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BELIZE AND THE RBGE: REFLECTING ON 16 YEARS OF COLLABORATIVE TRAINING

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Between 2001 and 2017, the Royal Botanic Garden Edinburgh conducted training and research in Belize built around an annual two-week field course, part of the Edinburgh M.Sc. programme in *Biodiversity and Taxonomy of Plants*, focused on tropical plant identification, botanical-collecting and tropical fieldwork skills. This long-term collaboration in one country has led to additional benefits, most notably capacity building, acquisition of new country records, completion of M.Sc. thesis projects and publication of the findings in journal articles, and continued cooperation. Detailed summaries are provided for the specimens collected by students during the field course or return visits to Belize for M.Sc. thesis projects. Additionally, 15 species not recorded in the national checklist for Belize are reported. The information in this paper highlights the benefits of collaborations between institutions and countries for periods greater than the typical funding cycles of three to five years.

Keywords. Capacity building, collections, field course, herbarium specimens, identification, new country records, tropical field botany.

Introduction

Scientists from the Royal Botanic Garden Edinburgh (RBGE) teach a two-week field course in tropical field botany as part of the Edinburgh M.Sc. programme in *Biodiversity and Taxonomy of Plants*. For 16 years this course was held in Belize, in Central America. This paper summarises the outcomes and discusses the secondary benefits of the RBGE's long-term training and research programme in Belize, with a focus on capacity building, botanical collecting and publications, thus providing stimulus for further development of the field course and similar courses in other locations. It also provides detailed summaries of the specimens collected by students during the field course or return visits to Belize for M.Sc. thesis projects.

Belize

Belize is a small (22,965 km^2), mainly English-speaking country in Central America, notable for its well-preserved biodiversity, with c.36% of its terrestrial area under some form of protection (Fig. 1). Belize is in the southern part of the Yucatán Peninsula, with the

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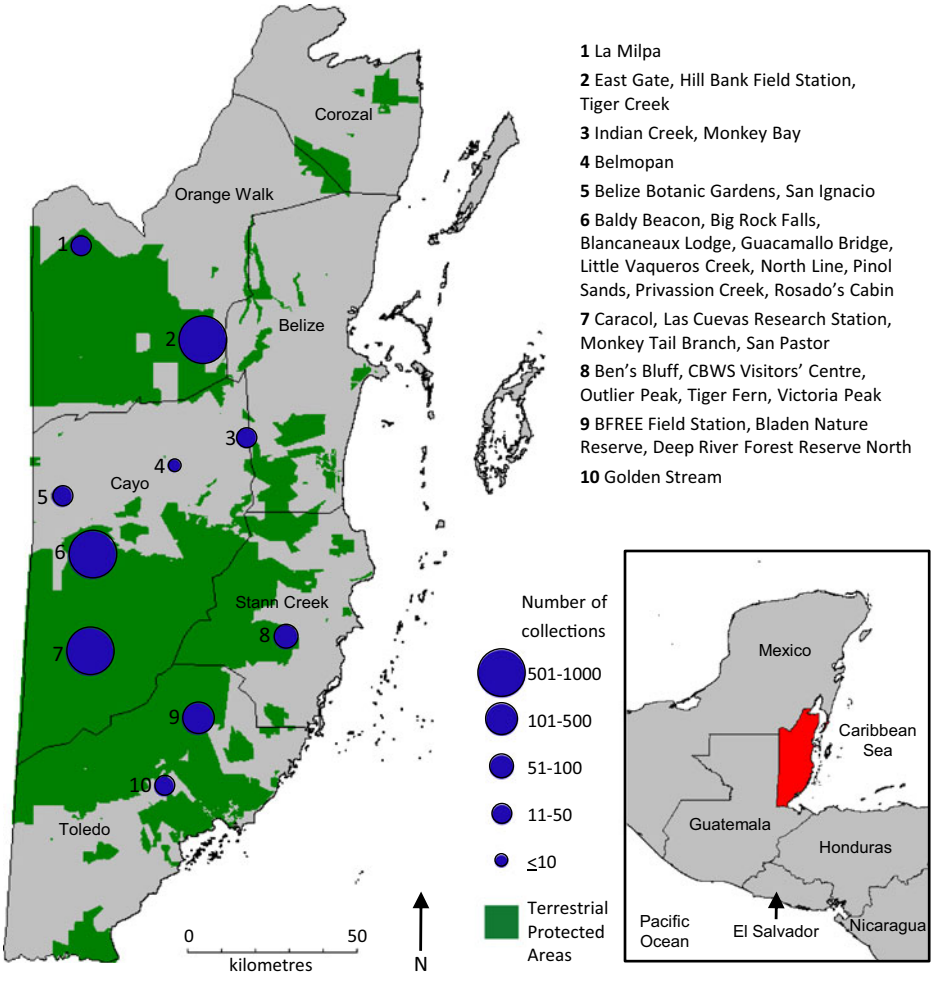

FIG. 1. Map of Belize. Areas 1–10 represent individual collecting localities or clusters of collecting localities (31 in total) visited by students on the Royal Botanic Garden Edinburgh's *Biodiversity and Taxonomy of Plants* field course. The different sizes of circle indicate the approximate number of herbarium specimens collected during the field course or return visits to Belize for M.Sc. thesis projects (see Table 2). Inset, location of Belize within Central America. BFREE, Belize Foundation for Research and Environmental Education; CBWS, Cockscomb Basin Wildlife Sanctuary.

