THE ROLE OF BOTANICAL GARDENS IN THE CONSERVATION OF ORCHID BIOCULTURAL DIVERSITY IN SICHUAN PROVINCE, CHINA

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAI`I AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

BOTANY

August 2017

By

Barnabas C. Seyler

Dissertation Committee:

David C. Duffy, Chairperson
Orou G. Gaoue
Ya Tang
Tamara Ticktin
Teresita D. Amore

To my parents:
Your love and support has allowed me to reach heights I would have never imagined.

明薛网 《兰花》
Orchids by Xuewang Ming

我爱幽兰异众芳，不将颜色媚春阳。
西风寒露深林下，任是无人也自香。

I love the unique orchid, whose color never flatters the sunshine.
Growing in a secluded forest chilled by the western wind,
emitting its fragrance without ever being noticed.

To the Ernest K.F. Lum family:
Without you, my Hawai`i family, I would not have finished this difficult journey.

Ecclesiastes 4:12 (NIV)
Though one may be overpowered, two can defend themselves. A cord of three strands is not quickly broken.

To my brother from another mother, Adam:
Friends don’t use “谢谢”, so onward to many more epic adventures it is!

ACKNOWLEDGMENTS

I would like to first thank each of my dissertation committee members for their tremendous guidance, encouragement, and support over these last five-plus years. From introducing me to ethnobotanical theories and methods (Gaoue & Ticktin), to suggesting field locations and professional contacts (Tang & Amore), aid in statistical analysis (Gaoue), and providing tremendous advice (all) and financial support (Duffy & Tang), I will forever remember this time with gratitude to each of you. Thank you, 非常感谢, salamat po!

This project would also not have been possible without the tremendous help of five very talented and hard-working field assistants: Ercong Aba, Kede Ayu, Erha Abi, Hongfang Qisha, and Xuan Liang. Thanks also to Professor Jing Wang from Chengdu University who mentored two of these students and provided the initial connection. Mr. Shidu Liu, President of the Huili County Orchid Society provided tremendous aid with the selection and identification of the orchid taxa used in this project and first introduced me to orchid culture (兰花文化). Mr. Weihong Guo at the Orchid Exhibition Center of China (Chengdu), Mr. Tingfu Yang of the Puge Forestry Bureau, and Mr. Zhengyang Su each provided contacts and logistical assistance. Thanks also to the incredible communities of Puge and Huili Counties for their graciousness in cooperating with the demands of this study. To the management and staff of the six botanical garden case studies who welcomed me into their lives and helped me better appreciate their hard work of research, conservation, and public education: I am appreciative beyond words. Funding was partially covered by the US National Science Foundation (Award #1514945), the Ministry of Science and Technology of China, China Science and Technology Exchange Center, the East-West Center, as well as the Department of Botany, the Graduate Student Organization, and the Pacific Cooperative Studies Unit at the University of Hawai`i at Mānoa.

Thanks also to several truly inspirational people whose lives and careers have continued to motivate me: Dr. Shengji Pei, the ‘Father of Ethnobotany’ in China, whose example first charted a course for me to follow through SW China and Hawai`i; Bill McNamara, President and Executive Director of Quarryhill Botanical Garden, who encouraged me to pursue my investigation of China’s incredible flora and who first introduced me to Sichuan; Dr. Peter

Raven, President Emeritus of the Missouri Botanical Garden, who was never “too busy” to talk with me and graciously answer my many questions; Paul Meyer, The F. Otto Haas Executive Director of the Morris Arboretum of the University of Pennsylvania, and Paul Redman, President and CEO of Longwood Gardens, who helped me truly understand what public garden directors should be; and Dr. Chung-min Maria Tu (杜老师), Assistant Professor of Chinese at the University of Delaware, who first taught me the incredible beauty of the Chinese language and culture.

ABSTRACT

The orchid species richness of Sichuan Province is second highest in China, but price speculation and overharvest have led to significant population collapses in recent years. Though the integral link between biological and cultural diversity is well documented, understanding of the cultural impact of biological extinction events is limited. This dissertation tested the hypothesis that the loss of biodiversity results in an associated loss of cultural knowledge in relation to the orchid biocultural diversity in Sichuan. It was divided into four parts. 1) A knowledge survey to test the relationship between orchid biodiversity decline and cultural knowledge loss on four different orchid knowledge types in eight villages in rural Sichuan. 2) A complementary knowledge survey to test how the impacts of urbanization on people's orchid knowledge differed based on knowledge type, with interviews conducted in three jurisdictions in Sichuan with differing levels of urbanization. 3) A social network analysis of the same 8 villages from part 1, tested how an individual's social position within a community and a network's overall structure might mitigate the loss of knowledge resulting from local species extinction. 4) An in-depth literature review and case study analysis of six key Chinese botanical gardens to identify which model(s) are most effective at orchid biocultural diversity conservation. Results revealed species extinction drives significant cultural knowledge loss, across all types of knowledge. Social network structure and rural proximity to natural areas are not sufficient by themselves to preserve a community's knowledge following species extinction. Comprehensive botanical gardens are uniquely positioned to effectively maintain *ex situ* collections of threatened plant species and cultural knowledge, manage *in situ* populations, work to restore natural ecosystems, and reintroduce species back into the wild and traditional knowledge back into local communities. However, the current botanical garden institutional capacity within Sichuan is inadequate to address these conservation goals, with the need for three to five new BG in the province. These findings help advance our understanding of how biodiversity loss affects cultural knowledge loss, with implications for biocultural diversity conservation more generally.

TABLE OF CONTENTS

ACKNOWLEDGMENTS iv
ABSTRACT vi
LIST OF TABLES xi
LIST OF FIGURES xiv
LIST OF ABBREVIATIONS xvi
CHAPTER 1: INTRODUCTION 1
CHAPTER 2: ORCHID BIODIVERSITY DECLINE DRIVES THE LOSS OF ETHNOBOTANICAL KNOWLEDGE IN SICHUAN PROVINCE, CHINA 5
2.1. Introduction 5
2.2. Methodology 8
2.2.1. Study system 8
2.2.2. Village-level selection 10
2.2.3. Individual-level selection: age, sex, ethnicity, education, and activity level 11
2.2.4. Orchid selection: rarity and economic valuation 12
2.2.5. Interview process 12
2.2.6. Response verification 14
2.2.7. Data analysis 14
2.3. Results 16
2.3.1. Effect of rarity and species extinction 17
2.3.2. Effect of socio-demographic variables 19
2.4. Discussion 24
2.4.1. Orchid knowledge, species rarity, and economic valuation 24
2.4.2. Role of knowledge type 26
2.4.3. Other socio-demographic attributes 26
2.4.3.1. Sex 27
2.4.3.2. Age 27
2.4.3.3. Education and orchid activity levels 29
2.5. Conclusion 30
CHAPTER 3: MODERATE URBANIZATION PROMOTES ORCHID KNOWLEDGE AS ORCHID POPULATIONS DECLINE IN SICHUAN, CHINA 31
3.1. Introduction 31

3.2. Methodology 34
3.2.1. Study area........ 34
3.2.2. Participant selection 36
3.2.3. Interview process 37
3.2.4. Response verification 38
3.2.5. Data analysis 39
3.3. Results........ 40
3.4. Discussion 44
3.5. Conclusion 48
CHAPTER 4: SOCIAL NETWORK STRUCTURE DOES NOT MITIGATE CULTURAL KNOWLEDGE LOSS FROM ORCHID POPULATION DECLINE IN SICHUAN, CHINA 50
4.1. Introduction........ 50
4.1.1. Actor centrality 51
4.1.2. Homophily 52
4.1.3. Brokers and network bridges 52
4.2. Methodology 54
4.2.1. Study system 54
4.2.2. Preliminary study 54
4.2.3. Social network data collection 55
4.2.4. Data analysis 56
4.3. Results........ 58
4.3.1. Han villages with significant orchid activity 58
4.3.2. Han villages without significant orchid activity 59
4.3.3. Yi villages with significant orchid activity 61
4.3.4. Yi villages without significant orchid activity 62
4.3.5. Effect of network structure on knowledge distribution........ 63
4.4. Discussion 64
4.5. Conclusion 66
CHAPTER 5: THE EFFECTIVENESS OF BOTANICAL GARDENS AT PROMOTING ORCHID BIOCULTURAL DIVERSITY CONSERVATION 67
5.1. Introduction........ 67
5.2. Methodology 68
5.2.1. Literature Review........ 68
5.2.2. Case Studies 69

5.3. Results 71
5.3.1. Literature Review 71
5.3.1.1. Biocultural Diversity Conservation and Sustainable Development 73
5.3.1.2. Chinese Botanical Gardens 74
5.3.1.3. Criticisms of Botanical Gardens 74
5.3.1.4. On Establishing New Botanical Gardens 80
5.3.1.5. A Rubric for Comprehensive Botanical Gardens 80
5.3.2. Insights from Case Studies 82
5.3.2.1. Orchid Conservation 82
5.3.2.2. On Ethnobotany 85
5.3.2.3. Need for New BG 86
5.3.2.4. Definition of Botanical Garden 87
5.3.2.5. Domestic & International Collaboration 88
5.3.2.6. Balancing Scientific Mission 90
5.3.2.7. Urban Versus Rural Location 90
5.4. Discussion 91
5.5. Conclusion 93
CHAPTER 6: CONCLUSION 94
APPENDIX A: SUPPLEMENTAL TABLES 97
APPENDIX B: SUPPLEMENTAL FIGURES 108
APPENDIX C: DESCRIPTIONS OF CHINESE BOTANICAL GARDEN CASE STUDIES 111
6.2. Sichuan Case Studies 111
6.2.1. Chengdu Botanical Garden 111
6.2.2. Emei Mountain Botanical Garden 112
6.2.3. West China Subalpine Botanical Garden 114
6.3. Non-Sichuan Case Studies 115
6.3.1. Kunming Botanical Garden 115
6.3.2. Shanghai Chen Shan Botanical Garden 118
6.3.3. Xishuangbanna Tropical Botanical Garden 121
BIBLIOGRAPHY 125

LIST OF TABLES

Table 2-1: Village units and relevant variables. Population present at time of interviews is given with total in parentheses. Bolded items indicate which villages reach the minimum threshold necessary in each village-level selection criteria: ethnicity (⩾80% target) and orchid activity level (⩾10% of village population). An asterisk* indicates that the number is an estimate. 11

Table 2-2: Identification and economic value of 9 naturally occurring Cymbidium taxa used for photographic cue cards. Rarity code refers to: (CR) formerly common but now locally rare, (CE) formerly common but now locally extinct, (RE) formerly rare but now locally extinct. 13

Table 3-1: Identification and economic value of 9 naturally occurring Cymbidium taxa used for photographic cue cards. Rarity code refers to: (CR) formerly common but now locally rare, (CE) formerly common but now locally extinct, (RE) formerly rare but now locally extinct. 37

Table 3-2: GLMMs coefficients for the effects of urbanization on each domain of orchid knowledge. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1. 40

Table 4-1: Villages in Puge and relevant variables. The population present at time of interviews (including ineligible individuals) is given with total given in parentheses. Bolded items indicate which villages fall within the minimum threshold necessary for each village-level selection criteria: ethnicity (⩾80% target) and active orchid activity (⩾10% of village population). SNA Contacts refers to how many actors were included in our SNA analyses at each village (⩾80% of those eligible). An asterisk* indicates that the number is an estimate. 55

Table 4-2: SNA interview questions used to gauge social network ties/guanxi of each contact per village. 56

Table 5-1: Chinese Botanical Garden Case Studies. Weibo is a social network platform widely used in China that is similar to Twitter; Weixin is a social network platform more like Facebook. An asterisk (*) indicates numbers listed in thousands. 70

Table 5-2: Total number of arboreta worldwide that are accredited by the Morton ArbNet Arboretum Accreditation Program, listed according to accreditation tier (Tier IV being the most rigorous level). These 185 institutions contrasts with the >1100 arboreta listed on the Morton Register of Arboreta. 79

Table 5-3: Rubric analysis of six Chinese botanical garden case studies. 83

Table A-1: [Chapter 2 & 3] Interview questions used to gauge local knowledge of each orchid taxon. 97

Table A-2: [Chapter 2] Global GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on global orchid knowledge. Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 98

Table A-3: [Chapter 2] GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on the ability to correctly identify the orchid taxa (plant ID). Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 99

Table A-4: [Chapter 2] LEK GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on local ecological knowledge. Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 100

Table A-5: [Chapter 2] BMK GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on business/market knowledge. Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 101

Table A-6: [Chapter 2] OCK GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on orchid cultural knowledge. Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 102

Table A-7: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on mean orchid knowledge distribution (with Puge 6 excluded due to lack of variability). Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1 103

Table A-8: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of actor-level centrality measures on mean orchid knowledge distribution (with Puge 6 and Puge 7 excluded due to lack of variability). Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1 103

Table A-9: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on distribution of knowledge for formerly common but now rare (CR) orchids (with Puge 6 excluded due to lack of variability). Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 104

Table A-10: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on distribution of knowledge for formerly common but now locally extinct (CE) orchids (with Puge 6 excluded due to lack of variability). Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 104

Table A-11: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on distribution of knowledge for formerly rare but now locally extinct (RE) orchids (with Puge 6 excluded due to lack of variability). Significance codes: ‘***’ <0.001, ‘**’ <0.01, ‘*’ <0.05, ‘.’ <0.1, n.s. >0.1. 104

Table A-12: [Chapter 5] Questions for BG Case Studies. 105

Table A-13: [Chapter 5] Objectives & Targets of the Global Strategy for Plant Conservation (2011-2020). 106

Table A-14: [Chapter 5] Rubric for Comprehensive Botanical Gardens. 107

LIST OF FIGURES

Figure 2.1: Map of Puge County. A. Liangshan Yi Autonomous Prefecture (dark gray) located within Sichuan Province (light gray), China (white). B. Puge County (dark gray) within Liangshan Prefecture (light gray). 9

Figure 2.2: Effect of rarity on type of knowledge. Significance level p<0.001, except for (B) p<0.05. 18

Figure 2.3: Effect of socio-demographic variables on global knowledge. Significance levels: (A) and (D) p<0.05, (E) p<0.001 19

Figure 2.4: Effect of age on specific knowledge type. Significance level p<0.05, except for (D) p<0.01. 20

Figure 2.5: Effect of gender on specific knowledge type. All contrasts are not significant. 21

Figure 2.6: Effect of ethnicity on specific knowledge type. Significance level p<0.001, except for (B) which is not significant. 22

Figure 2.7: Effect of education on specific knowledge type. Significance levels: (A) and (B) not significant; (C) p<0.05; (D) all contrasts significant at p<0.001, except 'b' p<0.01 23

Figure 2.8: Effect of orchid activity on specific knowledge type. Significance level p<0.001 24

Figure 3.1 A. Location of Sichuan Province (dark gray) within China. B. Research site locations (dark gray), 1) High urbanization (Chengdu City) in central Sichuan; 2) Medium urbanization (Huili County) and 3) Low urbanization (Puge County), located within Liangshan Yi Autonomous Prefecture (light gray) in southwest Sichuan Province. 35

Figure 3.2: Correlation between global orchid knowledge score and each specific knowledge score (as proportions of maximum possible scores). Plant ID (Blue), local ecological knowledge (Red), business/market knowledge (Purple), and orchid cultural knowledge (Green). 39

Figure 3.3: Effect of urbanization on type of knowledge. Significance levels: (A), (B), (D), and (E) p<0.001; (C) 'b' p<0.001, 'c' p<0.05. 41

Figure 4.1: Homophily by actor attribute. Negative scores indicate the presence of homophily (perfect homophily = -1) and positive scores indicate the absence of homophily (non-homophily = 1). 64

Figure B-1: [Chapter 2] Correlation between classical knowledge score analysis (summing the scores across individual questions) and principal component analysis (PCA). r >0.9; Significance level: "***" = p<0.001. 108

Figure B-2: [Chapter 2] Pairwise Spearman correlation between ability to correctly identify the plant (PlantID), global knowledge (GlobalK), local ecological knowledge (LEK), business/market knowledge (BMK), and traditional Han orchid cultural knowledge (OCK). Significance levels: "***" = p<0.001, "**" = p<0.01, "*" = p<0.05, and "ns" =not significant. 109

Figure B-3: [Chapter 3] Pairwise Spearman correlation between ability to correctly identify the plant (PlantID), global knowledge (GlobalK), local ecological knowledge (LEK), business/market knowledge (BMK), and traditional orchid cultural knowledge (OCK). Significance level: "***" = p<0.001........ 110

LIST OF ABBREVIATIONS

AIC –Akaike Information Criterion

APGA –American Public Gardens Association <https://publicgardens.org/>

BBG –Beijing Botanical Garden, IOB, CAS (中国科学院植物研究所北京植物园) <http://garden.ibcas.ac.cn/>

BG –Botanic(al) Garden(s)

BGCI –Botanic Gardens Conservation International <https://www.bgci.org/>

BMK –Business/Market Knowledge

CAS –Chinese Academy of Sciences

CBD –UN Convention on Biological Diversity

CBG –Chengdu Botanical Garden <http://www.cdzwy.com/>

CBIK –Center for Biodiversity and Indigenous Knowledge (云南省生物多样性和传统知识研究会) <http://www.cbik.org/>

CE –*Cymbidium* species that were formerly common, but now locally extinct

CITES –Convention on International Trade in Endangered Species of Wild Fauna and Flora

CR –*Cymbidium* species that were formerly common, but now locally rare

CSBG –Shanghai Chenshan Botanical Garden (上海辰山植物园) <http://www.csnbgsh.cn/>

CUBG –Chinese Union of Botanical Gardens (中国植物园联盟) <http://www.cubg.cn/>

EBG –Emei Mountain Botanical Garden (峨眉山植物园)

ERA –Ecological Restoration Alliance of Botanic Gardens <http://www.erabg.org>

GK –Global Knowledge; referring to collective knowledge score for all knowledge types

GLMMs –Generalized Linear Mixed Effect Model

GSPC –Global Strategy for Plant Conservation

Int'l Agenda –International Agenda for Botanic Gardens in Conservation (2nd Edition) <https://www.bgci.org/policy/international_agenda/>

IOB –Institute of Botany, CAS, Beijing (中国科学院植物研究所) <http://ib.cas.cn/>

IPM –Integrated Pest Management

IUCN –International Union for the Conservation of Nature

KBG –Kunming Botanical Garden (昆明植物园) <http://kbg.kib.cas.cn/>

KIB –Kunming Institute of Botany, CAS (中科院昆明植物研究所) <http://www.kib.cas.cn/>

LABG –Lijiang Alpine Botanical Garden, KIB (丽江高山植物园)

LEK –Local Ecological Knowledge

Liangshan –Liangshan Yi Autonomous Prefecture, Sichuan (凉山彝族自治州)

OCK –Orchid Cultural Knowledge

PCA –Principal Component Analysis

PSESP –Plant Species of Extremely Small Populations

RBGE –Royal Botanic Garden Edinburgh <http://www.rbge.org.uk/>

RE –*Cymbidium* species that were formerly rare, but now locally extinct

SBG –Shanghai Botanical Garden (上海植物园) <http://www.shbg.org/>

SNA –Social Network Analysis/Analyses

UN –United Nations

USFWS –United States Fish and Wildlife Service <https://www.fws.gov/>

WCBG –West China Subalpine Botanical Garden (华西亚高山植物园) <http://eco.ibcas.ac.cn/huaxi/>

WWF –World Wide Fund for Nature

Xishuangbanna –Xishuangbanna Dai Autonomous Prefecture, Yunnan (西双版纳傣族自治州)

XTBG –Xishuangbanna Tropical Botanical Garden, CAS (中国科学院西双版纳热带植物园) <http://www.xtbg.cas.cn/>

CHAPTER 1: INTRODUCTION

The Chinese people have long attributed great cultural significance to *Cymbidium* (*lánhuā* or 兰花). This is particularly the case with the Han-majority ethnicity (汉族), but also true of several ethnic minorities such as the Bai (白族), Manchu (满族), and Hui (回族). Confucius (551-479 BC) reportedly stated that the "acquaintance with good men was like entering a room full of fragrant orchids" (Teoh 2005), and he personified *Cymbidium* as the "king of all fragrances" (Chen and Tang 1982; Goody 1993; Du Puy and Cribb 2007). Although many scholars today dispute whether the Chinese word used by Confucius was intended to refer to a plant in Orchidaceae or more likely a fragrant member of Asteraceae, Confucius' unparalleled influence and many sayings historically attributed to *Cymbidium* has greatly contributed towards what has become known as "orchid culture" ('*lánhuā wénhuà'* or '兰花文化' in Chinese), which refers to a veneration of *Cymbidium* in all Chinese art forms, depicting them in classical paintings, calligraphy, pottery, architecture, musical compositions, and poetry (Chen and Luo 2003; Du Puy and Cribb 2007; Liu et al. 2014).

Many orchids, including several *Cymbidium* species, have long been used in traditional Chinese medicine (Luo et al. 2003; Du Puy and Cribb 2007; Perner and Luo 2007; Liu et al. 2010; Seaton et al. 2013; Liu et al. 2014), with references in the ancient Chinese classic *Compendium of Materia Medica* (*Běncǎo Gāngmù* or 本草纲目) (Bretschneider 1882; Bretschneider 1895; Bensky et al. 1993). Orchids were also referenced in the *Book of Songs* (*Shījīng* or 诗经) and the *Book of Rites* (*Lǐjì* or 礼记), two of the "Five Classics" of ancient Chinese scholarly literature. *Cymbidium* cultivation (horticulture) became a popular pastime for scholars and the gentry during the Song Dynasty (960-1279 A.D.), and *Cymbidium* came to allegorize the gentry scholar: "unassuming, enduring, chaste, and ascetic," as well as the ideals of love and beauty, standing for "grace, refinement, fragrance and all things considered noble and elegant in a woman" (Teoh 2005). *Cymbidium* (representing spring), together with plum blossom (*Prunus mume*, winter), bamboo (summer), and *Chrysanthemum* (autumn), depict the four seasons in Chinese artistic expressions. Known as the "Four Gentlemen" of plants (四君子), and collectively referred to as *méi lán zhú jú* (梅兰竹菊), they assumed the pinnacle of reverence in Chinese culture, and came to represent, more generally, the cyclical nature of life (Goody 1993). Consequently, the diverse uses, material culture, oral and literary traditions, and medicinal applications of numerous *Cymbidium* species throughout Chinese history is a source of great pride and cultural identity for many Chinese (Hew 2001; Teoh 2005; Du Puy and Cribb 2007).

Botanically, the immense diversity of orchids in China is well documented (Li and Li 1997; Luo et al. 2003; Perner and Luo 2007; Chen et al. 2009b; Xu et al. 2010; Zhang et al. 2015; Zhou et al. 2016). Globally, the greatest diversity of *Cymbidium* species is found from the eastern Himalayas into China, and though *Cymbidium* has a large range across southern China, the focus of many distributions lies in Southwest China, including Sichuan Province (Du Puy and Cribb 2007; Chen et al. 2009b; Zhou et al. 2016). Economically-driven overcollection pressures resulting from their pharmaceutical potential, rarity, fragrance, and beauty, as well as habitat loss, continue to risk the extinction of many Chinese *Cymbidium* species (Du Puy and Cribb 2007; Seaton et al. 2013; Liu et al. 2014; Zhang et al. 2015). Du Puy and Cribb (2007) note that orchid dealers regularly visit local villages in southwest China with offers to buy hundreds of kilograms of wild-collected *Cymbidium*. Since these dealers are not concerned with typical specimens but are searching for rare mutations, "such as variegated and peloric forms, that can fetch high prices" among collectors, the more typical forms "are discarded or sold in the marketplace for low prices" (Du Puy and Cribb 2007). The species most often targeted are *Cymbidium ensifolium* (建兰), *C. faberi* (惠兰), *C. goeringii* (春兰), *C. kanran* (寒兰), *C. floribundum* (多花兰), *C. sinense* (墨兰), and *C. tortisepalum* (莲瓣兰), depending on the region of China, but all of these species' native ranges include Sichuan Province (Du Puy and Cribb 2007; Zhou et al. 2016). The collecting pressure is so severe that newly discovered species such as *C. wenshanense* (文山红柱兰) and *C. nanulum* (珍珠兰) in Southwest China's Yunnan Province were nearly extirpated from the wild shortly after they were first described (Du Puy and Cribb 2007).

This project's preliminary fieldwork in Sichuan (summer 2013) included interviews with orchid experts, merchants, collectors, government officials, farmers, and other local people throughout the province. These conversations revealed that the price for Chinese *Cymbidium* grew exponentially between the 1980s and early 2000s, greatly contributing to the unsustainable overharvest of wild populations. Initially, the price boom was due to foreign orchid speculators, but a growing domestic demand fueled the continued wild harvest and trade even after foreign export was banned. Collectors in the city of Huili (会理) explained that one wild-collected natural mutation of *C. tortisepalum* (known as '*Jīnshā shùjú*' or '金沙树菊' in Chinese) sold for more than ¥4.6 million Chinese RMB (approximately US$800,000). At the height of the market (2006-2008), just one Huili collector's personal orchid collection was valued at >¥80 million RMB (~US$13 million). At each stage of the market chain (harvesters, middlemen, merchants, and collectors), people became wealthy, further fueling overharvest.

This widespread wild-collection and trade of *Cymbidium* positively impacted the livelihoods of many communities across Sichuan, but the unsustainable overharvest greatly threatened the long-term survival of many species. Due to their understanding of the natural habitats, throughout the province, rural villagers went out daily to collect wild orchids from the mountains and plant them in their fields, with the hope that they could be sold for high prices. Even common orchid species were indiscriminately wild-collected in hopes of discovering a valuable oddity. Yet almost all wild-collected orchids were never purchased, and, due to the value of land to impoverished sustenance farmers, tens of thousands of individual collections were plowed under or otherwise discarded. This phenomenon greatly contributed to steep population declines and local extinction of even formerly common and commercially less valuable orchid species. More recently, *Dendrobium* species have faced similar threats. The lure offered to possibly "strike it rich" through the collection of wild *Cymbidium*, *Dendrobium*, and other orchid species continues to pose a major threat to orchid conservation in China.

Many of the elderly interviewees, particularly those who were experts in "orchid culture" expressed concern for the implications of wild *Cymbidium* population decline on traditional culture. They described how when they were young children, they had been taken to the mountains by elderly family members who taught them about orchids when they were in flower. It was these encounters that first inspired them to begin learning the long, complex history and lore of orchid culture. They feared that since there are now fewer and fewer orchids in the wild, and they can no longer take young people to the mountains to see orchids in flower, there are no longer any opportunities to encourage inspiration among the youth to learn orchid culture.

Though the rapid decline in Chinese *Cymbidium* populations is widely recognized, little attention has been paid to formally documenting the implications of their loss, particularly in relation to the cultural persistence of orchid cultural knowledge as the nation becomes increasingly urbanized and detached from its traditional rural way of life. If, for example, declining wild orchid populations does negatively impact the promulgation of China's traditional orchid culture due to decreasing opportunities to "inspire" young people, the loss of wild *Cymbidium* populations would prove to be both an ecological and cultural problem. Thus, the first component of this study (chapter 2) seeks to investigate what impact orchid species decline has on the prevalence of local orchid cultural knowledge. Chapter 3 tests what relationship increasing urbanization may have on this relationship between species decline and knowledge loss. Chapter 4 focuses on testing the effect that a community's social network structure may have in mitigating against the loss of cultural knowledge related to species decline. Finally, chapter 5 investigates the effectiveness of botanical gardens at conserving both orchid species germplasm and cultural knowledge.

CHAPTER 2:
ORCHID BIODIVERSITY DECLINE DRIVES THE LOSS OF ETHNOBOTANICAL KNOWLEDGE IN SICHUAN PROVINCE, CHINA

2.1. Introduction

Scholarship in the natural and social sciences have recently focused much attention documenting the strong spatial correlations between biological, ethnic, and linguistic diversities, collectively termed *biocultural diversity*, as well as the common factors threatening their survival (Moore et al. 2002; Sutherland 2003; Stepp et al. 2004; Loh and Harmon 2005; Maffi 2005). Loh and Harmon (2005) define biocultural diversity to include all levels of biological diversity, "from genes to populations to species to ecosystems," and all manifestations of cultural and linguistic diversity "ranging from individual ideas to entire cultures," as well as all the complex interactions between them. The high correlations between these various types of diversity have been documented on the global level (Sutherland 2003; Stepp et al. 2004; Loh and Harmon 2005; Maffi 2005), in the Americas (Wilcox and Duin 1994; Lizarralde 2001; Smith 2001), Africa (Moore et al. 2002; Cocks and Wiersum 2014), Asia (Hakkenberg 2008; Shen et al. 2012), and Oceania (Mühlhäusler 2001; McMillen et al. 2014). However, beyond simply documenting the correlation of coterminous geography/spatial overlap, it is important to develop a more integrative, interdisciplinary investigation of how changes in each type of diversity impact the others (Loh and Harmon 2005; Maffi 2005; Pretty et al. 2009). This requires greater "theoretical and empirical work to resolve" the complicated issues driving cultural evolution and global biocultural diversity loss (Smith 2001; Loh and Harmon 2005) on differing cultural and spatial scales (Smith 2001; Pretty et al. 2009; Cocks and Wiersum 2014; McMillen et al. 2014).

Languages and cultures have coevolved with the biotic and abiotic environments in which they developed (Mishler 2001; Smith 2001; Maffi 2004 & 2005; Loh and Harmon 2005). Smith (2001) defines culture as "*socially transmitted information*, where 'information' refers to beliefs, values, knowledge, and the like," and by emphasizing social transmission, this definition "emphasizes that culture is a system of inheritance and distinguishes culture from genetic inheritance. This last point implies that culture, like genetic information, is subject to evolutionary change (through drift, natural selection, and possibly other means)." Thus, the loss of linguistic and cultural knowledge, like the loss of biological diversity, can lead to an overall loss of resilience in terms of community sustainability, public health, and economic vitality, especially in light of global climate change (Carlson 2001; Mishler 2001; Maffi 2004; Pretty et al. 2009; McMillen et al. 2014).

The rapid decline in a community's collective ecological knowledge following a biological extinction event is known as 'shifting baseline syndrome' (Pauly 1995; Turvey et al. 2010; Hanazaki et al. 2013; Zhang et al. 2014). Essentially, after a major environmental change, the collective "memory" (knowledge) of how ecological conditions used to be is quickly lost, such that "each new generation accepts the state of the planet they see around them as being the norm and uses that baseline to evaluate changes in the environment taking place in its lifetime" (Seaton et al. 2013). This shifting baseline in knowledge of past ecological conditions creates a social phenomenon "whereby age- or experience-related differences in perception of the state of the environment are present within communities" (Turvey et al. 2010). Other studies show that younger generations choose to learn and retain knowledge perceived as valuable (Voeks and Leony 2004; Müller-Schwarze 2006; Srithi et al. 2009; Reyes-García et al. 2013). Since "different cultures interact with nature in different ways and forge different relationships with their local environments" (Pretty et al. 2009), it is critical to test how changes in local biodiversity impacts local knowledge dynamics to demonstrate concretely how these factors interact. Though studies often focus on the ecological and environmental impacts of biodiversity decline, our understanding of the effect of species extinction/rarity on the cultures that depend on and have coevolved with them is limited (Turvey et al. 2010). Further, differences in how knowledge is defined and measured can result in conflicting results (Zarger and Stepp 2004; Müller-Schwarze 2006; Reyes-García et al. 2007b; Souto and Ticktin 2012; Vandebroek and Balick 2012), so investigating the impact of species decline on cultural knowledge should consider the effects on different *types* of knowledge.

