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PROJECT SUMMARY

Overview:

The herbaria at the Fairchild Tropical Botanic Garden (FTG) and the University of South Florida (USF) contain about 260,000 herbarium specimens from the 13-state region of the southeastern United States (SEUS), the vast majority of which are absent from the 107 herbaria in the SouthEast Regional Network of Expertise and Collections (SERNEC) Thematic Collections Network (TCN) (www.sernecportal.org). The collections at FTG and USF are particularly abundant in Florida specimens as well as states just outside of Florida, with specimens dating back to the 1840s. The collections are well-curated, having been studied by numerous botanists for various past and ongoing regional and national flora projects. We propose to add the 260,000 SEUS specimens held at FTG and USF to the SERNEC TCN, which would require transcription and imaging of 90,000 specimens and georeferencing of 225,000 specimens. About 160,000 SEUS specimens at these herbaria have already been digitized and 87% require additional georeferencing. We estimate about 13% of the 260,000 specimens already have latitude and longitude on the labels. To accomplish the task of adding herbarium data to the SERNEC TCN, FTG will utilize its strong volunteer network; USF will utilize its large student population; citizen scientists through Notes from Nature will transcribe additional specimens to enhance efficiency; and the USF Water Institute will transfer data to iDigBio, SERNEC, and GBIF. The USF Water Institute has over 10 years of experience in managing digitial herbarium specimen data and georeferencing projects. The curators at FTG and USF both have extensive digitization experience and will directly train volunteers and students to produce high-quality transcription metadata and images. The curators will review transcriptions and images weekly to correct errors, monitor progress to ensure completion of the dataset within three years, and work with the USF Water Institute to complete georeferencing efforts.

Intellectual Merit:

This project will add the richly informative collections at FTG and USF to one of the most robust and informative networks (SERNEC) existing across a large geographic scale. This TCN will be useful for not only its information content but also as a model for expanding upon other regions beyond the SEUS. FTG and USF contain unique collections from across the SEUS including more specimens from central and south Florida than any other herbarium. The aggregation of herbarium data into the SERNEC Symbiota portal mobilizes efforts needed by users to quickly find information on a multitude of topics such as the plant species points of occurrence, range distributions, extirpations, expansions, phenology, species habitat preferences, morphology, identification characters, potential sources of DNA, and the history of collecting activity. Flora projects will benefit from the nearly exhaustive content of known vouchered plant occurrences provided by the vast network of herbaria, leading to discoveries of species new to states, county records, and range extensions. For example, recent digitization efforts by the Florida National Park system have led to the discovery of over 100 county records in Florida and studies of collections at FTG continue to add species and county records to the flora of Florida.

Broader Impacts:

This project will train 50+ USF undergraduate students and ~750 BioTECH sophomore students in digitization and increase their literacy in the botanical sciences. Direct mentoring from the Co-PIs will ensure adequate training and optimal educational impacts. Pre- and post-assessments administered by the Co-PIs and assistant curators will allow continual improvement to training, education, workflows, and workshops. Hired USF assistant curators will attend regional meetings to present results from this project. Online herbarium data are used more and more in many disciplines in the SEUS, including natural area preservation (county, state, and federal preserves) and acquisition, mining impacts (e.g. limestone, phosphate, sand, titanium), large-scale developments, highway widening and runoff, and storage of reclaimed excess water. Educators increasingly use online herbarium data to guide instruction for plant diversity and taxonomy courses, such as the numerous Florida teachers who rely upon the Atlas of Florida Plants. The SERNEC dataset will undoubtedly be a lavish resource for the 13-states of the SEUS and beyond, which will see a growing user base each year as the dataset increases from the inclusion of more herbaria (such as FTG and USF) and is continually refined to high-quality standards.

Digitization PEN: Integrating the herbaria of peninsular Florida, a biodiversity hotspot of endemism, rarity, and richness

Proposal overview: Partnership to the SERNEC TCN: Central and south Florida (south of 29°N) are biologically and climatically distinct within the southeastern USA (SEUS). The herbaria of the Fairchild Tropical Botanic Garden (FTG) and University of South Florida (USF) contain ~260,000 vascular plant specimens from the SEUS, with more from central and south Florida (~150,000 combined) than any other herbarium (Table 1; Fig. 1). Data from these two herbaria would fill a crucial gap in the SouthEast Regional Network of Expertise and Collections (SERNEC) Thematic Collections Network (TCN), which is mobilizing herbaria of the SEUS to centralize data for assessment and research. This proposal seeks funding to unite the data from FTG and USF with the SERNEC TCN to maximize its impact and value.

Environmental change in the SEUS: Since 1880, the SEUS human population has risen from about 15 million (U.S. Department of the Interior 1882) to 40 million in 1960 (U.S. Department of Commerce 1961) and to more than 80 million today (U.S. Census Bureau 2014), resulting in non-native introductions, species extirpations, soil disturbance, edge effects, and overall habitat degradation to the unique community assemblages of the SEUS biodiversity hotspot (Sorrie & Weakley 2001; Noss et al. 2015), including its mountainous forests, pyrogenic communities, and extensive wetlands and coastlines. Population growth will likely continue to alter and degrade habitats and a warming climate is expected to hasten sea level rise and alter moisture regimes, resulting in changing species compositions impacting the quality and dynamics of local resources.

Ongoing increases in temperature and sea level as well as changing moisture regimes (Trenberth et al. 2014) may cause some species to migrate or expand northward and further inland (Osland et al. 2013; Cavanaugh et al. 2015) or upland (Morueta-Holme et al. 2015), potentially populating from lower elevations or southern latitudes such as Florida, whilst other species may contract in range (Zhu et al. 2011; Reece et al. 2013; Bell et al. 2014) resulting in fragmented, isolated populations and local extinctions (Valladares et al. 2014; Woolbright et al. 2014). Sea level rise projections of 0.3–1.2 m by 2100 (Kopp et al. 2014; Koch et al. 2015) could encompass much of the Everglades, Florida Keys, and Miami where many endemic taxa and rare habitats (e.g. pine rockland) occur. Climate and management practices also change fire seasonality (Higuera et al. 2014; Platt et al. 2015) which many SEUS species are dependent upon. Changes in phenology could diminish pollination success (Gienap et al. 2014). Contrarily, continued direct habitat disturbances may preclude the potential observable effects of climate change (Nowacki & Adams 2014).

Evidence of anthropogenic and climatic change in the environment is recorded and reflected in the projected 4.7 million specimens from 107 herbaria in the SERNEC TCN (~2 million specimens available online as of 26 Sep 2016), with specimens dating back to the 1830s (e.g. collectors M.A. Curtis and J.L. Riddell). Historic floristic information from herbaria is vital to understanding the past and future human-induced impacts upon the environment. The aggregation of herbarium data dramatically strengthens our abilities to sense floristic patterns responding to such changes and apply sound logic to environmental policies and decision-making. Herbarium records are a primary source of data for assessing a species' vulnerability to climate change and human disturbance (e.g. distribution, moisture and soil type preferences), which can then be used to inform best practices in directing resources for conservation and habitat management (Morton & Schlesinger 2014). To model environmental changes in the SEUS, the herbarium records of FTG and USF from central and south Florida would constitute an integral dataset due to the region's high species diversity, subtropical climate, and rapid population growth.

SERNEC TCN: The SERNEC TCN (NSF award no. 1410069) is a collaborative effort across a 13-state region (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia) to unify 4.7 million vascular plant specimens from 107 herbaria into easily accessible databases (www.sernecportal.org and iDigBio). The focus of the SERNEC TCN is to make herbarium data available for the SEUS biodiversity hotspot (Estill & Cruzan 2001; Sorrie & Weakley 2001; Graham et al. 2010; Noss et al. 2015), in order to address wildlife management & research, climate change, environmental impacts, and urban planning.

Since herbarium specimens are geographically and temporally stochastic, a uniform distribution of collections for any species or geographic area is unlikely, leading to potential gaps in data, weakening

hypotheses, and faulty predictions. Analyses by Franck (2011) estimated that only 19% of the Florida counties (13/67) had a well known county-level flora (>90% of the estimated plant diversity documented with herbarium specimens). It is critical that as many records as possible are integrated into the SERNEC TCN to maximize inferences and reveal real patterns in order to accurately inform environmental policies in the rapidly changing SEUS. The herbaria of the FTG and USF both contain a unique assemblage of specimens from across the SEUS (Tables 1–2; Fig. 1). Uniting the herbaria of FTG and USF with SERNEC would significantly diversify the data to 5 million specimens from 109 herbaria and greatly increase the power of this TCN to address humanity's environmental challenges.

Broader impacts of herbarium specimen databases: The 107 herbaria in the SERNEC TCN dramatically broaden their utility by being widely accessible online. Online floristic databases that incorporate herbarium data are an invaluable resource used extensively by researchers, land managers, businesses, and education programs. As an example of the impact these online resources have, hundreds to thousands of professionals rely upon the University of South Florida specimen database provided through the online *Atlas of Florida Plants* (AFP) (Wunderlin et al. 2016). Like the SERNEC TCN, this website provides data such as specimen images, label data, maps of distributions, and live plant photos for 4,339 native or naturalized vascular plants of Florida, in collaboration with several herbaria (e.g. FLAS, FSU, and FTG). Over the past seven years (2009–2016), the AFP has averaged 134,000 different users and 1.9 million page views per year (avg. session 5 min, 7 pg./session, 51.4% bounce rate), 65% of the use from the SEUS and 83% from the USA (Google Analytics; Franck 2016). Regular users include county, state, and federal land managers, environmental consultants involved in reclamation and monitoring, and numerous schools and universities involved in research and teaching The two Co-PIs of this proposal (Alan R. Franck, USF Herbarium Director, & Brett Jestrow, FTG Herbarium Curator) interact nearly everyday with these users and are acutely aware of the significance of these floristic resources. Upon completion of the ~5 million specimen dataset, the SERNEC TCN will undoubtedly bolster science and education in the SEUS.