Mexican state of Quintana Roo to the north, the Guatemalan department of Petén to the south and west, and the Caribbean Sea to the east (see Fig. 1 inset). Its climate is subtropical, with a marked dry season between February and May and a hurricane season between June and November. There is a significant precipitation gradient between the north (c.1200 mm/year) and the south (c.4300 mm/year), with maximum rainfall occurring around Doyle's Delight in Toledo District.

Belize is part of the Mesoamerican biodiversity hotspot (Myers *et al.*, 2000), an area occupying less than 0.5% of the terrestrial surface of the planet but thought to contain more than 16,000 vascular plant species, of which 5624 (34%) are endemic to the region (Ulloa Ulloa *et al.*, 2017). Despite this richness, botanical capacity in Belize is hindered by the lack of a comprehensive identification guide. There is no national flora for Belize, and the national checklist of vascular plants (Balick *et al.*, 2000) now needs updating, particularly given the acceleration of botanical collecting and research efforts in the country (Goodwin *et al.*, 2015). Belize is covered by several regional floras that are either out of date, such as the *Flora of Guatemala* (Standley *et al.*, 1946–1977), or yet to be completed, such as the *Flora Mesoamericana* (Davidse *et al.*, 1994–) and *Flora Neotropica* (Zanoni, 1967–).

The RBGE's M.Sc. in *Biodiversity and Taxonomy of Plants* field course

Organised jointly by the RBGE and the University of Edinburgh, the Edinburgh M.Sc. in *Biodiversity and Taxonomy of Plants* is a one-year postgraduate programme with an emphasis on collection-based plant diversity research. It is delivered via two terms of full-time teaching followed by completion of a four-month research project. One module in the taught part of the programme is a two-week field course. This was held in Belize between 2001 and 2017, before being moved to Colombia in 2018.

The primary aim of the field course is to teach students the basics of tropical plant identification to family level, using sterile characters in the field following Gentry's *A Field Guide to the Families and Genera of Woody Plants of Northwest South America* (Gentry, 1993) (Fig. 2A,B,I). To complement this learning, students also gain training and experience in best-practice herbarium specimen collecting; acquire an understanding of the ecology and flora of tropical ecosystems; and are introduced to methods for conducting qualitative and quantitative ecological surveys, to show how their new-found identification skills would be used in a practical context (see Fig. 2C–H,J,K). The teaching methods and principles used on this field course are discussed in detail in Harris *et al.* (2015) and have been used successfully in courses across tropical Africa and Asia (Iwamoto & Ronse De Craene, 2014; Harris *et al.*, 2015).

Capacity Building

The two-week field course is a discrete module in the M.Sc. programme. It is held at two primary study sites with contrasting vegetation types and is attended by about 15–25 students. This arrangement allows students from other institutions, conservation and research professionals, and members of the public to join the course for training.

In 2006, the field course started to attract interest from researchers and organisations within Belize. In response, in 2010, non-M.Sc. student participation in the field course was formalised in two ways: first, by the development of the *Certificate in Tropical Field Botany*, awarded by the RBGE to all students who complete the field course; and second, by the creation of scholarship places on the field course for two Belizean students each year. These scholarships were funded by the Darwin Initiative initially (Stuart *et al.*, 2012)

FIG. 2. The primary learning objectives for students on the Royal Botanic Garden Edinburgh's *Biodiversity and Taxonomy of Plants* field course are to understand how to examine plants systematically (A) and to be able to use sterile characters to identify tropical plants to family level (B). During morning sessions in the field, students work in groups to also learn basic vegetation survey techniques, such as the use of quadrats (C) and plots (D), and additional skills such as how to measure tree heights (E) and sample trees (F). To ensure the collection of high-quality herbarium specimens, students learn how to collect and press plants in the field (G) and prepare the specimens for drying in the evenings (H). During afternoon sessions, students use Gentry's *A Field Guide to the Families and Genera of Woody Plants of Northwest South America* (Gentry, 1993) and other relevant taxonomic accounts and field guides to identify plant material collected during the morning (I). The students then record their findings and the related specimen data in notebooks (J) before entering the latter into a database via laptop computer (K).

and were funded by the RBGE between 2012 and 2018. Candidates for the scholarship were selected by colleagues at the Environmental Research Institute of the University of Belize. Belizean participants were primarily university students and early-career professionals from a conservation, biology or horticulture background.