The orchid biocultural diversity of Southwest China provides an ideal context to examine how species rarity and extinction alters local people's knowledge of these species. As the historical buffer area between China and other regional powers, Southwest China has significant ethnocultural diversity (Harrell 1990; Attané and Courbage 2000; Tu et al. 2005; Yang et al. 2005). Its unique geography and highly varied topography have also yielded a high rate of orchid endemism (Li and Li 1997; Luo et al. 2003; Perner and Luo 2007; Chen et al. 2009b; Xu et al. 2010; Zhang et al. 2015; Zhou et al. 2016). Southwest China's Sichuan Province has the second highest incidence of Orchidaceae species, after Yunnan, and many orchids have substantial economic, cultural, and commercial importance (Luo et al. 2003; Du Puy and Cribb 2007; Perner and Luo 2007; Liu et al. 2010; Seaton et al. 2013; Liu et al. 2014). The Chinese people (specifically the Han majority-ethnicity) have long ascribed great cultural significance to *Cymbidium* (*lánhuā* or 兰花). Confucius' (551-479 BC) unparalleled cultural influence and many sayings historically attributed to orchids have contributed towards what has become known as "orchid culture" ('*lánhuā wénhuà'* or '兰花文化' in Chinese). This "orchid culture" is a veneration for *Cymbidium* in all Chinese art forms, including classical paintings, calligraphy, pottery, architecture, musical compositions, and poetry throughout Chinese history (Chen and Luo 2003; Du Puy and Cribb 2007; Liu et al. 2014), and serves as a source of cultural pride for many Chinese (Hew 2001; Teoh 2005; Du Puy and Cribb 2007). However, over-exploitation and illegal harvest in recent years have resulted in precipitous population collapse of many Chinese orchids and significantly affected their long term viability (Du Puy and Cribb 2007; Seaton et al. 2013; Liu et al. 2014; Zhang et al. 2015), and many experts in "orchid culture" fear the decline in orchid populations will negatively affect the continued promulgation of this specialized cultural knowledge.

To test how species rarity and extinction alters local people's knowledge, we must consider how the local people perceive, understand, and classify plants as based on their own unique local cultural context and worldviews (Müller-Schwarze 2006; Brandt et al. 2013). Based on the historic diversity and unique cultural importance of *Cymbidium* in China, we identified four types of knowledge associated with orchids in China: (a) the ability to correctly identify (ID) the taxa; (b) local ecological knowledge (LEK) such as how/when to locate, harvest, grow, and propagate orchids; (c) business/market knowledge (BMK) such as where to buy/sell and who pays the highest price/sells the best quality; and (d) traditional orchid cultural knowledge (OCK) such as the awareness of orchid literary classics, idiomatic expressions, poetry, paintings, and associated scholars. We hypothesized that the loss of orchid biodiversity in Sichuan results in an associated loss of cultural knowledge. We anticipated an overall reduction of orchid knowledge concerning taxa that are now locally extinct as opposed to those that persist in the wild. We predicted that the presence of orchid knowledge of all types (ID, LEK, BMK, OCK) would differ between ethnic communities, with the Han communities having more orchid knowledge overall. Regardless of ethnicity, we expected that individuals with ongoing orchid activity would have higher incidences of orchid knowledge than those without, even for recently extinct or rare species. Older individuals were expected to possess more knowledge for each category of orchid knowledge than were younger ones, regardless of ethnicity or orchid-activity level.

In this study, we specifically addressed the following research questions on the relationship between orchid knowledge and species rarity/extinction, as well as how this depends on orchid knowledge type and human socio-demographic characteristics: 1) Is the knowledge that local people possess of currently present orchid species greater than their knowledge of recently extinct species? 2) Does this relationship differ depending on the type of knowledge? 3) Does the possession of orchid knowledge vary between orchid stakeholders of differing socio-demographic attributes (e.g., sex, age, ethnicity, and education)? 4) What role does active participation in the orchid trade have in predicting the prevalence of each knowledge type? 5) How does economic valuation of orchids impact the acquisition and maintenance of orchid knowledge?

2.2. Methodology

2.2.1. Study system

Puge County (普格县; 102°26'~102°46'E and 27°13'~27°30'N) comprising 1918 km^2 is located in southwest Sichuan Province (92˚21'~108˚12'E and 26˚03'~34˚19'N), near the convergence of the Sichuan Basin and Yunnan-Guizhou Plateau (Figure 2.1). With a population of 155,740 (2010 census), Puge is the second least populated of the 17 county-level jurisdictions under the administration of the Liangshan Yi Autonomous Prefecture (凉山彝族自治州). The county's two primary ethnic groups are the Yi (彝族) at 74.8% and Han (汉族; the majority ethnicity in China) at ~24%. The county seat of Puji Town (普基镇; population ~19,000) lies approximately 74 km southeast of the prefectural capital Xichang City (西昌市). The county has a subtropical humid monsoon climate, with a mean annual rainfall of 1169.8 mm (90% falling between May to October) and a mean annual temperature of 16.8 °C.

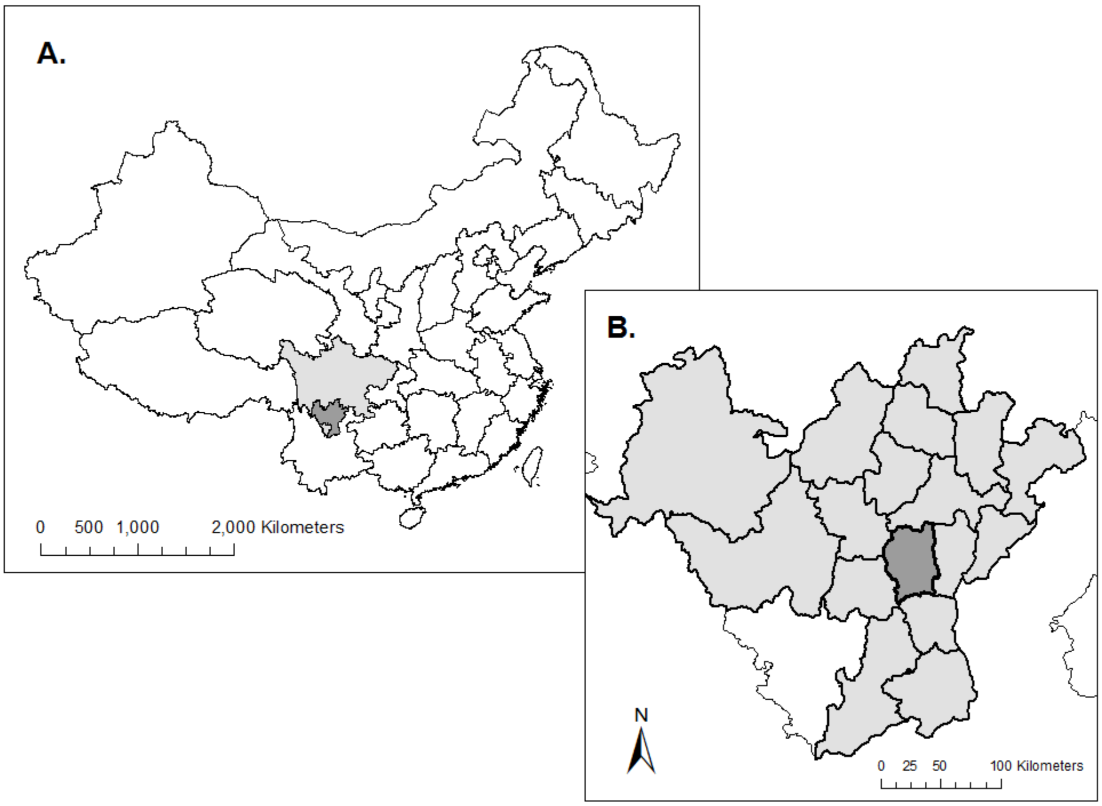

Figure 2.1: Map of Puge County. A. Liangshan Yi Autonomous Prefecture (dark gray) located within Sichuan Province (light gray), China (white). B. Puge County (dark gray) within Liangshan Prefecture (light gray).

Outside of Puji Town, the majority of the rural population from both ethnic groups engages primarily in subsistence farming. The Han tend to live at lower elevations, especially in the river valleys where the merchants are almost uniformly Han, while the Yi tend to live at higher elevations, with villages ascending even to mountain peaks. Buckwheat (*Fagopyrum tataricum*) and potato (*Solanum tuberosum*) are commonly cultivated for food. The most common cash crop among the high elevation Yi is tobacco (*Nicotiana tabacum*), but for the Han and Yi living at lower elevations, rice (*Oryza sativa*) and corn (*Zea mays*) are also commonly grown with surplus sold at market. Seasonally, wild-collected herbs, fungi, and medicinal plants are collected by both ethnic groups in the montane forests, and sold at street markets or in Puji Town. Chicken, pigs, and goats are tended primarily for local consumption, but sometimes sold to fund life events such as medical care, schooling, or paying bride-price.

Due to extreme poverty in Puge, many young and middle-aged people of both ethnic groups have moved away for school or, more commonly, work in wealthier counties and other provinces. This is a concept called *dǎgōng* (打工) in Chinese, in which many people migrate from rural to urban areas to find jobs to raise money for family at home. Some of these regularly return to their home villages, but in most cases, they do not. This has caused much strain to traditional ways of life in rural communities, and contributed to high village fragmentation. Of Puge's rural villages, as many as 40-70% of the population is absent, with the elderly and minors accounting for the bulk of those who remain (personal observation).

2.2.2. Village-level selection

The Chinese term usually translated as "village" in English, *cūnluò* (村落), refers more to a governmental administration level than to a geographic unit of settlement. The area under administration of a *cūnluò* is often vast, with several cohesive subunits far apart but organized under a single governmental unit. The Chinese term for these sub-village units is *zǔ* (组), and, for the purposes of this paper, the term 'village' refers to a particular *zǔ* not *cūnluò*. In some cases, multiple *zǔ* were selected from the same *cūnluò*, but the *zǔ* were far enough from each other (~3 km) that residents of each had minimal to no interactions with those outside of their own *zǔ* despite being within the same *cūnluò*.

Eight villages in Puge County were selected for an in-depth knowledge survey to test the link between the possession of orchid knowledge (globally and for the four knowledge types) and the specified demographic variables (Cunningham 2001; Turvey et al. 2010; Bernard 2011). Of these eight villages, four were >80% Han-majority and four were >80% Yi-majority (Table 2-1). Two of each group were selected because they had significant ongoing orchid activity (defined as at least 10% of the population actively engaged in collecting, cultivating, or selling

Cymbidium), while two of each were selected for their absence of significant ongoing orchid activity for at least five years. Orchid activity level was counted as *total* residents engaged in orchid activity by village (regardless of ethnicity) since individuals within a village tended to communicate regularly with each other. Most Yi people who actively grew/traded orchids lived in the county seat, rather than the villages, so there were not many villages in which most of the Yi people grew orchids themselves. More commonly, they had participated in collecting/selling orchids, and much of what they knew they had learned from their Han neighbors.

Table 2-1: Village units and relevant variables. Population present at time of interviews is given with total in parentheses. Bolded items indicate which villages reach the minimum threshold necessary in each village-level selection criteria: ethnicity (≥80% target) and orchid activity level (≥10% of village population). An asterisk* indicates that the number is an estimate.

Village	*Cūnluò*	*Zǔ*	% Han	% Yi	Households	Population	Activity
Puge 1	*Chěchějiē Cūn*	#2 of 5	**90%**	10%	78*	153 (303)	**Yes (48%)**
Puge 2	*Gěngdǐ Cūn*	#3 of 5	**86%**	14%	70	126 (200)*	**Yes (31%)**
Puge 3	*Gěngdǐ Cūn*	#4 of 5	8%	**92%**	106	145* (460)	No (7%)
Puge 4	*Chéngxi Cūn*	#1 of 3	<1%	**>99%**	173*	350 (812)	**Yes (10%)**
Puge 5	*Chéngxi Cūn*	#2 of 3	0%	**100%**	82	125 (400)	**Yes (22%)**
Puge 6	*Chéngxi Cūn*	#3 of 3	0%	**100%**	43	57 (190)	No (6%)
Puge 7	*Tiánbà Cūn*	#4 of 7	**84%**	16%	45	55 (160)	No (2%)
Puge 8	*Xiàbà Cūn*	#4 of 4	**100%**	0%	23	38 (100)	No (0%)

2.2.3. Individual-level selection: age, sex, ethnicity, education, and activity level

At each village, five individuals were randomly selected from each of three age strata (<35, 35-50, >50) for a total of 120 participants (15 people/village). For the Han-majority villages, the Yi households were excluded, and vice versa. In some villages, the village heads had printed name lists (Puge 1, 7, & 8), so these assisted with forming the strata, but these lists had not been recently updated, so the names of the deceased and those who were working elsewhere had to be removed before random selection. In the other villages, there were no name lists available, so we had to compile them ourselves. For these, the village heads helped greatly by introducing us to families and influential people, even summoning the entire village (of those present) so they could be randomly selected in person. The exact ages of some were unknown, especially Yi people older than about 60; for these, their given age was often an estimate.

Due to the high village fragmentation rate and unforeseen factors, it was not always possible to interview the first five people randomly selected in each stratum. Rather than randomly selecting five names in each stratum, we randomly selected seven names; interviewing them in order of selection, moving to the next only if the first proved ineligible. In no cases did the lists of seven names not suffice. However, in a few cases, the actual number of eligible names per strata were not more than five or six, since children and youth younger than 18 as well as the elderly with dementia could not be interviewed. Socio-demographic variables for all participants were collected, including: age, sex, ethnicity, education level, and orchid activity.

2.2.4. Orchid selection: rarity and economic valuation

For species that are rare and locally extinct, collecting accurate ecological knowledge is not possible, so it is appropriate to identify "local experts" to assist in identifying the benchmark for past conditions (Davis and Wagner 2003; Hallwass et al. 2013; Zhang et al. 2014). Thus, in consultation with the president of the Huili County Orchid Society (会理县兰花协会), who is well known for his breadth and depth of knowledge for the *Cymbidium* flora in Sichuan, we identified nine *Cymbidium* varieties within three categories of rarity for this study: (1) three that were formerly common but now locally rare (CR), (2) three that were formerly common but now locally extinct (CE), (3) three that were formerly rare but now locally extinct (RE). These are not strictly botanical species, but are wild-collected species, subspecies, and/or natural varieties named and recognized as distinct strains in the local Chinese nomenclature (Table 2-2). Photographs of each taxon were obtained from the president of the Huili Orchid Society, and these were printed in color and laminated. These photographic cue cards were used to assess participants' knowledge of the nine orchid taxa (Turvey et al. 2010; Bernard 2011).

2.2.5. Interview process

Between July and September 2015, in-person interviews were conducted of the 120 selected individuals. To minimize potential confusion or distrust among local participants, all interviews were conducted by the first author with the assistance of a local speaker of the participant's native language (Mandarin Chinese or relevant Yi dialect). Participants were first asked if they recognized the plant shown on a given cue card, and, if so, they were prompted to provide a name, and then asked for additional names for the same plant. Based on these responses, participants were assigned an ID knowledge score for each orchid from zero to four (with zero being incorrect and four being the most detailed, accurate answer). Specific orchid knowledge was then assessed for each orchid taxon by asking questions related to each of the other three types of knowledge: LEK, BMK, and OCK (Appendix A, Table A-1). The questions for the four types of knowledge were asked in consecutive order for one cue card before moving on to the next cue card, with the order of cue cards randomized for each interview. Since there were nine different orchid cue cards, and approximately 15 questions/cue card, an interview with a knowledgeable participant could take as long as an hour and a half, or be as short as 15 minutes for less knowledgeable participants.

Table 2-2: Identification and economic value of 9 naturally occurring Cymbidium taxa used for photographic cue cards. Rarity code refers to: (CR) formerly common but now locally rare, (CE) formerly common but now locally extinct, (RE) formerly rare but now locally extinct.

Rarity Code	*Cymbidium* Species Name			Cultivar Name		Economic Value	
	Latin	Chinese	Romanized	Chinese	Romanized	2006-08	2015
CR	*C. tortisepalum* Fukuy.	莲瓣兰	liánbàn lán	普通花	pǔtōng huā	¥10-30	¥10-30
CR	*C. kanran* Makino	寒兰	hán lán	夏寒兰	xià hánlán	¥500-1,000	¥100
CR	*C. cyperifolium* var. *szechuanicum* (Y.S.Wu & S.C.Chen) S.C.Chen & Z.J.Liu	送春兰	sòngchūn lán	送春素	sòngchūn sù	¥10,000	¥300-800
CE	*C. nanulum* Y.S.Wu & S.C.Chen	珍珠兰	zhēnzhū lán	珍珠矮	zhēnzhū ǎi	¥1,000	¥200-300
CE				珍珠素	zhēnzhū sù	¥3-5,000	¥500
CE	*C. serratum* Schltr.	豆瓣兰	dòubàn lán	豆瓣素	Dòubàn sù	¥10,000	¥1,000
RE	*C. tortisepalum* Fukuy.	莲瓣兰	liánbàn lán	金沙树菊	Jīnshā shùjú	¥4.6 Mil	¥3,000
RE				金莲	Jīnlián	¥400-500,000	¥5-10,000
RE				翡翠素荷	Fěicuì sùhé	¥150,000	¥500-1,000

Due to the illegality of harvesting wild orchids in China, interviewing orchid stakeholders who have participated in illegal activity raised special concerns for research methodology and ethics (Gavin et al. 2010). At no time were participants asked if they engaged in illegal activity. Interview questions, methodology, and confidentiality procedures were approved prior to use by the University of Hawai`i Institutional Review Board. All interviews were digitally recorded and subsequently transcribed and translated. Coding and analysis of interview data was aided by the NVivo 11 Plus for Windows software package (http://www.qsrinternational.com/nvivo-product/nvivo11-for-windows/plus).

2.2.6. Response verification

To assess the veracity of responses and to objectively assign knowledge scores for each participant and plant, we used *agreement with experts* techniques (Davis and Wagner 2003; Reyes-García et al. 2006; Kightley et al. 2016). Members of the Huili Orchid Society were interviewed in the same way as the participants in Puge and their answers were used as baseline. These responses were compared to the entirety of responses at each village, to ensure answers of the ‘experts’ were appropriate within the local context.

As an interview progressed, many participants answered “same” or “same as before” for multiple questions. Rather than determining which “previous answer” was intended, these responses were assigned a score of ‘zero’. Though some participants may have intended to refer to a previous answer given for a different taxon (e.g., stating "same" in reference to a previously more detailed explanation), this was not always the case. Multiple participants used "same" to refer to a previous statement of "I don't know", requiring a ‘zero’ score. Since cue card order was randomized in each interview, grading all responses of "same" equally as zero would not bias the knowledge scores for one orchid over another. Though the knowledge scores of knowledgeable but less verbose individuals may have been negatively impacted, this was balanced by avoiding artificially inflating the scores of those intending "same" to mean "I don't know".

2.2.7. Data analysis

Four matrices were compiled based on the knowledge scores assigned for each question asked/person/orchid: (a) global knowledge (GK) which included the scores for all knowledge types (including one for ID, 14 questions total), as well as (b) LEK (five questions), (c) BMK (four questions), and (d) OCK (four questions). We averaged the knowledge scores by rarity, so that each participant had three knowledge scores per question (one for each rarity status). For each matrix, we calculated Cronbach α (Romney et al. 1986; Reyes-García et al. 2006) to determine the appropriateness of the given questions to represent each knowledge type construct. The Cronbach α's for the global, LEK, and BMK matrices were all >0.8 suggesting that they represent meaningful contrasts as distinct constructs for further analysis. However, for OCK, the Cronbach α was only 0.54, well below the 0.7 cutoff. Thus, OCK, at least as it was measured in this study, may not represent a meaningful construct for a distinct knowledge type in the local context of Puge. However, to see the implications of testing for this knowledge type in contrast to the others, we continued to use OCK as a construct for each additional analysis, noting that these results must be interpreted cautiously.

To combine the scores of each knowledge type for further analysis, we followed two approaches: 1) classical analysis (summing the scores across individual questions) and 2) principal component analysis (PCA; Reyes-García et al. 2006; Furusawa 2009). Finding that the two approaches strongly correlated for all knowledge types (r >0.8 needed), we decided to use the classical approach for representing knowledge scores for subsequent analyses (Appendix B, Figure B-1). We conducted pairwise Spearman correlation between plant ID and the other knowledge scores (GK, LEK, BMK, & OCK) to determine the appropriateness of using each knowledge type to represent an individual's plant knowledge (Appendix B, Figure B-2; Reyes-García et al. 2006; Furusawa 2009). For each type of knowledge, we converted the classical scores into proportion data by dividing each by the maximum possible score.

To test how knowledge is related to plant rarity status, we used a generalized linear mixed effect model (GLMMs) using package "glmmADMB" in R version 3.3.2 (R Core Team 2016) with a beta error distribution (Ferrari and Cribari-Neto 2004), rarity as fixed effect, and participant as the random effect to account for the fact that each participant was asked about the three categories of rarity. Testing for the robustness of the relationship between knowledge and plant rarity status, specifically the additive and/or interactive effects of the socio-demographic variables, we included participant age, gender, ethnicity, education, and orchid activity level as additional fixed effects. Starting with the full, saturated model that included all fixed effects, we reduced that model to create twelve nested models (Appendix A, Table A-2). Akaike Information Criterion (AIC) was estimated (Burnham et al. 2011) for each of the twelve models and we used ΔAIC (the difference between the AIC of a given model and the smallest AIC) to measure the level of support for each of these models. We used package "MuMIn" (Barton 2013) to conduct model averaging to estimate the effects of each predictor on knowledge across all models (Mazerolle 2006; Grueber et al. 2011).

Testing the effect of plant extinction and rarity on knowledge, we compared the effect sizes and their significance for two main rarity scenarios: 1) orchids that were formerly common/ now extinct (CE) versus those that were common before/rare now (CR), and 2) orchids that were formerly common/now extinct (CE) versus those that were formerly rare/now extinct (RE). In addition, we also compared the effect size of age (three levels), sex (two levels), ethnicity (two levels), education (five levels), and orchid activity (two levels). Similar GLMMs were developed to test the effects of these parameters on each type of knowledge (ID, LEK, BMK, and OCK as separate response variables; Appendix A, Tables A3-A6).

2.3. Results

All types of knowledge significantly correlated (Appendix B, Figure B-2), indicating each construct was an acceptable proxy for an individual's orchid knowledge. Global knowledge was positively and strongly correlated with local ecological knowledge ($r = 0.96$, $p < 0.001$), business/market knowledge ($r = 0.94$, $p < 0.001$), plant identification by participant ($r = 0.82$, $p < 0.001$), and orchid cultural knowledge ($r = 0.89$, $p < 0.001$). However, we found weaker correlation between plant identification by participant with orchid cultural knowledge ($r = 0.69$, $p < 0.001$), and with each other knowledge type (Appendix B, Figure B-2). Participants, particularly in the two oldest age groups, made many references to the economic value of orchids *and* the perceived economic value of orchid knowledge. For example, one explained "to us, orchids are more valuable than gold." Another stated, "I do not know much about orchids, but if I did, I would be rich." Yi participants noted "many Han people had become wealthy by trading orchids," and there was a common awareness in both ethnic groups that a unique variety or particularly unusual specimen could fetch as high as a few million RMB.

2.3.1. *Effect of rarity and species extinction*

We found a significant effect of extinction on global knowledge (Figure 2.2, Appendix A, Table A-2). For the first rarity scenario (CE vs. CR), people had a significantly higher global knowledge score for orchid species that were formerly common, but that are now rare (CR), than for species that were formerly common but now extinct (CE) (effect size $\beta = 0.727 \pm 0.131$, $p<0.001$). For the second rarity scenario (CE vs. RE), there was no significant difference in global knowledge for orchid species that were previously common or rare prior to local extinction ($\beta = 0.128 \pm 0.131$, $p<0.33$). This relationship between knowledge and rarity held true across all types of knowledge (Figure 2.2, Appendix A, Tables A3-A6). People had a significantly higher plant ID knowledge ($\beta = 0.426 \pm 0.213$, $p<0.05$), local ecological knowledge ($\beta = 0.641 \pm 0.144$, $p<0.001$), orchid business/market knowledge ($\beta = 0.796 \pm 0.116$, $p<0.001$), and orchid cultural knowledge ($\beta = 0.545 \pm 0.139$, $p<0.001$) for formerly common but now rare orchids than for those that are now extinct (CE vs. CR).

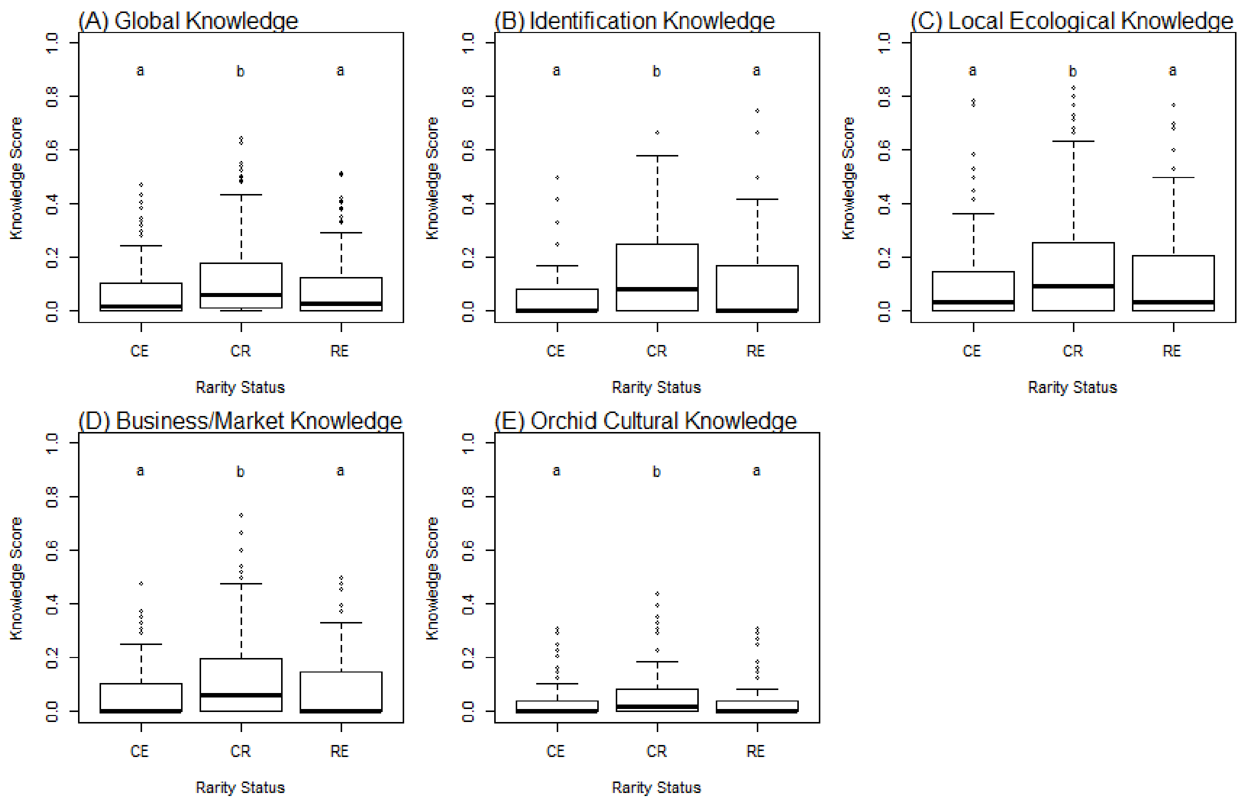

Figure 2.2: Effect of rarity on type of knowledge. Significance level $p<0.001$, except for (B) $p<0.05$.

The precipitous decline in wild orchid populations (increasing rarity) also appeared to alter how individuals identified orchids. For example, many participants of both ethnic groups had never seen orchid *flowers* in the wild before so they could only recognize the *leaves*, even of currently extant species. Though many older participants remembered *Cymbidium* colonies once having the diameter of a dinner table, and they could remember seeing flowers on them, they explained that these had long since been dug out and mature specimens no longer exist in the wild. Many young participants commented that they had never seen an orchid in flower before. Even those actively engaged in the orchid trade noted the near impossibility of seeing flowers in their own collections since they usually sold their orchids to collectors or speculators before they first flowered. In light of the widely recognized decline in wild orchid populations, multiple participants expressed a belief that those who harvest orchids have a social responsibility to conserve the limited resources, saying “if you pluck a part, you must leave a part.” Several explained that *Cymbidium* grew from ‘eggs’ (most likely referring to pseudobulbs), and they emphasized "when you dig the whole plant, you must leave the eggs behind" and "after about two years the eggs will grow into new plants."

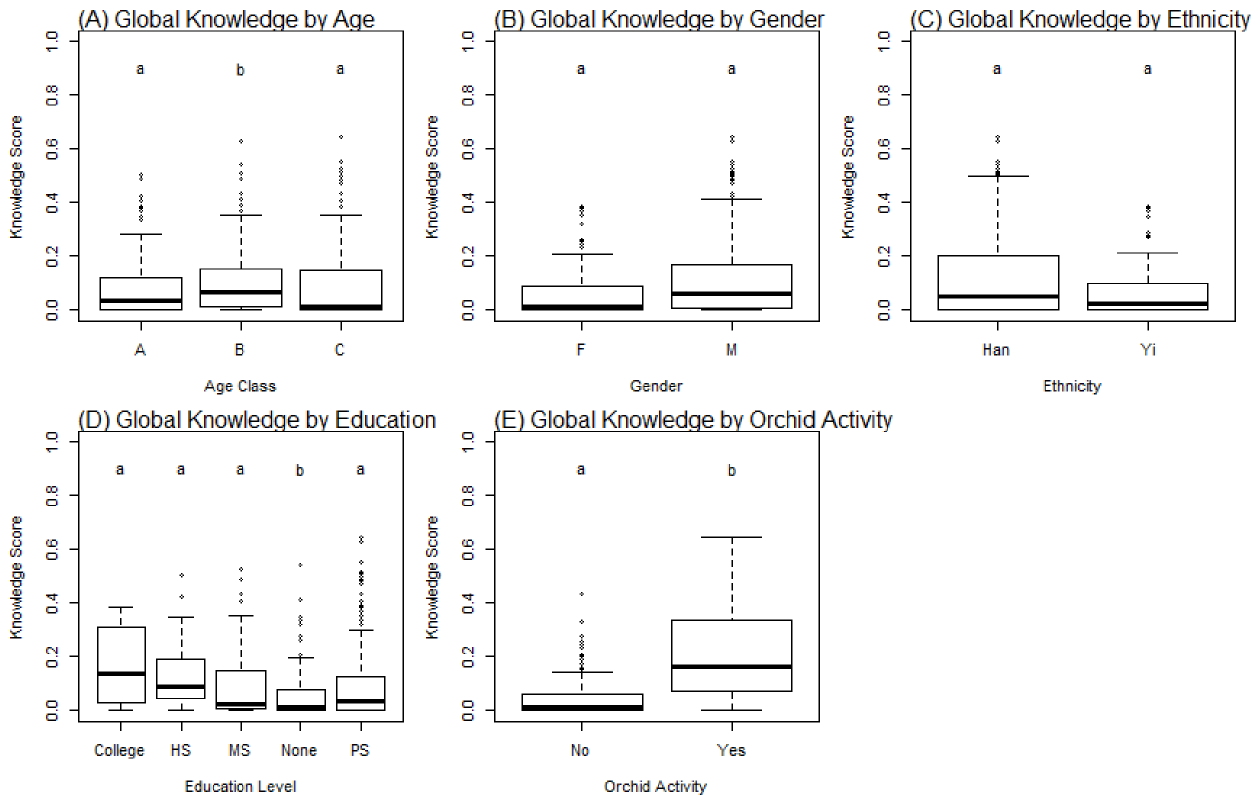

Figure 2.3: Effect of socio-demographic variables on global knowledge. Significance levels: (A) and (D) $p<0.05$, (E) $p<0.001$.