Specific examples of research utilizing and citing the AFP in the past six years include predictions of south Florida tree species diversity relative to rising sea level and warming temperatures (Ross et al. 2016), rare species demography of the endemic *Hypericum edisonianum* and impacts of climate change (Abrahamson & Vander Kloet 2014), latitudinal species migration of mangroves (Williams et al. 2014), taxonomy and distribution of the SEUS endemic *Zigadenus glaberrimus* (Zomlefer et al. 2014), habitat quality indices in south Florida (Mortellaro et al. 2012), invasive species and biofuel prospecting (Gordon et al. 2010), hybridization and niche modeling of the invasive species *Schinus terebinthifolia* (Mukherjee et al. 2011), seed bank longevity on the Lake Wales ridge (Ficken & Menges 2013), Everglades restoration (Chimney 2012), diversity surveys of salt marshes (Goldberg & Rillstone 2012), weed control of *Solanum* spp. (Bryson et al. 2012), biological control of invasive species in Florida (Diaz et al. 2012, 2015), and wetland measurement indices (Deimeke et al. 2013).

Herbarium specimen images are educational resources useful for teaching plant identification, morphology, phenology, and biogeography. These specimens are the most accurate tool for confirming plant identification to online users. The identifications of herbarium specimens are often confirmed or reviewed by the collector, herbarium curator, and a monographic researcher. Their two-dimensional aspect has advantages over live plant photos which frequently focus only on flowers. On a specimen, the entire inflorescence, leaf arrangement, branching patterns, and root structures are often available to study, characters which are almost never together on a live photograph. Importantly, herbarium specimens are also the foundation of plant nomenclature and scientific communication, fixing names to specimens and real populations. Lastly, with the potential for improving public awareness through increased accessibility comes the potential for increasing the public value placed on biodiversity which thus favors conservation. The SERNEC TCN serving the SEUS will be significantly impactful to a wide audience, and we wish to increase its potential value by sharing the FTG and USF datasets, which together hold 260,000 specimens from the SEUS, with more from central and south Florida than any other herbarium (Table 1; Fig. 1).

Richness of the flora of Central & South Peninsular Florida: Of the 8,024 vascular plant taxa found in the SEUS, over half (4,339, 54%) are known from Florida and ca. 2,919 of those are found in central & south peninsular Florida (~29°N southward) (Sorrie & Weakley 2001; USDA 2016; Wunderlin et al. 2016). An estimated 1,208 taxa are exclusively known from central & south peninsular Florida (~29°N

southward), i.e. not found elsewhere in the SEUS (USDA 2016; Wunderlin et al. 2016). These 1,208 plant taxa comprise an astonishing amount of listed species (24%), endemics (11%), extirpated taxa (2%), non-natives (47%), and invasives (7%) (Table 3). Many SEUS taxa reach their southern limit in this region around Lake Okeechobee (e.g. *Gordonia lasianthus*, *Styrax americanus*), whilst many tropical Caribbean taxa reach their current northern limit near 29°N (e.g. *Myrsine cubana*, *Tillandsia fasciculata*).

Central & south peninsular Florida contain two regions especially rich in endemic and rare plant taxa: the Lake Wales ridge and the extreme southern tip of Florida (Noss et al. 2015). The elevated interior of central peninsular Florida is characterized by the Lake Wales ridge, which was identified as one of six centers of endemism in the southeastern coastal plain (Estill & Cruzan 2001; Sorrie & Weakley 2001; Noss et al. 2015). Extreme south Florida contains an abundance of rare and endemic Caribbean taxa (Sorrie & Weakley 2001; Noss et al. 2015).

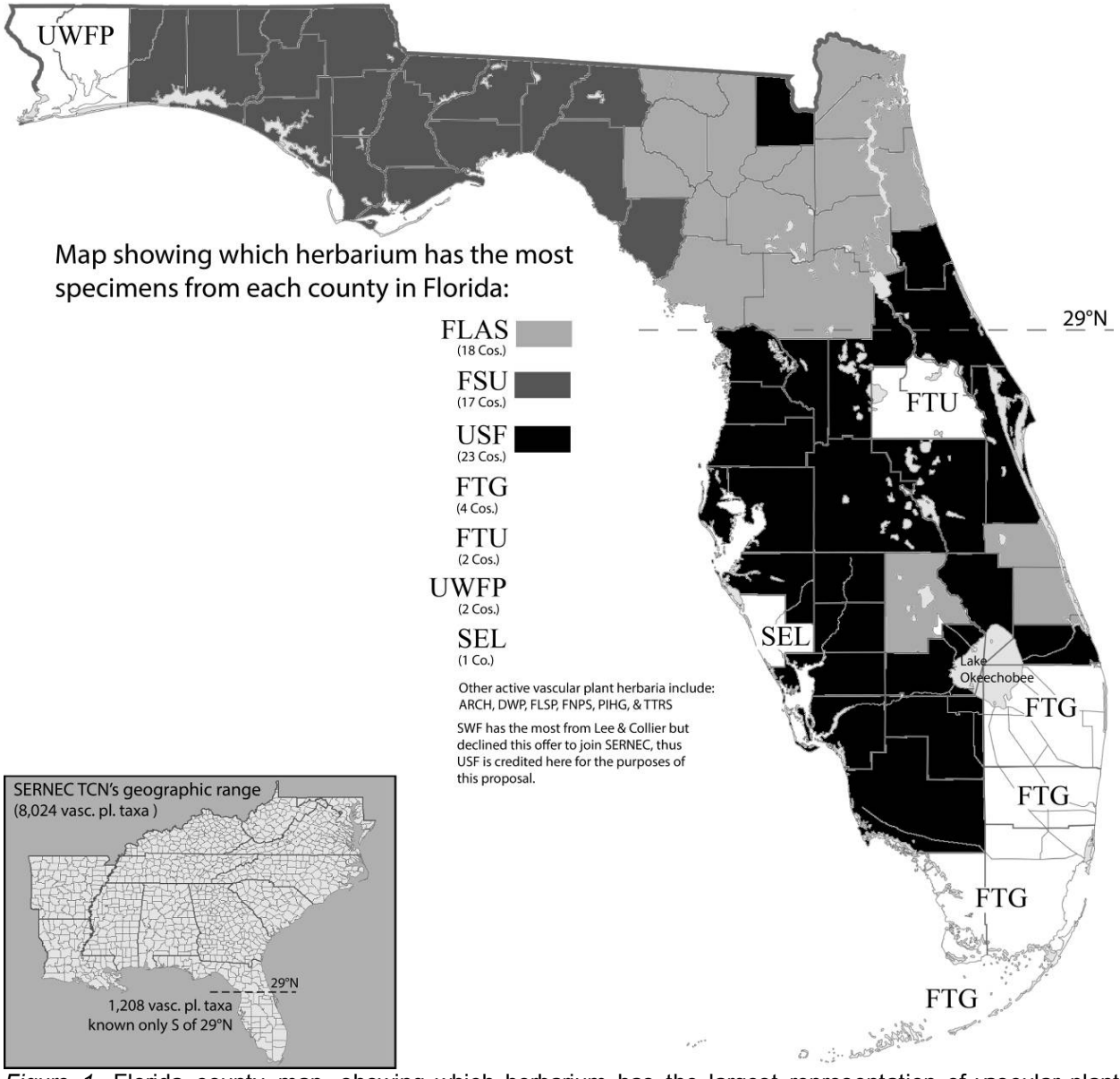

Figure 1. Florida county map, showing which herbarium has the largest representation of vascular plant specimens from each county. All herbaria with the largest county holdings are part of SERNEC, except FTG, USF, and SWF. SWF has the most specimens from Lee (7,300) and Collier (8,200) Cos. but declined to join this PEN proposal and USF is listed which has the 2nd most for these two counties. About 1,208 vascular plant taxa are found only south of 29°N, and not found elsewhere in the SEUS.

Table 1. The 67 Florida counties and the herbarium which best represents each county, with the estimated number of specimens that particular herbarium has from that county. Curators were contacted to assist in the estimate of their Florida holdings: FLAS (Kent Perkins), FLSP (Rosalind Rowe), FNPS (Jimi Sadle), FSU (Katelin Stanley), FTU (Elizabeth Harris), PIHG (Marc Frank), SEL (Bruce Holst), SWF (George Wilder), and UWFP (James Burkhalter). [1]SWF has the most specimens from Lee (7,300) and Collier (8,200) Cos. and declined to join this PEN proposal, thus USF is listed which has the 2nd most.

County	No. of specimens	Herbarium	County	No. of specimens	Herbarium
Alachua	23,650	FLAS	Lee[1]	4,220	**USF**
Baker	480	**USF**	Leon	10,835	FSU
Bay	2,795	FSU	Levy	7,680	FLAS
Bradford	500	FLAS	Liberty	6,000	FSU
Brevard	3,420	**USF**	Madison	840	FSU
Broward	1,980	**FTG**	Manatee	2,985	**USF**
Calhoun	2,680	FSU	Marion	4,880	FLAS
Charlotte	1,740	**USF**	Martin	4,035	**USF**
Citrus	2,630	**USF**	Miami-Dade	24,200	**FTG**
Clay	1,960	FLAS	Monroe	9,600	**FTG**
Collier[1]	5,240	**USF**	Nassau	1,660	FLAS
Columbia	2,820	FLAS	Okaloosa	2,190	FSU
DeSoto	1,320	**USF**	Okeechobee	615	**USF**
Dixie	890	FSU	Orange	8,800	FTU
Duval	1,960	FLAS	Osceola	1,285	**USF**
Escambia	11,000	UWFP	Palm Beach	4,000	**FTG**
Flagler	950	**USF**	Pasco	3,340	**USF**
Franklin	8,780	FSU	Pinellas	5,100	**USF**
Gadsden	4,635	FSU	Polk	6,500	**USF**
Gilchrist	600	FLAS	Putnam	4,200	FLAS
Glades	720	**USF**	Santa Rosa	2,000	UWFP
Gulf	1,670	FSU	Sarasota	7,190	SEL
Hamilton	695	FLAS	Seminole	3,300	FTU
Hardee	1,180	**USF**	St. Johns	1,320	FLAS
Hendry	610	**USF**	St. Lucie	1,230	FLAS
Hernando	3,160	**USF**	Sumter	1,745	**USF**
Highlands	4,800	FLAS	Suwannee	1,900	FLAS
Hillsborough	12,000	**USF**	Taylor	1,960	FSU
Holmes	575	FSU	Union	400	FLAS
Indian River	1,075	FLAS	Volusia	2,510	**USF**
Jackson	5,400	FSU	Wakulla	7,755	FSU
Jefferson	2,670	FSU	Walton	1,705	FSU
Lafayette	790	FLAS	Washington	1,990	FSU
Lake	2,830	**USF**			

Table 2. Estimated number of SEUS specimens at FTG and USF, over several time periods.