Non-M.Sc. postgraduate students have been a regular presence on the field course, with Ph.D. students and postdoctoral students attending either informally (2008, 2009 and 2012) or joining the field course as part of the Natural Environment Research Council (NERC) *Advanced Training Short Courses* programme (2015 and 2017).

Over the 16 years in Belize, the field course of the M.Sc. programme in *Biodiversity and Taxonomy of Plants* has provided training for 244 M.Sc. students, 26 Belizeans, 25

postgraduate researchers, and nine students from other backgrounds. Three of the M.Sc. students have returned to Belize to teach on the field course.

The combination of different types of students on a single field course benefited all participants. The M.Sc. students brought their botanical training; the Belizean students, their field experience and their knowledge of local ecology and conservation challenges; and the non-M.Sc. postgraduate students, their varied practical experiences and theoretical backgrounds.

The M.Sc. programme in *Biodiversity and Taxonomy of Plants* has become an important source of botanists and other scientists. Of the 209 students who graduated from the programme between 2003 and 2017, 69 (33%) went on to study towards a Ph.D. and 46 (22%) progressed to a career in botany. This is significant because a shortage of trained taxonomists (Boero, 2001; Paton *et al.*, 2008), particularly due to lack of available training (de Carvalho *et al.*, 2007, 2008), is thought to be a major contributor to the 'taxonomic impediment' (de Carvalho *et al.*, 2005, 2007; Secretariat of the Convention on Biological Diversity, 2010) preventing humanity from fully addressing the global biodiversity crisis.

The field course has had a lasting positive impact on the development of botanical capacity within Belize. Belizean graduates of the field course have progressed to further education abroad or a range of careers in ecological research, conservation, forestry, ecotourism, horticulture and education, working for non-governmental organisations and local government within the country. Thus, Belizean graduates may go on to use these skills directly in their future career or be able to influence national policy through their increased understanding of plant identification and the importance of herbarium specimens. For example, German Lopez, who was recruited and trained as part of the *Conservation of the Lowland Savanna Ecosystem in Belize* Darwin Initiative project (project no. 17-022), began his botanical training as a student on the field course in 2010 (Stuart *et al.*, 2012). In the following years, he returned as a course instructor and assisted in teaching undergraduate botanical courses at the University of Belize (Kay, 2012).

Collections

The collection of high-quality herbarium specimens by students attending the field course is extremely rewarding for them and, we believe, scientifically valuable. During the course, each student must collect at least five herbarium specimens. Between three and seven duplicates of each collection are made, including one to be held within the host country (in the case of Belize, for example, at the National Herbarium in Belmopan, BRH). Further duplicates are distributed to the herbaria of the Royal Botanic Garden Edinburgh (E), the Natural History Museum in London (BM), the Royal Botanic Gardens Kew (K), Universidad Nacional Autónoma de México in Mexico City (MEXU) and Missouri Botanical Garden in St Louis (MO). Additionally, one duplicate is sent to plant group specialists if these exist for the group in question.

During the field course, students usually collect a total of 50–200 specimens per year (Table 1). As a result, students have collected more than 1700 specimens of more than 600 different identified species from the 24 Belizean collecting localities visited during the

TABLE 1. Summary of herbarium specimens collected from Belizean localities ($n = 24$) by students on the Edinburgh M.Sc. programme in *Biodiversity and Taxonomy of Plants* field course, ordered by date of visit

Month and year	Approximate no. of collections[a]	Collecting locality or localities
March 2001	110	Hill Bank Field Station, Las Cuevas Research Station, Monkey Tail Branch
April 2002	290	Caracol, Guacamallo Bridge, Hill Bank Field Station, Las Cuevas Research Station, Monkey Tail Branch
April 2003	220	Caracol, East Gate, Guacamallo Bridge, Hill Bank Field Station, Las Cuevas Research Station, Monkey Tail Branch
February 2004	140	East Gate, Guacamallo Bridge, Hill Bank Field Station, Las Cuevas Research Station, Tiger Creek
March 2005	50	Hill Bank Field Station, Indian Creek, Las Cuevas Research Station
April 2006	100	Hill Bank Field Station, Las Cuevas Research Station, Monkey Tail Branch, San Pastor
January 2007	100	Ben's Bluff, Cockscomb Basin Wildlife Sanctuary Visitors' Centre, Hill Bank Field Station, Outlier Peak, Tiger Fern
January 2008	130	Belize Botanic Garden, Big Rock Falls, Las Cuevas Research Station, Privassion Creek
January 2009	80	Las Cuevas Research Station, Rosado's Cabin
January 2010	100	Hill Bank Field Station
January 2011	60	Hill Bank Field Station
January 2012	40	Hill Bank Field Station, Monkey Bay
January 2013	90	Baldy Beacon, La Milpa, Little Vaqueros Creek
January 2014	40	Blancaneaux Lodge, La Milpa, Rosado's Cabin
January 2015	< 5	Belize Botanic Garden, Hill Bank Field Station
January 2016	< 5	Las Cuevas Research Station
January 2017	210	Belize Foundation for Research and Environmental Education Field Station, Bladen Nature Reserve, Hill Bank Field Station
	Total: ≥ 1760	

[a] To the nearest 10, except for January 2015 and January 2016.

course. An estimated 840 additional specimens (not including the Trevaskis collections; see Table 4), representing about 400 species, have been collected by students during return visits to Belize for M.Sc. thesis projects, bringing the number of species represented by the collections to more than 850. This number represents at least a quarter (24.9%) of the known flora of Belize (Balick *et al.*, 2000).

