	Moraceae	1	
Chua 111	*Litsea luzonica* (Blanco) Fern.-Vill.	Lauraceae	1	
Chua 112	*Wikstroemia ovata* C. A. Mey.	Thymelaeceae	1	
Chua 113	*Costus speciosus* (J. Koenig) Sm.	Costaceae	1	
Chua 014	*Ficus scaberrima* Blume	Moraceae	2	1
Chua 035	*Euphlebium bicolense* (Lubag-Arquiza) M. A. Clem. & Cootes	Orchidaceae	2	1
Chua 036	*Calanthe* sp. nov.	Orchidaceae	2	1
Chua 046	*Maesa denticulata* Mez	Primulaceae	2	1
Chua 101	*Ficus carpenteriana* Elmer	Moraceae	2	1
Chua 032	*Cyrtandra pallida* Elmer	Gesneriaceae	2	1
Chua 033	*Medinilla* cf. *merrittii* Merr.	Melastomataceae	2	1
Chua 048	*Rhaphidophora* aff. *philippinensis* Engl. & K. Krause	Araceae	2	1
Chua 073	*Pavetta indica* L.	Rubiaceae	2	1
Chua 099	*Medinilla* sp. nov. aff. *amplifolia* Merr.	Melastomataceae	2	2
Chua 020	*Ardisia* sp.	Primulaceae	3	1
Chua 049	*Dendrochilum* sp.	Orchidaceae	3	1
Chua 055	Fabaceae	Fabaceae	3	1
Chua 088	Acanthaceae	Acanthaceae	3	1
Chua 095	*Ficus* sp.	Moraceae	3	1
Chua 018	*Lasianthus* sp.	Rubiaceae	3	1
Chua 019	*Ixora* sp.	Rubiaceae	3	1
Chua 039	*Lasianthus* sp.	Rubiaceae	3	1
Chua 042	*Piper* sp.	Piperaceae	3	1
Chua 045	*Lasianthes* sp.	Rubiaceae	3	1
Chua 070	*Piper* sp.	Piperaceae	3	1
Chua 103	*Calanthe* sp.	Orchidaceae	3	1
Chua 006	*Cyrtandra* sp. 1	Gesneriaceae	3	2
Chua 013	*Pandanus* sp.	Pandanaceae	3	2
Chua 025	*Pandanus* sp.	Pandanaceae	3	2
Chua 031	*Zingiber* sp.	Zingiberaceae	3	2
Chua 054	*Cyrtandra* sp. 2	Gesneriaceae	3	2
Chua 061	*Alpinia* sp.	Zingiberaceae	3	2
Chua 072	*Alpinia* sp.	Zingiberaceae	3	2
Chua 079	*Cyrtandra* sp. 3	Gesneriaceae	3	2
Chua 109	*Cyrtandra* sp. 4	Gesneriaceae	3	2

[a] Species name and authorship follows IPNI.
[b] Family follows APG III (2009).
[c] 1 = identified to species with high confidence; 2 = identified to species with low confidence; 3 = identified only to genus or family.
[d] 1 = photographic details inadequate for identification; 2 = taxonomy of the genus too poorly understood.