Herb.	1840–1899	1900–1929	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s+	Total
FTG	150	400	2300	2200	9500	16300	16350	15300	13500	19000	95000
USF	1150	2200	1250	1350	15750	27200	29200	27000	23000	36950	165000
Total	1300	2600	3550	3550	25250	43500	45550	42300	36500	55950	**260000**

Table 3. Vascular plant flora exclusive to central and south peninsular Florida (C&S penFL) and not found elsewhere in the SEUS. State-listed and federally listed include threatened or endangered taxa. Extirpated taxa are derived from (Gann et al. 2002). Invasive taxa are from the FLEPPC (2015) list.

Exclusive to C&S penFL	Endemic	State-listed	Federally listed	Extirpated	Non-native	Invasive
1,208	130	288	37	30	567	88
(100%)	(11%)	(24%)	(3%)	(2%)	(47%)	(7%)

Biodiversity Hotspots Represented in the FTG and USF Herbaria: Both FTG and USF contain a wealth of data on rare, endemic, and endangered taxa characteristic of the SEUS biodiversity hotspot. The Lake Wales ridge center of endemism is centralized around Lake and Polk Cos., nearly completely encompassing both counties (Estill & Cruzan 2001; Sorrie & Weakley 2001). USF has more herbarium specimens from Lake and Polk Cos., the Lakes Wales ridge region, than any herbarium (Table 1; Fig. 1), and in 2015 acquired the historic Florida Southern College herbarium (FSCL) which has thousands of specimens from this region, nearly all dating from 1929–1984.

Within the contiguous USA, extreme southeast Florida (Miami-Dade Co.) was identified as a hotspot of rarity and richness (Stein et al. 2000), and the Florida Keys (Monroe Co.) were identified as one of nine areas most in need of conservation (Jenkins et al. 2015). FTG has far more herbarium specimens from these two counties than any other herbarium (Table 1; Fig. 1). The richly endemic south Florida phytogeographic region comprising the southernmost seven counties (as identified by Sorrie & Weakley 2001) is best represented by the FTG and USF herbaria. A large number of specimens documenting the northernmost and southernmost localities for many species are found in the FTG and USF herbaria.

The herbaria of FTG and USF are essential to understanding environmental and urban change in Florida and the SEUS, both housing numerous specimens that have been widely studied due to ongoing floristic work (FNA 2003–2015; Wunderlin & Hansen 2015, 2016). With 260,000 specimens from the SEUS dating as far back as the 1840s (Table 2), FTG and USF contain more specimens from central & south peninsular Florida (~150,000 combined) than any other herbaria (Table 1; Fig. 1).

Overview of the FTG Herbarium: FTG contains approximately 160,000 plant specimens, of which about 95,000 are from the SEUS (Table 1), the majority (~90%) from Florida. About 45,000 have already been digitized, mostly by ~30 long-term (>5 yrs of service) volunteers. Their current herbarium database is nearly defunct and is no longer currently updated, due to a lack of IT support and funding. The remaining 50,000 specimens from the SEUS are in need of digitization at FTG.

FTG contains more specimens from southern peninsular Florida and the Florida Keys than any other herbarium (Fig. 1), the majority as unicates (collections without duplicates in other herbaria). FTG's proximity to the Everglades, coastal Miami area, and the Florida Keys has resulted in the accumulation of numerous unique records dating back to the late 1890s. Several prolific collectors have been based at FTG or have deposited a plethora of their specimens there, the majority of which are not found in the SERNEC TCN (Table 4). Its rich West Indies collection (outside the SEUS) has enabled researchers to accurately identify and apply sound taxonomy to the various rare species exclusive to southern Florida within the SEUS. The herbarium specimens at FTG make their collections uniquely powerful in addressing subtropical floristic changes.

Table 4. SEUS collectors with large collections at FTG, estimated number of specimens from the SEUS at FTG, and number of specimens found in the SERNEC portal as of 1 Aug 2016.

Collector	Dates active	No. of FTG specimens from SEUS	Current no. in SERNEC from SEUS
Buswell, W.M.	1890s–1940s	5,000	10
Woodbury, R.	1930s–1990s	1,500	9
Craighead, F.C.	1950s–1970s	2,500	38
Gillis, W.T.	1960s–1970s	3,500	20
Avery, G.N.	1960s–1980s	1,500	6
Correll, D.S.	1970s–1980s	6,000	945
Orzell, S.L.	1980s–1990s	8,000	756
Bradley, K.A.	1990s–2010s	6,000	200

Overview of the USF Herbarium: USF contains approximately 260,000 plant specimens, of which about 165,000 are from the SEUS (Table 2). About 110,000 Florida specimens are already digitized and available through their herbarium search page at the Atlas of Florida Plants (AFP). The majority (>80%) of the Florida specimens at USF were meticulously transcribed by curatorial staff who were also prolific collectors (B.F. Hansen, J.M. Kunzer, and A.R. Franck). Current support from the Florida Fish & Wildlife Conservation Commission funds the AFP (Wunderlin et al. 2016), primarily the salaries of undergraduate students who curate, mount, digitize, organize, and file Florida specimens (e.g. the 3,000–5,000 Florida specimens annually received, 7,000 recently donated from the FSCL herbarium, and 1,500 exchanges of many FL cultivated taxa recently received from A/GH at Harvard).

USF contains more specimens from peninsular Florida than any other herbarium (Table 1; Fig. 1), the majority of which are not found in the SERNEC TCN (Table 5). Numerous collectors and floristic authors deposited the majority of their collections at USF. USF recently acquired the Florida Southern College Herbarium (FSCL) consisting of about 1,000 Florida specimens from the 1910–1930s from M. Mulvania, ~500 specimens from miscellaneous collectors from the 1940s, and 4,000 Florida specimens from M.L. Gilbert from the 1950s–1980s. Most of the FSCL collections were funded by NSF grants (nos. 6219766, 6325496, 64E4900, 64E4161, and 640U724) in the 1960s to catalogue central Florida wildlife with undergraduate students.

Table 5. Florida collectors with large collections at USF, estimated number of specimens from Florida at USF, and number of specimens found in the SERNEC portal as of 1 Aug 2016.

Collector	Dates active	No. of USF specimens from Florida	Current no. in SERNEC from Florida
Mulvania, M.	1910s–1930s	1,000	0
Kral, R.	1950s	2,000	1,431
Ray, J.D.	1950s–1960s	1,000	50
Cooley, G.R.	1950s–1970s	4,000	192
Lakela, O.L.	1950s–1970s	10,000	132
Long, R.W.	1950s–1970s	4,000	30
Gilbert, M.L.	1950s–1980s	4,000	0
Shuey, A.G.	1970s–1980s	2,500	98
Wunderlin, R.P.	1970s–2000s	6,000	72
Hansen, B.F.	1970s–2000s	9,000	53
vanHoek, C.	1970s–2010s	3,000	0
Kunzer, J.M.	2000s–2010s	2,500	6
Franck, A.R.	2000s–2010s	3,000	7

Table 6. SEUS (excluding Florida) collectors with large collections at USF, estimated number of specimens from SEUS outside of Florida at USF, and number of specimens found in the SERNEC portal as of 1 Aug 2016.

Collector	Dates active	No. of USF specimens from SEUS (excluding FL)	Current no. in SERNEC, SEUS (excluding FL)
Batchelder, C.F	1880s–1930s	300	40
Small, J.K.	1890s–1930s	100	250
Brass, L.J.	1940s–1960s	700	37
Ray, J.D.	1950s–1960s	1,500	2,700
Ford, M.G.	1960s	500	0
Caudle, C.F.	1960s	500	1
Cooley, G.R.	1950s–1970s	2,000	550
Lassiter, J. & R.	1960s–1980s	100	0
Wilhelm, G.	1980s	1,000	3
Orzell, S.L.	1980s–1990s	2,000	600
Longbottom, W.D.	2010s	1,000	214

About 55,000 USF specimens lie within the SEUS outside of Florida and ~10,000 of those are already digitized. Approximately 7,000 of these specimens were digitized by five undergraduate

volunteers in the 2015–2016 academic year, and trained by the Co-PI (Franck, USF Herbarium Director) as part of a pilot program to digitize the SEUS specimens. An additional 45,000 specimens in the SEUS outside of Florida are still in need of digitization at USF and the Co-PI continues to train volunteers working towards this goal, of which another 5,000–7,000 will likely be digitized by May 2017.

Numerous historic specimens from states in the SEUS outside of Florida exist at USF that are absent from other SERNEC herbaria (Table 6), much of it due to the great interest in developing a SEUS flora, as an update to Small's (1933) last treatment, during USF's founding (Franck 2016). The founder of the USF Herbarium, George R. Cooley, had a close association with Harvard and many other botanical institutions interested in the SEUS flora. The acquisition of the FSCL herbarium also added about 1,000 unicates collected during the 1950s–1960s from the SEUS outside of Florida.

Proposal goals: This proposal seeks 1) to digitize the remaining 95,000 specimens out of the 260,000 specimens from the SEUS at FTG and USF (165,000 are already digitized), 2) to georeference 225,000 specimens from the SEUS at FTG and USF, and 3) to support IT personnel to join the 260,000 herbarium specimens from FTG and USF to the SERNEC TCN (Table 7).

Table 7. Overview of FTG and USF vascular plant collections in the SEUS and digitization needs.

		Previous or currently funded work	Requesting NSF funding for work below	
Institution	**Total no. from SEUS**	**No. already digitized from SEUS**	**No. not yet digitized from SEUS**	**No. needing georeferencing**
FTG	95,000	45,000	50,000	85,000
USF	165,000	120,000	45,000	140,000
Totals	**260,000**	**165,000**	**95,000**	**225,000**[1]

[1]About 13% of the specimens have latitude and longitude already transcribed and do not need additional extraneous georeferencing effort.

Response to previous reviews: This proposal is a resubmission of NSF proposal no. 1602074, "Digitization PEN: Patterns of floristic change in South Florida herbarium collections." Based on the previous NSF review, we have addressed identified shortcomings in seven main areas. 1) We have more directly tied in the relevance of the FTG and USF collections with the theme and significance of the SERNEC TCN, highlighting the rich biodiversity of endemics and rare species represented by FTG and USF in central and south Florida that are biogeographically depauperate in other SERNEC herbaria (Tables 1–6; Fig. 1). 2) We have initiated collaborations with iDigBio and have consulted several of their staff (Shari Ellis, Shelley James, and Joan McCaffrey, pers. comm.) to understand how we can best complement this network. 3) Our broader impacts are developed with the local educational community, including specific outreach towards high school and undergraduate students. 4) Our mentoring plan identifies training and educational goals to be developed for student and volunteer transcribers and imagers. 5) Target metrics and deliverables are identified for each year for each herbarium in order to monitor progress towards complete digitization of the SEUS FTG and USF dataset. 6) Risks of project incompletion are identified and mitigated through NfN activities and workshops. 7) Our local sustainability plan for long-term data maintenance is elucidated in the data management plan.