The total number of species represented is undoubtedly higher, because approximately 660 specimens of the c.2540 collected during the course or return visits for M.Sc. thesis projects (26%) remain determined only to genus or family. This number may appear high, but it reflects the observation in other groups that large proportions of herbarium specimen remain indeterminate in the absence of examination by a specialist (Goodwin *et al.*, 2015).

A specimen may be unavailable for identification during the time it takes for it to be processed and progress from a field collection to a mounted herbarium specimen. In our experience at the RBGE this takes about ten years, therefore most specimens collected in 2014 or later are still awaiting mounting. Very often, only duplicates of these specimens at certain herbaria are being examined and identified by experts after distribution from the RBGE.

Additionally, only recently have significant numbers of images of herbarium specimens from the Neotropics become available online via the Field Museum (continuously updated), JSTOR Global Plants (continuously updated) and Tropicos (Missouri Botanical Garden, continuously updated). This highlights the need to get specimens seen by specialists whether by distribution of duplicates or through digitisation of collections, and for further effort to establish integrated systems that match specimen names between duplicates held at different herbaria.

Students collected herbarium specimens from 24 Belizean localities during the field course and from an additional seven localities during return visits to Belize for M.Sc. thesis projects (Table 2). These collecting localities are in clusters across ten areas, including protected areas, across the country (see Fig. 1).

The number of specimens collected from each locality during the field course has reflected the number of visits to that locality: the most frequently visited localities have yielded the greatest number of collections. Approximately 490 specimens were collected during 12 visits to Hill Bank Field Station in the Rio Bravo Conservation and Management Area, and 320 specimens were collected during nine visits to Las Cuevas Research Station in the Chiquibul National Park (see Table 2 and Fig. 1).

These specimens contribute greatly to our knowledge of the flora of Belize, because they consist of two types of collections. First are the large numbers of collections made during single trips to under-collected locations and reserves, for example Cockscomb Basin Wildlife Sanctuary (2007) and Indian Creek (2005). Second are collections made during repeated visits over many years to a single locality. When revisiting localities, it became increasingly difficult over time to find previously uncollected species (hence the low collection numbers in 2015 and 2016). However, this practice did allow thorough floristic inventories of these locations to be completed. Three reserves have been particularly well collected: the Rio Bravo Conservation and Management Area, with 581 collections from 14 visits; the Chiquibul National Park, with 457 collections from nine visits; and the Mountain Pine Ridge (including Guacamallo Bridge), with 353 collections from seven visits (see Fig. 1).

New Country Records

We currently estimate that specimens of 15 species not recorded in the national checklist (Balick *et al.*, 2000) have been collected by students during the M.Sc. field course or return visits to Belize for M.Sc. thesis projects (Table 3). Many of the specimens that represent new records for Belize were collected from the three reserves visited repeatedly by field course participants: the Chiquibul National Park (nine new records), the Mountain Pine

TABLE 2. Summary of herbarium specimens collected from Belizean localities by students on the Edinburgh M.Sc. programme in *Biodiversity and Taxonomy of Plants* during the field course or return visits to Belize for M.Sc. thesis projects, ordered alphabetically by name of locality

Locality (area no. in Fig. 1)	Reserve and/or district	Latitude, longitude	Altitude (m)	Approximate total no. of collections (plus number of collections made for thesis projects; relevant student name, year)[a]	Year(s) of field course
Baldy Beacon (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°00′00′′N, 88°46′59′′W	1000	50	2013
Belize Botanic Garden (5)	Cayo	17°05′46′′N, 89°04′05′′W	400	10 (+ 5; S. Sylvester, 2009)	2008, 2015
Belize Foundation for Research and Environmental Education Field Station (9)	Belize Foundation for Research and Environmental Education Biological Reserve, Toledo	16°33′10′′N, 88°42′00′′W	50	50	2017
Belmopan (4)	Cayo	17°14′30′′N, 88°45′45′′W	80	0 (+ 2; S. Sylvester, 2009)	Not applicable
Ben's Bluff (8)	Cockscomb Basin Wildlife Sanctuary, Stann Creek	16°46′30′′N, 88°27′10′′W	100	20	2007
Big Rock Falls (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°02′00′′N, 88°58′25′′W	400	30 (+ 5; S. Sylvester, 2009)	2008
Bladen Nature Reserve (9)	Toledo	16°33′23′′N, 88°43′27′′W	100	150 (+ 6; S. Sylvester, 2009)	2017
Blancaneaux Lodge (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°02′00′′N, 88°57′55′′W	400–600	20 (+ 5; S. Sylvester, 2009)	2014
Caracol (7)	Caracol Archaeological Site, Cayo	16°44′00′′N, 88°59′00′′W	600	30	2002, 2003
Cockscomb Basin Wildlife Sanctuary Visitors' Centre (8)	Cockscomb Basin Wildlife Sanctuary, Stann Creek	16°46′51′′N, 88°27′29′′W	60	20 (+ 20; R. Akers, 2007)	2007