2.3.2. Effect of socio-demographic variables

The effects of orchid rarity status on participant knowledge was not mediated by their socio-demographic characteristics (Appendix A, Tables A2-A6). However, there were significant additive effects of certain socio-demographic variables for each knowledge type. We found no significant difference (Figure 2.3, Appendix A, Table A-2) in global knowledge between genders ($\beta = 0.071 \pm 0.264$, $p<0.80$) or ethnicities ($\beta = -0.448 \pm 0.234$, $p<0.06$). However, participants who were 35-50 years old ($\beta = 0.778 \pm 0.326$, $p<0.05$) and who were engaged in orchid activity ($\beta = 1.911 \pm 0.264$, $p<0.001$) had greater global knowledge than others. Participants with no formal education had less global orchid knowledge than others ($\beta = -1.405 \pm 0.661$, $p<0.05$).

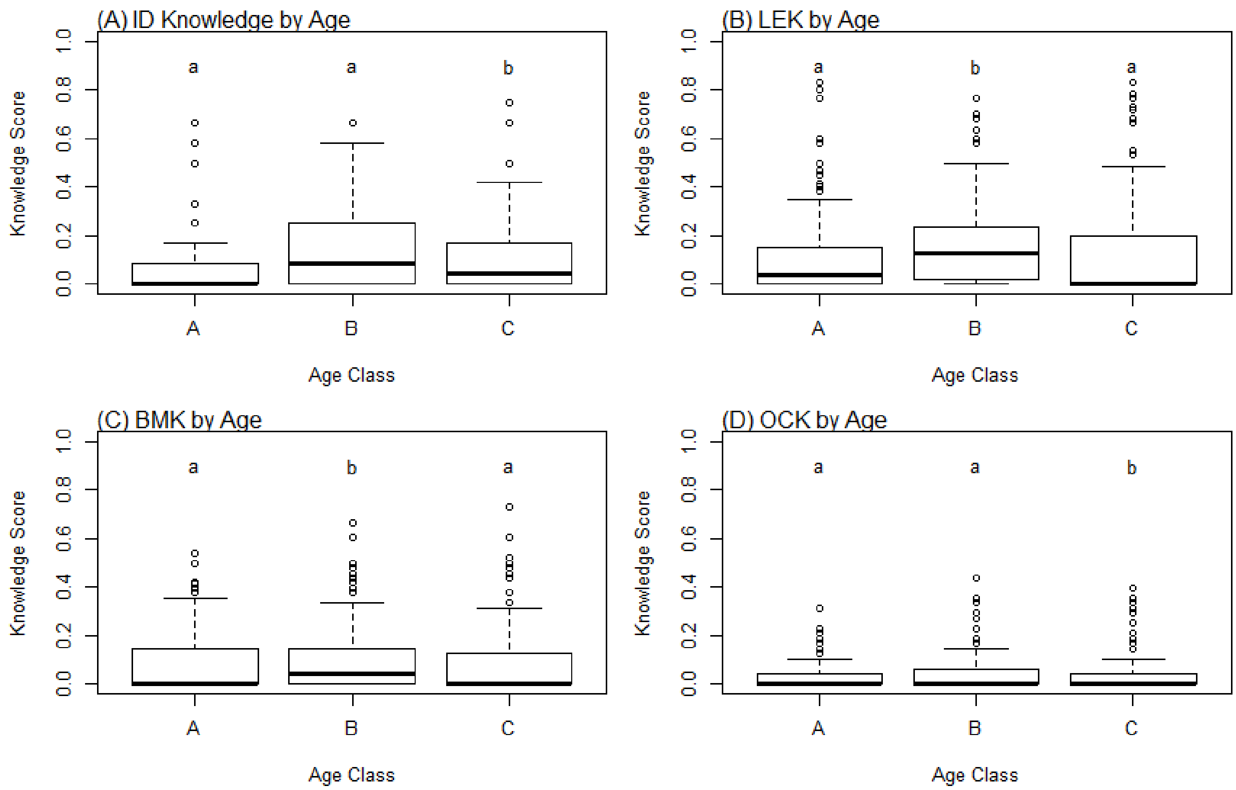

Figure 2.4: Effect of age on specific knowledge type. Significance level p<0.05, except for (D) p<0.01.

The mediating effect of the socio-demographic variables on the possession of orchid knowledge varied with each specific knowledge type (Figures 2.4-2.8, Appendix A, Tables A3-A6). For example, the oldest age group (>50 years old) scored significantly higher for plant ID knowledge (β = 0.545 ± 0.232, p<0.05) and orchid cultural knowledge (β = 0.623 ± 0.236, p<0.01) than did the younger age groups. Conversely, the middle age group (35-50 years old) had significantly more local ecological knowledge (β = 0.646 ± 0.326, p<0.05) and orchid business/market knowledge (β = 0.623 ± 0.317, p<0.05). Younger participants expressed feeling disconnected from their parents' way of life, and this also related to the perceived lack of value of orchid knowledge. One participant explained: "I work elsewhere, and although my parents still live here, my roots here are not very deep." Another said, "How would I know [about orchids]? These days, young people are all away working *dǎgōng*, no one is collecting orchids anymore." Several young Han explained why they had no interest in orchids, despite their parents' interests because orchids are "not around anymore" or "no longer valuable since the market has slowed." Several young participants also commented that though they assumed their parents would know about orchids, they would be more likely to look for answers on the internet than to ask older family members.

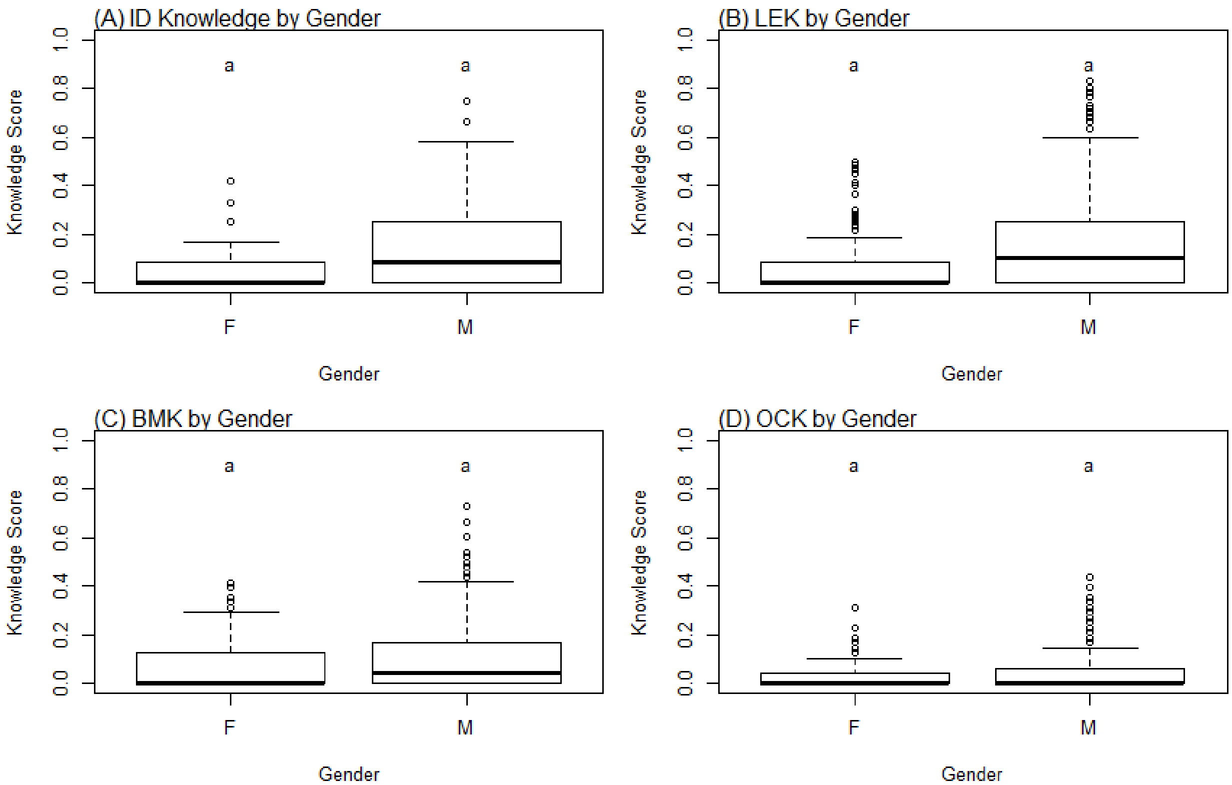

Figure 2.5: Effect of gender on specific knowledge type. All contrasts are not significant.

There was no significant difference between men and women for any knowledge type (Figure 2.5). However, unlike global knowledge, ethnicity had a significant effect on specific knowledge, with the Yi people scoring significantly lower for plant ID ($\beta = -0.551 \pm 0.160$, $p<0.001$; Figure 2.6), orchid business/market knowledge ($\beta = -0.844 \pm 0.236$, $p<0.001$), and orchid cultural knowledge ($\beta = -0.649 \pm 0.181$, $p<0.001$), but not for local ecological knowledge ($\beta = -0.317 \pm 0.242$, $p<0.2$).

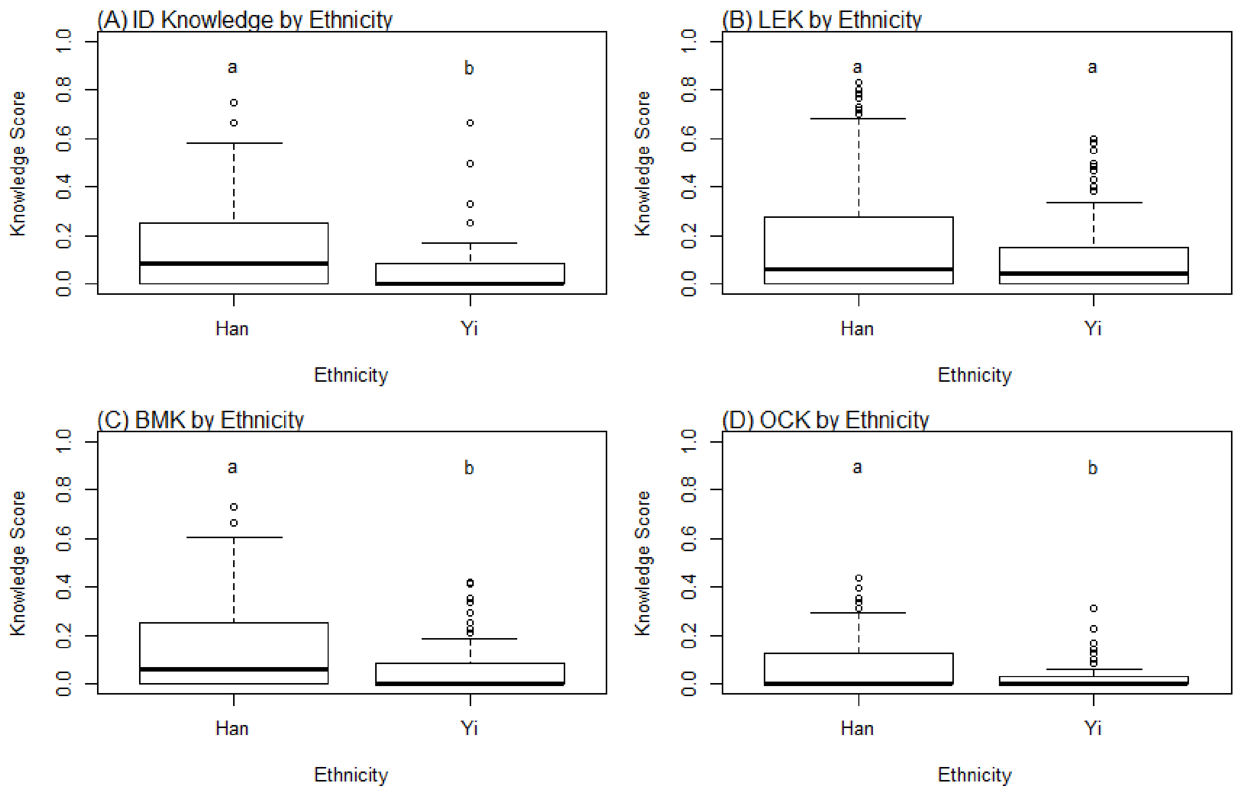

Figure 2.6: Effect of ethnicity on specific knowledge type. Significance level *p*<0.001, except for (B) which is not significant.

Participants with only a primary school education scored significantly lower for orchid business/market knowledge than those with a college education ($\beta = -1.307 \pm 0.605$, $p<0.05$), but there was no significant difference in plant ID and local ecological knowledge between participants of different educational levels (Figure 2.7). Participants with college education scored significantly higher for orchid cultural knowledge than those with no education ($\beta_{None} = -1.737 \pm 0.499$, $p<0.001$), those with primary school education ($\beta_{PS} = -1.628 \pm 0.452$, $p<0.001$), middle school education ($\beta_{MS} = -1.567 \pm 0.461$, $p<0.001$), and high school education ($\beta_{HS} = -1.419 \pm 0.493$, $p<0.01$).

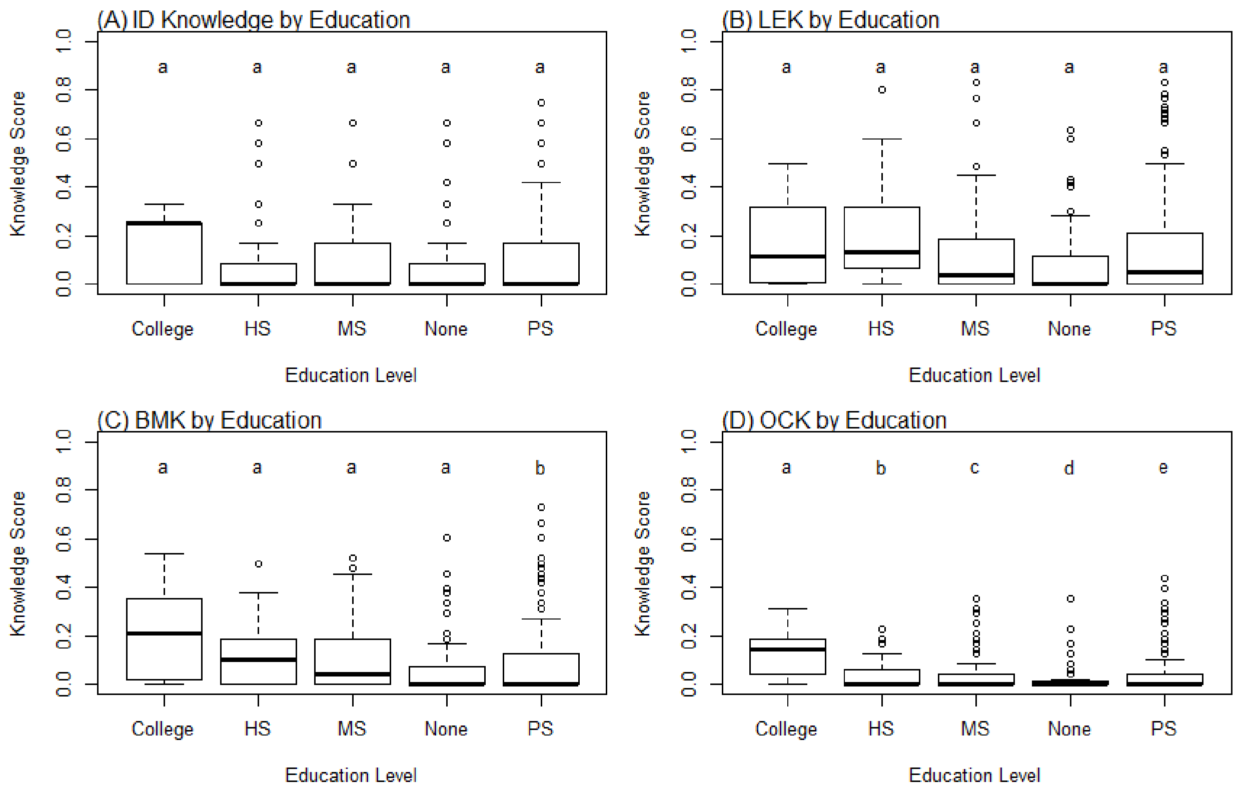

Figure 2.7: Effect of education on specific knowledge type. Significance levels: (A) and (B) not significant; (C) $p<0.05$; (D) all contrasts significant at $p<0.001$, except 'b' $p<0.01$.

Participants with ongoing orchid activity knew significantly more about each knowledge type than those without (Figure 2.8), including for plant ID ($\beta = 1.754 \pm 0.188$, $p<0.001$), local ecological knowledge ($\beta = 1.953 \pm 0.275$, $p<0.001$), business/market knowledge ($\beta = 1.813 \pm 0.267$, $p<0.001$), and orchid cultural knowledge ($\beta = 1.481 \pm 0.209$, $p<0.001$).

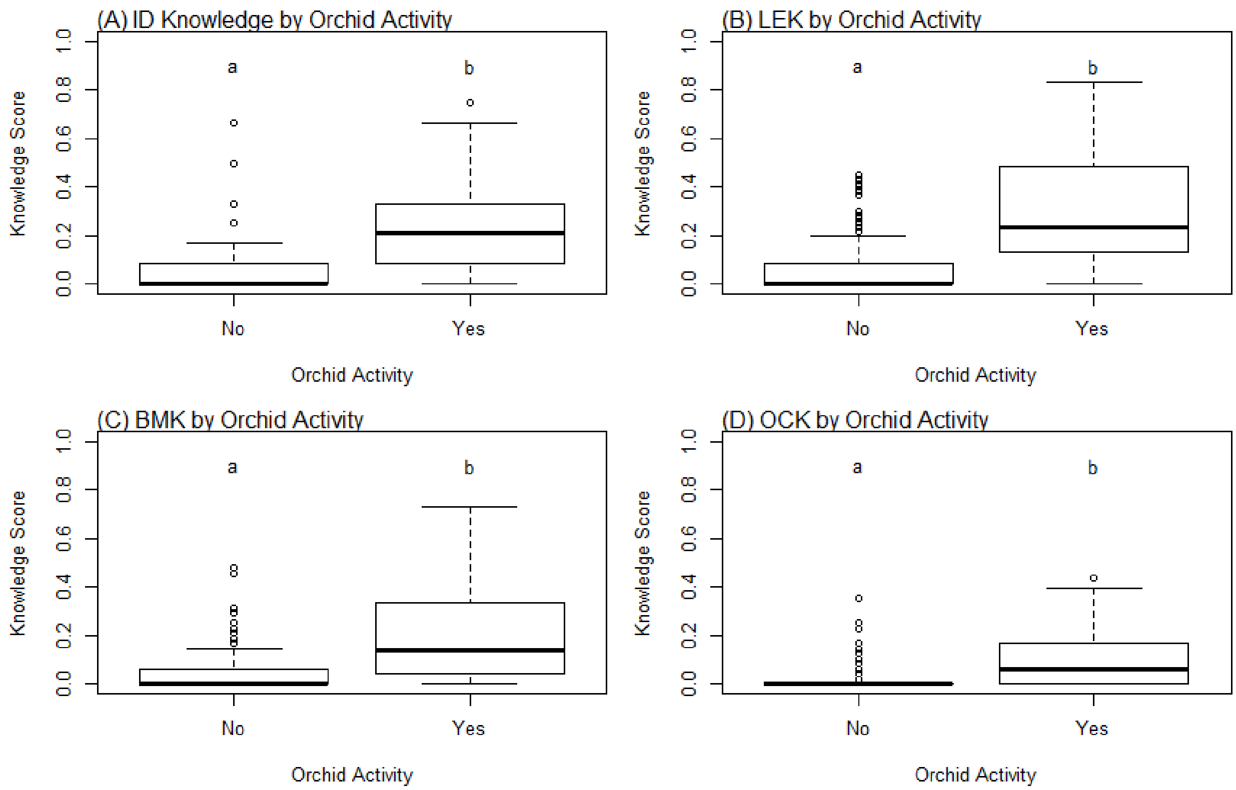

Figure 2.8: Effect of orchid activity on specific knowledge type. Significance level *p*<0.001.

2.4. Discussion

2.4.1. Orchid knowledge, species rarity, and economic valuation

Our data showed that local knowledge of orchids was negatively impacted by plant extinction, and this adverse relationship was robust, occurring across all knowledge types and regardless of species rarity prior to extinction. This indicates that an extinction event largely diminishes any knowledge "dominance" a formerly common species once held in a local community. These findings further support studies that have found a loss of knowledge associated with faunal extinctions (Turvey et al. 2010; Zhang et al. 2014). Our results also lend credence to the 'shifting baseline syndrome' (Pauly 1995; Turvey et al. 2010; Hanazaki et al. 2013; Zhang et al. 2014) as wild *Cymbidium* in Puge County occur now as small seedlings and re-sprouts (rather than mature colonial stands), with little local recollection of what flowers look like (the new 'baseline'). Since nearly all participants had trouble identifying species by flower, they needed to clearly see leaves for identification. This may also explain why some otherwise knowledgeable individuals could only identify taxa to the species level, rather than subspecies or variety level due to their inability to distinguish floral peculiarities.

Thus, humans, through their activities (e.g., overharvest), not only shape the environment, but the resulting changes to the environment (e.g., plant extinction) can also significantly impact human culture through the loss of knowledge. Although we specifically tested how changes in the environment (e.g., species extinction) affect knowledge, we did not directly test how changes in knowledge affect the environment. This was only indirectly examined in how perception of economic value contributes to overharvest. Since the rarer orchids were known to be more valuable (Table 2-2), economic valuation did motivate continued harvest, despite local awareness that it was not sustainable. This may also explain why there was no significant difference between the knowledge held for orchid species that were formerly rare in the wild, but now locally extinct (RE), and those species that were formerly common, but now extinct (CE). One would expect that the knowledge retained within a community after local extinction would be higher for formerly common species than formerly rare species (Turvey et al. 2010), but our study found otherwise, likely due to the economic value of the rarer species.

Economic valuation of orchids also appeared to counter the prevailing cultural influences for knowledge acquisition/loss. Since Sichuan's Yi people's traditional culture has not highly valued *Cymbidium* in the same way as Han culture (*ethnicity* variable), testing for the presence of orchid knowledge by *age* and ethnicity served as a proxy for the dynamic role that economic incentives have in driving knowledge acquisition. For example, the Yi people who were active in the orchid trade (particularly in the 35-50 age group) had learned a lot about orchids from their Han friends and neighbors, in contrast to their traditional culture's lack of concern for orchids. Similarly, the decline in orchid valuation in recent years also appeared to amplify the generational differences in cultural appreciation. The younger Han participants, whose traditional culture highly valued *Cymbidium*, tended to have less interest in orchids than their parents' and grandparents' generations, based on their lower knowledge scores and personal comments. This supports the findings of other studies that found young people no longer acquire traditional knowledge when it is not seen as valuable to them (Srithi et al. 2009; Reyes-García et al. 2013).

Thus, increasing economic valuation appears to motivate individuals to learn about plants against their prevailing cultural influences (Yi), while decreasing economic evaluation inhibits knowledge acquisition in contrast to traditional cultural motivations (Han).

2.4.2. Role of knowledge type

The strong correlations between knowledge types indicate that each was an acceptable construct for gauging an individual's orchid knowledge, with the weakest correlations being those with plant ID (Appendix B, Figure B-2). These high correlations also explain why we found the link between plant extinction and knowledge loss was consistent across knowledge types. Nevertheless, this should not be construed to mean that the knowledge types are indistinguishable or should not be considered individually. Smith (2001) explains that a major difficulty in understanding the relationship between biodiversity and cultural/linguistic diversity is in how boundaries are defined as to what constitutes a cultural "unit" analogous to a biospecies. He argues clear boundaries between entities are unnecessary "to find it useful to distinguish them; if that were the case, we would never differentiate day from night, or summer from winter. As long as we take care not to reify these 'constructed' entities or view them as strictly bounded and impermeable" (Smith 2001). This suggests that score comparison analyses, at least in the beginning of a broader study, are necessary to verify whether a knowledge construct is appropriate within a local context. For example, though many studies in ethnobiology use an individual's ability to correctly identify a plant as a proxy for their plant knowledge (Jinxiu et al. 2004; Zarger and Stepp 2004; Shenton et al. 2011), we found LEK to be the best construct for capturing global knowledge. So, in the local context of Puge, if plant ID were used as a global knowledge proxy, we would only capture ~82% of the knowledge held, as opposed to 89-96% for the other knowledge types (Appendix B, Figure B-2).

2.4.3. Other socio-demographic attributes

The significant overall loss of knowledge we found due to plant extinction occurred across the board regardless of socio-demographic variables. This indicates that though an individual may know more/less than another, their relative advantage/disadvantage within the community holds stable even as overall knowledge on the *community* level declines following an extinction event. Various socio-demographic variables (i.e., sex, age, ethnicity, and educational level) can help to explain the disparity of plant knowledge individuals possess within a community (Voeks and Leony 2004; Albuquerque et al. 2011). But, like other studies that have noted the synergistic effect of socio-demographic variables (Souto and Ticktin 2012; Brandt et al. 2013), we found that the effect of one variable (e.g., ethnicity) largely depended on the level of others (e.g., education or orchid activity level). This shows why it is important to understand the specific context in which the effects of a variable matter for a given study and test them appropriately.

2.4.3.1. Sex

Due to different culturally-defined gender roles, many studies show that men and women can possess different kinds of knowledge, so the *type* of knowledge a study investigates matters (Albuquerque et al. 2011; Souto and Ticktin 2012; Brandt et al. 2013). However, our data showed that the orchid knowledge held by women and men was not significantly different (Figure 2.3), and this was true across all knowledge types (Figure 2.5). This indicates that orchid knowledge is not a culturally-defined domain of a single gender in our study region, and this further supports findings of Torres-Avilez et al. (2016) whose meta-analysis found no gender-based disparity in knowledge. Nevertheless, during the interviews, many female participants indicated that orchid knowledge was a male domain, with comments like "we women usually never go to see [orchids in the wild] so we do not understand," "I have not seen [orchids] before, but the men say they have seen them before," and "my brother [made a lot of money] selling orchids, but we women do not usually deal with these things." These comments were likely expressions of modesty, since anecdotally, during interviews, women seemed less likely to feign knowledge, readily admitting when they did not know rather than guessing or pretending.

2.4.3.2. Age

Our data showed that the middle age group (35-50 years old) knew significantly more about orchids (globally) than the older and younger age groups (Figure 2.3). This is contrary to our hypothesis that older individuals would know more (Voeks and Leony 2004; Srithi et al. 2009; Albuquerque et al. 2011). However, when considering the specific-knowledge scores (Figure 2.4), several possible explanations emerge for this trend. In keeping with our hypothesis, the oldest age group (>50) knew significantly more than the younger groups for plant identification (ID) and orchid cultural knowledge (OCK), while the middle age group (35-50) only knew more for local ecological (LEK) and business/market knowledge (BMK). Considering that the middle group came to adulthood during the height of the orchid economic valuation boom in the late 1980s, 1990s, and early 2000s, the economic incentive to learn how to find/locate orchids (LEK) and sell for profit (BMK) likely caused them to outpace their culture's previous baseline for orchid knowledge acquisition. However, the older age group's advantage in OCK may be due to their longer time studying it, while their advantage with plant ID seems to derive from their familiarity with now extinct orchids and with the previous baseline of wild orchids in flower.

Considering the severity of knowledge loss within a community following biological species extinction, the negative impact of species extinction on cultural knowledge may also be exacerbated generationally. As with linguistic theories related to 'language shifts' and 'language revitalization' (Dwyer 2011), older generations avoid passing on knowledge after it is no longer seen as necessary for the younger generations. Similarly, youth cease acquiring and retaining knowledge that is no longer seen by them as valuable (Voeks and Leony 2004; Müller-Schwarze 2006; Srithi et al. 2009; Reyes-García et al. 2013). Moreover, an individual's length of *residency* within a community can sometimes be a better predictor of certain knowledge types than their age (Souto and Ticktin 2012; Gandolfo and Hanazaki 2014). Thus, the effects of the severe community fragmentation in Puge caused by rural to urban migration (*dǎgōng*) likely amplify these generational differences.

Combined with the new "baseline" for wild orchid ecology in our study area in terms of orchids primarily being small root-sprouts and decreasing local recollection of floral characteristics, these various factors that contribute to a divergence in generational understanding of orchids may yield a cultural "bottleneck effect." Population bottlenecks are well-studied in terms of conservation biology (e.g., inbreeding depression and minimum viable populations) and biological species resilience (Cozzolino et al. 2003; Peery et al. 2012), as well as language extinction (Mishler 2001; Dwyer 2011), but the interrelatedness of the different types of diversities indicates there may also be a "bottleneck effect" of sorts for knowledge transmission making communities less able to adapt to environmental changes (Voeks and Leony 2004; Srithi et al. 2009; Souto and Ticktin 2012).

2.4.3.3. Education and orchid activity levels

Overall, participants with a college education had significantly higher global knowledge scores than those with no formal schooling (Figure 2.3), which is contrary to studies that found a negative correlation between advanced education and traditional knowledge (Voeks and Leony 2004; Srithi et al. 2009). When specific knowledge is examined (Figure 2.7), no difference is found between educational levels for either plant ID knowledge or local ecological knowledge. Yet, college-educated participants did know significantly more about orchid business/market knowledge than those with only a primary school education. Since college-educated participants also knew significantly more orchid cultural knowledge than all other educational levels, acquisition of this knowledge type may be aided by advanced formal education and would be less prevalent in communities lacking access to higher education. Yet, this advantage may not necessarily be due to *length* of education, but rather the *location* or *type* (vocational versus liberal arts) of the education that matters. For example, there are no colleges or universities in Puge County, so all college-educated individuals had to travel to cities to study. The advantages offered in cities, including cultural institutions such as universities, libraries, museums, and botanical gardens, may be particularly important for this type of knowledge. Anecdotally, several participants associated their lack of orchid knowledge with the *type* of education they had received. For example, one participant with a middle school education said “When we went to school, we studied every day how to build things and be farmers. We never learned about orchids.” Another stated, “We never learned this stuff in school.”

Being active in the orchid trade (a form of informal education) seems to partially answer why an individual who knows more than others before an extinction event would still know relatively more after the plant is lost even as knowledge declines overall. As hypothesized, we found individuals active in the orchid trade had significantly *higher* global knowledge scores than those who were not active (Figure 2.3). They also had significantly *higher* knowledge scores for all four specific knowledges (Figure 2.8). Thus, the negative impact of extinction on knowledge is exacerbated when one no longer has access to the plants in any form. Due to orchid activity's influence on knowledge acquisition, after an extinction event knowledge persists longer in communities where hobbyists grow locally extinct orchids in their own collections.