Integration with iDigBio: Through this proposal, we anticipate sharing ~260,000 specimens combined from FTG and USF with iDigBio. As of 23 Sep 2016, 129,248 vascular plant herbarium records from USF are already available in iDigBio (and the Global Biodiversity Information Facility [GBIF]). Of the 389,222 land plant records from Florida available in iDigBio, USF represents 108,290 of those records, the largest dataset from Florida, with the next largest being FLAS and FSU at ~50,000 specimens each from Florida in iDigBio (as of Sep 23 2016). USF data are regularly ingested by iDigBio. All textual transcriptional metadata from the USF dataset are duplicated at iDigBio (and GBIF). Reduced-resolution ~150 kb images of each USF specimen (at 96 dpi) are also stored by iDigBio. The iDigBio records also provide links to the image file hosted at USF. The AFP also provides active links to iDigBio and the USF publisher page on iDigBio. Data use statistics indicate that individually a USF specimen has been represented 30 billion times in iDigBio searches during Sep 2016. USF's AFP was also tapped for its exhaustive

synonymy list of Florida taxa so that iDigBio could adequately withhold locality information from rare plant taxa in their database from a suite of alternate taxonomic names. Data use statistics in iDigBio and those generated by data managers through SERNEC will be readily obtainable.

Funding from this proposal would go toward setting up a functional database for FTG to continue entering their transcriptions. The FTG data would be locally managed by USF (USF Water Institute). About ~45,000 specimens at FTG are already digitized and with the help of USF, these data can be made immediately available to iDigBio during year 1 of the proposal project and will be continually uploaded to iDigBio throughout the project and beyond.

The Co-PIs will maintain dialogue with iDigBio through email listservs, and Franck is already a member of several of their listservs. The Co-PIs will continually monitor the schedule of webinars offered by iDigBio to identify webinars relevant to this proposal. Not only can the Co-PIs learn from these webinars, but they can also participate to ask relevant questions and offer sound advice, as both Co-PIs have several years of experience with digitization, collections management, and community engagement. On 21 Sep 2016, the USF Co-PI (Franck) participated in the webinar "Integrating Natural History Collections into Undergraduate Education: Creating the Resources and Growing the Community".

Both Co-PIs plan to participate in the GEOLocate Toolkit webinar hosted by the iDigBio Symbiota Working Group on 18 Nov 2016, to further understand current protocols for georeferencing. The USF Co-PI is already a member of the iDigBio Symbiota Working Group listserv and both Co-PIs plan to further integrate with the iDigBio Symbiota Working Group, as we feel that our work experiences best complement this group. The Co-PIs of this proposal (Franck & Jestrow) have established regular contact with the SERNEC TCN lead PI (Zack Murrell) and advisor (Michael Denslow). The Co-PIs will attend the iDigBio summit meeting during year 1 of this project.

Broader impacts specific to this proposal: FTG and USF will engage high school students, undergraduate students, and volunteers in the herbarium sciences to accomplish the digitization goals of this proposal. FTG will train ~30 working class volunteers from the local community and ~750 BioTECH Magnet High School students with the curatorial and digitization skill sets of the herbarium. USF will train ~50 USF undergraduates and ~50 working class volunteers from the local community with the curatorial and digitization skill sets of the herbarium.

FTG broader impacts with local volunteers: The FTG Herbarium has a close connection with its local community due to its affiliation with the Fairchild Tropical Botanic Garden (FTBG) as well as Montgomery Botanical Center. FTBG harbors 100s of volunteers and the FTG herbarium hosts ~30 volunteers per year. Most of these 30 volunteers are working class professionals (some retired) that have been at FTG for over 5 years each and have intimate knowledge of the activities at the herbarium. However, since FTG has not had IT support for their digitization efforts, the volunteers lack experience with digitization. With a new web interface developed by USF for digitization through this proposal, FTG expects to train ~30 working-class volunteers over the course of three years to digitize their remaining 50,000 specimens from the SEUS. FTG aims to have seven volunteers digitizing 315 specimens per week, and overall about 15 volunteers digitizing ~15,750 specimens per year. Each digitizer will have a goal of digitizing 45 specimens over 3 hours per week, or 15 per hour. Additionally, with the online interface and the ability of transcribers to work from home, FTG expects to be able to increase its number of volunteers and their hours to surpass its digitization goals.

FTG broader impacts with BioTECH High School: FTG has an ongoing collaboration with the BioTECH High School (Richmond Heights, Miami, Florida), a magnet school for which the Co-PI (Jestrow) is already actively engaged with. The focus of this high school is to give students experience with novel research projects gathering new data. Students are allowed to choose a major in zoology or botany, for which ~2/3 chose botany this current year. Their work at FTG is regularly shared on Twitter by Thaddeus Foote, "@BioTECHRichmond". Already this year the Co-PI (Jestrow) has led a workshop with these students on the various kinds of microscopy and oversees DNA work in the FTG laboratory.

For this proposal, the FTG Co-PI (Jestrow) is collaborating with Amy Padolf (BioTECH director of education) and Thaddeus Foote (BioTECH lead) to run an additional workshop focused on the herbarium at FTG for the 250 sophomore botany majors at BioTECH. The day-long Herbarium Workshop will be held 10 times per year (25 students per class) to accommodate the 250 sophomores annually, totaling 750 students over three years. With emphases on plant diversity, morphology, classification, and biogeography, this workshop will cover parts of three Florida Science standards: Standard 14: Organization and Development of Living Organisms: SC.912.L.14.53 Discuss basic classification and

characteristics of plants. Identify bryophytes, pteridophytes, gymnosperms, and angiosperms.; Standard 15: Diversity and Evolution of Living Organisms: SC.912.L.15.4 Describe how and why organisms are hierarchically classified and based on evolutionary relationships.; and Standard 17: Interdependence: SC.912.L.17.8 Recognize the consequences of the losses of biodiversity due to catastrophic events, climate changes, human activity, and the introduction of invasive, nonnative species.

This BioTECH Herbarium Workshop will focus on the knowledge contained within a herbarium, including digitization. It will be divided into a morning and afternoon session driven by an investigative approach, including directed questions and activities for the students to complete. The BioTECH students will meet at the FTG herbarium at ~9 am for the Co-PI (FTG curator Jestrow) to give the initial introduction to the herbarium, e.g. What kinds of organisms are in these herbarium cases? How are they organized? And what sorts of questions can we answer with these specimens (identification, floristics, biogeography, medicinal use, paleoecology, etc.)?

Students will bring in their own specimens (or be given a real herbarium specimen) so the FTG curator can train them to carefully make/mount their own herbarium specimens, and in so doing, pay particular attention to plant organs and the display of morphological characteristics. Emphasis will be placed on a well-made label (e.g., date, collector, location, ephemeral characters, habit, etc.), e.g. climatic data based on temperature and stomatal density rely on accurate label dates and locations. Students are often surprised that the species identification is not critical for label preparation, as identifications can always be added later, which is how many new species are discovered. Duplicate specimens will be introduced as examples of sharing knowledge and preserving it through disasters (e.g. the Berlin herbarium during WWII), e.g. how can we prove that the live oak in Miami is the same species as the one in Tallahassee with the resources contained within FTG? The notion of type specimens will also be introduced (how can a species name be given a permanent definition?).

For the afternoon session, students will meet at the Science Village at Fairchild Tropical Botanic Garden (FTBG), in the computer lab. With 16 available computers, students will work in groups of two. With the understanding of a well-made specimen label, students will be trained to transcribe label data from herbarium specimens into the FTG virtual herbarium, with a goal of 5 transcriptions per group in one hour (~80 total/day, ~800/year, ~2,400/3 years). Part of the digitization procedure will be identifying if the specimen contains flower buds, mature flowers, immature fruits, or mature fruits. The importance of digitization will be demonstrated to them with the The Million Orchid Project.

As part of their sophomore curriculum, the BioTECH students are involved with The Million Orchid Project, an initiative of FTBG. The goal of this project is to propagate over a million native orchids, and reestablish the native orchid diversity across the Miami Metropolitan Area. The students, over the course of the year, started by learning aseptic micropropagation techniques, and will be able to take the epiphytic orchid seed from germination through planting them onto trees of the community. Their first step anent the herbarium will be to compile geographic localities of a rare, near-endemic, or endemic SEUS species with herbarium data from the SERNEC portal and the Atlas of Florida Plants (AFP), e.g. the native butterfly orchid, *Encyclia tampensis*.

Through SERNEC, students will answer these questions: How many herbaria have specimens of *E. tampensis*? Are the herbaria near Miami? Are any of the specimens duplicates? What specimen(s) provide the best evidence that these orchids are native? How do we know which species should be replanted for restoration projects and in what geographic localities? Do any institutions conceal locality data for other orchids and why would they do this? How many have been collected since 2000? How many before 1980? What is the nearest specimen of the species to BioTECH? What is the distribution of collections known from Miami-Dade county? Since SERNEC conceals most data for *E. tampensis*, FTG and USF will provide images of specimens (with exact locality data concealed) for their use.

Another epiphyte, *Pleopeltis polypodioides*, commonly co-occurring with *E. tampensis*, will be used to explore the interactive map feature of the SERNEC portal. How does its range differ from the orchid? What limits their ranges?

Next these same questions will be framed with a non-native species, e.g. the naturalized orchid, *Eulophia graminea*, demonstrating how collections are used in tracking the spread of exotic species. This species, native to Asia, was first found in Florida in 2007. Currently only two specimens of *E. graminea* exist in the SERNEC database, however, FTG and USF contain many specimens of the species from Florida (the students may have to first map these by hand). These specimens will be available for the course to show how local herbaria contribute to modern science. Through pre- and post-questionnaires developed with the BioTECH educators and given to each student, this workshop will be continually

evaluated and improved for effectiveness and learning outcomes.