TABLE 2. *(Continued)*

Locality (area no. in Fig. 1)	Reserve and/or district	Latitude, longitude	Altitude (m)	Approximate total no. of collections (plus number of collections made for thesis projects; relevant student name, year)[a]	Year(s) of field course
Deep River Forest Reserve North (9)	Toledo	16°32′00″N, 88°42′00″W	40	0 (+ 37; S. Sylvester, 2009)	Not applicable
East Gate (2)	Rio Bravo Conservation and Management Area, Orange Walk	17°31′00″N, 88°42′00″W	20	20	2003, 2004
Golden Stream (10)	Golden Stream Corridor Preserve, Toledo	16°22′00″N, 88°47′30″W	30	0 (+ 16; S. Sylvester, 2009)	Not applicable
Guacamallo Bridge (6)	Border of Mountain Pine Ridge Forest Reserve and Chiquibul National Park, Cayo	16°44′00″N, 88°59′00″W	450	90 (+ 315; L. Urban, 2003)	2002, 2003, 2004
Hill Bank Field Station (2)	Rio Bravo Conservation and Management Area, Orange Walk	17°35′00″N, 88°42′00″W	20	490	2001, 2002, 2003, 2004, 2005, 2006, 2007, 2010, 2011, 2012, 2015, 2017
Indian Creek (3)	Manatee Forest Reserve, Belize	17°12′54″N, 88°33′19″W	25	20	2005
La Milpa (1)	Rio Bravo Conservation and Management Area, Orange Walk	17°45′00″N, 89°09′00″W	160	50	2013, 2014
Las Cuevas Research Station (7)	Chiquibul National Park, Cayo	16°44′35″N, 88°59′18″W	550	320 (+ 320; S. Queenborough, 2001)	2001, 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2016
Little Vaqueros Creek (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°03′30″N, 88°58′05″W	400	< 5	2013
Monkey Bay (3)	Belize	17°19′00″N, 88°33′55″W	50	20	2012

TABLE 2. *(Continued)*

Locality (area no. in Fig. 1)	Reserve and/or district	Latitude, longitude	Altitude (m)	Approximate total no. of collections (plus number of collections made for thesis projects; relevant student name, year)[a]	Year(s) of field course
Monkey Tail Branch (7)	Chiquibul National Park, Cayo	17°00′00′′N, 88°46′59′′W	500	130	2001, 2002, 2003, 2006
North Line (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°10′00′′N, 88°55′00′′W	600	0 (+ 9; S. Sylvester, 2009)	Not applicable
Outlier Peak (8)	Cockscomb Basin Wildlife Sanctuary, Stann Creek	16°46′34′′N, 88°77′19′′W	600	20	2007
Pinol Sands (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°04′37′′N, 88°59′02′′W	400	0 (+ 6; S. Sylvester, 2009)	Not applicable
Privassion Creek (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°02′05′′N, 88°56′50′′W	450	70	2008
Rosado's Cabin (6)	Mountain Pine Ridge Forest Reserve, Cayo	17°01′55′′N, 88°57′30′′W	400	70	2009, 2014
San Ignacio (5)	Cayo	17°09′38′′N, 89°04′10′′W	90	0 (+ 2; S. Sylvester, 2009)	Not applicable
San Pastor (7)	Chiquibul National Park, Cayo	16°41′05′′N, 88°58′00′′W	700	20 (+ 90; J. Hicks, 2007)	2006
Tiger Creek (2)	Rio Bravo Conservation and Management Area, Orange Walk	17°31′00′′N, 88°42′00′′W	20	30	2004
Tiger Fern (8)	Cockscomb Basin Wildlife Sanctuary, Stann Creek	16°46′50′′N, 88°26′29′′W	250	20	2007
Victoria Peak (8)	Cockscomb Basin Wildlife Sanctuary, Stann Creek	16°48′43′′N, 88°37′11′′W	1100	0 (+ 20; R. M. Akers, 2007)	Not applicable

[a] To the nearest 10.