2.5. Conclusion

The overarching narrative documenting a global correlation between biological and cultural/linguistic diversities (biocultural diversity) has been helpful in galvanizing interdisciplinary interest in this phenomenon, but it has been largely unable to identify the lower level factors that interact to contribute to this broader trend (Pretty et al. 2009). Our study focused on testing one side of this complex feedback loop (how environmental changes affect human knowledge) to better understand which socio-demographic factors might impact this link. We found strong evidence to support the hypothesis that a loss of biodiversity (species extinction) drives an overall loss of cultural knowledge. This relationship held true for both global knowledge and each specific type of orchid knowledge, but this relationship had no interactive effect from the socio-demographic variables. Of interest for biocultural diversity conservation efforts, our study indicates that if overharvest of wild orchids continues to drive species to extinction, a multifaceted and highly refined yet significant component of Han Chinese culture is also at risk of being lost. One could argue that Han Chinese culture would survive even if its traditional "orchid culture" disappeared completely, and though the loss of one aspect of a broader culture may not be that noticeable in and of itself, the broader trajectory within a culture as it becomes more homogenous and less diverse has profound implications on its long-term resilience (Maffi 2001; Mishler 2001; McMillen et al. 2014). Better understanding these local drivers of cultural evolution and biodiversity loss therefore has important implications for biocultural diversity conservation.

CHAPTER 3:
MODERATE URBANIZATION PROMOTES ORCHID KNOWLEDGE AS ORCHID POPULATIONS DECLINE IN SICHUAN, CHINA

3.1. Introduction

According to the United Nations Department of Economic and Social Affairs (2014), the year 2007 marked the first time in history in which a majority of the world's population lived in urban areas. By UN projections, the entirety of global population growth between 2014-2050 will be in urban areas, with city-dwellers expected to reach two-thirds of global population over that timeframe (UN Department of Economic and Social Affairs 2015). Consequently, the socio-economic, political, and environmental implications of increased urbanization have been studied across a wide diversity of academic disciplines. The economic opportunities, infrastructure, and modern amenities (e.g., formal education and Western healthcare) available in cities are major drivers for rural populations to continue migrating into urban centers (Zhang and Song 2003; Brandt et al. 2013). Though rural-to-urban migration may relieve overburdened rural ecosystems by "decreasing extractive dependence on native species for survival," this can also negatively affect cultural resilience by decreasing "long established links with nature, both materially and cognitively" (Voeks and Leony 2004).

Several studies report a negative impact of urbanization, modernization, and rural-to-urban migration on the preservation and retention of local ethnobotanical knowledge (Voeks and Leony 2004; Reyes-García et al. 2007b; Srithi et al. 2009; Brandt et al. 2013; Reyes-García et al. 2013; Gandolfo and Hanazaki 2014). Since local knowledge develops in coexistence with the natural environment, as people migrate away or become engaged in economic activities unrelated to it, the value of the knowledge diminishes as it becomes detached from the local environment and "cultural milieu" in which it developed (Voeks and Leony 2004; Reyes-García et al. 2007b; Gandolfo and Hanazaki 2014). Consequently, traditional knowledge is no longer acquired when deemed to be of little practical or economic benefit or otherwise no longer relevant to present needs (Voeks and Leony 2004; Müller-Schwarze 2006; Srithi et al. 2009; Reyes-García et al. 2013). Yet other studies find that knowledge is modified or transformed in urban environments or otherwise not negatively impacted by urbanization, suggesting that the relationship between urbanization and knowledge loss is either not universal or not directly comparable (Zarger and Stepp 2004; Müller-Schwarze 2006; Furusawa 2009; Mathez-Stiefel et al. 2012; McMillen 2012; Vandebroek and Balick 2012). For example, some studies have found that migration to cities can actually increase overall plant knowledge as populations borrow, share, and adapt or reconfigure knowledge within the diverse multicultural settings of cities (Cocks 2006; Furusawa 2009; Vandebroek and Balick 2012).

Disparities in how knowledge is defined and measured across different studies may help to explain these contradictory results related to urbanization's role in ethnobotanical knowledge loss (Zarger and Stepp 2004; Müller-Schwarze 2006; Reyes-García et al. 2007b; Souto and Ticktin 2012; Vandebroek and Balick 2012). Reyes-García et al. (2007b) explain that "local knowledge has many domains (i.e., myth, cosmology), including local ecological knowledge, which itself comprises many subdomains, such as plants, animals, insects, or soils," and due to differences in utility, each domain of knowledge may react differently to urbanization (Benz et al. 2000; Voeks and Leony 2004; Reyes-García et al. 2007a; Furusawa 2009). There are also different *dimensions* of knowledge, in that what someone knows (*knowledge*) and how they apply this knowledge (*use*) are not the same (Reyes-García et al. 2007b; Srithi et al. 2009), with multiple authors making a distinction between *active* knowledge (the practical dimension) and *passive* knowledge (the theoretical dimension) (Müller-Schwarze 2006; Reyes-García et al. 2007a; Reyes-García et al. 2007b; Brandt et al. 2013; Kightley et al. 2016). Thus, the impacts of urbanization, migration, and modernization may differ for each type of knowledge (Vandebroek and Balick 2012). However, studies on the impacts of urbanization often fail to differentiate between the non-overlapping domains and dimensions of knowledge (Reyes-García et al. 2007a; Reyes-García et al. 2007b; Brandt et al. 2013).

The high urbanization rate and unique orchid biocultural diversity in Southwest China's Sichuan Province provides an ideal environment to test how the effect of urbanization on the distribution of local knowledge is mediated by the cultural knowledge domains that are targeted. China has experienced the world's largest flow of rural-to-urban migration in history beginning with the implementation of economic reforms in 1978 (Zhang and Song 2003). As the world's most populace nation, China's unprecedented domestic migration has seen the movement of more than 440 million people (Heikkila and Xu 2014; Zhao et al. 2015). There are 667 cities in China (Heikkila and Xu 2014), including 51 of the world's 99 fastest growing municipalities, 2 of the world's 5 largest cities, 6 of the world's 28 megacities with populations of at least 10 million, and 16 cities with populations of at least 5 million (UN Department of Economic and Social Affairs 2015). Such increasing urban population growth and changing market dynamics have fueled a rapid overcollection of many Chinese orchid species, resulting in wild population collapse and heightened extinction risk (Du Puy and Cribb 2007; Seaton et al. 2013; Liu et al. 2014; Zhang et al. 2015). The collecting pressure is so severe that newly discovered species such as *Cymbidium wenshanense* and *C. nanulum* in Southwest China's Yunnan Province were nearly extirpated from the wild shortly after they were first described (Du Puy and Cribb 2007). Though the rapid decline in Chinese *Cymbidium* populations is widely recognized, little attention has been paid to formally documenting the implications of their loss, particularly in relation to the cultural persistence of orchid knowledge as the nation becomes increasingly urbanized and detached from its traditional rural way of life.

The great diversity of orchids in China (Li and Li 1997; Luo et al. 2003; Perner and Luo 2007; Chen et al. 2009b; Xu et al. 2010; Zhang et al. 2015; Zhou et al. 2016) is the foundation for a variety of uses in traditional Chinese medicine and the long history of cultivation and cultural appreciation (Luo et al. 2003; Du Puy and Cribb 2007; Perner and Luo 2007; Liu et al. 2010; Seaton et al. 2013; Liu et al. 2014). Based on the vibrant historic and ongoing orchid trade, the importance of *Cymbidium* to Chinese traditional culture, and the geographic distribution of wild orchid populations, we have identified four domains of knowledge associated with *Cymbidium* in China: (a) the ability to correctly identify (ID) the taxa; (b) local ecological knowledge (LEK) such as how to locate, harvest, grow, and propagate orchids; (c) business/market knowledge (BMK) such as where to buy/sell and who pays the highest price/sells the best quality; and (d) traditional orchid cultural knowledge (OCK; '*lánhuā wénhuà'* or ‘兰花文化’ in Chinese) such as the awareness of orchid literary classics, poetry, paintings and associated scholars, orchid material culture, and the symbolism of the Chinese orchid aesthetic.

In this study, we address the following research questions: 1) What impact does urbanization have on the distribution of orchid knowledge threatened by the decline in wild populations? 2) Does this relationship depend on type of knowledge? 3) Which type(s) of orchid knowledge are most at risk due to increasing urbanization? 4) Which are aided by increasing urbanization? We hypothesized that the effect of urbanization on orchid ethnobotanical knowledge depends on the type of knowledge being considered. We anticipated that local ecological knowledge would have a negative relationship with urbanization, since rural people who live closer to the orchids’ natural habitats would have more regular contact with the orchids in the wild. Conversely, we expected that the orchid cultural knowledge would have a positive relationship with urbanization since this knowledge is closely associated with formal schooling.

3.2. Methodology

3.2.1. Study area

This study was conducted in three locales with distinct levels of urbanization in central and southwest Sichuan Province (92˚21’~108˚12’E and 26˚03’~34˚19’N), China (Figure 3.1). All three are known to currently have active orchid stakeholders with cultural and economic connections to the orchid trade. Chengdu (成都; 102°54'~104°53' and 30°05'~31°26'N), the highly urbanized capital city, is located in central Sichuan and is the most urban and wealthy locale in the province. All ethnic groups in the province are represented in the capital. As the largest sub-provincial city in West China, Chengdu’s total area is 14,605 km^2 (population ~15.7 million), divided into 20 county-level jurisdictions, with the highly developed urban core comprising 1007 km^2 (population ~8 million). Chengdu is the historic locus for major cultural institutions in the province, such as universities, museums, herbaria, and libraries. The breadth of orchid society members, orchid collectors, orchid vendors, and orchid growers is quite extensive. Transportation routes and government offices are based in and radiate out from Chengdu.

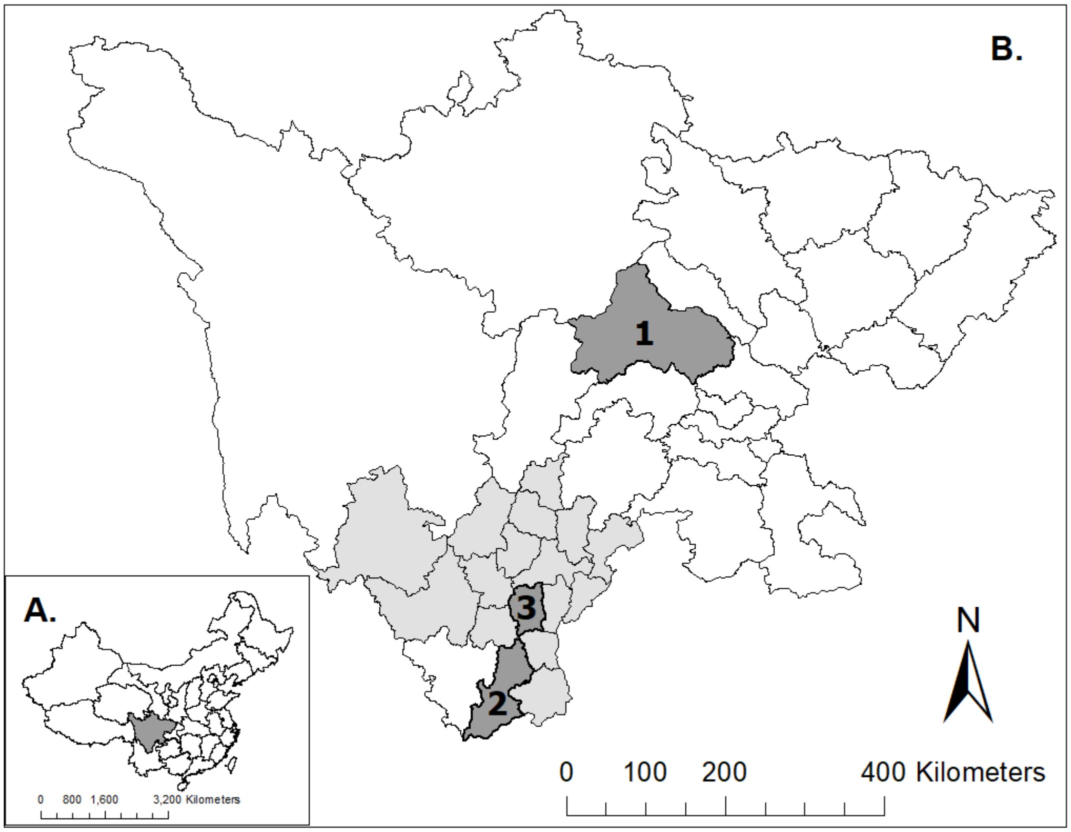

Figure 3.1 A. Location of Sichuan Province (dark gray) within China. B. Research site locations (dark gray), 1) High urbanization (Chengdu City) in central Sichuan; 2) Medium urbanization (Huili County) and 3) Low urbanization (Puge County), located within Liangshan Yi Autonomous Prefecture (light gray) in southwest Sichuan Province.

The other two locations are in Liangshan Yi Autonomous Prefecture (凉山彝族自治州) in southwest Sichuan. The moderately urban/peri-urban Huili County (会理县; 101°52 '~102°38'E and 26°5'~27°12'N) comprises 4528 km^2 at the southernmost tip of Sichuan, bordering Yunnan Province to the south. Having a population of 439,100 (2012), Huili is the second most populous of the 17 county-level jurisdictions of Liangshan. The county's two primary ethnic groups are the Han (汉族; the majority ethnicity in China) at ~83.2% and the Yi (彝族) at 15.9%. With an urban population of ~48,000, the county seat Chengguan Town (城关镇) lies 180 km south of the prefectural capital Xichang City (西昌市). Huili has been historically associated in China with its beautiful *Cymbidium*, and it has an active orchid society. In 2011, Chengguan Town was named the 118th "National Historical and Cultural City" (国家历史文化名城) by the State Council, in part due to its long history in the orchid trade and influence in traditional orchid culture.

Rural Puge County (普格县; 102°26'~102°46'E and 27°13'~27°30'N) comprises 1918 km^2, and, with a population of 155,740 (2010 census), it is the second least populated county-level jurisdiction in Liangshan Prefecture. The county's two primary ethnic groups are the Yi at 74.8% and Han at ~24%. The county seat of Puji Town (普基镇; population ~19,000) lies approximately 74 km southeast of Xichang City. The first author's previous fieldwork (summer 2013) documented that many of Puge's rural villages were actively involved with the collection and sale of wild-collected orchids from the surrounding mountains, and many individuals continued to maintain household orchid collections. The three levels of urbanization, therefore, are high (Chengdu), moderate (Huili), and low (Puge).

3.2.2. Participant selection

Due to the extreme difference in scale of each jurisdiction, the selection of interview participants occurred in two ways. In Chengdu and Huili, since the pool of orchid experts consisted of a relatively "elite group" with members "scattered over a large area," a "snow-ball sampling" process was utilized (Bernard 2011). In each location, initially pinpointed orchid stakeholders were interviewed and asked to identify other orchid stakeholders within their social networks. Following the referrals of the initial contacts, the network of orchid stakeholders expanded widely throughout the respective jurisdictions. In Chengdu, orchid nurserymen and women were interviewed at the Orchid Exhibition Center of China (中国兰花博览园) and the Chengdu Gaodianzi Flower Market (成都高店子花卉交易市场), as were academics, orchid collectors, and members of the Chinese Orchid Society (中国兰花学会), Orchid Society of Sichuan (四川省兰花学会), and the Shuangliu County Orchid Society (双流县兰花协会). In Huili, members of the Huili County Orchid Society (会理县兰花协会), as well as orchid merchants and hobbyists, were interviewed.

In Puge County, to capture the knowledge held by orchid stakeholders on the rural scale, two Han-majority sub-village jurisdictions were selected, one from Chechejie Village (扯扯街村) and one from Gengdi Village (耿底村), due to their significant ongoing orchid activity (with at least 30% of the population actively engaged in collecting, cultivating, or selling *Cymbidium*). Villagers within each were selected for interview via random sampling techniques (Bernard

2011), by creating name lists of eligible interviewees and randomly selecting within each. Children and youth younger than 18 as well as the blind, mentally disabled, and elderly with dementia were not included. To exclude the possible effects of ethnic culture, only ethnic-Han individuals were selected at each urbanization level. In total, 91 individuals were interviewed, with 31 from Chengdu, 30 from Huili, and 30 from Puge (15/village).

3.2.3. Interview process

In consultation with the president of the Huili County Orchid Society, as a local expert (Davis and Wagner 2003; Hallwass et al. 2013; Zhang et al. 2014) who is well known for his expertise in Sichuan's *Cymbidium* flora, we identified nine *Cymbidium* taxa spanning different levels of rarity for use in this knowledge survey. These were naturally-occurring species, subspecies, and/or natural varieties, named and recognized as distinct strains in the local Chinese nomenclature and native to central and southwest Sichuan (Table 3-1). Photographs of each were obtained from the society's president and printed in color and laminated. These photographic cue cards (Turvey et al. 2010; Bernard 2011) were used between July and December 2015 for in-person interviews with each of the 91 orchid stakeholders.

Table 3-1: Identification and economic value of 9 naturally occurring *Cymbidium* taxa used for photographic cue cards. Rarity code refers to: (CR) formerly common but now locally rare, (CE) formerly common but now locally extinct, (RE) formerly rare but now locally extinct.

Cue Card	*Cymbidium* Species Name			Cultivar Name	
	Latin	Chinese	Romanized	Chinese	Romanized
1	*C. tortisepalum* Fukuy.	莲瓣兰	liánbàn lán	普通花	pǔtōng huā
2	*C. kanran* Makino	寒兰	hán lán	夏寒兰	xià hánlán
3	*C. cyperifolium* var. *szechuanicum* (Y.S.Wu & S.C.Chen) S.C.Chen & Z.J.Liu	送春兰	sòngchūn lán	送春素	sòngchūn sù
4	*C. nanulum* Y.S.Wu & S.C.Chen	珍珠兰	zhēnzhū lán	珍珠矮	zhēnzhū ǎi
5				珍珠素	zhēnzhū sù
6	*C. serratum* Schltr.	豆瓣兰	dòubàn lán	豆瓣素	Dòubàn sù
7	*C. tortisepalum* Fukuy.	莲瓣兰	liánbàn lán	金沙树菊	Jīnshā shùjú
8				金莲	Jīnlián
9				翡翠素荷	Fěicuì sùhé

Each interview was conducted by the first author with aid from a local speaker of the participant's preferred language (Mandarin Chinese and/or Sichuan dialect). Participants were first given a photographic cue card and asked to identify the plant shown by providing a name. If they provided a name, they were asked if they knew other names for the same plant. Each participant was then assigned an ID knowledge score, based on their responses, ranging from zero (incorrect) to four (being the most detailed, accurate answer). Questions related to each of the other three types of specific knowledge (local ecological, business/market, and orchid cultural knowledge) were then asked in consecutive order (Appendix A, Table A-1) for the same cue card before participants were handed a new cue card. The order of photographic cue cards was randomized for each interview, and with nine different cue cards and about 15 questions each, interviews ranged between 15 minutes to an hour and a half, averaging about forty minutes.

Since harvesting wild orchids is illegal in China, interviewing those who may have engaged in illicit behavior raised special concerns for research methodology and ethics (Gavin et al. 2010). To minimize risk, participants were never asked if they had engaged in illegal activity. All interview questions, methods, and confidentiality procedures were approved prior to use by the University of Hawai`i Institutional Review Board. Interviews were digitally recorded, transcribed, and translated, with coding and analysis of interview data aided by NVivo 11 Plus for Windows qualitative data analysis software package (QSR International 2016).

3.2.4. Response verification

We used *agreement with experts* techniques to verify response accuracy and objectively assign knowledge scores (Davis and Wagner 2003; Reyes-García et al. 2006; Kightley et al. 2016). Since there were only two participants who correctly identified all nine specimens, those participants who scored on average 3.5 or higher for the ID category across all nine orchid taxa were treated as experts (14 individuals in total), and their answers to other questions (only for correctly identified species) were used as baseline. These responses were compared to the entirety of responses at each location, to ensure answers of the 'experts' were appropriate within each local context. Many participants answered "same as before" for multiple questions. Rather than determining which "previous answer" may have been intended, these responses were scored as ‘zero’. Since cue card order was randomized in each interview, grading all responses of "same" equally as zero did not bias the knowledge scores.

3.2.5. Data analysis

Based on the knowledge scores assigned for each question asked per person per orchid, four matrices were created: (a) global knowledge which included the scores for all knowledge types (including one for ID, 14 questions total), as well as (b) local ecological knowledge (five questions), (c) business/market knowledge (four questions), and (d) orchid cultural knowledge (four questions). We calculated Cronbach α (Romney et al. 1986; Reyes-García et al. 2006) to determine the appropriateness of the given questions to represent each knowledge type. The Cronbach α’s for the global, LEK, and BMK matrices were all >0.8 suggesting that they represent meaningful contrasts as distinct knowledge domains for further analysis. However, for OCK, the Cronbach α was only 0.67, slightly below the 0.7 cutoff. Due to the importance of this type of knowledge to Han Chinese culture, and to see the implications of testing for this knowledge type in contrast to the others, we continued to use OCK as a construct for each additional analysis, noting the need for cautious interpretation.

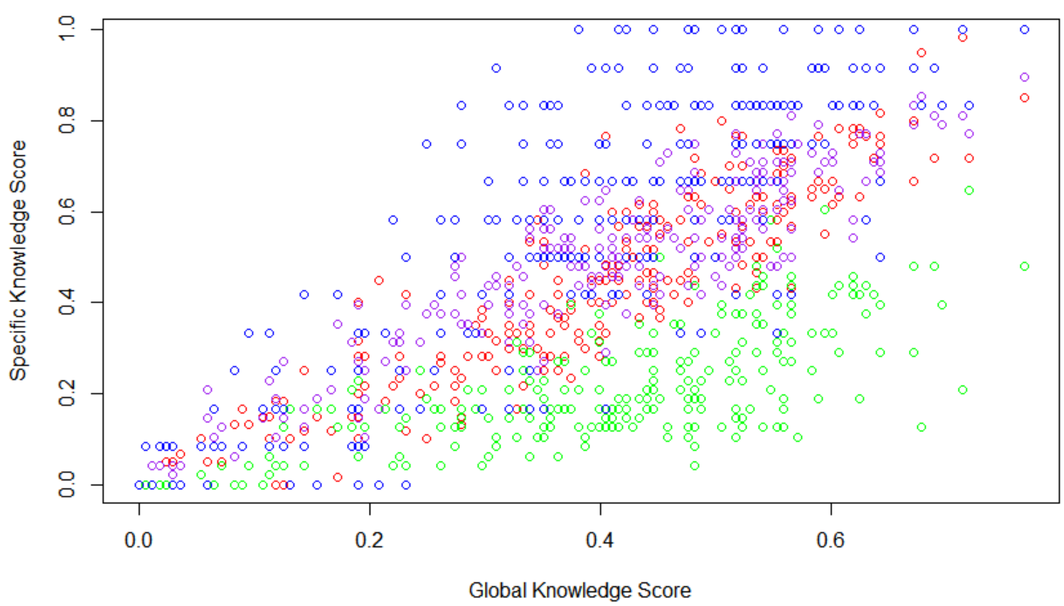

Figure 3.2: Correlation between global orchid knowledge score and each specific knowledge score (as proportions of maximum possible scores). Plant ID (Blue), local ecological knowledge (Red), business/market knowledge (Purple), and orchid cultural knowledge (Green).

To combine the scores of each knowledge type for further analysis, we summed the scores across individual questions for each knowledge type and converted these to proportion data by dividing each by the maximum possible scores. All knowledge types strongly correlated (Figure 3.2; Appendix B, Figure B-3). To test how orchid knowledge depends on urbanization level, we used a generalized linear mixed effect model (GLMMs) using package "glmmADMB" in R version 3.3.2 (R Core Team 2016) with a beta error distribution (Ferrari and Cribari-Neto 2004), urbanization as fixed effect, and participant as the random effect to account for the fact that each participant was asked about each orchid. Testing the effect of urbanization on global orchid knowledge distribution, we compared the effect sizes and their significance for two urbanization scenarios: 1) high urbanization (Chengdu) versus low urbanization (Puge), and 2) high urbanization (Chengdu) versus moderate urbanization (Huili). Similar GLMMs were developed to test the effects of urbanization on each domain of orchid knowledge (ID, LEK, BMK, and OCK as separate response variables; Table 3-2).

Table 3-2: GLMMs coefficients for the effects of urbanization on each domain of orchid knowledge. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

Domain	Scenario	Estimate	Std. Error	z value	Pr(>|z|)
Global AIC: -521.9	Intercept	-0.339	0.216	-1.57	0.116
	High:Low	-1.330	0.228	-5.83	5.7e-09 ***
	High:Medium	0.380	0.225	1.69	0.092 .
Plant ID AIC: -724	Intercept	0.640	0.310	2.07	0.039 *
	High:Low	-2.302	0.313	-7.35	2e-13 ***
	High:Medium	1.581	0.315	5.03	5e-07 ***
Local Ecological AIC: -373.5	Intercept	-0.359	0.255	-1.41	0.15821
	High:Low	-1.048	0.294	-3.57	0.00036 ***
	High:Medium	0.719	0.291	2.47	0.01340 *
Business/Market AIC: -447.4	Intercept	0.124	0.205	0.61	0.545
	High:Low	-1.634	0.224	-7.29	3.2e-13 ***
	High:Medium	0.393	0.221	1.78	0.076 .
Orchid Cultural AIC: -734.8	Intercept	-1.187	0.273	-4.35	1.4e-05 ***
	High:Low	-1.556	0.253	-6.14	8.1e-10 ***
	High:Medium	-0.043	0.246	-0.17	0.86

3.3. Results

We found a significant effect of urbanization on global knowledge distribution (Figure 3.3, Table 3-2). People in Chengdu, the most urban region, had a significantly higher global orchid knowledge score than those in rural Puge (effect size β = -1.330 ± 0.228, p<0.001). However, there was no significant difference in global knowledge between the highest two urbanization levels of Chengdu and Huili (β = 0.380 ± 0.225, p=0.092). The relationship between knowledge and urbanization level differed for each knowledge domain (Figure 3.3, Table 3-2). People in the highly urban city (Chengdu) were more capable of correctly identifying plant species (β = -2.302 ± 0.313, p<0.001) and had significantly more local ecological knowledge (β = -1.048 ± 0.294, p<0.001), business/market knowledge (β = -1.634 ± 0.224, p<0.001), and orchid cultural knowledge (β = -1.556 ± 0.253, p<0.001) than did people in the rural villages (Puge).

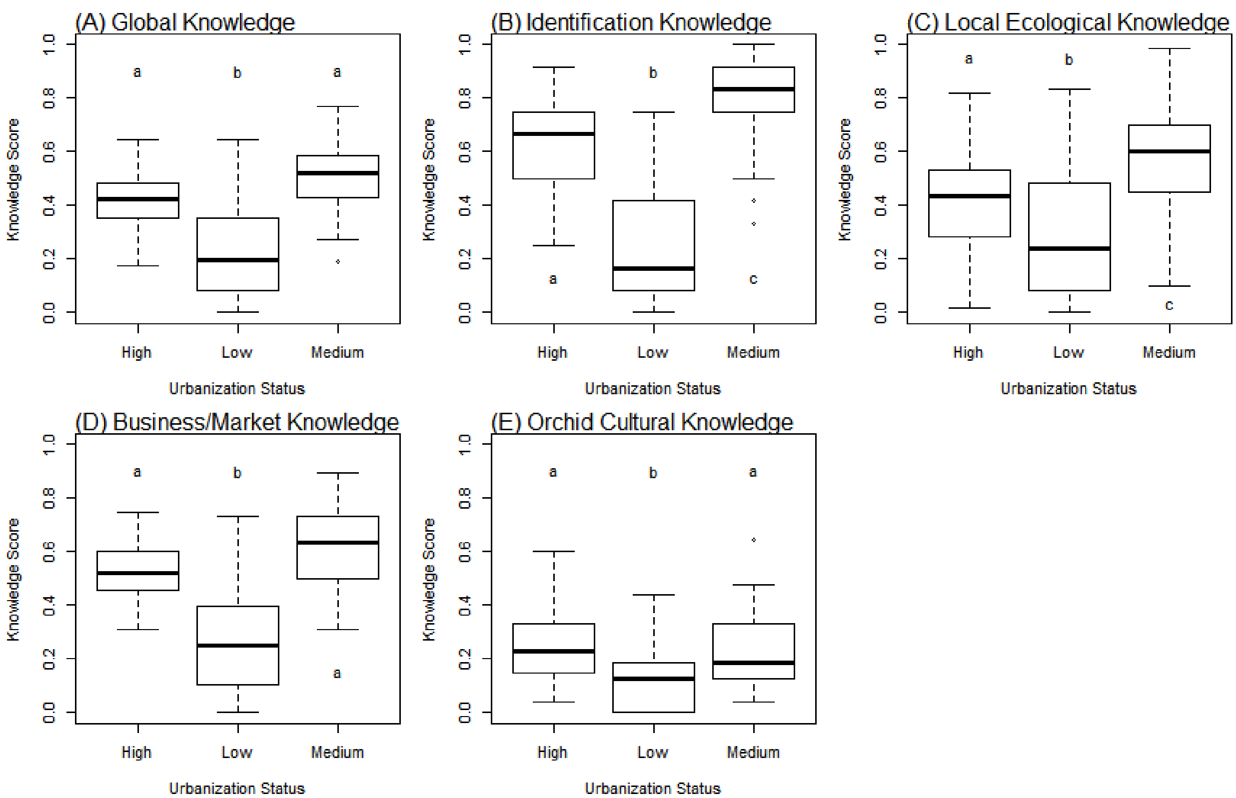

Figure 3.3: Effect of urbanization on type of knowledge. Significance levels: (A), (B), (D), and (E) p<0.001; (C) 'b' p<0.001, 'c' p<0.05.

Interviews revealed two large-scale trends that appeared to be influencing knowledge acquisition and perceptions of knowledge utility at each urbanization level: 1) an awareness of the decreasing orchid populations in the wild (including local extinction) and 2) changing market dynamics in the more urban areas. Regarding the first trend, many participants made comments indicating that the overharvest of wild orchids has been so severe that those in rural areas no longer benefit from access to wild plant resources and this may be contributing to a loss of knowledge there. For example, several Huili participants commented in reference to varieties of *Cymbidium nanulum* (taxa #4 and #5, Table 3-1) that though they used to be common, they are now “basically facing extinction” and “there are no longer any on the mountains anymore.” Several participants from Chengdu also noted that many *Cymbidium* taxa no longer persist in the wild, with all but the most common species having been collected to the point of local extinction. However, participants from both of these more urban areas noted that they still had access to the locally extinct species that were held in private collections (including their own). In contrast, many participants in Puge noted that they had never seen orchids in flower before. Even those in Puge who maintained orchid collections rarely saw the rarer orchids flower before being sold to collectors and brokers from cities (in Sichuan and other provinces). Similarly, due to the severe overharvest, Puge participants noted that the only orchids left in the wild are small seedlings and root resprouts rarely getting large enough to flower before being collected and sold at market, with many species now locally extinct. One participant said in relation to a local variety of *Cymbidium tortisepalum* (taxa #7, Table 3-1), “I have never seen this before in the wild. I have only seen it in books,” while another made the same comment for *C. nanulum* (taxa #5).