FTG Virtual Herbarium: This proposal will generate an online interface to allow FTG to transcribe herbarium specimen metadata. USF will design a webpage to allow FTG to login, access images, and transcribe specimen metadata into Darwin core fields. FTG and USF will collaborate to extend the life of this online transcription tool beyond the SERNEC project to allow FTG to continually digitize their specimens in the coming decades.

USF broader impacts: USF will utilize and train undergraduates from two courses taught at USF: Plant Identification (EVR 4930) and Medical Botany (BOT 3850). The USF Co-PI (Franck) is partnering with Laurie Walker (USF Botanical Gardens Director) to run a workshop for Laurie Walker's Plant Identification (EVR 4930) class. This class averages about 30 students every fall semester and meets once per week for 3 hours. The USF Co-PI (Franck) will lead this workshop once during the semester. The workshop will include the same basic introduction to a herbarium as done for the BioTECH students to educate students on the knowledge and potential applications of the herbarium. The USF Co-PI (Franck) annually gives several tours (and talks) per year to students and the local community for the herbarium. The second part of the EVR 4930 class at USF will incorporate a transcription exercise. We anticipate the undergraduates providing ~100 transcriptions during the class. The greater benefit will be recruiting students to extend their involvement with the herbarium for advanced training in curation and digitization. During brief exploratory interactions with the fall 2016 EVR 4930 students' this year, already two students are each committing 3–5 hours per week during the fall 2016 semester, digitizing ~50 specimens each per week. We thus anticipate that 2–5 long-term volunteers will be recruited from the USF Plant Identification (EVR 4930) course each semester.

The USF Co-PI (Franck) teaches Medical Botany (BOT 3850) to ~200 students every semester, and a total of 400 students per year. During the past 5 semesters, the Co-PI (Franck) has recruited ~10 undergraduate students each semester (~50 total) to gain experience in herbarium curation and specimen digitization. Half are trained for digitization and the other half are trained for mounting and filing specimens. The past 2015–2016 academic year, five students from BOT 3850 were trained in specimen digitization and digitized a total of 7,000 specimens over two semesters. Currently (fall 2016 semester) four from BOT 3850 are digitizing SEUS specimens and four are mounting and filing. We anticipate that ~5–10 long-term volunteers for digitization will continue to be recruited from the USF Medical Botany (BOT 3850) course each semester.

USF expects to recruit about 15 students per semester from two courses for digitization. From these undergraduates, an especially interested and talented student will be hired at USF with funding from this proposal as a dedicated assistant curator to continually oversee training, digitization, and integration with FTG and the broader community. A USF assistant curator would also enable all student volunteers to digitize, the training for which is much more intensive than mounting and filing. The assistant curator will also be presenting results at ASB and FNPS meetings. As a minor component, plant biogeographical questions utilizing online specimens will also be integrated into the BSC 2011L plant identification lab at USF to explore distributions of plants.

Notes from Nature: FTG and USF will utilize SERNEC's partnership with Notes from Nature (NfN) to accelerate the digitization rate of their specimens. Although our primary goals are to transcribe most data in-house at each herbarium to maximize and standardize transcription metadata quality through direct supervision and training (i.e. a training module), obstacles towards complete digitization are inevitable. Thus, both Co-PIs will monitor monthly digitization rates at their own institutions and partner with NfN to meet annual digitization goals. At a minimum, FTG and USF expect to share 1,000 images (and up to 5,000) with NfN annually for transcription via citizen scientists to facilitate collaborations between the institutions. Notifications will be advertised via Facebook (i.e. Florida Botany Group III) and local chapters of the Florida Native Plant Society to increase participation of local Florida citizens. These collections may also be showcased during WeDigBio events. For a pilot run, USF shared 500 images during the last WeDigBio event in Oct 2015, all of which have been successfully transcribed.

USF herbarium workshop: The USF Co-PI (Franck) will host a herbarium workshop for interested members of the local community (e.g. students, working-class professionals) 2–4 times per semester (dependent on interest level), advertised through campus flyers, Facebook (i.e. Florida Botany Group III), and local chapters of the Florida Native Plant Society. During past herbarium invitations, about 10 members per native plant society chapter had attended, and there are three chapters local to the herbarium area. About 15 students have attended past invitations directed towards them. The workshop will be capped at 15, due to the space available within the herbarium. The morning session of this

workshop will be hosted at the USF Botanical Gardens (director, Laurie Walker) to cover plant diversity and methodologies of specimen collecting. The afternoon session will be hosted at the herbarium and begin with a tour of the herbarium, its purpose, and contents. We will then transition to the impact that these members of the community can have by assisting in the digitization process. The workshops would be ideally be held in May or December, when classes are not in session and the weather is tolerably comfortable. If interest exceeds expectations, up to 4 workshops may be held during the year. Up to 100 transcriptions may be achieved during the workshop itself, but the primary goal is to catalyze attendees to transcribe at home through NfN or become regular volunteers at the herbarium. Similar workshops have been given previously by the USF Co-PI, but this initiative will focus on the importance of digitization.

Mentoring Plan: The mentorship goals of this proposal are to give students meaningful experiences in the botanical sciences and help the students realize their own impact to science through their work at the herbarium. The accomplishment of these goals will be assessed for each workshop/semester with pre- and post-surveys in accordance with IRB standards to gauge comprehension, interest, and continued involvement. The ~750 BioTECH sophomores and ~50 USF undergraduates will specifically be expected to develop techniques in mounting and digitizing herbarium specimens, increase their knowledge of geography (GPS, county divisions, states of the SEUS), gain familiarity of herbarium practices (duplicates, type specimens), understand the purpose of plant classification and organization within a herbarium, gain awareness of herbarium databases, and improve their recognition of plant taxa and of plant parts. The USF Co-PI (Franck) always makes it a point to talk to the student digitizers about the significance of each plant taxon they work with, so that the students establish a connection and vested interest between the specimen and the real world. With several years of experience teaching Medical Botany and working on the Florida flora, the USF Co-PI is able to discuss with the students environmental or medicinal impacts for numerous SEUS taxa in the herbarium. The USF undergraduate assistant curator(s) will gain experience in presenting results of this project at scientific meetings (ASB, FNPS), networking with other plant researchers in the SEUS, and management skills in training of other undergraduates. The BioTECH sophomores will learn more about the spread of exotic taxa and the historic and current distribution of native plant taxa. Through mentorship with their BioTECH teachers, these students will have opportunities to present the results of the herbarium research to their classrooms and improve their presentation skills, and will be further encouraged to attend meetings of external organizations (e.g. Dade Chapter of the Florida Native Plant Society).

Under-represented groups at FTG and USF: Both FTG and USF recruit directly from their community, which both have large populations of under-represented groups that are strongly represented at each herbarium to engage and reflect these populations in our communities. During past and current digitization workflows with student volunteers at USF, most have been part of under-represented groups. Of the under-represented groups at the USF Tampa campus, the student diversity is 57% women, 12% black, and 21% Hispanic. During the 2015–2016 academic year, as part of a pilot workflow on digitization for this grant application, five volunteers were recruited for digitization of herbarium specimens at USF. Of the five volunteers for the 2015–2016 academic year at USF, 80% were from under-represented groups; one was a black Haitian male (Nicholas Fethiere), one a Hispanic Puerto Rican male (Victor Perez), and two Asian females (Zein Barakat, Samra Kazim). The digitization workflow for the fall 2016 semester at USF currently includes five undergraduate volunteers from under-represented groups: two black females (Jahnii Bell, Crystal WIliams) and three white females (Nicole Seiden, Shannon Lenhart, Amanda Shuttleworth). FTG draws heavily from the local community, with over ¾ of its 30 volunteers being female and having a large Hispanic representation. FTG's partnership with BioTECH High School will bring in a significant number of under-represented groups into the herbarium and botanical sciences. The demographics for under-represented groups at BioTECH are ~50% female, ~20% black, and Hispanic ~25%. As 250 BioTECH sophomores chose botany as their major, black and Hispanic students will have a high representation at FTG through the herbarium workshop programs.

Participants: Primary Investigators: The FTG curator (Co-PI, Jestrow) and USF herbarium director (Co-PI, Franck) are full-time employees who will directly train the assistant curator, students, and volunteers to image, transcribe, and participate in georeferencing. The curators have 15+ years of combined digitization experience, personally involved in >85% (150,000+ specimens) of the digitization efforts at each institution, and a combined 20+ years of experience in identifying vascular plants of the SEUS. The

Co-PIs have extensive database management experience, through projects such as the AFP and other Symbiota databases funded by previous NSF grants (bryophtyes s.l., lichens, fungi, and macroalgae). Both curators are greatly familiar with the temporal, geographic, and collector diversity of the specimens. The curators will verify the species identification and most up-to-date taxonomy.

Assistant Curator: This proposal requests funds to support a part-time assistant curator at USF to train and oversee the digitization efforts and maintain integration with FTG. At 15–20 hours per week over three years, the assistant curator will be essential in maintaining the digitization efforts and efficiency. Based on preliminary runs this past academic year (2015–2016) in training new students to transcribe, it takes ~10 hours of transcribing with oversight to enter consistent and accurate data across the diverse array of collectors and label formats. It is estimated together the director (Co-PI) and assistant curator will be able to oversee 15 student digitizers per week.

Students: USF will utilize undergraduate students to image and transcribe. USF (Tampa) has one of the largest student populations in the USA with about 30,000 undergraduate and 9,000 graduate students. With two imaging stations and an undergraduate assistant curator, we estimate at least 50 undergraduate students will be directly involved in the digitization effort over three years (nine semesters, 10–15 student transcribers and imagers per semester). The students will be recruited primarily from two courses: Plant Identification (EVR 4930) and Medical Botany (BOT 3850).

Volunteers: FTG will utilize its strong network of volunteers to transcribe and image. The FTG Herbarium averages 15–20 volunteers per week (30 per year), each averaging three hours per week, and most with over five years of experience at FTG. The volunteers are local residents and working-class professionals that are very active in the botanical community.

Citizen Scientists: Transcription efforts will also engage citizen scientists through Notes from Nature in order to maximize digitization efforts at FTG and USF who will also be locally solicited.

USF Water Institute: The USF Water Institute comprises many experts in information technology who are experienced and familiar with managing herbarium data and georeferencing natural phenomena. The USF Water Institute has developed and maintained USF's online herbarium technologies since their initial digitization efforts in 2003. FTG has had problematic discontinued outsourced IT support with differing information formats and file types, broken links, and occasional data loss. FTG will be transferring and entering all of their data into USF databases to create one unified information format and ensure data access and security through backed-up servers managed by USF.