TABLE 3. Species, previously not recorded as present in Belize by Balick *et al.* (2000), for which specimens were collected from Belizean localities by students on the Edinburgh M.Sc. programme in *Biodiversity and Taxonomy of Plants* during the field course or return visits to Belize for M.Sc. thesis projects

Species	Family	Voucher(s) and collection locality
Blechnum appendiculatum Willd.	Blechnaceae	*A.D. Forrest* 43, Monkey Tail Branch, Chiquibul National Park, Cayo
Cuphea aristata Hemsl.	Lythraceae	*J. Tosh* 7, Las Cuevas Research Station, Chiquibul National Park, Cayo
Gelsemium sempervirens (L.) J.St.-Hil.	Gelsemiaceae	*R.M. Akers* 24,[a] Victoria Peak, Cockscomb Basin Wildlife Sanctuary, Stann Creek
Gyminda tonduzii Loes.	Celastraceae	*A.L. Caldwell* 5 and *M.I. Livingstone* 1, Las Cuevas Research Station, Chiquibul National Park, Cayo
Ipomoea aristolochiifolia G.Don	Convolvulaceae	*D. Bell* 1 and *C.M. Brown* 14, Las Cuevas Research Station, Chiquibul National Park, Cayo
Lobelia guatemalensis (B.L.Rob. ex Donn. Sm.) Wilbur	Campanulaceae	*R.M. Akers* 29,[a] Victoria Peak, Cockscomb Basin Wildlife Sanctuary, Stann Creek
Marsdenia propinqua Hemsl.	Apocynaceae	*C.M. Brown* 20, Guacamallo Bridge, border of Mountain Pine Ridge Forest Reserve and Chiquibul National Park, Cayo
Matelea magnifolia (Pittier) Woodson	Apocynaceae	*M.D. Binder* 6, Monkey Tail Branch, Chiquibul National Park, Cayo
Microgramma squamulosa (Kaulf.) de la Sota	Polypodiaceae	*K. Vint* 3, Hill Bank Field Station, Rio Bravo Conservation and Management Area, Orange Walk
Nephrolepis pectinata (Willd.) Schott	Lomariopsidaceae	*R.M. Akers* 26,[a] Victoria Peak, Cockscomb Basin Wildlife Sanctuary, Stann Creek
Pecluma pectinata (L.) M.G.Price	Polypodiaceae	*A.D. Forrest* 78, Monkey Tail Branch, Chiquibul National Park, Cayo
Pinguicula sharpii Casper & K.Kondo	Lentibulariaceae	*D.T. Cayetano* 1, Baldy Beacon, Mountain Pine Ridge Forest Reserve, Cayo
Robinsonella lindeniana (Turcz.) Rose & Baker	Malvaceae	*M.D. Binder* 4, Monkey Tail Branch, Chiquibul National Park, Cayo
Selaginella flagellata Spring	Selaginellaceae	*R. Lewis* 19, Belize Botanic Garden, Big Eddy, Cayo
Solandra maxima (Sessé & Moc.) *P.S.Green*	Solanaceae	*T.E. Särkinen* 5013, Las Cuevas Research Station, Chiquibul National Park, Cayo

[a] Voucher specimen.

Ridge (two new records) and the Rio Bravo Conservation and Management Area (one new record) (see Table 3). A notable example is a new genus record in 2013 (*Pinguicula sharpii* Casper & K.Kondo) from Baldy Beacon, a peak of 1000 m in the Mountain Pine Ridge. Baldy Beacon could be considered well collected (to our knowledge, there had been more

TABLE 4. M.Sc. thesis projects (in chronological order) by students who completed the Edinburgh M.Sc. programme in *Biodiversity and Taxonomy of Plants*, with related journal articles and specimen collections