At each urbanization level, participants commented on the high economic value of orchids. Participants from Huili explained that in 2006, twenty-six Huili families pooled resources to buy a wild-collected natural mutation of *C. tortisepalum* (taxa #7; known as ‘*Jīnshā shùjú*’ or ‘金沙树菊’ in Chinese) for more than ¥4.6 million Chinese RMB (approximately US$800,000). Each “shareholder” became wealthy by selling vegetatively-propagated clones of this orchid and many other valuable varieties. One participant in Huili said that during the height of the orchid market he had traded two orchids for a brand-new BMW from a car dealer in Yunnan Province. Several Chengdu and Huili participants said that their personal orchid collections used to value in the tens of millions of dollars (USD equivalent). A Huili collector explained that he used to have so many orchids that the top of his building was full of them (in greenhouses), employing four people to take care of them. He also had to hire armed guards

(2005-2006) due to threat of theft of the most valuable varieties. Though on a much smaller economic scale, multiple residents in Puge County mentioned they had made tens of thousands of dollars over the years selling locally collected orchids to “orchid speculators” and brokers from the big cities. In Chengdu, one participant, an officer of the Shuangliu County Orchid Society (双流县兰花协会), said that there were ~50,000 active orchid growers throughout the city, demonstrating the high pressure on natural resources to support this demand.

Unlike the distribution of global orchid knowledge, people in Huili County (moderate urbanization) had significantly higher knowledge scores than those in the city of Chengdu (high urbanization) for plant identification ($\beta = 1.581 \pm 0.315$, $p<0.001$) and local ecological knowledge ($\beta = 0.719 \pm 0.291$, $p<0.05$), but there was no significant difference in business/market knowledge ($\beta = 0.393 \pm 0.221$, $p=0.08$) or orchid cultural knowledge ($\beta = -0.043 \pm 0.246$, $p=0.90$). Even so, multiple participants in Huili mentioned that they believed their orchid knowledge was not as extensive as it had once been since the noticeable downturn in the orchid market in recent years (particularly since 2008) had made acquiring orchid knowledge less worthwhile. Consequently, the membership of the Huili Orchid Society had also declined. Prior to 2010, there were hundreds of members, but now the membership had declined to only a few dozen enthusiasts. One participant explained, “The people are still here, but the value of orchids is not so good anymore, so now many have transitioned into other businesses. They are not as free to attend orchid meetings anymore.” The most prominent orchid shop in downtown Chengguan Town (Huili County) in 2013 had closed down by 2015, and the building had been converted into an English education business. Nevertheless, even as the economic valuation of orchids declined in recent years, several participants said that to the hobbyists, orchids “remain priceless” and are “the most valuable thing there is.”

Anecdotally, the first author also noticed distinct changes in the orchid markets within Chengdu between 2013 and 2015. In 2013, there were many shops in the Gaodianzi Flower Market (Chengdu) which sold only *Cymbidium* (primarily wild-collected from rural areas throughout the province). But at that time, about five of them had begun to shift over to selling *Phalaenopsis* and *Dendrobium* hybrids with larger/showier flowers. These were tissue cultured and seen as catering more to a “Western” aesthetic of beauty, which was increasingly more popular with the younger, urban, and growing middle class. In 2013, one of the shop owners said "I used to only sell *Cymbidium*, but one day a man came in and gave me his business card, explaining he had a business that sold *Phalaenopsis*, *Dendrobium*, *Oncidium*, and hybrid cultivars of *Cymbidium* grown from tissue culture in his greenhouses. He was a scientist with a business mind, so he offered to help me start growing and selling them." By 2015, nearly all of the shops had moved away from selling *Cymbidium* (in fact, many of the older shops had closed entirely), only a few were still dedicated exclusively to *Cymbidium*. Similarly, in 2013, many orchid collectors throughout Sichuan Province had adamantly insisted there was "no value" in artificially hybridized *Cymbidium* cultivars, believing that only wild-collected specimens were valuable. Although wild-collected, naturally-occurring mutants are still the most valuable/sought after, the increasing willingness to buy hybrids and tissue-cultured clones among many urban orchid collectors (and the broader Chinese public) has strong implications for the long-term effect of urbanization/migration on natural resource demands in China.

3.4. Discussion

The conflation of different kinds of knowledge is also of concern for investigations into the impact of urbanization on knowledge loss since some knowledge types may benefit from urbanization to the detriment of other types. Reyes-García et al. (2007a) explain that a "major burden for empirical research on individual ethnobotanical knowledge is the lack of conceptual consistency" across studies. To be generalizable "a comprehensive measure of ethnobotanical knowledge should include all the non-overlapping dimensions" (Reyes-García et al. 2007a). Another reason to explain conflicting results across studies is that each study may not be testing the effects of urbanization on knowledge domains as conceived by the *local* community. For example, how local people perceive, understand, and classify plants is based on their unique local cultural context and worldviews, and these should be the same categories a researcher uses to test for changes caused by other factors (Müller-Schwarze 2006; Brandt et al. 2013). In other words, a researcher may design a study to test for the knowledge held locally about "woody" or "herbaceous plants" but local people may not conceptualize plants in this way, instead seeing them as "domestic," "food," "medicinal," or "weaving plants." Thus, testing for the effects of urbanization may not reveal an impact on knowledge associated with "woody" plants, but it might for ‘weaving plants,’ etc. (Brandt et al. 2013). In our study, we tested for four different domains of orchid knowledge identified from previous fieldwork, but our Cronbach α tests verified that these knowledge constructs were appropriate to use in the local context.

We found significant effect of urbanization on orchid knowledge distribution. Contrary to the many studies that have found a negative relationship between increasing urbanization and ethnobotanical knowledge (Voeks and Leony 2004; Reyes-García et al. 2007b; Srithi et al. 2009; Brandt et al. 2013; Reyes-García et al. 2013; Gandolfo and Hanazaki 2014), we found a positive relationship more similar to the findings of Vandebroek and Balick (2012). Though we expected that some domains of orchid knowledge would have a positive relationship with urbanization while others would have a negative relationship, we found instead that every domain we tested had a generally positive relationship. Nevertheless, the extent of this relationship differed for each domain of orchid knowledge which supports our main hypothesis that urbanization’s effect on orchid cultural knowledge would depend on the knowledge type (Benz et al. 2000; Voeks and Leony 2004; Reyes-García et al. 2007a; Furusawa 2009).

Although we predicted that local ecological knowledge would be negatively impacted by urbanization, our data showed otherwise. Local ecological knowledge was significantly lower in Puge County’s rural villages (low urbanization level), than either Huili County (moderate urbanization) or Chengdu City (high urbanization) (Figure 3.3). But this was not a linear relationship, since Huili had significantly higher LEK than either urbanization extreme. Though local ecological knowledge was present at every level of urbanization, it seemed to manifest itself differently. For example, in the most urban location (Chengdu), the information provided by participants as to where each orchid could be found in the wild was more general (e.g., participants tended to indicate orchid native ranges by naming provinces and altitudes). In contrast, in the rural villages (Puge), participants tended to provide the names of specific mountains and valleys where the orchids had been found growing, rarely mentioning localities further than Yunnan or Guizhou (neighboring provinces). Yet at the moderately-urbanized Huili County, participants tended to combine both methods to denote species nativity, in that they would mention the exact locations (mountains/valleys) where they had previously seen the orchid species growing, while also providing the geographic range of the species by naming provinces and altitudes as well. This difference in scale of answer did not affect how the participants were scored, however, since higher scores were based on specificity within the scale used, not due to using multiple scales. Nevertheless, the moderately-urbanized Huili appeared to draw knowledge benefits from the strengths of both other urbanization levels.

The ability to correctly identify the species (plant ID) followed a similar pattern, in that the highest knowledge scores were at moderately-urbanized Huili, being significantly higher than both extremes (with the average being >80% correctly identified, vs. <70% for highly-urbanized Chengdu and <20% for rural Puge) (Figure 3.3). Though significantly lower than Huili, the ability to correctly identify orchids in Chengdu City (high urbanization) was significantly higher than in Puge (low urbanization level). As participants were asked to identify each taxon, those in Puge who recognized an orchid tended to provide its unique morphological characteristics as common names (e.g., "common flower," "large-petaled," or "unspotted") rather than the actual names. In Chengdu, participants usually only provided the technical names without elaborating. In contrast, Huili participants tended to do both, providing both the technical names *and* differentiating features. For this study, participants were scored based on *accuracy* regardless of which of the three methods they employed, but the participants in Huili seemed to make less mistakes in identifying the technical names due to their reliance also on differentiating morphological characteristics. Thus, moderately-urbanized Huili seemed to benefit from the ID knowledge perspectives of both urbanization extremes. This example also illustrates that one need not know the *name* of a plant to correctly recognize and distinguish it, and this draws into question whether using plant identification (Jinxiu et al. 2004; Zarger and Stepp 2004; Shenton et al. 2011) is the best proxy for measuring an individual's ethnobotanical knowledge. Based on the context of this particular study, the domains of local ecological knowledge and business/market knowledge would be better proxies to measure an individual's orchid ethnobotanical knowledge (Appendix B, Figure B-3).

As we expected, orchid cultural knowledge was the least abundant domain of orchid knowledge, and it had a positive relationship with urbanization (Figure 3.3). There was no significant difference between the city of Chengdu (high urbanization level) and Huili (moderate) for this domain, but they were both significantly higher than that of Puge (low urbanization) (Table 3-2). This overall trend was also observed for orchid business/market knowledge as well. Since people abandon knowledge when it is not seen as valuable (Reyes-García et al. 2013), this may indicate that these two knowledge domains were more likely to be viewed as valuable in the urban environments. But for orchid cultural knowledge in particular, its positive relationship with urbanization may also be due to how this type of knowledge is acquired, being closely associated with formal schooling and personal study. There are no colleges or post-secondary schools located in Puge County, and due to the economic constraints of the prevalent subsistence farming lifestyle in the rural setting, participants from Puge generally had less “free” time to pursue hobbies such as reading orchid poetry and classical texts.

These trends highlight the importance of further studying knowledge distribution in different local contexts and on different geographic scales (Zarger and Stepp 2004; Furusawa 2009). As the various factors associated with urbanization are studied, “we may find that environmental knowledge is resilient and mutable, persisting in some contexts while it is changed or lost in others” (Zarger and Stepp 2004). Though orchid cultural knowledge may tend to increase with continued urbanization, since this domain of orchid knowledge is the rarest, it may also be most at risk as wild species continue to go extinct. Multiple participants who scored highly in orchid cultural knowledge, expressed a concern that the recent collapse of local orchid populations would negatively affect this highly refined aspect of Chinese culture. They explained the necessity to view orchids in the wild to fully appreciate the traditional Chinese orchid aesthetic and properly interpret historic classics in Chinese material culture (paintings, pottery, etc.) and scholarly literature (poetry, pilgrimage accounts, pharmacopeias, etc.). Several participants were first inspired to learn this domain of knowledge as youths when older friends or family members took them to the mountains to see the orchids in flower. Thus, without healthy wild orchid populations, this critical value of “inspiring” young minds to acquire orchid cultural knowledge may be greatly hampered.

This may also explain why, contrary to our expectations, the local ecological knowledge domain was higher in urban areas than in the rural region. Since access to plant resources is one of the drivers of knowledge acquisition, there may be a delayed effect to knowledge decline in urban environments following more noticeable declines in rural areas due to the continued access to wild-extinct species in urban collections. Benz et al. (2000) ask "to what extent can traditional knowledge coexist with changing values and modernization?" Even though we found that all of the orchid knowledge domains are currently positively correlated with increasing urbanization, there is a need for follow-up studies to test if this relationship is robust over time (Zarger and Stepp 2004; Reyes-García et al. 2013). Of particular interest for public policy and biocultural diversity conservation efforts, as species decline further in the wild, this may further disadvantage rural people from acquiring this type of knowledge. Since locally-extinct orchids are no longer available in the wild, the only people who can view them are the wealthy with personal collections or those who have access to pubic repositories such as parks and botanical gardens.

3.5. Conclusion

This project adds to our understanding of the impact increasing urbanization has on knowledge by specifically investigating the prevalence of four domains of orchid knowledge in three Sichuan communities of differing urbanization levels, with implications for the ongoing maintenance (and vulnerability) of the four types of knowledge as wild orchid populations continue to decline. The prevalence of orchid knowledge is significantly less in rural Puge County (low urbanization) than in the city of Chengdu (high urbanization) and county of Huili (moderate urbanization), indicating that urbanization may be beneficial to the maintenance of these domains of orchid ethnobotanical knowledge. Though certain kinds of knowledge may be aided by living in rural communities by seeing species more regularly in their natural habitat, this benefit lessens as wild populations decline and rural peoples have less access to them. There are also distinct advantages to living in urban communities, such as better infrastructure and greater access to higher education and major cultural institutions such as museums, libraries, herbaria, and botanical gardens. The fact that each domain of orchid knowledge was significantly higher at the medium urbanization level suggests that moderately-sized or peri-urban jurisdictions may be best suited for local orchid knowledge preservation and retention, drawing from the strengths of modern urban amenities as well as close proximity to the natural habitat of species. Our findings support our main hypothesis that the impact of urbanization on cultural knowledge depends on the type of knowledge considered. In light of increasing global urbanization, environmental changes, and plant extinctions, these findings provide insight to add to the biocultural diversity conservation efforts in China, the United States, and around the world.

CHAPTER 4:
SOCIAL NETWORK STRUCTURE DOES NOT MITIGATE CULTURAL KNOWLEDGE LOSS FROM ORCHID POPULATION DECLINE IN SICHUAN, CHINA

4.1. Introduction

Social network analyses (SNA) are increasingly used in various disciplines to investigate the interplay between natural systems and human knowledge systems (Bian et al. 2005; Bodin et al. 2006; Crona and Bodin 2006; Butts 2008; Hopkins 2011; Prell 2012; Barnes et al. 2016). A social network is defined as a set of relations (or *ties*) that apply to a set of entities (*actors*), together with additional socio-demographic variables (*attributes*) about those entities (Butts 2008; Prell 2012). Smith (2001) defines culture as "*socially transmitted information*, where 'information' refers to beliefs, values, knowledge, and the like." Knowledge is embedded in social ties, not just in books, and "through these social ties, individuals and groups learn about innovations, opinions and perspectives, learn new tasks, or reinforce or question previously held ideas" (Prell et al. 2008). Social networks are key vehicles for knowledge dissemination as well as social and individual learning, which contributes to both environmental and cultural preservation (Crona and Bodin 2006; Prell et al. 2008; Mbaru and Barnes 2017).

Studying SNA is particularly important in a relationship culture like China where one's network of social relationship ties (*guanxi* or '关系' in Chinese) serves as a culturally significant conduit of information, business loyalty and competitive advantage, and social resilience (Bian et al. 2005; Lin 2011; Ma 2011). Rooted in Confucianism (Lin 2011; Ma 2011), the Chinese concept of *guanxi* is seen as an "interpersonal resource" established "to help one get through all kinds of difficulties in life" and "to promote mobility of individual or social transactions between two sides" (Lin 2011). *Guanxi* conveys power, influence, and social status and serves as the means for control and transmission of limited resources (including knowledge) (Ma 2011). Receiving an invitation to attend a wedding, birthday, funeral, or other gathering, or being consulted on personal or business matters all indicate an individual's "membership" in the originator's *guanxi* (Bian et al. 2005; Lin 2011). To "save face," leverage one's social network position, and ensure access to limited resources within the network, *guanxi* must be cultivated and maintained.

Does *guanxi* play any role in preserving knowledge at risk of being lost within a local social network? In a related study, we found that the local knowledge about orchids held in eight villages in rural Sichuan Province, China, was negatively impacted by orchid extinction, and this adverse relationship was robust, occurring across all types of orchid knowledge and regardless of species rarity prior to extinction. Various studies have investigated how social network structural variables can contribute to the amount of knowledge an individual and community may possess, as well as how it is transmitted within the community (Bodin et al. 2006; Crona and Bodin 2006; Hopkins 2011; Barnes et al. 2016; Lauer and Matera 2016; Mbaru and Barnes 2017). But to understand how *guanxi* might affect threatened knowledge within a community, a review of several key concepts in the SNA literature is necessary.

4.1.1. Actor centrality

When examining social networks, one of the most common questions investigators have considered is who are the "most important" actors within the network (Wasserman and Faust 1994; Frank 2002; Prell 2012). In other words, which actor(s) occupy the most *central* or influential positons within a given social network and who are most critical to maintaining network function and cohesion? Does an individual's position within a network predict what (s)he will know? For example, Crona and Bodin (2006) found that in coastal Kenya, fishermen's centralized positions within their social networks contributed to their "more holistic perception of the seascape," thereby affecting their worldview and knowledge base. Various measures of centrality have been identified that emphasize different aspects of an actor's central position within their social network. These include the absolute (undirected) number of ties an actor has to and from others in the network (*degree centrality*), the relative *degree* of all other individuals adjacent to (having ties with) an actor (*eigenvector centrality*), how often an actor lies *between* any other two actors within the network (*betweenness centrality*), how *close* an actor is to all other actors in the network (*closeness centrality*), and the net positive/negative effect derived from the centrality of all other individuals connected to the focal actor (*beta centrality*, also referred to as *Bonacich Power*) (Wasserman and Faust 1994; Prell 2012).

4.1.2. Homophily

Hopkins (2011) explains that "most traditional ecological knowledge and skills in rural areas are acquired through situational learning and unsolicited advice between people who interact on a daily basis." Similarly, Crona and Bodin (2006) note that people are most strongly influenced by those with whom they most frequently interact, so "individuals are likely to develop an understanding of the status of a natural resource similar to other members of the same stakeholder group." Building on the impact of actor centrality on network function, various authors have observed that individuals most commonly associate with those who are most similar to themselves, a concept known as *homophily* (Prell et al. 2008; Barnes et al. 2016). Barnes et al. (2016) explains that "strong homophily-driven clustering can result in segregated or fragmented networks, where social ties tend to be restricted within groups of similar people." This segregation on sociodemographic lines can negatively affect knowledge persistence, ecological sustainability, and community resilience, as communication and learning across groups diminishes, and knowledge and behavior become localized in smaller, homogenous groups (Barnes et al. 2016). Thus, in heavily fragmented communities, homophily tends to inhibit the diffusion of innovations, novelties, and other forms of knowledge across the wider network (Valente 1996; Barnes et al. 2016).

4.1.3. Brokers and network bridges

In networks with strong homophily, various studies have found that certain individuals can play particularly important roles within the broader network by bridging between otherwise separated subgroups. These *network bridges* or *brokers* maintain exclusive links between "groups that would otherwise not be in direct contact with each other" (Bodin et al. 2006). These individuals score highly in *betweenness* centrality, particularly in highly fragmented networks, so they occupy important positions within the network by contributing to community resilience, cohesion, and adaptive capabilities (Bodin et al. 2006; Prell et al. 2008).

Thus, identifying which actors register as central, understanding how homophily drives network fragmentation, and determining which actors serve as bridges between otherwise segregated groups can greatly assist with biocultural conservation efforts. These help ascertain whether a community is positioned to conserve traditional knowledge, adapt to environmental changes, implement community based management of limited resources, and maintain ecological sustainability (Bodin et al. 2006; Crona and Bodin 2006; Barnes et al. 2016; Mbaru and Barnes 2017). In this study, we address several research questions at two levels of analysis to investigate how social network structure (network level) and network position (actor level) affect the broader relationship of orchid knowledge loss due to species extinction.

Network level: 1) Do network structural variables (e.g., centralization, density, fragmentation, etc.) predict the level of knowledge that a community has? (i.e., Does the network structure drive how much knowledge is acquired within a community?) 2) Do network structural variables impact the relationship between species extinction and knowledge loss? (e.g., Do more centralized or denser networks have greater knowledge of rare/extinct species than more fragmented networks?) 3) Do villages with high homophily tend to have higher or lower overall knowledge for rare/extinct species? We expect that orchid knowledge would be greatest in networks with high density but low fragmentation. We also expect that networks with high fragmentation would have greater disparities of knowledge between subnetworks of high homophily.

Actor Level: 1) Does an actor's position in the network predict how much (s)he knows? (e.g., Do more centralized actors have greater knowledge than less centralized actors?) 2) Does a person's position in a network impact the relationship between species extinction and knowledge loss? (e.g., Do more centralized actors have greater knowledge about rare/extinct plants than less centralized actors?) 3) Are the most knowledgeable people less central in more fragmented communities? We anticipate that more centralized actors will have greater knowledge about orchids than less centralized actors. We expect this to hold true even for recently extinct orchid species, since their position within their networks would help to mitigate against knowledge loss.

4.2. Methodology

4.2.1. Study system

Puge County (102°26'~102°46'E and 27°13'~27°30'N) is the second least populated of the 17 county-level jurisdictions within the Liangshan Yi Autonomous Prefecture (Figure 2.1) in southwest Sichuan Province (92˚21'~108˚12'E and 26˚03'~34˚19'N). Having a total population of 155,740 (2010 census), the two primary ethnic groups in Puge are the *Yí* at 74.8% and the *Hàn* (China's majority ethnicity) at about 24%. Outside of the county seat of Puji Town (population ~19,000), the Han tend to live at lower elevations and the Yi tend to live at higher altitudes, but many villages, especially near roads and market hubs are home to both groups. The villages in Puge County have become heavily fragmented in recent years as many young and middle-aged people of both ethnic groups have escaped the impoverished conditions in Puge to work in wealthier jurisdictions and other provinces. This concept, called *dǎgōng* in Chinese, has contributed to the largest rural-to-urban migration in world history (Zhang and Song 2003), as many Chinese have abandoned rural lifestyles and moved to urban areas to find jobs, raise money, and seek better opportunities. With such high fragmentation in rural communities resulting from *dǎgōng*, traditional ways of life have become strained. In Puge County, as many as 40-70% of the population (depending on village) are away on *dǎgōng*, with the remainder largely consisting of the elderly, minors, and disabled.

4.2.2. Preliminary study

To directly test the impact of network structure on knowledge loss due to species extinction, the eight village units in Puge County selected for the in-depth knowledge survey were also used as the locations of this SNA. Four were selected for being at least 80% Han-majority and four for being at least 80% Yi-majority (Table 4-1). Two of each group had significant ongoing orchid activity (with ≥10% of the total population, regardless of ethnicity, actively engaged in collecting, cultivating, or selling *Cymbidium*), while two of each lacked significant activity for ≥five years. For the knowledge survey, five individuals of the village's majority ethnic group were randomly selected from each of three age strata (<35, 35-50, >50) for a total of 120 participants (15 people/village). Three sets of knowledge scores derived from the knowledge survey, consisting of the scores for three knowledge domains (local ecological knowledge, business/market knowledge, and orchid cultural knowledge, see methods in chapter 1) were used for this SNA.

Table 4-1: Villages in Puge and relevant variables. The population present at time of interviews (including ineligible individuals) is given with total given in parentheses. Bolded items indicate which villages fall within the minimum threshold necessary for each village-level selection criteria: ethnicity (≥80% target) and active orchid activity (≥10% of village population). SNA Contacts refers to how many actors were included in our SNA analyses at each village (≥80% of those eligible). An asterisk* indicates that the number is an estimate.

Village	% Han	% Yi	Households	Population	Orchid Activity	SNA Contacts
Puge 1	**90%**	10%	78*	153 (303)	**Yes (48%)**	71
Puge 2	**86%**	14%	70	126 (200)*	**Yes (31%)**	76
Puge 3	8%	**92%**	106	145* (460)	No (7%)	76
Puge 4	<1%	**>99%**	173*	350 (812)	**Yes (10%)**	188
Puge 5	0%	**100%**	82	125 (400)	**Yes (22%)**	74
Puge 6	0%	**100%**	43	57 (190)	No (6%)	47
Puge 7	**84%**	16%	45	55 (160)	No (2%)	54
Puge 8	**100%**	0%	23	38 (100)	No (0%)	42

4.2.3. Social network data collection

To measure the various network and actor-level social network structural variables for each village, between July and September 2015, in-person interviews were conducted with ≥80% of all eligible villagers present at the time of data collection. Although total data collection occurred over two and a half months, each village took between 2-10 days to complete. All individuals older than 18, who were currently living in the village, excluding the blind, mentally disabled, and elderly with dementia were eligible. To build trust and reduce likelihood of confusion, all interviews were conducted by the first author with the assistance of a local speaker of the participant’s native language (Mandarin Chinese or relevant Yi dialect), or by field assistants from the local community trained and overseen by the first author. Socio-demographic variables for all participants were collected, including: age, sex, ethnicity, education level, and orchid activity. For each SNA interview, participants were asked questions related to who in their village they would consult with on matters related to each domain of orchid knowledge (local ecological, business/market, and orchid cultural knowledge; Table 4-2). Several participants responded as "I don't ask anyone, they all come and ask me!" In these cases, we would follow up by asking "who in this village would you most likely talk with about this topic?" The answers were then compiled into matrices and used to construct social networks of each knowledge domain per village for structural analysis using the UCINET social network analysis software package (Borgatti et al. 2002). It is important to note that for each SNA question asked, a different social network results, even for the same group of actors. Since each person operates in a variety of social domains, each question reveals a different aspect of their knowledge network. Consequently, the three questions asked of each participant at the eight villages yielded a total of twenty-four distinct social networks.

Table 4-2: SNA interview questions used to gauge social network ties/guanxi of each contact per village.

Knowledge Type		English & Chinese Questions 中英采访问题
Local Ecological 本地生态	LEK	Who do you ask if you need assistance/help identifying an orchid, finding an orchid in the wild, or cultivating an orchid? 当您需要帮助识别兰花，在野外寻找兰花，或者培育兰花的时候，谁帮助您？
Business/ Market 商业/市场	BMK	Who do you ask if you need assistance/help buying or selling an orchid? 如果你需要帮助购买或出售的兰花，您平常问谁？
Orchid Cultural 兰花文化	OCK	In regards to orchid history and culture, who do you discuss/interact with? 关于兰花的历史和文化，您平常跟谁讨论/交流？

4.2.4. Data analysis

For each social network, key structural metrics at the actor level (degree, eigenvector, betweenness, closeness, and beta-centrality) and network level (average distance, closure, compactness, degree centralization, density, diameter, and fragmentation) were calculated (Wasserman and Faust 1994; Bodin et al. 2006; Prell 2012; Barnes et al. 2016). Note, since each network was of differing size (i.e., the total number of actors varied in each), we used the normalized scores of each structural variable so that they could be compared across networks (Borgatti et al. 2002; Prell 2012). In addition, since closeness centrality cannot be calculated on fragmented networks (Prell 2012), we first isolated the main component of each network and calculated closeness centrality on the main component only, assigning a score of zero to all other actors (Borgatti et al. 2002). The homophily of each network was also calculated for each of the five actor socio-demographic attributes (Prell et al. 2008; Barnes et al. 2016). For further analysis, two matrices were compiled: one for actor level (including the structural variables and knowledge scores for the fifteen people/village randomly selected for the knowledge survey) and one for village level (including the average knowledge scores and structural variables for each village). Due to lack of any variability in several structural variables, we had to exclude Puge 6 in the network-level analysis and Puge 6 and Puge 7 in the actor-level analysis.

To test the effect of social network structure on knowledge distribution within a network, at each level of analysis we used generalized linear mixed effect models (GLMMs) with package "glmmADMB" in R version 3.3.2 (R Core Team 2016) and beta error distribution (Ferrari and Cribari-Neto 2004), mean knowledge scores as a function of each social network structural variable (fixed effects), and with village and knowledge type as random effects. Starting with the full, saturated models that included all fixed effects, we reduced each model to create six (actor-level) and eight (village-level) nested models (Appendix A, Table A7-A8). Akaike Information Criterion (AIC) was estimated for each model (Burnham et al. 2011) and we used ΔAIC (the difference between the AIC of a given model and the smallest AIC) to measure the level of support for each of these models. We used package "MuMIn" (Barton 2013) to conduct model averaging to estimate the effects of each predictor on knowledge across all models (Mazerolle 2006; Grueber et al. 2011). To test for the impact of the network structural variables on the loss of knowledge due to plant extinction, at the network-level analysis, similar GLMMs were developed for non-averaged knowledge scores separated by rarity of orchid in three different classes: 1) formerly common to now rare (CR), 2) formerly common to now locally extinct (CE), 3) formerly rare, now locally extinct (RE), with each as separate response variables (Appendix A, Tables A9-A11).

4.3. Results

4.3.1. Han villages with significant orchid activity

The first village, **Puge 1** (Han-majority, active in the orchid trade), had 71 nodes (actors), and for the LEK network, it had 155 ties in 2 components (disconnected sub-groups), with a network diameter of 6, average path distance of 2.634, degree centralization of 0.481, and density of 0.061, with essentially no network fragmentation (0.028). It had strong homophily by ethnicity (-0.858), but was only slightly homophilous for sex (-0.110). The BMK network for Puge 1 differed in the following variables: 123 ties in 6 components, average distance (2.776), degree centralization (0.393), density (0.047), and fragmentation (0.137). It remained strongly homophilous by ethnicity (-0.854), but was also moderately homophilous by sex (-0.236) and orchid activity (-0.155). The OCK network differed in number of ties (103) and components (12), as well as diameter (5), average distance (2.681), degree centralization (0.311), density (0.040), and fragmentation (0.311). Homophily was similar to that of the BMK network, being strongly homophilous by ethnicity (-0.845), and slightly homophilous for sex (-0.185) and orchid activity (-0.107).

At the actor-level of analysis, two key actors were strongly central for all five measures of centralization across all three knowledge networks (P1-01 and P1-04), with two additional actors being central for all measures of all networks except in the OCK network for closeness (P1-05) and betweenness and closeness (P1-24). In all, 24 actors were central in at least one measure in at least one network, with eight actors only scoring central in one measure for one network, and an additional four scoring as central in one measure in two networks. All four highly central actors were Han males who were active in the orchid trade. In general, across all three networks, females were mostly clustered around highly-central males. Of the five females who scored central in some way, they were all Han and two of them were active in the orchid trade. There was only one Yi individual active in the orchid trade in this village (P1-06), and he scored highly central in both degree and betweenness across all three networks, serving as a bridge for four other Yi to connect to the broader LEK network and five other Yi to connect to the BMK and OCK networks. One other Yi male (P1-48), not active in the orchid trade, scored high for eigenvector centrality only in the OCK network.

In the other Han-majority village active in the orchid trade, the network relations of **Puge 2**'s 76 nodes closely paralleled the structure and general trends of Puge 1 except that for all three knowledge networks, Puge 2 was completely connected (having a single component, no isolates, and a fragmentation score of 0). For the LEK network, it had 151 ties, with a network diameter of 6, average path distance of 2.261, degree centralization of 0.782, and density of 0.052. The BMK network differed in ties (130), average distance (2.356), degree centralization (0.775), and density (0.045). The OCK network differed in ties (132), diameter (4), average distance (2.231), degree centralization (0.802), and density (0.046). For all three knowledge networks, Puge 2 was less homophilous by ethnicity than Puge 1 (LEK: -0.378; BMK: -0.370; OCK: -0.349), and it was only slightly homophilous by sex (LEK: -0.113; BMK: -0.123; OCK: -0.046), but not at all for orchid activity. Two key actors were strongly central in all five measures of centralization across all three knowledge networks (P2-08 and P2-09), with three additional actors being strongly central in all measures except betweenness in all three networks (P2-70), as well as for closeness in LEK (P2-69) and eigenvector and closeness for BMK (P2-71). Sixteen actors were central in at least one measure in at least one network, with four actors only scoring central in one measure for one network, and an additional five scoring as central in at least one measure in at least two networks. As with Puge 1, all five highly central actors were Han males who were active in the orchid trade, and females mostly clustered around highly-central males. Only one female (Han) scored as central in any category (P2-02). One Yi individual scored as central (P2-40) for betweenness in the LEK network, as did the Han village leader (P2-34). The former was not active in the orchid trade, but the latter was.