USF Curator Emeritus: Retired curator emeritus B.F. Hansen will continue to devote a few hours per week actively transcribing newly mounted and accessioned specimens at USF, most from the SEUS.

SERNEC data manager: FTG and USF are in contact with Herrick Brown to ensure data standardization and efficient data transfer from USF servers to the Symbiota servers.

SERNEC advisor: FTG and USF have been working closely with Michael Denslow to review the workflow and ensure feasibility and completion of the project.

SERNEC state-level PI: Austin Mast, is the state-level PI for the Florida portion of SERNEC, and will be integral for consultation of WeDigBio events and transcription success through Notes from Nature.

SERNEC director: Zack Murrell is coordinating communication among all relevant SERNEC teams, including the potential members FTG and USF. Murrell will coordinate progress assessments of FTG and USF digitization efforts and meet with the Co-PIs at the Association of Southeastern Biologists annual meeting. FTG and USF have been in continuous contact with Murrell to optimize successful integration with SERNEC.

Travel: The Co-PIs will attend the Association of Southeastern Biologists' (ASB) meetings (held each year in late Mar/early Apr), the primary meeting for SERNEC participants where further networking increases coordination and effective streamlining of digitization procedures. The hired USF assistant curator will attend the Florida Native Plant Society meetings (held in late May each year), the primary meeting for Florida botany and herbaria, as well as the Association of Southeastern Biologists' (ASB) meeting to present summary results of this project in year 3. The Co-PIs will attend the iDigBio summit during the first year, which is also normally attended by the SERNEC TCN PIs (Z. Murrell & M. Denslow, pers. comm.)

Year-one metrics: With 45,000 FTG specimens already digitized from prior work and a target of 16,650 new transcriptions, FTG's goal is to upload 61,650 digitized specimens to iDigBio, the SERNEC portal, and GBIF during the first year, training 15 volunteers per year, each volunteer contributing ~45

transcriptions and images per week. FTG aims to have seven volunteers digitizing 315 specimens per week, and overall about 15 volunteers digitizing ~15,750 specimens per year. Each digitizer will have a goal of digitizing 45 specimens over 3 hours per week, or 15 per hour. Additionally, with the online interface and the ability of transcribers to work from home, FTG expects to be able to increase its number of volunteers and their hours to surpass its digitization goals.

USF will digitize 15,000–20,000 specimens the first year training 15–30 students per year. With 120,000 USF specimens already digitized and a target of 15,000 new transcriptions and images, USF will have 135,000 digitized specimens from the SEUS available in iDigBio, the SERNEC portal, and GBIF during the first year. With each student digitizing ~50 specimens per 3 hours per week, we estimate digitizing ~20,000 specimens from USF annually, which would exceed our annual goal. USF will handle the data sharing for FTG and USF and incorporate front-end and batch back-end georeferencing.

Year-two metrics: During year two, FTG will digitize 16,650 specimens and USF will digitize 15,000–20,000. FTG will then have a total of 78,300 and USF a total of 150,000 georeferenced specimens available in iDigBio, the SERNEC portal, and GBIF.

Year-three metrics: During year three, FTG will digitize 16,700 specimens and USF will digitize 15,000–20,000. FTG will then have a total of 95,000 and USF a total of 165,000 georeferenced specimens available in iDigBio, the SERNEC portal, and GBIF. We anticipate USF completing its SEUS dataset early (as digitization efforts are currently underway) and being able to transcribe FTG specimens in year 3 of the project.

Project Management Plan: The goal of this project is to image and transcribe 95,000 specimens, georeference 225,000 specimens, and make about 260,000 specimen images and data available in the SERNEC portal, iDigBio, and GBIF. Both FTG and USF have been digitizing since around 2003 and thus have continually optimized their workflow over time, generally following the recommendations of iDigBio (2013) and Nelson et al. (2015). We anticipate achieving the goals laid out in this proposal in three years. These goals are already being worked towards with the resources available at each herbarium. The funds in this proposal will significantly increase the rate and efficiency of achieving these goals in a timely manner. Both Co-PIs and herbaria personnel are deeply committed to the project. Digitization extends access to the herbarium, which the Co-PIs are always striving to increase to maintain an active, recognized, and supported herbarium.

During the prior fall 2015–spring 2016 academic year, USF utilized five undergraduate volunteers to digitize ~7,000 specimens (~20% of the SEUS (excluding FL) specimens at USF). USF has another five undergraduates currently digitizing for the fall 2016 semester. USF thus anticipates already having 15,000 of their SEUS specimens digitized by May 2016, based on current volunteer rates, which would put USF ahead of their digitization target rates. It is anticipated that USF-mediated volunteers will be able to switch to transcribing FTG material during project year 3. Hiring a half-time assistant curator will allow several more volunteers to be trained and managed, while the assistant curator will also be digitizing and the full-time director will maintain the same level of involvement. FTG does not have a transcription platform and is currently unable to transcribe label data; only internal imaging is done (not currently shared online).

TASK 1: predigitization curation and staging—Specimen identification and up-to-date taxonomy will be confirmed or corrected by the curators, following the Flora of North America (1993–2015), USDA (2016), Wunderlin et al. (2016), or other more recent taxonomic revisions.

TASK 2: specimen imaging—USF students will photograph specimens using a DSLR camera (e.g. Canon 5D) with a 50mm macro lens fixed in place onto a pole stand with a mounting bracket lighted by two strobe lights, one controlled by the camera and the other operating as a slave. Scale bars are placed onto each specimen ere imaging. A high f-stop (F14) is used to keep bulky specimens such as pine cones in focus with the sheet. The camera is connected to a PC and the image is immediately deposited there. The first specimen imaged each day is inspected to ensure proper framing and focusing; from then on inspection is done about every 100th specimen. A template on the copy stand allows the specimen to be placed perfectly within the camera frame to optimize efficiency. FTG volunteers will continue use of the Epson 11000XL scanner to digitize images. The volunteers are very experienced with this technology and have not had any problems with focus, lighting, or resolution for bulky specimens (based on researcher responses).

Because 165,000 specimens are already digitized at FTG and USF without barcodes, barcoding is not a planned component of this project as it would entail a costly burden with respect to the resources

and scope of this project. We are concerned that barcoding would be too costly to retrofit to these 165,000 specimens, re-image the specimen with the barcode, and add barcode metadata to the specimen. Barcoding the 165,000 specimens already digitized would also result in considerably more specimen damage upon handling. Both FTG and USF use local unique identifiers (accession numbers) and duplicate accession numbers are not allowed in USF's database. Our image handling system and transcription application are programmed to elicit errors/warnings by the PC when a duplicate accession number is detected. Images are named by their unique accession number and overwrites are forbidden. While barcodes can be advantageous for specimen tracking, especially loan processing, we can easily locate, compile, and export records that are already digitized and being sent out on loan. The standard protocol for FTG and USF is to digitize all loan requests before sending them out.

TASK 3: image processing—Students and volunteers will batch process images and rotate them with Adobe LightRoom. No cropping is done as the camera or scanner's field of view is setup to be tight around the standard specimen size (11.5" x 16.5") and only a black background shows around the border of specimens if there is a non-standard-sized specimen. Image files are named by the unique herbarium accession number, as has been done for the 165,000 previously digitized specimens. Duplicate file names and accession numbers are also prevented by elicited warnings during this stage. Location information on labels will be visually obscured from images of sensitive taxa (i.e. rare or endangered) based on the SERNEC list (http://sernecportal.org/portal/collections/misc/rarespecies.php).

TASK 4: specimen transcription—Metadata from labels will be transcribed by trained students and volunteers through a web application designed by the USF Water Institute and further developed by the USF Co-PI (Franck 2016: 46–50), modified from the Virtual Herbarium Express application developed by the New York Botanical Garden. Currently, transcription can only be done in-house through a desktop-installed virtual herbarium database that uses the Microsoft Access software program. The USF Water Institute will migrate the virtual herbarium online, using a Microsoft SQL database and a secure online forms-based front-end website in order to allow multiple users to transcribe specimen data from their own PCs. The online transcription application, database, and image files will be housed on the existing virtual servers managed by the University of South Florida, who provides secure, redundant, archived, virtualized information technology resources to support these technologies.

Transcribers will enter in these metadata: Continent, Country, State, County/Parish, Location, Habitat, Description, Collector(s), Date, Latitude and Longitude, Elevation, Accession Number, Family, Genus, Species, Authors, Rank, Infraspecies, Authors, Determiner, and Determination Date. Many of these metadata have recognition fields to ensure correct spelling and format. For example, usually only the first 3–6 letters are needed to find the correct entry for the collector field and only the first 1–3 letters for the county, state or country field. The following metadata have recognition fields: Country, State, County/Parish, Collector, Family, Genus, Species, Author, Rank, Infraspecies Author, and Determiner. Recognition fields will greatly improve data entry speed.

To increase transcription efficiency, citizen scientists through Notes from Nature will also be utilized to produce skeletal records for a portion of specimens for these fields: Country, State, County/Parish, Location, Habitat, Description, Collector(s), Date, and Scientific Name and then additional fields will be entered by students and volunteers, including (if present on the label): Latitude and Longitude, Elevation, Determiner, and Accession Number. The skeletal records can be used to identify duplicates in the SERNEC portal and copy the additional metadata fields associated to reduce processing times.

Each institution needs to transcribe and image ~50,000 specimens (Table 7) over three years. Our plan and goals per institution are thus: 64 transcriptions and images per weekday, 320 per week, 1400 per month, and 15,000–20,000 per year. Co-PIs will monitor weekly and monthly digitization rates and accommodate deficits by ramping up external efforts (e.g. more images uploaded for transcription to Notes from Nature). Both Co-PIs will be actively reviewing specimen data (and images) to catch and correct any errors and monitor progress.