Thesis	Journal articles based on findings reported in thesis	Collection nos., date(s) and localities
Queenborough, Simon (2001). *The floristics and phytogeography of Central American tropical forests of Belize*. M.Sc. thesis, University of Edinburgh, ix + 113 pp.	Not applicable	*Queenborough* SQ33–SQ350, June 2001, Las Cuevas Research Station
Urban, Lilis (2003). *The floristic survey of the Macal River*. M.Sc. thesis, University of Edinburgh, iv + 67 + xvi pp.	Urban, Lilis *et al.* (2006). The Macal River: a floristic and phytosociological study of a threatened riverine vegetation community in Belize. *Edinburgh Journal of Botany* 63(1): 95–118.	*Urban* 16–430, 16 April to 13 May 2003, Guacamallo Bridge
Hicks, Jeff (2007). *Describing the plant diversity of Belizean savannas: a floristic survey of San Pastor Savanna*. M.Sc. thesis, University of Edinburgh, x + 75 pp.	Hicks, Jeff *et al.* (2011) A floristic description of the San Pastor Savanna, Belize, Central America. *Edinburgh Journal of Botany* 68(2): 273–296.	*Hicks* [sometimes with a *JR* prefix] 31–120*, May–June 2007, San Pastor Savanna
Akers, Ruth (2007). *Checklist of the vascular plants of the Cockscomb Basin Wildlife Sanctuary*. M.Sc. thesis, University of Edinburgh, 97 pp.	Not applicable	*Akers* [sometimes with an *RA* prefix] 8–29, May 2007, Cockscomb Basin Wildlife Sanctuary including Victoria Peak Also collected with *Z.A. Goodwin* (691–743) as part of Darwin Initiative Project 14-025: *Developing Integrated Assessment of Biodiversity in Secondary Forest in Belize*
Renshaw, Olivia (2008). *Are plant functional types based on leaf, seed and growth traits a useful tool for management and conservation purposes?* M.Sc. thesis, University of Edinburgh, 187 pp.	Not applicable	Not applicable
Sylvester, Steven P. (2009). *Identification keys to the grasses of Belize*. M.Sc. thesis, University of Edinburgh, 238 pp.	Sylvester, Steven P. (2016). An illustrated generic key and updated list of the grasses (Poaceae) of Belize. *Edinburgh Journal of Botany* 74(1): 33–75.	*Sylvester* 8–102, July 2009, Belmopan, Deep River Forest Reserve North, Bladen Nature Reserve, Golden Stream, Big Rock Falls, Pinol Sands, Blancaneaux Lodge, North Line, San Ignacio, Belize Botanic Gardens.
Oldroyd, Lizzie (2009). *Illustrated user-friendly identification key to the Cyperaceae of Belize*. M.Sc. thesis, University of Edinburgh, 160 pp.	Not applicable	Not applicable
Trevaskis, Alexander (2011). *Extent to which soil properties contribute to oak (*Quercus oleoides *Schltdl. & Cham.) distribution within the lowland savannas of Belize*. M.Sc. thesis, University of Edinburgh, 33 pp.	Not applicable	Specimen data unknown

than 200 collections at the summit by 16 botanists before 2013), yet this species appears never to have been previously collected in Belize. It was previously known only from Chiapas, Mexico, so recent colonisation cannot be ruled out; however, it is small and ephemeral and was observed in a small population (< 10 m across) in a disturbed location at a time of year (January) when collecting rates are low for the country (Goodwin *et al.*, 2013).

As mentioned earlier, large numbers of specimens remain incompletely determined; more than 660 specimens remain unidentified or have been determined only to the level of family or genus. It is likely that complete identification of the material collected by the students will reveal additional new species records for the country.

Projects and Publications

Although contribution towards research is a secondary aim of the field course, information obtained and specimens collected during the course has been used in floristic research programmes and floral morphology studies. For example, since 2001 the M.Sc. field course collections have been cited or used in studies (Bridgewater *et al.*, 2002; Ronse De Craene, 2005; Bridgewater *et al.*, 2006; Wanntorp & Ronse De Craene, 2009; Wanntorp *et al.*, 2011; Farrar & Ronse De Craene, 2013; Goodwin *et al.*, 2013) and reports (Goodwin *et al.*, 2011a, 2011b) and have contributed towards a book on the natural history of the Chiquibul Forest (*A Natural History of Belize: Inside the Maya Forest*; Bridgewater, 2012).

The final third of the M.Sc. programme in *Biodiversity and Taxonomy of Plants* is dedicated to completion of a four-month thesis project. Eight M.Sc. students chose to return to Belize for their project or based their project on specimens collected during the M.Sc. field course in Belize (Table 4). Four thesis projects resulted in floristic inventories of the Macal River (Urban, 2003), the Chiquibul Forest (Queenborough, 2001), the disjunct San Pastor Savanna (Hicks, 2007) and the Cockscomb Basin Wildlife Sanctuary (Akers, 2007). Two thesis projects produced taxonomic identification keys to the grass and sedge genera of Belize (Sylvester, 2009, and Oldroyd, 2009, respectively). Two thesis projects were carried out to tackle more ecological questions: a morphological study of the seeds and leaves of plants in the Chiquibul Forest (Renshaw, 2008) and a study of the impact of soil properties on the distribution of oak in the lowland savanna (Trevaskis, 2011). The findings of three of these thesis projects have been published as journal articles (Urban *et al.*, 2006; Hicks *et al.*, 2011; Sylvester, 2016).

After completing the M.Sc. programme, a small number of former students returned to Belize to conduct further research in single expeditions, such as the 2006 Upper Raspaculo study (H. M. Baden, T. E. Särkinen and H. Vandrot; findings published in Baden *et al.*, 2016), or as botanical support (R. Whittet and C. Rosique; see Graham *et al.*, 2017). Others have returned to carry out long-term research in Belize (G. L. Stott and Z. A. Goodwin; see, for example, Maskell *et al.*, 2009; Stuart *et al.*, 2012; Brewer & Stott, 2017).

Lessons Learned

The M.Sc. in *Biodiversity and Taxonomy of Plants* field course was held in Belize between 2001 and 2017, before it was moved to Colombia in 2018 due to staff turnover and for

logistical reasons. Looking back, what lessons can be learned for the future from the 16 years of running this course in Belize, for the field course itself and for similar courses that aim to combine postgraduate level education with high-quality herbarium specimen collection?