4.3.2. Han villages without significant orchid activity

In contrast to Puge 1 and 2, Puge 7 and Puge 8 are Han-majority with <10% of their communities actively participating in the orchid trade, and they are structurally much more fragmented. **Puge 7** had 54 nodes, and the LEK network had 46 ties in 8 components, a network diameter of 4, average path distance of 2.471, degree centralization of 0.417, and density of 0.032, with a network fragmentation of 0.475. The BMK network only differed slightly in average distance (2.461) and degree centralization (0.437). In contrast, the OCK network had one more tie (47) and one fewer component (7), but it only differed slightly in diameter (5), average distance (2.504), degree centralization (0.436), density (0.033), and fragmentation (0.448). Unlike Puge 1 and Puge 2, the homophily by sex was much stronger for each network in Puge 7 (LEK and BMK: -0.217; OCK: -0.192) than the slight homphily by ethnicity (LEK: -0.087; BMK: -0.044; OCK: -0.064). In contrast to the other villages that had multiple very central actors, in Puge 7 there were only five actors who were central in at least one measure in at least one network. Two of these were highly central in all measures and across all three networks; one was an Yi male active in the orchid trade (P7-20) and the other was a Han male who was also the village leader (P7-29). Despite the low percentage of the population engaged in the orchid trade, two out of five of the central actors were actively engaged (P7-20, and a Han male P7-30). The other two central actors were Han females (P7-44 and P7-51). This analysis at the actor-level seems to explain the low network-level homophily (by ethnicity) score. In particular, actor P7-20 was a minority both ethnically (Yi) and in terms of being actively engaged in the orchid trade, but he was the most highly central actor across the board, including in terms of betweenness, meaning that he served as a bridge between subgroups that would otherwise be disconnected if he were not there. Incidentally, this village was previously highly active in the orchid trade, but the vast majority of the villagers have not been active for more than 5 years. Those who remain active are primarily Yi people, likely explaining why this village has close to zero homophily by ethnicity, countering prevailing cultural expectations.

There were 42 nodes in **Puge 8**, and all three knowledge networks were very similar, each having 28 ties and 15 components, diameters of 5, densities of 0.031. They differed slightly on average path distance (LEK: 2.085; BMK: 2.275; OCK: 2.429), as well as degree centralization (LEK and BMK: 0.095; OCK: 0.121), and all were highly fragmented (LEK: 0.905; BMK: 0.894; OCK: 0.870). Due to the homogeneity in Puge 8 by ethnicity and its lack of orchid activity, it was perfectly homophilous for both of these attributes (-1.0). Sex also showed a moderate homophily for each knowledge network (LEK: -0.214; BMK: -0.357; OCK: -0.214). In contrast with the two highly-centralized actors in Puge 7 that served as bridges and minimized the three knowledge networks from fragmenting further, in Puge 8 there were 14 actors that scored central in at least one measure, but none that scored highly central for all measures in all networks. Two did come close, with P8-15 (the village head) scoring highly in every measure and every network except for degree centrality in the LEK network, and P8-08 which scored highly in all three networks for all measures of centrality except for degree. Both were Han males.

4.3.3. Yi villages with significant orchid activity

Of all the villages, **Puge 4** had the largest set of nodes (188) and the most ties (LEK: 259; BMK: 256; OCK: 251), but each network had relatively few components (LEK and OCK: 13; BMK: 11). The LEK network had a diameter of 9, average path distance of 3.369, degree centralization of 0.299, and density of 0.015, with moderate fragmentation of 0.229. The BMK network differed from LEK in average path distance (3.479), degree centralization (0.315), and fragmentation (0.210). The OCK network differed in average path distance (3.439), degree centralization (0.326), and density (0.014). At the actor-level, 35 individuals registered as holding a central position for at least one centrality measure in at least one network, eight of these were only central at one measure in one network, thirteen were active in the orchid trade, none were Han and none were female. The three most highly central individuals were P4-60 (central for all five measures in all three networks), P4-151 (central for all measures except betweenness in all networks), and P4-119 (central for all measures in LEK, but only degree and betweenness in BMK, and betweenness and beta-centrality in OCK). The latter two were also orchid growers. Sixteen others scored high for betweenness in all networks, indicating that they serve as bridges between otherwise disconnected portions of the networks.

In **Puge 5**, there were 74 nodes with ties of 152 in two components (LEK), 138 in one component (BMK), and 140 in one component (OCK). The LEK network had a diameter of 6, average path distance of 2.329, degree centralization of 0.618, and density of 0.056, with negligible fragmentation (0.027). The BMK network differed in average path distance (2.404), degree centralization (0.609), and density (0.051), with no fragmentation. OCK differed in average distance (2.383), degree (0.623), density (0.052), and with one component, also having no fragmentation. With no Han individuals in this village, homophily by ethnicity was not relevant, but there was slight homophily by sex (LEK: -0.158; BMK: -0.130; OCK: -0.157). Fourteen individuals were central for at least one centrality measure in at least one network, and of these, eight were active in the orchid trade, two were female (P5-35, active, and P5-62, non-active), and one was the village head (P5-50, non-active). Two (one male and one female) were central for only one measure in one network. The five most central actors were P5-14 (central for all five measures in all three networks), P5-57 (central for all measures and in all networks except for beta-centrality in BMK), P5-66 and P5-67 (both central for all measures except for betweenness in all three networks), and P5-35 (central for degree, eigenvector, and closeness in all three networks). All of these were active in the orchid-trade, but only one (P5-35) was female.

4.3.4. Yi villages without significant orchid activity

Puge 3 and Puge 6 were Yi-majority villages without significant orchid activity (<10% engagement). **Puge 3** had 76 nodes, and each network had a slightly different number of ties (LEK: 109; BMK: 108; OCK: 106) with few components (LEK and OCK: 3; BMK: 2). The LEK network had a diameter of 8, average path distance of 3.454, degree centralization of 0.276, and density of 0.038, with fragmentation of 0.127. The BMK network differed in diameter (9), average distance (3.644), degree (0.262), and fragmentation (0.052). The OCK network differed from LEK in average distance (3.472), degree (0.263), and density (0.037). Across all three networks, there was significant homophily for orchid activity (LEK: -0.321; BMK: -0.315; OCK: -0.302) and by ethnicity (LEK and BMK: -0.963; OCK: -0.962). Twenty-eight individuals were central for at least one measure in at least one network, and of these, three were active in the orchid trade (P3-05, P3-44, P3-58, all male), and nine were female. Four were only central for a single measure in one network, while sixteen were only central in two or three networks for just one measure of centrality (betweenness, eigenvector, or beta-centrality). The two most central actors were central for all measures in all networks, both were male, and one was active in the orchid trade (P3-05), while the other was not (P3-10), but the latter was the village head. Two additional highly central actors were central in all networks for all measures except eigenvector (P3-41) or betweenness (P3-58). Both were male, but only the latter was active in the orchid trade.

Puge 6 was heavily fragmented (0.858 in all networks), with very little structural variability between the three knowledge networks. There were 47 nodes with 34 ties and 13 components in each network. The diameter (3), average path distance (1.791), degree centralization (0.308), and density (0.031) were also the same for each network. Similar to Puge 5, with no Han individuals in the village, homophily by ethnicity was irrelevant. There was significant homophily for orchid activity across all three networks (-0.765). Since Puge 6 was heavily fragmented, the structural variables were largely focused on the main star-shaped component with P6=10 as the focal node. He was highly central for all measures and in all networks, and this was likely due to him being the village head. Of the 18 actors that were central for at least one measure in at least one network, fifteen of these were surrounding P6-10 (including all central females). The only central actors that were not in this main component were P6-01 (for betweenness in all three networks) and P6-35 (for Beta-centrality in all three networks), were united together in a different component. Surprisingly, of the four individuals in the village who were active in the orchid trade, none of them measured as central in any way, which likely is due to the high homophily by orchid activity.

4.3.5. Effect of network structure on knowledge distribution

We found no significant effect for any of the social network structural variables on the distribution of orchid knowledge at the network-level (Appendix A, Table A-7). This also held true for the distribution of knowledge by orchid rarity status (Appendix A, Tables A9-A11). However, at the actor-level, we did find significant effect of degree centrality (normalized) on the distribution of orchid knowledge (effect size $\beta = 5.821 \pm 1.956$, $p<0.001$; Appendix B, Table A-8). Since age and educational level did not prove to be homophilous for any network, this indicates that these attributes are not contributing to network fragmentation. There was, however, high homophily by ethnicity (except for Puge 2, with moderate homphily, and Puge 7 with negligible homophily), moderate homophily by sex (in all villages except for Puge 3 and Puge 6), and moderate to high homophily by orchid activity (in Puge 3 and Puge 6) (Figure 4.1). However, anecdotally, several elderly interviewees who were active in the orchid trade explained that they had first been inspired to learn about orchids as youths when elderly people took them to the mountains to see the orchids. They expressed concern that with declining orchid populations the younger people are less interested now in learning about orchids.

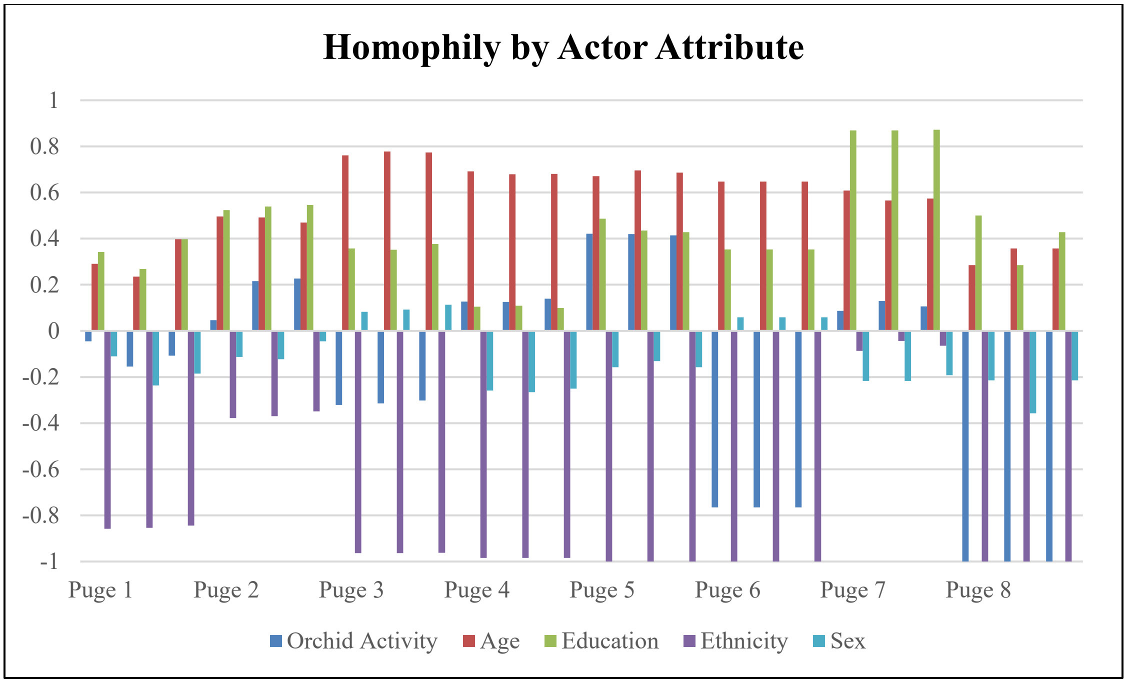

Figure 4.1: Homophily by actor attribute. Negative scores indicate the presence of homophily (perfect homophily = -1) and positive scores indicate the absence of homophily (non-homophily = 1).

4.4. Discussion

Barnes et al. (2016) explain, "social networks can profoundly affect human behavior, which is the primary force driving environmental change." Consequently, understanding the structural characteristics of social networks can help explain differing types and depths of knowledge, as well as how and why knowledge is or is not disseminated within a community (Granovetter 1983; Valente 1996; Bodin et al. 2006; Butts 2008; Hopkins 2011; Prell 2012). Contrary to our expectations, we did not find that network structural variables predict the level of knowledge that a community has (at the network-level). Since they also did not affect the relationship between species extinction and knowledge loss, this does not bode well for the prospect of conserving knowledge within the local community in light of declining orchid populations. Essentially, network structure does not affect (and therefore cannot be the cause of) the loss of knowledge resulting from species decline. Thus, irrespective of the pattern of knowledge flow within a community, the knowledge will still be lost when species become rarer and go extinct. Since social network structure does not counter the negative effect of rarity on knowledge, there is no justifiable expectation that network structure itself will work to rescue knowledge from being lost. This suggests that conservation requires an outside-the-network force to ensure not only species conservation, but also conservation of species-related knowledge.

We used knowledge associated with *Cymbidium* in rural Sichuan Province, China, due to their documented cultural importance and the recent overharvest and local extinction of many species. However, we believe our results point to a broader trend beyond the specific taxa and local context of our study. For example, Turvey et al. (2010) and Zhang et al. (2014) found similar declines in knowledge resulting from animal extinctions in China. Although they did not specifically address the social network structural variables in their studies, they sampled at similar local scales. Moreover, our findings support those of Lauer and Matera (2016) who found that social network structure did not significantly affect the ability of rural villagers in the Solomon Islands to detect ecological changes following a major tsunami. Though more studies should be done to document whether this trend is true in other contexts and with other species, effort should also be made to measure what outside forces are best able to help local communities preserve cultural knowledge in complement with efforts to conserve their biodiversity (Lauer et al. 2012; Cocks and Wiersum 2014; Mbaru and Barnes 2017).

Though we did find a significant effect of degree centrality (at the actor-level) on knowledge distribution, this may not necessarily provide "hope" at the individual level that some people will continue indefinitely to retain knowledge due to their central positions within the network. Other studies have found that knowledge is no longer acquired by younger generations when it is no longer seen as valuable to their future (Srithi et al. 2009; Reyes-García et al. 2013). Combining this with the anecdotal comments of multiple elderly participants in our study expressing concern for the lack of interest among youth to learn about orchids (and the inability to inspire them in light of decreasing wild orchid populations), it appears that the degree centrality of knowledgeable individuals in the networks may be more due to the awareness of their knowledge within the local community (i.e., knowledge drives degree centrality), rather than being the *cause* of their higher knowledge. Since we also found that the knowledge mean of each community correlated with its variance, essentially, the higher the knowledge the higher the variance, meaning that a few people know a lot, but this knowledge is not necessarily being passed on to others. Consequently, in villages with higher knowledge, it tends to be held only by a few people (hence their high degree centrality). Thus, if society seeks to preserve the cultural knowledge about rare and extinct species, additional actions must be taken to preserve these knowledge resources outside the network structure itself.

4.5. Conclusion

In this study, we tested what if any influence network structure (network level) and network position (actor level) may play in mitigating the broader impact of species extinction on knowledge loss in eight villages in southwest Sichuan Province, China. These levels of social network analysis can be thought of as measuring the influence also of the Chinese concept of *guanxi*. We found that social network structure had no role in influencing this relationship, with mixed results at the actor level (degree centrality being the only centrality measure with significant effect on the distribution of orchid knowledge). Thus, though leveraging one's *guanxi* may indeed provide avenues to acquire advantageous knowledge, there is nothing about the social network structure itself that will prevent knowledge from being lost as a result of species decline if it is no longer deemed valuable to know. Since the communities tend to be highly fragmented by ethnicity, this poses an additional danger to knowledge preservation along ethnic lines. Those individuals whose *guanxi* spans ethnic lines are the most valuable for countering this tendency towards network fragmentation. Furthermore, an individual's *access* to a plant resource through involvement in the orchid trade contributes to their likelihood of being central in their communities' knowledge networks, regardless of ethnicity, thereby increasing the likelihood that they occupy the position of a network bridge. Since social network structure is not sufficient by itself to preserve a community's knowledge following species extinction, this suggests the need for a force outside of the social network to effect meaningful conservation of threatened knowledge. These results and the insight derived from this project are of particular importance for stakeholders in biocultural diversity conservation such as government agencies, botanical gardens, not-for-profit organization, and universities.

CHAPTER 5:
THE EFFECTIVENESS OF BOTANICAL GARDENS AT PROMOTING ORCHID BIOCULTURAL DIVERSITY CONSERVATION

5.1. Introduction

The rich orchid biodiversity in Southwest China is under significant extinction pressure due to the region's widespread overharvest of wild species, rapid economic development, and habitat destruction. Balancing conservation and economic development is seen as an "unresolved conflict in China" (Li and Pritchard 2009; Liu et al. 2014; Liu et al. 2015). As a signatory of the UN Convention on Biological Diversity (CBD), and in response to the significant threats to the country's biodiversity, beginning in 2001, China began implementing an aggressive national program to conserve wildlife and preserve species diversity *in situ* by establishing new nature reserves (Enright and Cao 2010; Seaton et al. 2010; Zhang et al. 2015). Orchids were identified as one of the 15 key taxa deemed most urgently in need of protection (Seaton et al. 2010). There are now more than 2,600 national and provincial-level terrestrial and marine nature reserves in China (Zhao et al. 2014; Zhang et al. 2015). However, despite the rapid expansion in size and number in recent years, resource exploitation rates inside and outside the reserves are almost indistinguishable due to complex logistics, limited management budgets, and dearth of trained staff to patrol and monitor the areas (Enright and Cao 2010).

Due to the interconnectedness between human socio-cultural systems and the environment, failure to incorporate an understanding of the human dimension, including local motivations for plant resource extraction and use, lessens the effectiveness of research and conservation efforts (Maffi 2005; Prell et al. 2008; Bodin et al. 2011; Bodin and Tengö 2012; Barnes et al. 2016). A greater understanding of the multifaceted interactions between biological diversity and cultural knowledge diversity is also increasingly recognized as critical in efforts to conserve both (Smith 2001; Pretty et al. 2009; Cocks and Wiersum 2014; McMillen et al. 2014). With more than a quarter of China's Orchidaceae species used medicinally and as food supplements, this is particularly the case in Southwest China, where economic and cultural incentives are driving overharvest of many wild species beyond their ability to naturally recover even within established nature reserves (Liu et al. 2014).

Botanical gardens (BG) today comprise the world's "single largest biological institutional capacity, able to deliver effective plant conservation on all continents" (Swarts and Dixon 2009). There is growing recognition in China that the country's acute biodiversity conservation challenges require: 1) greater "development of *ex situ* collections in botanical gardens" (Enright and Cao 2010), 2) greater emphasis on both *in situ* and *ex situ* conservation efforts (Seaton et al. 2010), and 3) greater integration of BG to manage *in situ* ecosystems, integrating "long-term monitoring, active restoration, educational outreach, agricultural extension services, and policy involvement" (Chen et al. 2009a). This study investigates how BG activities can help conserve orchid biocultural diversity in Southwest China's Sichuan Province and assess the effectiveness of current conservation efforts, with implications for policy and conservation stakeholders.

5.2. Methodology

To determine the effectiveness of current orchid biocultural diversity conservation efforts in Sichuan, assess the province's current BG institutional capacity, and determine which models of BG are most effective at meeting the current conservation challenges, this project was broken into two methodological components: 1) an in-depth literature review and 2) a case study analysis of six Chinese BG.

5.2.1. Literature Review

A multi-stage review of published literature was conducted to isolate which aspects of BG are most effective at addressing conservation concerns globally and with specific reference to the status of orchid conservation efforts in Southwest China. In August 2014 and May 2017, queries were conducted of the University of Hawai`i at Mānoa's library resources via the *OneSearch Mānoa* search platform, which combines the holdings of the library's catalog (called *Voyager*), as well as the its digital collections, indices of academic journals and conference papers, among other resources. Queries utilized various combinations of the following keywords: "botan* garden," "conservation," "Orchidaceae," "China," "Southwest China," and "Sichuan." Similar queries were made of the journals published by internationally recognized BG, including the *Annals of the Missouri Botanical Garden*, New York Botanical Garden's *Brittonia*, The Arnold Arboretum of Harvard University's *Arnoldia*, and the Royal Botanic Gardens at Kew's *Kew Bulletin*. The extensive repository of research from the 50 years of master's theses from the Longwood Graduate Program in Public Horticulture (1967-2017) held at the University of Delaware's library was also referenced. Publications documenting both the positive *and* negative implications of BG activities were sought. Resulting publications were sorted for relevance and coded for themes for further analysis of the case studies.

5.2.2. Case Studies

To document the inherent strengths and weaknesses of various BG models, their unique characteristics, successes and challenges, as well as the role they play in the conservation of threatened cultural knowledge and biodiversity within their communities, six Chinese BG were chosen for institutional case studies. Three of these were located within Sichuan Province (every extant garden at the time): 1) Chengdu Botanical Garden (CBG), 2) Emei Mountain Botanical Garden (EBG), and 3) West China Subalpine Botanical Garden (WCBG), and three were located in other provinces: 1) Kunming Botanical Garden (KBG), 2) Shanghai Chen Shan Botanical Garden (CSBG), and 3) Xishuangbanna Tropical Botanical Garden (XTBG) (Table 5-1). These gardens were selected using variables pertinent to Sichuan's context, including their locations and their relevant research, conservation, and community engagement activities. General questions were developed (Appendix A, Table A-12) to document various measures of size, capacity, and function of each garden, including number of taxa (including rare and orchid taxa); institutional missions and visions; number of staff and organizational structure; chief research and education priorities; public outreach and programming activities; ethnobotanical work; annual visitation and demographics of visitors. Methodology, questionnaires, and informed consent forms (in English and Chinese) were approved before use by the University of Hawai`i's Human Subjects Institutional Review Board.

Table 5-1: Chinese Botanical Garden Case Studies. Weibo is a social network platform widely used in China that is similar to Twitter; Weixin is a social network platform more like Facebook. An asterisk (*) indicates numbers listed in thousands.

#	Case Study	Founded	Staff	Visitation*	K-12 Students*	Weibo*	Weixin*	Total Taxa*	Orchid Taxa	Rare Taxa	Acreage	CAS	CUBG	BGCI	ERA	Int'l Agenda
1	Chengdu Botanical Garden 成都市植物园 <http://www.cdzwy.com/>	1983	89	400	50	10	<1	2	0	70	106	---	Yes	---	---	Yes
2	Emei Mountain Botanical Garden 峨嵋山植物园 <http://www.scpri.ac.cn/> <http://www.scnrsa.com.cn/>	1984	18	20	8-10	0	0	2.4	70	100	9	---	Yes	Yes	---	---
3	West China Subalpine Botanical Garden 华西亚高山植物园 <http://eco.ibcas.ac.cn/station/huaxi/> <http://eco.ibcas.ac.cn/huaxi/>	1986	18	0.3	3	0	0	2	0	27	137	Yes	Yes	---	---	---
4	Kunming Botanical Garden 昆明植物园 <http://kbg.kib.cas.cn/> <http://www.kib.cas.cn/>	1938	50	850	5-10	0	1	6.2	200	700	109	Yes	Yes	Yes	---	---
5	Shanghai Chenshan Botanical Garden 上海辰山植物园 <http://www.csnbgsh.cn/>	2007	160	900	50	70	45	>15	697	432	512	(Yes)	Yes	Yes	---	---
6	Xishuangbanna Tropical Botanical Garden 西双版纳热带植物园 <http://www.xtbg.cas.cn/>	1959	340	600	5	100	10	13	439	>300	2,780	Yes	Yes	Yes	Yes	Yes

Following established procedures for mixed-method, case study analysis in the social sciences and humanities (Creswell 2003; Seyler 2009), semi-structured on-site interviews were conducted with the directors, key members of management including department heads, as well as researchers and graduate students at each BG between October and December, 2015. Representatives of each garden were initially contacted via email or telephone to schedule the site visits. A copy of interview questions and informed consent were provided to participants during the interviews, and informed consent was obtained orally. Interviews were conducted in both English and Mandarin Chinese (based on participant preference), digitally recorded, and subsequently transcribed and translated, as necessary. All interviews were coded for themes and, in most cases, direct quotes were identified to the institution or job title, with names removed to protect the privacy of individuals. Where available, additional information was also collected in the form of books, brochures, pamphlets, and internal institutional documents such as memos and PowerPoint presentations. Information was also obtained via each institution's website.

5.3. Results

5.3.1. Literature Review

There are more than 2,500 BG in the world today (Maunder 2008; Crane et al. 2009; Swarts and Dixon 2009), with more than half of these being established since 1950 (Crane et al. 2009). Beginning in the 1970s, as the public became increasingly aware of urgent threats to biodiversity, many BG became active agents in plant conservation around the world (Miller et al. 2004; Maunder 2008; Chen et al. 2009a; Donaldson 2009; Oldfield 2009; Akopian 2010). In 1984, the World Conservation Strategy was established jointly between the International Union for the Conservation of Nature (IUCN) and World Wide Fund for Nature (WWF), which became the impetus to found Botanic Gardens Conservation International (BGCI) in 1987 (Akopian 2010; BGCI 2017). With more than 500 BG institutional members in about 100 countries, BGCI is today the world's largest plant conservation network (Waylen 2006; BGCI 2017), whose mission is to "mobilize botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet" (BGCI 2017).

Leading BG are at the forefront driving international plant conservation law, serve as valuable consultants to governments, and collaborate with peer institutions around the world (Hackney Blackwell 2013). In 2002, to more proactively address the global plant extinction crisis, the Conference of Parties for the United Nations Convention on Biological Diversity (CBD) adopted the Global Strategy for Plant Conservation (GSPC) in part due to the organized efforts of the BG community as spearheaded by BGCI (Donaldson 2009; Oldfield 2009; Wyse Jackson and Kennedy 2009). The GSPC targets were updated and expanded in 2011 (Conference of the Parties 2011; Appendix A, Table A- 13). Many BG have contributed to "policies and actions within the CBD and GSPC and they have responded quickly to develop policy positions, strategies and action plans relating to climate change" (Donaldson 2009). In pursuance of the GSPC's targets, representatives from the Missouri Botanical Garden (USA) and Royal Botanic Gardens, Kew (UK), began in 2008 to develop a global checklist of all plant species (Wyse Jackson and Kennedy 2009). Officially launched in 2010, this global working list of all known plant species (*The Plant List*) combines the floristic datasets, nomenclatural resources, and collective efforts of Missouri Botanical Garden, Royal Botanic Gardens at Kew and Edinburgh, New York Botanical Garden, Conservatory and Botanical Gardens of the City of Geneva, South African National Biodiversity Institute, and multiple leading herbaria (The Plant List 2013).

To date, the most effectively implemented targets of the GSPC have been those that built upon the strengths of the BG community, including "*ex situ* conservation, network development, education and the identification of important areas of plant diversity" (Wyse Jackson and Kennedy 2009). The CBD defines *ex situ* conservation as "the conservation of components of biological diversity outside their natural habitats" in contrast to *in situ* conservation (Oldfield 2009). *Ex situ* conservation measures, including seed banks and living collections, have long been an active focus of BG research and practice (Donaldson 2009), and *ex situ* seed conservation in particular is estimated to cost as little as 1% of *in situ* efforts such as management of natural areas (Li and Pritchard 2009). Nevertheless, *in situ* conservation is generally regarded as the ideal option for long term species conservation, allowing them to fulfill their ecological functions and more robustly preserve genetic diversity (Oldfield 2009). Article 9 of the CBD identifies *ex situ* conservation as primarily complementary to *in situ* conservation (Maunder et al. 2001; Oldfield 2009). However, due to increasing risks afflicting *in situ* populations, *ex situ* techniques and the efforts of BG in storing germplasm are indispensable to conservation efforts (Maunder et al. 2001; Seaton et al. 2010). Therefore, one of the goals of the GSPC (Target 8) is to have >75% of threatened plant species in *ex situ* collections, with at least 20% "available for recovery and restoration" programs before the year 2020 (Table A- 13).

5.3.1.1. Biocultural Diversity Conservation and Sustainable Development

BG and the conservation community more broadly now recognize the inseparable connection between human society, indigenous and local knowledge and practices, sustainable development, ecological restoration, and biodiversity conservation (Waylen 2006; Dunn 2008; Crane et al. 2009; Wyse Jackson and Kennedy 2009; Birkinshaw et al. 2013). BGCI seeks to "challenge the popular notion that botanic gardens are only 'pretty places', and to promote the involvement of botanic gardens in initiatives that use plants for human well-being" (Waylen 2006). Targets 9 and 13 of the GSPC (Table A- 13) now specifically address the importance of respecting, preserving, and maintaining indigenous and local knowledge, innovations, and practices. The missions of many living collections-based institutions around the world, including BG, increasingly focus also on human needs (Miller et al. 2004; Hedean 2005; Waylen 2006).

Crane et al. (2009) argue that the world is too complex for a one-size-fits-all approach to conservation, so solutions to the challenges facing biodiversity must be "place-based and varied, depending on the local context and the needs of local people." Many new BG have been purposely designed with the needs of local communities in mind (Waylen 2006). In many regions that do not have formal agricultural extension agents available in sufficient supply, BG perform cooperative extension services to "popularize" the scientific knowledge to local people and broadcast research results and conservation concerns to the broader public (Waylen 2006; Chen et al. 2009a; Donaldson 2009; Seyler 2009). Several major BG have recognized that effective implementation and management of *in situ* conservation programs for biodiversity cannot occur without also encouraging local economic development and sustainable harvest of economic plants (Naughton-Treves et al. 2005; Chen et al. 2009a; Hardwick et al. 2011; Birkinshaw et al. 2013). In this vein, the Missouri Botanical Garden's work to support community-based conservation across Madagascar has implemented successful *in situ* conservation programs by encouraging sustainable natural resource use, poverty alleviation, and ecological restoration (Birkinshaw et al. 2013).

5.3.1.2. Chinese Botanical Gardens

Like the rest of the world, China has seen a rapid increase in the number of BG since 1950 (Pei 1984; Maunder 2008; Wen 2008; Seyler 2009). At the time of the founding of the People's Republic of China in 1949, there were only three BG and one small arboretum in China. Between 1950 and 1965, in order to "promote worldwide plant exchange and conduct experiments in the discipline of plant introduction and acclimatization," the Chinese Academy of Sciences (CAS) began establishing BG and plant research institutes across the country (Pei 1984). By 1960, the number of BG established by the national and provincial governments had grown to 34 nationally (Maunder 2008), and by 2008 this number had reached at least 234, with as many as 1-5 new gardens constructed per year during the first decade of the 21st century (Wen 2008). Many of the most active Chinese BG involved in plant diversity conservation remain under the administration of the CAS. All CAS-affiliated BG are degree granting institutions with advanced research and conservation programs (Wen 2008; Chen et al. 2009a; Seyler 2009; Enright and Cao 2010).

Today, there are three general types of public horticulture institutions in China: 1) BG affiliated with the CAS, 2) BG established and primarily supported by municipal or provincial governments, and 3) municipal greening organizations and historic landscape administration bureaus (Pei 1984; Wen 2008; Seyler 2009). To better coordinate conservation, research, and education efforts across the various types of Chinese BG, in June 2013, XTBG in collaboration with the CAS, State Forestry Administration, and Ministry of Housing and Urban-Rural Development established the Chinese Union of Botanical Gardens (CUBG). The CUBG is focused on "advancing the standard construction and orderly development of Chinese botanical gardens, to achieve reasonable distribution, species resource sharing and technological exchanges and cooperation," and it now has 100 member BG across the country (CUBG 2017).