TASK 5: georeferencing— Georeferencing specimen collection locations will utilize batch processing of existing digital records and incremental georeferencing at the time of new data entry. Georeferencers will utilize the web-based and standalone version of the GEOLocate tool developed for batch processing of specimen data (http://www.museum.tulane.edu/geolocate/). The USF Water Institute will integrate the web services version of the GEOLocate tool (which incorporates a radius or polygon of uncertainty) into the virtual herbarium data entry front-end developed for Task 4. In addition, Geographic Information Systems trained staff at the USF Water Institute will perform bulk georeferencing using

existing GIS software (e.g., ESRI ArcGIS). Matching collector numbers in the SERNEC database will allow for detection of duplicates that may already have been georeferenced, and then data can be copied to the duplicates at FTG or USF. About 13% of specimens already have latitude and longitude indicated on the label and need no georeferencing. About 99% of records have county/parish data and can easily be verified for accuracy of georeferencing. As we will incorporate front-end georeferencing during transcription and back-end bulk georeferencing of previously transcribed data, we anticipate no shortcomings in georeferencing our specimens. If our datasets are completely transcribed before the end of the project, we will divert resources to validating GPS points, e.g. by examining data maps to identify geographic outliers. The United States Geological Survey Geographic Names Information System (http://geonames.usgs.gov/pls/gnispublic/) and Google Earth will be utilized to assist students and volunteers to verify latitude and longitude.

TASK 6: data transfer and links— The USF Water Institute will transfer herbarium specimen metadata to iDigBio, SERNEC portal, and GBIF. Data transfer from USF is already active for iDigBio and GBIF. Images will be transferred to CyVerse (formerly iPlant) and will be duplicated at USF servers.

TASK 7: sustainability and assessment—The curators will keep data transferring active beyond the life of the project as new collections are accessioned and digitized. Both curators will maintain active students and volunteers to keep up with new collections from the SEUS beyond this project timeline. The long-term partnership between the herbaria of USF and FTG (who have been in continuous collaboration since the 1970s), and between the USF Herbarium and the USF Water Institute (in collaboration since the early 2000s) will ensure continued commitment to sharing herbarium data, as these resources are constantly used by the global community. Questionnaires to students and volunteers will contribute to optimization of workflow, assess their understanding of the process and the purpose, and improve the overall digitization experience. Coordination with the SERNEC TCN program director (Murrell) and the state-level PI (Mast) will allow intermittent assessment and advice on improving interest and efficiency. Use of an admin-login editing interface (currently implemented by the USF Water Institute for the USF Herbarium database) allows the curators to correct any errors seen while viewing database records in the long-term, which are then overwritten into iDigBio, SERNEC portal, and GBIF. Data use statistics in iDigBio are readily available (including information on searches, downloads, records browsed, records viewed, and media viewed) and those generated by data managers through SERNEC will be readily obtainable.

Digitization training module: A training module for digitization (developed by the USF Co-PI during the previous proposal submission in 2015) will quickly train students and volunteers and teach them the context, purpose, and scientific merit of the project (Franck 2016: 35–50). When workers understand the context and purpose, they are more likely to perform at a higher quality to satisfy the known purpose.

Transcription visual layout: This is a screenshot of the transcription window, with numbers identifying each field and detailed instructions on how to transcribe each field: Country, State, County/Parish, Location, Habitat, Description, Collector(s), Date, Latitude and Longitude, Elevation, Accession Number, Family, Genus, Species, Authors, Rank, Infraspecies, Authors, Determiner, and Determination Date.

Standardization: We seek to standardize the format of each field entered to optimize quality and downstream application. Collector name fields use the format first (and middle) initial(s) and surname. Labels without collection numbers use “s.n.” Location and habitat fields represent sentences ending in a period. Semi-colons are used to separate related statements. All metric measurements are abbreviated as km, m, etc. All US customary units are abbreviated mi., ft., in., and yds. All township, range, and sections are entered in this formatted order: T32S, R16E, Sec. 32, SE¼ of SW¼. All highways are entered thusly: I-75, US 41, FL 70, C-769. “Ca.” may be used for approximately. Counties and parishes are entered as Co. and Par. No other abbreviations are allowed.

Georeferencing: Students and volunteers will be trained on accurate georeferencing. They will be expected to know the ranges for latitude and longitude for the SEUS to reduce errors. The expected numbers for latitude must fall into the range of 24.6°N (Florida) to 40.6°N (West Virginia) and for latitude the range runs from 75.0°W (Maryland) to 94.6°W (Arkansas).

Digitization PEN: Integrating the herbaria of peninsular Florida, a biodiversity hotspot of endemism, rarity, and richness

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PROFESSIONAL PREPARATION

Hocking Technical College	Nelsonville, OH	Wildlife Management	A.A.S.	2002
Ohio University	Athens, OH	Wildlife Ecology	B.S.S.	2004
University of South Florida	Tampa, FL	Plant Systematics	Ph.D.	2012
University of South Florida	Tampa, FL	Floristics	Postdoctorate	2012–14

APPOINTMENTS

2016–	**Director & Curator**, Herbarium, University of South Florida.
2014–	**Instructor**, Medical Botany (5 sections), University of South Florida.
2014–2016	**Assistant Director & Curator**, Herbarium, University of South Florida.
2014	**Instructor**, Biology II - Biological Diversity (1 section), University of South Florida.
2013	**Instructor**, Evolution (2 sections), St. Leo University.
2013	**Instructor**, Ecology Lab (1 section), St. Leo University.
2009–2014	**Assistant Curator**, Herbarium, University of South Florida.
″	**Instructor**, Biology I - Cellular Processes (6 sections), University of South Florida.
2010	**Lecture Teaching Assistant**, Cell Biology (1 section), University of South Florida.
2008–2009	**Lecture Teaching Assistant**, Genetics (2 sections), University of South Florida.
2008	**Lab Teaching Assistant**, Microbiology (1 section), University of South Florida.
″	**Lab Teaching Assistant**, General Physiology (2 sections), University of South Florida.
2006–2012	**Lab Teaching Assistant**, Genetics (18 sections), University of South Florida.
2006	**Instructor**, Honors Summer Biomedical Science (grades 7–8), University of South Florida.
2005, 2008	**Lab Teaching Assistant**, Biology I (3 sections), University of South Florida.
2003–2004	**Ornithologist**, National Fire and Fire Surrogate Study, Ohio University.
″	**Research Technician**, Weevil predation on oak acorns, National Fire and Fire Surrogate Study, Ohio University.
2002	**Naturalist**, La Merced National Wildlife Refuge, Costa Rica.
″	**Field Biologist**, Oak mast production, National Fire and Fire Surrogate Study, Ohio State University.
″	**Tutor**, Winter Dendrology & Intro to Forestry, Hocking Technical College.

PRODUCTS: CLOSELY RELATED TO PROPOSED PROJECT

2017 Wunderlin, R.P., B.F. Hansen, & **A.R. Franck**. Flora of Florida, vol. 4. Dicotyledons, Combretaceae through Amaranthaceae. University Press of Florida, Gainesville. 400 pp. ISBN 13: 978-0-8130-6248-8 (http://upf.com/book.asp?id=WUNDE007). [In press]

2017 Overholt, W.A. & **A.R. Franck**. The invasive legacy of forage grass introductions into Florida. Natural Areas Journal: in press.

2016 Koeser, A., H.L. Finley, M. Friedman, **A.R. Franck**, G. Hasing, & J.A. Schelb. Trees: South Florida and the Keys. University of Florida/IFAS Communications Services, Gainesville. [In press]

2016 **Franck, A.R.**, L.C. Anderson, J.R. Burkhalter, & S. Dickman. Additions to the flora of Florida, USA (2010–2015). Journal of the Botanical Research Institute of Texas 10: 175–190.

2012 **Franck, A.R.** Guide to *Agave, Cinnamomum, Corymbia, Eucalyptus, Pandanus,* and *Sansevieria* in the flora of Florida. Phytoneuron 2012-102:1–23.

PRODUCTS: OTHER SIGNIFICANT PRODUCTS

in review **Franck, A.R.**, P.A. Lewis, A. Oberli, A. Haynes-Sutton, P.E. Rose, &, K.E. Campbell. The Jamaican endemic *Exostema orbiculatum* belongs in *Erithalis* (Rubiaceae). Phytotaxa.

in review **Franck, A.R.** Typification of *Illicium floridanum* and *I. parviflorum* (Schisandraceae). Rhodora.

2015 **Franck, A.R.** & T.F. Daniel. Taxonomic and nomenclatural notes on six genera of Acanthaceae in the West Indies. Proceedings of the California Academy of Sciences 62:309–329.

2013 **Franck, A.R.**, B.J. Cochrane, & J.R. Garey. Relationships and dispersal of Caribbean *Harrisia* inferred from AFLPs and seven gene regions. Taxon 62:486–497.

2013 **Franck, A.R.**, B.J. Cochrane, & J.R. Garey. Phylogeny, biogeography, and infrageneric classification of *Harrisia* (Cactaceae). Systematic Botany 38:210–223 [cover photo]. http://dx.doi.org/10.1600/036364413X662105

SYNERGISTIC ACTIVITIES

Co-author, major content editor & tutorial development *for* Wunderlin, R. P., B. F. Hansen, A.R. Franck, & F.B. Essig. Atlas of Florida Plants. [S. M. Landry and K. N. Campbell (application development), USF Water Institute.] Institute for Systematic Botany, University of South Florida, Tampa. http://florida.plantatlas.usf.edu/ [yearly average: ~100,000+ users, 200,000+ sessions (~ 5 min, 7 pgs/session), 1,600,000+ page views (50% bounce rate)]

Guest presentations (2011–2016) *for* 9 external local groups (Hillsborough County Conservation and Environmental Lands Management Department, Hillsborough County Master Gardeners, Florida Wildflower Foundation, Heartland Native Plant Society, Nature Coast Native Plant Society, Suncoast Native Plant Society, USF Library Science Program, USF Honors College, & USF Biology Club) *all concerning* Herbarium history, collecting, curation, digitization, & research.

Volunteer & plant ID expert *for* Invasive Plant Removal Day for outdoor environmental classroom at Terrace Community Middle School, Tampa, FL.

Curriculum development *for* Plant Identification and the Virtual Herbarium Lab. BioDiversity lab (BSC 2011L). University of South Florida, Tampa.