First, provision of scholarships to students from the host country provides high-quality capacity building, with students later able to contribute to the original field course or to similar courses within the host country's education system. In addition to collaboration with local institutions, scholarships build goodwill and encourage the formation of long-lasting relationships that can last beyond the lifetime of the field course and facilitate the results and findings of scientific collaborations finding their way into policy discourse. The impact of the capacity building and collaborations cannot be underestimated in a country such as Belize, where the small population size means that it can be difficult to build a critical mass of expertise in any one field.

Second, the timing of the field course can influence both students and specimens. During the first five years, it shifted from February to late April, potentially increasing the range of fertile plant material available for collection, because different species flower and fruit as the dry season progresses. However, although the dry season can mean a rain-free field course, it also guarantees increasing heat. From 2007 to 2017 the course was held in mid-January, a period that we note to be under-represented in terms of specimen collection in Belize (Goodwin *et al.*, 2013). Furthermore, the climate at that time of the year is cooler and often damper, and therefore easier for students travelling from northern Europe to cope with.

Constant discussion and dialogue with in-country partners regarding where to focus future collecting and how to incorporate the work done and the specimens collected during the field course into bigger projects make the course more sustainable and benefits all those involved.

Collecting from a single location over multiple years can result in high-quality species sampling if it is well organised to avoid collection of duplicate specimens of individual species. Repeat visits can also allow course instructors otherwise unfamiliar with the local flora to expand their knowledge, for example by learning local exceptions to the general rules of tropical plant identification.

Flexibility in course design allows one or two days to be dedicated to thorough general collecting (so-called 'hay baling') of a novel site, such as a hilltop or disjunct habitat patch, when the opportunity arises. Students enjoy this team activity and understand its scientific value, and it can provide further valuable herbarium collections.

Now that the RBGE M.Sc. in *Biodiversity and Taxonomy of Plants* field course has switched to a new country, Colombia, what improvements are being made? First, from the start, all herbarium specimen records are being entered into a purpose-built database accessible via laptop computers taken on the course each year. We are using BRAHMS 7, because it has a rapid data entry system accessible to students, holds data to Darwin Core standard, and is easy to install on multiple laptop computers. This facilitates specimen data management in the field and rapid production of labels after our return to Edinburgh from the host country. It also allows instructors to keep track of the species collected in previous years. Use of the database reinforces to students the value of digitally available data, which

they are familiar with from classroom-based modules on collection-based taxonomy. Furthermore, it links the diversity the students encounter in the field to herbarium specimens and online resources such as digitised herbarium catalogues and data aggregators. Using BRAHMS 7 also allows us to easily exchange herbarium specimen data with our Colombian collaborators.

Second, photographs of each year's collections are being used to produce photographic guides to help teachers and students in future years decide what to collect at sites visited previously. Once the specimens recorded in the photographs have been identified by experts, we expect that these photographic guides may be used to produce high-quality field guides to the flora of the field stations and reserves visited.

Management of field course collections after our return from the host country can be difficult. Specimen processing can be time-demanding and resource-intensive; in particular, the correct identification of specimens can take many years (Goodwin *et al.*, 2015). We have traditionally struggled with processing specimens collected during the field course, because this is not a primary duty of the core-funded staff running the M.Sc. programme and specialist staff hired specifically to assist with the course are not involved in post-course activities, including identifications.

These problems are not unique to management of field course specimens (Baker *et al.*, 2017). However, as with the processing of any project-specific specimens, the use of post-collection workflow protocols to prioritise specimens can ensure relatively rapid labelling and mounting and distribution of duplicates. This enables timely access to the specimens by experts and thus expedites identification. Additionally, we have found that entry of specimen information data by students into a database immediately after collection, ideally on the evening of the same day, prevents data loss and ensures high-quality data.

SUMMARY

The RBGE's M.Sc. in *Biodiversity and Taxonomy of Plants* field course has contributed to botanical capacity within Belize in four distinct ways. First, 26 Belizeans have been trained in field identification and collection skills. Second, a large number of high-quality herbarium specimens have been collected (including collections representing new country records for an estimated 15 species), with duplicates held for reference by Belize-based researchers in their national herbarium (BRH) and available digitally via the online catalogue of the RBGE herbarium (E). Third, the course has generated valuable research outputs, both directly (M.Sc. theses and related publications) and indirectly (publications based on studies of specimens collected during the field course). Finally, it has provided graduates of the course with fieldwork expertise and enabled them to produce research outputs that they have been able to use during further research or careers in Belize.

This type of long-term collaboration is not encouraged by the short-term funding cycles of three to five years typical today. However, it is clear from the outcomes described in this paper that institutional commitment to a long-term relationship with a single country can lead to individual career development, knowledge and scientific findings that will continue to influence conservation and research in the host country for many years to come.

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