5.3.1.3. Criticisms of Botanical Gardens

The founding impetus of many BG around the world was largely due to European imperial ambition as colonial powers sought to identify and collect plants with economic and industrial value within their colonial possessions, transmit these to European BG, and then disseminate propagules to other BG throughout the colonial world (Rudyj 1988; Dawson et al. 2008; Seyler 2009). This history of rapid collection and transmission of plants across the world into new ecological regions has resulted in several, interrelated criticisms of BG activities. For example, many of the world's most valuable cash crops now posing major threats to biocultural diversity, driving rapid deforestation and conversion of traditional agricultural lands to monocultures, were first disseminated and established in their new locales through the efforts of BG, including rubber (*Hevea brasiliensis*), oil palm (*Elaeis guineensis*), and cinchona (*Cinchona pubescens*) (Riswan and Yamada 2006; Dawson et al. 2008; Qiu 2009; Hulme 2011a).

Another criticism focuses on how BG have historically been an avenue by which invasive plants and biological pests have been introduced and established into new regions around the world, with concern that their present collections and continued activities may still pose an invasive species risk (Dawson et al. 2008; Hulme 2011a; Hulme 2011b; Hulme 2015). Consequently, the 2nd World Botanical Gardens Conference, hosted by BGCI in 2004, resolved that all BG should make special effort to conduct invasive species risk assessments of their collections and curation practices (Dawson et al. 2008). However, several studies have noted that relatively few gardens have actually implemented these voluntary invasive species assessments, and little formal guidance has been provided on how to do so (Dawson et al. 2008; Hulme 2011a; Hulme 2015). Hulme (2015) notes that though many BG have made great progress in working towards meeting multiple GSPC targets, much less effort has been paid to Target 10, which specifically addresses minimizing the introduction and spread of invasive species. He argues that assessing the invasive risks "posed by living collections should have similar prominence as the targets for *ex situ* conservation when assessing the contribution of botanic gardens to global biodiversity goals" (Hulme 2015).

Though these are legitimate criticisms, the primary goals and activities of the global BG community have changed significantly since the colonial era to focus more on conservation and ecological restoration (Sharrock 2011). In addition, the concern that BG living collections may continue to negligently harbor invasive species is clouded by some misunderstandings evident in the study methodologies. For example, Hulme (2011a) cross-referenced BGCI's global, online, searchable BG collections database with that of a list of 450 invasive plant species and found that 96% of these invasives were housed in BG collections around the world. However, this study failed to incorporate a geographic component in its assessment of BG living collections when determining whether the plants in question were indeed invasive where they were housed. For example, three of the species he mentions, including *Lantana camara*, *Hedychium gardnerianum*, and *Eichhornia crassipes* are intractable weeds in much of the world, but they are not invasive in areas too cold to overwinter outdoors. Since each of these species have arguably great value for public education on issues such as plant morphology, adaptation, pollination syndromes, biodiversity, and even invasive species control (Hedean 2005; He and Chen 2012), institutions that contain these species in glass houses for public education reasons, such as BG in north temperate climes where they do not pose invasive risk, should not be seen as representative of all BG collections worldwide. The relatively few collections (50) globally that Hulme (2011a) found contained these species cannot be interpreted as a criticism of the collective BG community if their geographic locations are not considered.

A subsequent study by Hulme (2015) alleges that BG, on average, "cultivate four times as many invasive non-native species (20) as red-listed threatened species (5)." Although this study does partially incorporate a geographic component by measuring the severity of a specie's invasiveness (based on how many of nine geographic regions it is found to be invasive), there is no direct test correlating the presence of these species in a BG collection and whether the species are invasive in the BG's own region. Furthermore, it also does not consider the limitations of cultivating endangered species around the world. For example, Hulme (2015) found that BG living collections only contained 3,712 (28%) known IUCN red-listed plant species. Even though he noted two-thirds of species extinct in the wild were conserved in BG collections, "species of lower risk status were more frequently cultivated than more imperiled taxa" (Hulme 2015). But, in an absolute sense, rare plant species will necessarily be housed in relatively few collections. If, for a given taxa, there are only five living individuals in the world, the greatest number of collections that could house this species is only five, which would be inconsequential averaged across thousands of gardens. Thus, the relative rarity of IUCN Red List species when averaged across all BG collections is not a fair criticism of the BG community. Rarer plants will necessarily be cultivated more rarely, just as common plants will be cultivated more widely.

Similarly, for those endangered species controlled by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), if they are illegally transported across international borders, when confiscated by border control it is not always possible to return them to their country of origin (USBG 2017). Thus, in 1978 the US Fish and Wildlife Service (USFWS) established the U.S. Plant Rescue Center Program in which vigorously screened public and not-for-profit BG, arboreta, zoological parks, and research institutions could apply to be the permanent home of confiscated endangered plants in the event the country of origin did not seek their return. Participating institutions must pay to transport and house these acquisitions in perpetuity, so as of 2017 there are only 65 institutions in the entire United States that qualify as a Plant Rescue Center (U.S. Fish & Wildlife Service 2017). Consequently, averaging the absolute number of rare species across all institutions regardless of Plant Rescue Center status (or similar programs in other countries) is not an appropriate methodology for assessing the effectiveness of BG conservation efforts.

Another criticism relates to the relatively few BG in the world that have formally joined BGCI (588 as of 2017), committed to the targets of the International Agenda for Botanic Gardens in Conservation (472), or otherwise adopted an invasive species policy (<10% of the >3,300 BG listed on BGCI's global *Garden Search* database) (Hulme 2011b; Hulme 2015). However, the BGCI *Garden Search* database is meant to be used as a resource for the public, so BGCI staff list gardens in the database as they become aware of them regardless of BGCI membership. BGCI keeps a separate list of institutional member gardens. Furthermore, not all gardens have the budget or staffing dedicated to upload their garden and collections details to BGCI's searchable databases (Sharrock 2011; Hulme 2011b; BGCI 2016). Though the data within these BGCI databases are continuing to expand over time, and they do provide valuable insight, to accurately draw global conclusions a researcher cannot simply rely on what limited data is currently available in the databases without directly contacting each garden themselves. The relatively few gardens fitting these criteria may also be due to confusion as to what constitutes a BG. For example, the largest U.S. consortium of BG in the United States is the American Public Gardens Association (APGA), and yet their mission and membership is purposely targeted towards *public gardens*, which includes more diversity of institutions than strictly BG. According to the APGA (2017a) website:

A public garden is an institution that maintains collections of plants for the purposes of public education and enjoyment, in addition to research, conservation, and higher learning. It must be open to the public and the garden's resources and accommodations must be made to all visitors. Public gardens are staffed by professionals trained in their given areas of expertise and maintain active plant records systems.

Many related entities are part of American Public Gardens Association or benefit from member organizations. These entities include: Botanical gardens, arboreta, cemeteries, zoological gardens, sculpture gardens, college and university campuses, historic homes, urban greening organizations, natural areas, and city/county/state/federal parks.

The APGA notes that there is currently no agency which grants legal accreditation to BG and any institution can call itself a BG (APGA 2017b). Consequently, several research and conservation-focused institutions have expressed concern for the lack of clarity in definitions. BGCI's 2016 International Advisory Council meeting stated the need to draft a more rigorous definition of what officially constitutes a BG (BGCI 2016). Similarly, in 2011 the Morton Arboretum (Lisle, Illinois), in collaboration with APGA and BGCI, officially launched a new organization and website called ArbNet <http://www.arbnet.org/> to support the common purposes and interests of tree-focused public gardens. Like BGCI, this organization maintains two lists of gardens. The first, called the *Morton Register of Arboreta*, includes more than 1100 tree-focused public gardens from around the world. The Morton Register "is a constantly growing database and any identified or named arboretum, or public garden with a significant focus on woody plants, may be listed" (ArbNet 2017). The second list only includes the gardens that have passed the accreditation process through the *ArbNet Arboretum Accreditation Program*, with four tiered accreditation levels (ArbNet 2017) (Table 5-2). Thus, a study on the effectiveness of conservation and research programs of arboreta collectively should likely focus only on the accredited institutions, rather than all institutions listed on the first list.

A final criticism relates to how the early focus on BG establishment was concentrated in Europe and North America, such that today the vast majority of BG infrastructure and research/conservation capacity lies in the northern temperate areas, far removed from the epicenters of the conservation and extinction crises in the Global South (Maunder et al. 2001;

Chen et al. 2009a; Seaton et al. 2010). Yet, BG near the hotspots of threatened biodiversity (such as those in the tropics) tend to have more diverse collections of species than their temperate counterparts, which today often prefer displaying only showy, ornamental taxa for education and aesthetic purposes in their space-limited greenhouses (Maunder et al. 2001; Seaton et al. 2010). Moreover, *ex situ* collections are susceptible to disease and weather in a more acute way than *in situ* preserves (Maunder et al. 2001). Consequently, many experts suggest that a better conservation strategy is to have *ex situ* collections established near the *in situ* populations in the source countries, where they can be effectively managed along with the wild populations (Maunder et al. 2001; Chen et al. 2009a; Swarts and Dixon 2009). BG established near threatened *in situ* populations have a more natural long-term ability to maintain their living collections, conserve the overall plant diversity of their own locales, and are better adapted to the constraints of local cultural and political conditions (Chen et al. 2009a). But Chen et al. (2009) argue that there are currently insufficient BG in the most at-risk areas of plant diversity, and more gardens should therefore be established in these areas of greatest concern.

Table 5-2: Total number of arboreta worldwide that are accredited by the Morton ArbNet Arboretum Accreditation Program, listed according to accreditation tier (Tier IV being the most rigorous level). These 185 institutions contrasts with the >1100 arboreta listed on the *Morton Register of Arboreta*.

Tier	Arboreta	Countries	Continents
Tier I	79	7	5
Tier II	67	3	3
Tier III	19	6	3
Tier IV	20	4	3
Total	185	13	6

Hardwick et al. (2011) explain that though BG are particularly well-equipped for ecological restoration efforts, relatively few are currently doing so. Chen et al. (2009) urge BG around the world to prioritize collaborating with and assisting BG located near the biodiversity hotspots. Thus, to address the pressing needs of *ex situ* and *in situ* conservation efforts and to better coordinate BG and nature reserves to address Targets 4, 5, 7 and 16 of the GSPC (Table A- 13), BGCI facilitated the founding in 2012 of the Ecological Restoration Alliance of Botanic Gardens (ERA) to "build global capacity for pragmatic yet well-informed ecological restoration" (BGCI 2012). The ERA today includes three executive council members and 26 associate member BG in twelve countries across all six inhabited continents (ERA 2017).

5.3.1.4. On Establishing New Botanical Gardens

The criticisms and concerns related to BG activities, as well as the pressing needs of biocultural and ecological conservation, highlight the importance of not simply building new BG infrastructure, but to first isolate what models of BG are most effective so new gardens can be built in line with these characteristics and older gardens can be encouraged to incorporate them (Waylen 2006; Chen et al. 2009a; Sharrock 2011; Hulme 2011b; BGCI 2016). Despite the respected reputations and vast experience many BG have for plant conservation, Waylen (2006) notes that few recognize the "role they can play in linking this diversity with practical improvements to people's lives." She argues that it is therefore critical that successful examples of BG's work in this way be identified and be made better known. Similarly, considering the relatively ineffective current distribution of BG to meet the global extinction crisis, Swarts and Dixon (2009) ask "are there models that demonstrate how to link *ex situ* conservation collections in botanic gardens with effective *in situ* programs that deliver improved conservation management, reintroduction and ecological restoration outcomes?" Thus, identifying and highlighting effective BG models of biocultural diversity conservation is critical to amplify their effectiveness and encourage these successful models be adopted elsewhere as additional BG are established in threatened areas (Chen et al. 2009a; Hulme 2015).

5.3.1.5. A Rubric for Comprehensive Botanical Gardens

Due to the criticism of BG and confusion over how to properly define them, there is a need to develop a rubric to gauge the effectiveness of BG models. Published literature has highlighted several key aspects of BG activities that are essential for successful, comprehensive BG, and these were compiled into a rubric (Table A- 14) and expounded as follows:

1) <u>A clearly defined mission</u> that articulates institutional priorities and provides guidance for all other activities (Pepper 1978; Miller et al. 2004; Hedean 2005; Waylen 2006).

2) <u>Quality horticulture techniques</u>, which includes propagation and production techniques; design, installation, and maintenance of ornamental displays; proper pruning, fertilizing, and use of integrated pest management (IPM); as well as regular change-outs and redesign of seasonal ornamental displays (Wyman 1960; Dolinar 1987; Wen 2008; Seyler 2009).

3) Public education program, including passive learning components (such as labeled plants, brochures, short and long-term exhibits, and interpretive panels) as well as active learning components (K-12 school programs, youth camps, undergraduate and/or graduate education, agricultural-extension assistance programs, and professional training courses). Educational offerings should involve place-based/regional interpretation and seek to raise the public's awareness of issues concerning environmental protection, plant diversity, conservation, urban horticulture, and invasive species (Schwetz 1996; Maunder et al. 2001; Tunnicliffe 2001; Miller et al. 2004; Hedean 2005; Riswan and Yamada 2006; Waylen 2006; Wen 2008; Akopian 2010; Seyler and Lyons 2011; He and Chen 2012; Johnson 2013; Ling 2014).

4) Coordinated research program to support the mission of the institution and raise quality standards and best practices in all other components. The program should therefore include research and internal review protocols for diverse disciplines such as horticulture techniques; breeding and propagation; botany (taxonomy, systematics, and evolution); conservation and ecological restoration; education program effectiveness; visitor service satisfaction; invasive species control; and ethnobotany (Riswan and Yamada 2006; Waylen 2006; Crane et al. 2009; Seyler 2009; Hardwick et al. 2011; Hulme 2015).

5) A conservation program for *ex situ* and *in situ* conservation, management, and restoration of biological, cultural, and ecological diversity, focusing primarily on the institution's local flora, cultures, and ecosystems (Hedean 2005; Riswan and Yamada 2006; Chen et al. 2009a; Crane et al. 2009; Donaldson 2009; Seyler 2009; Akopian 2010; Hardwick et al. 2011; Birkinshaw et al. 2013; Liu et al. 2015).

6) Collection accessions and management policy in-line with the institutional mission; priority taxa must be clearly articulated with a focus on local and endangered flora, collecting data on provenance and maintenance, and containing protocols for monitoring and deaccessioning invasive species (Pepper 1978; Dawson et al. 2008; Chen et al. 2009a; Seyler 2009; Hulme 2011a; Hulme 2015).

7) A coordinated and intentional marketing and public outreach program, including advertising in traditional media; use of social media and regular website updates; patronage support and outreach within the local community; as well as domestic and/or international

collaborations and association memberships (Day 1984; Rudyj 1988; Daubmann 2002; Miller et al. 2004; Waylen 2006; Chen et al. 2009a; Seyler 2009; Johnson 2013; Levin Stevenson 2013; Ling 2014). BG should effectively engage with their local communities, build networks, and forge collaborations with fellow gardens, researchers, universities, non-governmental organizations, governmental agencies, and disparate community interests to affect positive change within local communities and within the larger scientific and conservation communities (Miller et al. 2004; Waylen 2006; Maunder 2008; Chen et al. 2009a; Crane et al. 2009; Donaldson 2009; Seaton et al. 2010; Johnson 2013).

5.3.2. Insights from Case Studies

Brief histories, descriptions, and institutional details for the six case study BG are described in Appendix C with the rubric analysis of each indicated in Table 5-3. These analyses revealed key insights related to the orchid conservation and BG infrastructure contexts in Sichuan Province, which are detailed as follows.

5.3.2.1. Orchid Conservation

Despite recognizing the importance of orchid conservation due to the high species diversity and current extinction crisis in the province, no BG located in Sichuan is specifically focused on conserving Orchidaceae species. CBG no longer collects orchids due to "security concerns," noting that their orchid collections had been regularly stolen and they had lost a lot of money with the thefts. Consequently, a CBG interviewee explained, as more people became aware of the value of orchids, "even having an iron fence cannot protect your collections." On the other hand, there used to be a natural resources and breeding sub-group that specialized in orchid conservation and research at EBG (particularly native *Dendrobium* spp.), but due to staffing and budget constraints, EBG no longer has the "ability to be so finely focused." Although EBG does still collect orchid species from their collection regions, it is no longer a specific priority. Similarly, due to WCBG's missional focus on the genus *Rhododendron*, Orchidaceae species are not collected.

Table 5-3: Rubric analysis of six Chinese botanical garden case studies.

Comp.	Detail	CBG	EBG	WCBG	KBG	CSBG	XTBG
1)	Clearly defined mission.	**5**	**5**	**5**	**5**	**5**	**5**
2)	Quality horticulture techniques and regular change-outs…	**3**	**4**	**2**	**5**	**5**	**5**
3)	Public education program:	**4**	**4**	**3**	**5**	**5**	**5**
a.	Labeled plants	Y	Y	N	Y	Y	Y
b.	Garden brochures and/or interpretative panels	Y	Y	N	Y	Y	Y
c.	Short and/or long-term exhibits	Y	Y	N	Y	Y	Y
d.	K-12 school programs; youth camps	Y	Y	Y	Y	Y	Y
e.	Undergraduate and/or graduate education	N	Y	Y	Y	Y	Y
f.	Agricultural-extension resources	Y	Y	Y	Y	Y	Y
g.	Professional training courses	N	N	N	Y	Y	Y
4)	Research program:	**3**	**4**	**4**	**5**	**5**	**5**
a.	Horticulture techniques	Y	N	Y	Y	Y	Y
b.	Breeding & propagation	Y	Y	Y	Y	Y	Y
c.	Botany: taxonomy, systematics, and evolution	N	Y	Y	Y	Y	Y
d.	Conservation and/or ecological restoration	N	Y	Y	Y	Y	Y
e.	Education and visitor service	N	N	N	Y	Y	Y
f.	Invasive species control	N	N	N	?	Y	Y
g.	Ethnobotany	N	Y	N	Y	Y	Y
5)	Conservation program:	**3**	**5**	**4**	**5**	**4**	**5**
a.	Biological (*ex situ*)	Y	Y	Y	Y	Y	Y
b.	Ecological conservation/restoration (*in situ*)	N	Y	Y	Y	N	Y
c.	Ethnobotanical, local cultural knowledge	N	Y	Y	Y	Y	Y
d.	Agronomic and/or horticultural varieties	Y	N	N	Y	Y	Y
6)	Collections accessions/management policy:	**3**	**5**	**5**	**4**	**5**	**5**
a.	Focus on local/regional flora	N	Y	Y	Y	Y	Y
b.	Focus on rare/endangered	N	Y	Y	Y	Y	Y
c.	Collects data on provenance	N	Y	Y	Y	Y	Y
d.	Invasive species assessment/deaccession program	N	?	N/A	N	Y	Y
e.	Priority taxa clearly articulated	Y	Y	Y	Y	Y	Y
7)	Marketing and public outreach program:	**4**	**3**	**4**	**5**	**5**	**5**
a.	Use of social media and regular website updates	Y	N	N	Y	Y	Y
b.	Use of traditional media and advertisements	Y	N	N	Y	Y	Y
c.	Local community patronage/outreach	N	Y	Y	Y	Y	Y
d.	Domestic/International collaborations	N	Y	Y	Y	Y	Y
e.	Domestic/International association memberships	Y	Y	Y	Y	Y	Y
Total Scores (out of 35)		**25**	**30**	**27**	**34**	**34**	**35**
Percentage Scores		71.4	85.7	77.1	97.1	97.1	100.0

In contrast, all three BG case studies from outside Sichuan do prioritize orchid collection as part of their conservation and research programs. For example, a member of management at CSBG explained that orchids are a very important and refined part of Chinese culture, and orchid collection is critical for "research, conservation, education, and culture, so for all these reasons, Chen Shan chose orchids as one of our collections priorities." There are approximately 8-10 CAS orchid research groups across China, and many of these are in BG, including KBG, XTBG, and South China BG (Guangdong Province). Interviewees also mentioned the National Orchid Conservation Center (国家兰科植物种质资源保护中心) located in Shenzhen, affiliated with the Shenzhen Fairylake BG, and the work of companies like Hengduan Mountains Biotechnology Ltd. (http://hengduanbiotech.com/), both of which have actively collected wild orchid germplasm for conservation purposes. Nevertheless, nearly all interviewees believed there was more need for *ex situ* conservation of Orchidaceae species since *in situ* collections were still facing such a heavy collection pressure. One researcher at CSBG explained that current conditions in China are "kind of 'mission impossible.' Even though you want to preserve the orchids in nature preserves, this is not as effective as using nature preserves to protect threatened trees. It is very difficult to remove a big tree from a nature preserve, but for such tiny, herbaceous and epiphytic species, it is so easy to smuggle these away." Thus, interviewees saw *ex situ* collections as critical for conservation purposes in the indefinite future, at least until collection pressures on Chinese orchids lessen.

The director of KBG noted that every region not only has its own orchid species diversity, but also a unique knowledge associated with orchids. He gave the example of the Bai people in Dali (northern Yunnan), whose traditional culture reveres *Cymbidium*, as well as the local cultures in other places in Yunnan like Baoshan, Xishuangbanna, and Lijiang, whose local people's traditional orchid cultures vary greatly. He has prioritized the collection and research of Chinese *Dendrobium* as a new collections priority for KBG, with the goal of collecting >90% of Chinese endemic and native *Dendrobium* spp. Moreover, due to taxonomic confusion and the difficulty of publishing papers on market surveys without a conservation or taxonomic component, KBG intends to establish a research unit on *Dendrobium* to encourage more graduate students to work on conservation-related projects. However, this is only one of many threatened Orchidaceae genera in China. It is impossible for one BG to collect or focus research on all threatened species. Thus, he explained, there remains much need for additional partners in other BG to set complementary priorities for other Chinese orchid genera.

5.3.2.2. On Ethnobotany

Although not all case study BG prioritized ethnobotanical research, all of them had some degree of ethnobotany in their research, conservation, and/or education programs. For example, the collections policies of both CBG and KBG prioritized collecting various cultivars of their city flowers (*Hibiscus mutabilis*, and *Camellia reticulata*, respectively). Staff at both gardens actively compile and promulgate the traditional "culture" associated with these plants ("Hibiscus culture," 芙蓉文化, and "Camellia culture," 茶花文化) in their educational materials, including stories, poems, and other plant-specific cultural knowledge. The KBG Camellia Garden is the oldest section of the garden, with nearly 4,000 specimens in >950 cultivars of *Camellia*, including >200 cultivars of *C. reticulata*. Around January every year, KBG hosts a month-long *Camellia* festival, coinciding with the Chinese New Year (Spring Festival) holiday. One of KBG's horticulture management staff (Prof. Zhonglang Wang) is also the official *Camellia* registrar for the International Camellia Society (https://internationalcamellia.org/).

Similarly, due to EBG's large native fern collection, the director is keenly interested in collecting and promoting poems, stories, and ethnobotanical knowledge related to China's traditional "fern culture" (蕨类文化). EBG's fern garden includes a wall of traditional fern poetry from ancient China inscribed on stone tablets. This wall has slowly grown over time and is now believed to be China's largest such wall. The garden's leadership views the promulgation of this type of traditional plant knowledge to be critical to help modern citizens feel a connection to the unique *place* where they live, and by connecting traditional plant culture with natural sciences BG can raise public awareness for the importance of conservation and environmental protection. Similarly, staff at WCBG collect local names, customs, and stories associated with *Rhododendron* among the communities where they collect, including Tibetan, Han, and Yi areas. At CSBG, one research group (headed by Dr. Daike Tian) focuses on the collection and research of Chinese *Begonia* spp. and *Nelumbo* cultivars. Dr. Tian was named the registrar for new *Nelumbo* cultivars by the International Waterlily and Water Gardening Society (http://iwgs.org/nymphaea-and-nelumbo-registration/). He and his research group constructed a website to spread the knowledge of lotus culture (荷花文化), which also serves as a platform for registering new lotus cultivars (www.nelumbolotus.com). The research group has begun compiling much documentation on the >2,500 years of history and symbolism of lotus in Chinese culture, including its culinary, medicinal, and religious uses, as well as literary and poetic references and paintings.

Although CSBG, KBG, and XTBG all have faculty that conduct ethnobotanical research or otherwise have ethnobotanical interests, perhaps the greatest example of ethnobotany's potential at a BG can be found in the example of XTBG. Shortly after Dr. Shengji Pei established the ethnobotany research program at XTBG, the focus was primarily on taking inventory of plants used by local ethnic groups including the Dai people. XTBG researchers compiled lists of plants used for food, medicine, fiber, dye, and for religious or ceremonial reasons. Research grew to also include studies on Dai holy hills and sacred forests, with implications for conservation. Many of these studies were published, and awareness of Dai ethnobotany became relatively widely known in academic circles. However, over time the traditional knowledge held by local people began to decline as youth adopted more "modern" or "Western" attitudes. The large volume of ethnobotanical data that XTBG had acquired was used in part to establish the Tropical Rain Forest Ethnobotany Museum, and culturally significant plants are grown throughout the gardens, utilizing interpretive panels and garden tours to explain the significance of these plants to visitors. By showcasing the local people's unique culture, customs, and worldviews for visitors, this museum has positively affected the reputation of Dai culture among tourists from other parts of China, as well as raised mutual respect between local people and XTBG. Furthermore, since XTBG hires young Dai women from surrounding villages to serve as docents for all visitor tours, they are trained by the museum about their own culture, learning what many of them did not already know. Consequently, the docent program has begun to counter the prevailing loss of local traditional knowledge, as these women take back to their villages the knowledge they had acquired about their own culture from XTBG (akin to cultural *ex situ* conservation), with inspiration to teach others as well (cultural restoration).

5.3.2.3. Need for New BG

For various reasons, the majority of case study interviewees both inside and outside the province, believed that current BG infrastructure in Sichuan was inadequate to address its pressing biocultural conservation needs. With such diversity in topographic features, from the humid, subtropical Sichuan Basin in the east to the alpine meadows and scree of the Qinghai-Tibetan Plateau and Hengduan Mountains in the west, the variety of climatic conditions producing Sichuan's floristic diversity is too great for a single BG to address. One KBG interviewee explained that "for each garden, the environment is not suitable for every plant, so that is why we need more botanical gardens." Another interviewee, a member of management at KBG, explained that such dramatic changes in elevation, from very low to very high, means that a BG located in Chengdu would be unable to conserve the threatened alpine flora. He recommended that the province needs at least three new BG operating out of different ecological zones to more adequately address the province's conservation challenges. Similarly, multiple members of management at CSBG suggested that Sichuan should have 5 comprehensive BG in different regions (one each in the north, east, south, west, and center parts of the province). EBG's current plans to establish Sichuan BG in Emei County, shows that there is need for more gardens, but Sichuan BG's conservation focus will only help address the needs of one of the underserved ecological zones. Similarly, a member of management at WCBG explained that there are many BG in the eastern part of China, but there are far fewer in the western provinces. He stated that though "we raise *Rhododendron* well, our staff and budget are not sufficient to conserve much else."

5.3.2.4. Definition of Botanical Garden

Many interviewees discussed differences between various models of Chinese BG, suggesting that confusion remains about how to objectively define what a comprehensive BG is. For example, one member of management at KBG explained that "Nowadays, people do not know the meaning of 'botanic garden.' But I tell you that a botanic garden is not equal to a plants garden, nor equal to a botanical park. It must have as its main purpose conservation research and public education." Multiple interviewees commented that though there may be >200 BG in China, only about 20 of these fit their own definitions of what a BG should be. One researcher at KBG explained that "most botanic gardens in China are just like parks, with a strong entertainment mentality, but with very little scientific meaning, and almost no concern for conservation." A member of management at CSBG explained that a BG must have some science component to its organizational structure or mission drift will trend away from research, conservation, and education and more towards "amusement." A member of management at XTBG explained that generally the configuration of current BG in China "is not enough, because of the existing botanical gardens, the gardens that especially focus on ecological conservation research are only about a dozen. But China is such a big country –this is not enough for conservation purposes."

Interviewee comments are similar, in many ways, to what has been described in the literature review above, but highlights with unique insights are summarized here. Interviewees described a comprehensive BG as having each of the following characteristics: 1) A clearly defined mission that articulates institutional priorities and justifies the necessity and purpose of the BG's existence. 2) A master plan for development, so that leadership knows how to prioritize funding and staffing decisions. 3) Sufficient and well-defined financial support. 4) Quality horticulture techniques that properly care for the collections, and changing aesthetic displays that help attract new and repeat visitation. Without beautiful landscapes, BG struggle to connect with their local communities and are less effective at justifying why their work is important to society. 5) A public education program, and, especially for those BG located in cities, education must specifically include K-12 programs. 6) Coordinated research and conservation programs for both *ex situ* and *in situ* management of priority species. 7) Must be open to the public, otherwise they are merely a research institute or field station, but not a BG. 8) Well managed collections, which would include a written collections policy, proper documentation of all accessions, properly labeled plants, and a dedicated curator or collections manager. 9) Public outreach program to enhance community stakeholder participation in and acceptance of the BG.

5.3.2.5. Domestic & International Collaboration

Multiple interviewees stressed the importance of collaborating with other institutions to ensure that stakeholders locally, nationally, and internationally can enhance a BG's effectiveness to better fulfill its mission. One researcher at KBG explained that "conservation is not only about one botanic garden's mission or task, it must necessarily be cooperative. If one plant has a duplicate in several botanic gardens, that is much more effective for conservation." In addition, several of the interviewees stressed that gardens must avoid being perceived as "alien" to or "condescending" towards their local communities. They must instead actively engage with them and demonstrate in tangible ways why the BG is a valuable member of their local community. Several interviewees explained the case of a BG in Guizhou Province that was asked by the local government to return the land, since the government saw the land as being more valuable than the BG itself. Thus, a BG cannot assume its value is understood, but must instead be proactive in demonstrating it through its public education and public outreach programs.

CSBG interviewees explained that their horticultural, research, public education, and collections management capabilities were greatly aided by collaborations with other gardens around the world. For example, they have sent staff to study at RBGE, the Missouri BG, and at Longwood Gardens, and they continue to maintain an ongoing staff exchange program with Longwood Gardens. Similarly, KBG has had a long-term exchange program with Toyama BG in Japan, and collaborates with RBGE closely on the development and planning related to LABG. Every few years XTBG will convene an international advisory committee, inviting experts from the world's most famous BG to discuss the development direction of XTBG and then set each department in this direction. An XTBG researcher commented that “without this we would never change, so this outside input is important so we can all focus on the important things.”

All three non-Sichuan BG were actively engaged as leaders in CUBG. They regularly host CUBG professional development training courses that target BG staff members, believing that BG capabilities can be enhanced by increased collaboration with other Chinese BG. Several interviewees also explained that visiting established, comprehensive BG can help stakeholders better understand BG potential. For example, the CSBG director, Dr. Yonghong Hu, explained that his garden would be willing to host visits from government delegations from other provinces to help them understand what a comprehensive BG is and could be. A researcher at KBG similarly explained that he had taken a visiting government official from a different province to visit KBG, explaining “though this is a small garden, it is still a good example to show, to demonstrate how important a botanic garden is, not only for sight-seeing or entertainment, but more importantly for conservation and for research. Conservation not only of plant species and biodiversity, but also of cultural diversity, both.”