Primary author, contributor & content editor *for* Clarendon Parish Botanical Committee**.** Flora of the Clarendon Parish Region [Jamaica]. [S. M. Landry and K. N. Campbell (original application development), USF Water Institute.] Institute for Systematic Botany, University of South Florida, Tampa. http://jamaica.plantatlas.usf.edu/

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Alan Franck	Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Non-Native Species in the Atlas of Florida Vascular Plants Website Database

Source of Support: Florida Fish and Wildlife Conservation Commission
Total Award Amount: $ 29,920 Total Award Period Covered: 07/01/16 - 06/30/17
Location of Project: University of South Florida
Person-Months Per Year Committed to the Project. Cal: 0.60 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Cypress Creek Preserve Study

Source of Support: Hillsborough County (Florida)
Total Award Amount: $ 3,040 Total Award Period Covered: 07/01/16 - 01/27/18
Location of Project: University of South Florida
Person-Months Per Year Committed to the Project. Cal: 0.15 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Double Branch Botanical Documentation Study

Source of Support: Hillsborough County (Florida)
Total Award Amount: $ 2,000 Total Award Period Covered: 07/01/16 - 01/27/18
Location of Project: University of South Florida
Person-Months Per Year Committed to the Project. Cal: 0.15 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Digitization PEN: Integrating the herbaria of peninsular Florida, a biodiversity hotspot of endemism, rarity, and richness

Source of Support: National Science Foundation
Total Award Amount: $ 156,390 Total Award Period Covered: 06/01/17 - 06/01/20
Location of Project: University of South Florida
Person-Months Per Year Committed to the Project. Cal: 2.40 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Digitization PEN: Integrating the herbaria of peninsular Florida, a biodiversity hotspot of endemism, rarity, and richness

Facilities, Equipment and Other Resources:
The University of South Florida has the hardware and software resources needed for the development and management of the proposed front-end web application for transcription, metadata database, and image files. Specifically, server technology that supports the proposed metadata transcription application is used to support projects such as WaterAtlas.org, Water-CAT.org, PlantAtlas.org, tampatreemap.org, and others. All servers are housed in a virtual server farm managed by the USF Information Technology department. Virtual servers are supported by nightly backups to an off-site facility, a diesel generator to ensure continuous power, multiple T3 and other internet connections, and a trained staff who manage these resources. The server farm was tested during the 2004 Florida hurricane season when the WaterAtlas.org remained online to provide local emergency management agencies with access to near-realtime hydrologic and meteorological sensor data.

The FTG and USF herbaria are located in secured buildings with limited access and contains hundreds of steel cases to house, preserve, and protect the specimens that will be imaged and transcribed. These buildings will also house the imaging equipment needed to complete this project.

The USF Herbarium director is the Co-PI, Alan Franck. His time and effort towards digitization at the herbarium are regarded as a normal function of his appointment at USF (thus no funds are being requested for his salary).

Digitization PEN: Integrating the herbaria of peninsular Florida, a biodiversity hotspot of endemism, rarity, and richness

DATA MANAGEMENT PLAN

1. Data Collected, Formats, and Standards: Data from this project are derived directly from physical herbarium specimens collected from the 13-state SEUS region present at FTG and USF. Data comprise jpeg images and text metadata in a SQL database. With about 260,000 specimen images and their transcribed label data, we estimate about 375 GB of data. High-resolution, compressed jpegs (minimum 2912 x 4368 pixels, minimum 300 dpi, for 11.5 inch × 16.5 inch herbarium sheet) average 1.5 MB in size (375 GB total) and associated metadata comprises about 1 KB per specimen (0.25 GB total).

Metadata transcribed from labels are stored in two tables in a Microsoft SQL Server database management system, following Darwin Core metadata standards. Transcription data will be recorded through a login-based web portal, modified by the USF Water Institute from the Microsoft Access Virtual Herbarium Express software application originally developed by the New York Botanical Garden. One table contains all metadata except the scientific name (i.e. Country, State, County/Parish, Location, Habitat, Description, Collector(s), Date, Latitude and Longitude, Elevation, and Accession Number). Error warnings built-in to the Virtual Herbarium software occur for duplicate Accession Numbers, invalid Dates, and invalid Latitude and Longitude. These errors must be corrected immediately before allowing the user to save the record and advance to the next one. The other table contains all determinations/identifications which includes Family, Genus, Species, Authors, Rank, Infraspecies, Authors, Determiner, and Determination Date. This table allows for multiple scientific names (annotation history) found on some specimens to all be linked with the same specimen image. The presence of multiple scientific names on a specimen occasionally occurs when there are differing taxonomic concepts or misidentifications. Proper spelling of scientific names will be validated by cross-checking on TROPICOS, the International Plant Names Index, and The Plant List. One transcriber works on all specimens of one taxon to enhance familiarity and reduce spelling errors. Internal lists of recently transcribed specimens are also made available to allow curators to continuously check transcription quality and correct errors. A training module, developed by the USF Herbarium curator (Co-PI), ensures all data is entered using the same standards by all student and volunteer digitizers. With extensive experience in georeferencing, the USF Water Institute will perform the bulk of georeferencing to incorporate radii or polygons of uncertainty to allow for varying levels of accuracy to the actual historical (unknown) collection point. Locations that are rare or unique in the datasets and cannot be batch processed will be georeferenced by students and volunteers. Export of all metadata is allowed on the SERNEC Symbiota portal and USF herbarium database as comma separated value (CSV) file.

2. Physical and Cyber Facilities for Storage and Preservation: High-resolution images will be maintained in duplicate at 1) the CyVerse (formerly iPlant Collaborative) infrastructure and 2) the USF servers. A low-resolution triplicate image is also maintained by iDigBio. For the CyVerse infrastructure image storage, at least three copies of all data will be maintained and checksums will be generated and used to ensure the integrity of all data stored over the lifetime of the project. CyVerse provides replication through two active online copies (one at the Texas Advanced Computing Center at the University of Texas at Austin and one at the University of Arizona) and a tape copy housed in a separate data center at the Texas Advanced Computing Center.

The specimen metadata will be maintained in quadruplicate, with these four institutions: 1) iDigBio, 2) SERNEC portal MySQL database as hosted by Arizona State University, 3) USF servers in a Microsoft SQL Server database, and 4) GBIF. USF servers will store specimen metadata and images during and after the project. Data will be managed by the USF Water Institute, which has an agreement with the USF Information Technology Department to provide database, GIS, and web servers to support applications and technology as a component of the same virtual servers farm for all core USF applications and data. All USF servers are backed-up nightly to an off-site facility. A diesel generator ensures continuous power to the USF servers during potential power outages. USF servers have provided herbarium data online without any significant access problems since 2003 on the *Atlas of Florida Plants* (AFP).

3. Media and Data Dissemination: Both USF and SERNEC seek to make data publicly available immediately. This will be accomplished by an IPT to continually transfer data from FTG and USF directly

to iDigBio, the SERNEC Symbiota portal, and GBIF after data has been reviewed by herbarium curators to ensure standards are followed. Current protocols regularly ingest data from USF every ~2–3 weeks to iDigBio and GBIF. By the completion of this project, all digitized collections (including those outside the SEUS) from FTG and USF will be publicly available on the SERNEC Symbiota portal, iDigBio, and GBIF and will also be available on the specimen search database hosted on the AFP. To increase access to data, taxa-specific links will be provided on each species page at the AFP (with >100,000 users annually) to the SERNEC portal taxa page. The scientific name present on the AFP containing the genus, species and, potentially, infraspecies will be used to produce a link in this format: http://sernecportal.org/portal/taxa/index.php?taxon="Genus"%20"species"%20"rank".%20"infraspecies".

4. Data Sharing Policies and Public Access: No personal data will be shared as part of this project. As a publicly-funded project, no claim to copyright or database ownership will be made of aggregated data in the SERNEC TCN. Licensing follows CC BY-NC rights (Creative Commons Attribution Non-Commerical) requiring attribution and free non-commercial use including sharing and adapting the information for reuse. Location information of sensitive taxa (based on the SERNEC rare, threatened and sensitive species list) will be hidden from the public on iDigBio, SERENC, AFP, and GBIF but made available to herbarium curators and PIs through an administrator login system in SERNEC and the AFP.

5. Roles and Responsibilities of Personnel: The USF Water Institute will be responsible for the transcription application, the bulk of georeferencing, maintaining data, transferring data to iDigBio, the SERNEC Symbiota portal, and GBIF, and ensuring continual online accessibility of metadata and images hosted on USF servers. The Co-PIs (Franck & Jestrow) will be responsible for ensuring metadata follow specified standards and images are of high-quality (in-focus, properly orientated), and will be responsible for confirming or correcting the identification of the specimens.

6. Local Sustainability Plan: Both FTG and USF will continue digitizing all incoming SEUS specimens and continue sharing them with iDigBio, SERNEC, and GBIF beyond the life of this 3-year project. The USF Water Institute will maintain data transferring protocols beyond the scope of the project in order to continue enhancing the SERNEC dataset with new accessions added to the FTG and USF herbaria.

Digitization is now integral to herbarium management and specimen organization at both institutions. To maintain an organized herbarium, the protocol of FTG and USF is to digitize systematically, by geography and taxonomy. Once the SEUS specimens of FTG and USF are digitized, any new specimens from the SEUS will be immediately digitized to maintain organization in the herbarium beyond the life of this 3-year project. USF organizes its herbarium into Florida specimen folders and SEUS specimen folders. For example, once all of USF's Asteraceae from the SEUS are digitized, any newly accessioned SEUS Asteraceae are automatically digitized before filing. Similarly, FTG is organized by Florida folders and USA folders (very few specimens outside of Florida). Once a taxon-geographic folder unit is digitized, the protocol is to keep that folder unit digitized indefinitely.

Both FTG and USF will continually train multiple new volunteers to digitize in the herbarium, as has been done since digitization efforts first began in these institutions. This training will continue, regardless of available funding, to maintain digitization initiatives to seek digitization of the the complete herbarium specimen holdings, inherent goals of both herbaria.

Data access, sharing, and usage are central to the mission of each herbarium. FTG and USF continually seek to expand their purpose and broaden their utility to increase their valuation in the global community. FTG and USF will maintain a close partnership with the digitization community to sustain its data sharing with iDigBio, SERNEC, and GBIF to continue to be impactful beyond the life of this project. Networks with the Association of Southeastern Biologists, Society of Herbarium Curators, SERNEC, and iDigBio will enable us to develop collaborative long-term solutions for maintenance, access, and continued digitization of our herbarium data.

FTG and USF are tightly integrated with local community environmental organizations, such as native plant societies, water management districts, and county, state, and federal park districts. The majority of the feedback from these communities refer to the utility of digitized specimens. Digitization will remain as core objectives to both institutions, as we both service to the local community. These organizations will be sought for continued funding to maintain online transcription tools, imaging, and data management, in order to maintain public access to our increasingly digitized collections.