5.3.2.6. Balancing Scientific Mission

Case study interviewees referenced several challenges associated with conducting research and finding proper balance with a scientific mission in a BG setting. Since funding and tenure/promotion for researchers at CAS-affiliated BG are allocated based on the number of research papers published in high impact journals, the fact that ethnobotanical research rarely gets published in high impact journals significantly deters researchers from engaging in these studies, despite the value they have for society. In addition, a member of management at XTBG explained that though BG must maintain quality public education, conservation, and horticulture programs to be successful to their missions, "we also have to do well on the standard CAS rules, which means we compete with other institutions, with molecular biologists, nuclear physicists, and material scientists, and we have to be publishing well in international journals." The need to publish to justify funding allocation thus increases the tension between practical conservation versus publishable research projects in CAS-affiliated BG. A member of management at KBG explained that "I tell people that botanic gardens are not research institutes, although they function as institutes, but we have two functions: conservation and dissemination of knowledge to the public. By helping people realize how important plants are, they are better equipped to protect the environment, protect the habitat, and we can help society by educating the young generations to become nature lovers."

5.3.2.7. Urban Versus Rural Location

Interviewees contrasted various strengths and weaknesses related to a garden's location being in a rural area (e.g., LABG, WCBG, XTBG) versus an urban or peri-urban location (e.g., CBG, EBG, KBG, CSBG). Though there are obvious advantages for a BG in a rural environment, such as more land area and greater access to the species you may wish to collect, interviewees from both WCBG and XTBG explained several logistical challenges associated with gardens being located in rural areas. Many people are unwilling to visit a garden that does not have easy transportation, and simple tasks like procuring chemicals and other supplies can become quite difficult when located away from major modes of transportation. For this reason, XTBG maintains an office in Kunming to assist with logistical tasks. In addition, since many of their staff are highly educated academics, XTBG has found it difficult to recruit new researchers since most candidates want to be able to send their children to highly-ranked primary and secondary schools, but these are not available in rural communities. Thus, to help ease the initial burden that the rural location posed to recruitment, XTBG established a kindergarten on-site, but many of the staff still apply for transfers to other CAS institutes when their children get older. Unlike urban gardens with large, highly-educated populations in close-proximity that present opportunities for large volunteer programs (such as CBG and CSBG), rural gardens (e.g., XTBG) found that they are unable to establish volunteer programs since differing economic realities make local people unavailable or unwilling to volunteer.

5.4. Discussion

The literature review and case study analysis highlighted deficiencies in BG infrastructure and current orchid biocultural diversity conservation efforts in Sichuan Province. Though there are currently three institutions identified as BG in Sichuan Province, only one of them (EBG) scored higher than 80% in the rubric analysis, but all three non-Sichuan gardens scored at or close to 100% (Table 5-3). However, EBG's small size and institutional capacity is not sufficient to meet the diverse conservation, research, and public education needs within the vast province. Interviews suggest that due to the large size, geographic diversity, and pressing conservation concerns, three to five new BG that meet all seven criteria on the rubric are needed to more adequately address conservation needs in Sichuan. Recognizing the need for additional comprehensive BG in Sichuan, the case studies also provide guidance on how these gardens should be established.

EBG, KBG, and XTBG all have experience working to establish new BG within their respective provinces to address research and conservation deficiencies. In particular, XTBG and KBG's ethnobotanical work and infrastructure building experiences are particularly relevant. Like Southwest Sichuan's Liangshan Yi Autonomous Prefecture (凉山彝族自治州), and western Sichuan's Garze Tibetan Autonomous Prefecture (甘孜藏族自治州) and Aba Tibetan and Qiang Autonomous Prefecture (阿坝藏族羌族自治州), XTBG is located in an ethnic minority-majority jurisdiction called Xishuangbanna Dai Autonomous Prefecture (西双版纳傣族自治州). In China, XTBG represents a unique BG model for addressing biocultural diversity concerns by working to preserve local biodiversity, enhancing local knowledge systems, and promoting the unique cultural identities (locally and nationally) of ethnic minorities and marginalized communities. Due to the superficial similarities between the bioculturally diverse regions of Liangshan in southwestern Sichuan and of Xishuangbanna in southern Yunnan, the XTBG biocultural conservation model in Xishuangbanna has particularly valuable applicability in Liangshan. Reyes-García et al. (2007) explain that "economic development and preservation of local ecological knowledge might be simultaneously achieved *only if* economic development takes place through activities that keep people in their habitat and culture. The challenge lies in finding and promoting local forms of economic development that do not undermine local ecological knowledge." The XTBG model shows why BG can bring about just this kind of locally-based and sustainable economic development, while increasing local education and decreasing local extractive dependence on native species for economic survival.

The *ex situ*/*in situ* model of germplasm conservation in many BG and their collaboration with natural areas/nature preserves serves as a helpful parallel to effective cultural conservation programs. Gardens with ethnobotanical research programs (KBG and XTBG) not only conserve threatened knowledge (*ex situ*), but they can also effect restoration of traditional knowledge and cultural understanding within local communities after it had already begun to decline (particularly through community engagement, education programs, economic development, and hiring and training docents from local communities, i.e. *in situ* management within the communities). The XTBG docent program demonstrates that BG can be effective at mitigating the negative effects of biocultural diversity loss by conserving both biological and cultural diversity in *ex situ* collections, and preserving them through application in implementing *in situ* management plans and effective community engagement (e.g. outreach and education). This parallels, in many ways, the findings of Voeks and Leony (2004), who found that local competition for the right to escort ecotourists in a local vicinity, can increase the monetary value associated with traditional plant knowledge and increase local desire to maintain and promulgate traditional practices.

The CSBG model demonstrates that successful BG do not require a long time to establish before yielding meaningful results. Going from being an idea in 2005, to breaking ground in

2007, and being fully operational by 2011, CSBG shows that a well-planned, new BG can quickly assume world-class status if they are properly designed to meet the seven criteria, key stakeholders are sufficiently engaged, and governance and funding mechanisms are adequately addressed. CSBG's regional collections focus and key orchid collections priority are also relevant for southwest Sichuan's orchid extinction crisis. Since it is impossible for one garden to conserve every threatened plant, BG must instead focus on its own local region's most threatened species.

The seven criteria of comprehensive BG that were identified in the literature review overlap significantly with the nine criteria isolated during the case study analysis. The criteria within each list are partially overlapping, for example, a comprehensive research program will have ongoing research on all other aspects and will likely coordinate with the other programs, while the horticulture program will necessarily overlap with the research and collections management programs. However, gardens must intentionally focus on these various aspects to maintain a comprehensive focus to meet the pressing biocultural diversity conservation and environmental education needs that were identified. Collaborations and affiliations with professional associations are seen as critical to increase accountability between and among the BG and ensure best practices are adopted and disseminated.

5.5. Conclusion

Due to their highly trained staff, expertise in a diversity of disciplines, and unique institutional resources, BG are uniquely well-qualified and effectively positioned to maintain *ex situ* collections of threatened plant species over time, manage *in situ* populations, restore natural ecosystems, and successfully reintroduce species back into the wild, while also working with local communities, bridging across local socio-economic concerns, and improving the economic conditions that contribute to over-harvest of plant resources. The motivations, strategic goals, and management philosophies of each BG case study revealed particular insights that are helpful for other gardens seeking to address similar conservation concerns. This study provides valuable insight for the BG community, governments and other stakeholders, and the conservation community more broadly.

CHAPTER 6: CONCLUSION

The first component of this dissertation project (chapter 2) tested the relationship between orchid biodiversity decline and cultural knowledge loss on four different orchid knowledge types held in eight villages in rural Puge County, Sichuan. Based on how they are acquired and transmitted, certain types of knowledge might be expected to disappear locally as species decline in the wild (e.g., ID and LEK). But other knowledge types (e.g., OCK) could be expected to persist even after species become locally extinct since they are based on literary accounts and cultural customs not directly tied to local ecological conditions. Yet contrary to predictions, results showed that the orchid knowledge held within each village was negatively impacted by species extinction across *all* knowledge types, regardless of pre-extinction rarity status, and regardless of participant socio-demographic variables. Further, the negative impact of extinction on knowledge is exacerbated when a locality no longer has access to the plants in any form. The elderly participants who were experts on orchid cultural knowledge (OCK) expressed concern that the dearth of wild orchid populations and rarity of seeing any orchid flower in the wild inhibited the promulgation of this culturally-significant knowledge by decreasing opportunities to “inspire” young people to become motivated learners of this refined knowledge type.

Considering China’s rapid urbanization, studies investigating the impact of urbanization on local knowledge loss have yielded conflicting results, possibly due to differing knowledge types not being adequately addressed in study methodologies. The second part of this project (chapter 3), therefore, investigated how the impacts of urbanization on people’s orchid knowledge differed based on knowledge type. Interviews were conducted in three jurisdictions of Sichuan Province, China, with differing levels of urbanization: Puge County (Low urbanization), Huili County (Medium), and Chengdu City (High). Contrary to expectations, results showed a significant positive relationship between orchid knowledge (all types) and urbanization. However, the strength of this relationship did vary between different types of specific knowledge. Overall, the moderately-urbanized jurisdiction (Huili) had significantly higher orchid knowledge, while the rural jurisdiction (Puge) had significantly lower knowledge in all categories. These findings suggest that the traditional knowledge advantage rural communities have enjoyed due to their proximity to wild orchid populations disappears as species decline in the wild, shifting the advantage to moderately-urbanized areas.

Similarly, results from the social network analysis (chapter 4) indicated that an individual's social position within a community and a network's overall structure do not mitigate the loss of knowledge resulting from local species extinction. Instead, an individual's *access* to a plant resource through involvement in the orchid trade enhanced the likelihood of being central in their communities' knowledge networks, regardless of ethnicity. Though communities were heavily fragmented by ethnicity, the individuals functioning as bridges between otherwise fragmented subnetworks tended to be active in the orchid trade regardless of ethnicity, and they also tended to have higher overall orchid knowledge. These results indicate that social network structure is not sufficient to preserve a community's cultural knowledge following species extinction. Since an individual's participation in the orchid trade increased their overall orchid knowledge, after an extinction event removes local access to wild populations, knowledge would be expected to persist only in those communities with access to *ex situ* populations (such as those held in private collections and conservation institutions).

Since species extinction drives cultural knowledge loss, and social network structure and rural proximity to natural areas are not sufficient by themselves to preserve a community's knowledge following species extinction, this suggests the need for an outside force to effect meaningful conservation of both threatened species and cultural knowledge. One possibility is to capture the orchid biocultural diversity and conserve it in an *ex situ* collection while preserving the applied knowledge via *in situ* management programs and community engagement (e.g. outreach and education) such as in botanical gardens (BG). However, confusion exists over what form or model of BG would be most effective. Thus, the final component of this study (chapter 5) involved an in-depth literature review and a case study analysis of six key Chinese BG (three inside and three outside of Sichuan) to identify which model(s) were most effective at orchid biocultural diversity conservation. Results show that current BG activities in Sichuan Province are not sufficient for the current conservation challenges facing its orchid biocultural diversity, with the need for three to five new comprehensive BG to be established throughout the diverse province. This study provides insight for orchid conservation stakeholders in China, with implications also for the broader conservation community as well.

APPENDIX A: SUPPLEMENTAL TABLES

Table A-1: [Chapter 2 & 3] Interview questions used to gauge local knowledge of each orchid taxon.

Knowledge Type		English & Chinese Questions 中英采访问题
Recognition 识别力	ID.1	*Do you recognize this plant?* 您认不认识这种植物？
	ID.2	*Can you tell me the name of this plant?* 你能告诉我这种植物的名字吗？
	ID.3	*Are there any other names for it?* 还有其它的名字吗？
Local Ecological 本地生态	LEK.1	*Where can this plant be found growing in the wild?* 在野外，哪里可以找到这种植物？
	LEK.2	*If someone wanted to harvest this plant, what time of the year would be best?* 如果有人想收获采集？这种植物，在每年什么时候是最好的？
	LEK.3	*How can this plant be harvested (e.g., dig up the whole plant, collect the seeds, etc.)?* 如何收割采集？这种植物（如: 挖走整个植物，收集种子等）？
	LEK.4	*How long does this plant take to flower (from seed, from a transplanted specimen)?* 这个植物第一次开花要多长时间（从种子，从移植）？
	LEK.5	*When was the last time you have seen it growing in the wild? How big were the plants at that time? How many were there? Where was it?* 你最后一次在野外看到这种植物是什么时候？它当时有多大？有多少？在哪里？
Business/ Market 商业/市场	BMK.1	*What is this plant used for (medicine, ornamental planting, collecting, etc.)?* 这种植物作用是什么（药物，观赏性种植，采集？等）？
	BMK.2	*If someone wanted to buy or sell this plant, what part of the plant would be most valuable?* 如果有人想购买或出售这种植物，哪一部分最有价值？
	BMK.3	*If someone wanted to buy/sell this plant, where could they get the best price for it?* 如果有人想购买或出售这种植物，在哪里能能买到最好的价格呢？
	BMK.4	*How much would it cost?* 买它要多少钱？
Orchid Cultural 兰花文化	OCK.1	*Are there famous poems that mention this plant? Can you give an example? What is the poem's name/poet's name?* 在脍炙人口或著名的诗词、著作中是否提到这个兰花？您能举个例子吗？诗词、著作的名字/诗人的名字？
	OCK.2	*Are there any famous paintings that depict this plant? Do you know the name(s) and/or artist?* 是否有描绘这个兰花的任何名画？你知道名画的名称和/或名画家的姓名？
	OCK.3	*Are there traditional uses for this plant? If so, what are they?* 这个兰花是否有什么传统用途？如果有，是什么？
	OCK.4	*How long has this plant been valued in China/your community?* 在中国和您住的地区，这个兰花被重视了多久？

Table A-2: [Chapter 2] Global GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on global orchid knowledge. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-3.437	0.5757	0.5777	5.948	<2e-16 ***
rarityCR	0.7270	0.1310	0.1313	5.539	<2e-16 ***
rarityRE	0.1283	0.1306	0.1309	0.980	0.3270
ageFacB	0.7777	0.3250	0.3261	2.385	0.0171 *
ageFacC	0.5216	0.3128	0.3139	1.662	0.0966 .
sexM	0.07116	0.2627	0.2636	0.270	0.7872
ethnicityYi	-0.4479	0.2331	0.2339	1.915	0.0556 .
educationHS	0.02299	0.6521	0.6544	0.035	0.9720
educationMS	-0.8227	0.6136	0.6157	1.336	0.1815
educationNone	-1.405	0.6582	0.6605	2.127	0.0334 *
educationPS	-1.019	0.6011	0.6032	1.689	0.0912 .
orchid_activityYes	1.911	0.2627	0.2636	7.250	<2e-16 ***
ageFacB:rarityCR	0.04059	0.1358	0.1359	0.299	0.7652
ageFacB:rarityRE	0.04136	0.1392	0.1393	0.297	0.7666
ageFacC:rarityCR	0.03407	0.1217	0.1218	0.280	0.7797
ageFacC:rarityRE	0.03301	0.1207	0.1209	0.273	0.7848
rarityCR:sexM	0.004381	0.04068	0.04074	0.108	0.9144
rarityRE:sexM	0.002245	0.03264	0.03273	0.069	0.9453
ethnicityYi:rarityCR	-0.0002862	0.01092	0.01095	0.026	0.9791
ethnicityYi:rarityRE	0.0001016	0.009971	0.01001	0.010	0.9919
educationHS:rarityCR	5.583e-06	0.002526	0.002533	0.002	0.9982
educationHS:rarityRE	-1.366e-05	0.003530	0.003537	0.004	0.9969
educationMS:rarityCR	1.543e-05	0.003691	0.003696	0.004	0.9967
educationMS:rarityRE	8.166e-06	0.002723	0.002730	0.003	0.9976
educationNone:rarityCR	8.293e-06	0.002968	0.002976	0.003	0.9978
educationNone:rarityRE	1.057e-05	0.003199	0.003207	0.003	0.9974
educationPS:rarityCR	3.824e-06	0.002369	0.002377	0.002	0.9987
educationPS:rarityRE	4.965e-06	0.002401	0.002409	0.002	0.9984
orchid_activityYes:rarityCR	1.668e-07	0.0004319	0.0004334	0.000	0.9997
orchid_activityYes:rarityRE	-6.379e-07	0.0005348	0.0005361	0.001	0.9991

Table A-3: [Chapter 2] GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on the ability to correctly identify the orchid taxa (plant ID). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-3.090	0.4192	0.4207	7.346	<2e-16 ***
rarityCR	0.4264	0.2122	0.2127	2.005	0.044974 *
rarityRE	0.2953	0.2039	0.2044	1.445	0.148596
ageFacB	0.2707	0.2944	0.2950	0.918	0.358769
ageFacC	0.5450	0.2308	0.2316	2.353	0.018624 *
sexM	0.09857	0.1814	0.1820	0.541	0.588208
ethnicityYi	-0.5511	0.1591	0.1597	3.452	5.57e-04 ***
educationHS	-0.4454	0.4369	0.4385	1.016	0.309708
educationMS	-0.6058	0.4097	0.4111	1.473	0.140618
educationNone	-0.4376	0.4400	0.4415	0.991	0.321684
educationPS	-0.5687	0.4012	0.4026	1.412	0.157817
orchid_activityYes	1.754	0.1870	0.1877	9.344	<2e-16 ***
ageFacB:rarityCR	0.1949	0.3708	0.3711	0.525	0.599485
ageFacB:rarityRE	0.1262	0.2706	0.2710	0.466	0.641425
ageFacC:rarityCR	0.03782	0.1774	0.1779	0.213	0.831654
ageFacC:rarityRE	0.05849	0.1943	0.1948	0.300	0.763948
rarityCR:sexM	0.003414	0.05765	0.05784	0.059	0.952924
rarityRE:sexM	0.009999	0.07397	0.07412	0.135	0.892688
ethnicityYi:rarityCR	-0.0009255	0.02272	0.02277	0.041	0.967585
ethnicityYi:rarityRE	-0.0005456	0.02012	0.02018	0.027	0.978430
educationHS:rarityCR	3.785e-06	0.002755	0.002763	0.001	0.998907
educationHS:rarityRE	-3.498e-06	0.002693	0.002702	0.001	0.998967
educationMS:rarityCR	1.470e-06	0.002427	0.002436	0.001	0.999518
educationMS:rarityRE	4.707e-06	0.002697	0.002705	0.002	0.998611
educationNone:rarityCR	5.759e-06	0.003111	0.003119	0.002	0.998527
educationNone:rarityRE	4.302e-06	0.002789	0.002797	0.002	0.998773
educationPS:rarityCR	2.786e-06	0.002482	0.002490	0.001	0.999107
educationPS:rarityRE	5.044e-06	0.002700	0.002706	0.002	0.998513
orchid_activityYes:rarityCR	3.310e-06	0.001616	0.001617	0.002	0.998366
orchid_activityYes:rarityRE	2.575e-06	0.001326	0.001328	0.002	0.998452

Table A-4: [Chapter 2] LEK GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on local ecological knowledge. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-3.6147403	0.6081503	0.6102813	5.923	<2e-16 ***
rarityCR	0.6407883	0.1432274	0.1436353	4.461	8.1e-06 ***
rarityRE	0.0519663	0.1383104	0.1387385	0.375	0.7080
ageFacB	0.6462509	0.3249253	0.3260576	1.982	0.0475 *
ageFacC	0.3418414	0.3134787	0.3145783	1.087	0.2772
sexM	0.1146833	0.2711195	0.2720671	0.422	0.6734
ethnicityYi	-0.3172148	0.2413619	0.2422098	1.310	0.1903
educationHS	0.5445706	0.6846538	0.6870551	0.793	0.4280
educationMS	-0.2937726	0.6440447	0.6462976	0.455	0.6494
educationNone	-0.4719329	0.6882112	0.6906233	0.683	0.4944
educationPS	-0.1740699	0.6292950	0.6315037	0.276	0.7828
orchid_activityYes	1.9534962	0.2738297	0.2747913	7.109	<2e-16 ***
ageFacB:rarityCR	0.0101124	0.0761815	0.0763220	0.132	0.8946
ageFacB:rarityRE	0.0058736	0.0674452	0.0676087	0.087	0.9308
ageFacC:rarityCR	0.0030010	0.0570924	0.0572812	0.052	0.9582
ageFacC:rarityRE	0.0029364	0.0609841	0.0611648	0.048	0.9617
rarityCR:sexM	0.0033560	0.0412974	0.0413648	0.081	0.9353
rarityRE:sexM	0.0027326	0.0373714	0.0374486	0.073	0.9418
ethnicityYi:rarityCR	-0.0009236	0.0226957	0.0227593	0.041	0.9676
ethnicityYi:rarityRE	0.0005110	0.0213163	0.0213863	0.024	0.9809
educationHS:rarityCR	0.0014380	0.0542617	0.0544339	0.026	0.9789
educationHS:rarityRE	-0.0051749	0.0842669	0.0843753	0.061	0.9511
educationMS:rarityCR	0.0054123	0.0866238	0.0867248	0.062	0.9502
educationMS:rarityRE	0.0043568	0.0732729	0.0733780	0.059	0.9527
educationNone:rarityCR	0.0031190	0.0662073	0.0663545	0.047	0.9625
educationNone:rarityRE	0.0042116	0.0739173	0.0740369	0.057	0.9546
educationPS:rarityCR	0.0013687	0.0516581	0.0518207	0.026	0.9789
educationPS:rarityRE	0.0029078	0.0584274	0.0585507	0.050	0.9604
orchid_activityYes:rarityCR	0.0006831	0.0194752	0.0195012	0.035	0.9721
orchid_activityYes:rarityRE	-0.0001760	0.0122247	0.0122651	0.014	0.9886

Table A-5: [Chapter 2] BMK GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on business/market knowledge. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-3.093	0.5772	0.5792	5.340	1e-07 ***
rarityCR	0.7959	0.1153	0.1157	6.881	<2e-16 ***
rarityRE	0.1723	0.1169	0.1173	1.469	0.141732
ageFacB	0.6227	0.3161	0.3172	1.963	0.049632 *
ageFacC	0.5958	0.3056	0.3066	1.943	0.052018 .
sexM	-0.02092	0.2629	0.2638	0.079	0.936793
ethnicityYi	-0.8435	0.2352	0.2360	3.574	0.000352 ***
educationHS	-0.3081	0.6541	0.6564	0.469	0.638833
educationMS	-0.8119	0.6147	0.6168	1.316	0.188115
educationNone	-1.272	0.6607	0.6630	1.918	0.055062 .
educationPS	-1.307	0.6032	0.6053	2.160	0.030779 *
orchid_activityYes	1.813	0.2661	0.2670	6.789	<2e-16 ***
ageFacB:rarityCR	0.002453	0.04302	0.04315	0.057	0.954678
ageFacB:rarityRE	0.004510	0.05036	0.05048	0.089	0.928805
ageFacC:rarityCR	0.002018	0.04237	0.04250	0.047	0.962130
ageFacC:rarityRE	0.004185	0.04941	0.04952	0.084	0.932662
rarityCR:sexM	0.001367	0.02535	0.02538	0.054	0.957034
rarityRE:sexM	0.0005668	0.01816	0.01822	0.031	0.975179
ethnicityYi:rarityCR	2.499e-05	0.005346	0.005365	0.005	0.996283
ethnicityYi:rarityRE	8.206e-05	0.006365	0.006381	0.013	0.989739
educationHS:rarityCR	2.831e-08	0.0004364	0.0004380	0.000	0.999948
educationHS:rarityRE	-5.733e-08	0.0004378	0.0004394	0.000	0.999896
educationMS:rarityCR	-1.566e-07	0.0004712	0.0004726	0.000	0.999736
educationMS:rarityRE	-8.992e-08	0.0004096	0.0004110	0.000	0.999825
educationNone:rarityCR	-1.618e-07	0.0005130	0.0005146	0.000	0.999749
educationNone:rarityRE	1.901e-07	0.0005088	0.0005102	0.000	0.999703
educationPS:rarityCR	-6.310e-08	0.0004264	0.0004279	0.000	0.999882
educationPS:rarityRE	1.696e-07	0.0004482	0.0004495	0.000	0.999699
orchid_activityYes:rarityCR	3.232e-08	0.0001293	0.0001296	0.000	0.999801
orchid_activityYes:rarityRE	-1.805e-08	0.0001046	0.0001049	0.000	0.999863

Table A-6: [Chapter 2] OCK GLMMs Model-averaged coefficients (full average) for effect of rarity and socio-demographic variables on orchid cultural knowledge. Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-2.862	0.4341	0.4357	6.568	<2e-16 ***
RarityCR	0.5447	0.1382	0.1387	3.928	8.57e-05 ***
rarityRE	-0.02808	0.1302	0.1306	0.215	0.829826
ageFacB	0.2545	0.2456	0.2465	1.033	0.301827
ageFacC	0.6227	0.2348	0.2357	2.642	0.008237 **
sexM	-0.1267	0.2006	0.2013	0.629	0.529102
ethnicityYi	-0.6488	0.1806	0.1813	3.579	0.000345 ***
educationHS	-1.419	0.4916	0.4933	2.877	0.004018 **
educationMS	-1.567	0.4591	0.4607	3.401	0.000671 ***
educationNone	-1.737	0.4971	0.4988	3.483	0.000496 ***
educationPS	-1.628	0.4500	0.4515	3.606	0.000311 ***
orchid_activityYes	1.481	0.2084	0.2092	7.080	<2e-16 ***
ageFacB:rarityCR	0.01901	0.1085	0.1086	0.175	0.861054
ageFacB:rarityRE	0.004557	0.06909	0.06931	0.066	0.947578
ageFacC:rarityCR	0.002693	0.06558	0.06580	0.041	0.967351
ageFacC:rarityRE	-0.001651	0.06516	0.06539	0.025	0.979851
rarityCR:sexM	0.003234	0.04050	0.04056	0.080	0.936447
rarityRE:sexM	-0.0002084	0.02728	0.02737	0.008	0.993926
ethnicityYi:rarityCR	0.0002357	0.01106	0.01108	0.021	0.983030
ethnicityYi:rarityRE	0.0001524	0.009944	0.009974	0.015	0.987808
educationHS:rarityCR	5.468e-06	0.002649	0.002654	0.002	0.998356
educationHS:rarityRE	-1.772e-06	0.001902	0.001908	0.001	0.999259
educationMS:rarityCR	6.624e-06	0.002827	0.002831	0.002	0.998133
educationMS:rarityRE	-1.833e-06	0.001738	0.001744	0.001	0.999161
educationNone:rarityCR	2.356e-06	0.002045	0.002051	0.001	0.999084
educationNone:rarityRE	3.812e-07	0.001841	0.001848	0.000	0.999835
educationPS:rarityCR	3.527e-06	0.002041	0.002045	0.002	0.998624
educationPS:rarityRE	1.606e-06	0.001663	0.001668	0.001	0.999232
orchid_activityYes:rarityCR	6.921e-07	0.0006332	0.0006347	0.001	0.999130
orchid_activityYes:rarityRE	-1.128e-06	0.0007983	0.0007995	0.001	0.998874

Table A-7: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of <u>network-level</u> structural variables on mean orchid knowledge distribution (with Puge 6 excluded due to lack of variability). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-2.698	0.5653	0.6115	4.413	1.02e-05 ***
Degree Centrality	0.1825	0.6446	0.6788	0.269	0.788
Fragmentation	-0.00235	0.1616	0.1756	0.013	0.989
Density	-0.0545	1.842	1.878	0.029	0.977
Closure	0.00871	0.5165	0.5173	0.017	0.987
Average Distance	-4.314e-06	0.002461	0.002605	0.002	0.999
Diameter	-4.074e-10	1.485e-05	1.703e-05	0.000	1.000
Compactness	9.815e-10	2.411e-04	2.411e-04	0.000	1.000

Table A-8: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of <u>actor-level</u> centrality measures on mean orchid knowledge distribution (with Puge 6 and Puge 7 excluded due to lack of variability). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-3.322259	0.387877	0.389410	8.532	< 2e-16 ***
Normalized Betweenness	-0.132077	0.160953	0.161674	0.817	0.41397
Normalized Degree	5.821510	1.947880	1.955819	2.977	0.00292 ***
Normalized Eigenvector	-0.005268	0.010748	0.010769	0.489	0.62475
Closeness (by Main Component)	0.309406	0.826953	0.828008	0.374	0.70865
Normalized Beta Centrality	0.015999	0.070443	0.070686	0.226	0.82094

Table A-9: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on distribution of knowledge for formerly common but now rare (CR) orchids (with Puge 6 excluded due to lack of variability). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-2.355	0.6108	0.6548	3.596	0.000323 ***
Compactness	0.5106	1.228	1.278	0.400	0.689515
Diameter	-0.00169	0.01717	0.01818	0.093	0.925933
Average Distance	0.0003236	0.02277	0.02483	0.013	0.989603
Closure	-0.0001829	0.04209	0.04473	0.004	0.996738
Density	-7.846e-06	0.02330	0.02566	0.000	0.999756
Degree Centrality	-2.730e-09	1.734e-04	1.955e-04	0.000	0.999989
Fragmentation	5.504e-11	3.147e-05	3.259e-05	0.000	0.999999

Table A-10: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on distribution of knowledge for formerly common but now locally extinct (CE) orchids (with Puge 6 excluded due to lack of variability). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-3.104	0.8150	0.8730	3.555	0.000377 ***
Compactness	0.2664	1.220	1.302	0.205	0.837909
Diameter	-0.01216	0.07725	0.07910	0.154	0.877874
Average Distance	0.007342	0.1353	0.1398	0.053	0.958124
Closure	2.075e-04	0.08544	0.09445	0.002	0.998247
Density	-4.856e-04	0.2395	0.2495	0.002	0.998447
Degree Centrality	-9.344e-08	0.001027	0.001130	0.000	0.999934
Fragmentation	7.387e-10	1.349e-04	1.421e-04	0.000	0.999996s

Table A-11: [Chapter 4] GLMMs Model-averaged coefficients (full average) for effect of network-level structural variables on distribution of knowledge for formerly rare but now locally extinct (RE) orchids (with Puge 6 excluded due to lack of variability). Significance codes: '***' <0.001, '**' <0.01, '*' <0.05, '.' <0.1, n.s. >0.1.

	Estimate	Std. Error	Adjusted SE	z value	Pr(>|z|)
Intercept	-2.840	0.6983	0.7489	3.792	0.000149 ***
Degree Centrality	0.3208	0.9761	1.010	0.317	0.750896
Fragmentation	0.003185	0.3505	0.3607	0.009	0.992955
Density	-0.6036	7.088	7.133	0.085	0.932557
Closure	0.2140	2.560	2.565	0.083	0.933517
Average Distance	-1.479e-05	0.006772	0.007639	0.002	0.998456
Diameter	-7.599e-08	1.403e-04	1.482e-04	0.001	0.999591
Compactness	1.366e-08	8.857e-04	9.602e-04	0.000	0.999989

Table A-12: [Chapter 5] Questions for BG Case Studies.

Question	English & Chinese Questions 中英采访问题
1	*Can you tell me a brief history of your garden?* 请您介绍一下植物园历史？
2	*What is your garden's institutional mission/vision statement(s)?* 您的植物园使命和愿景是什么？
3	*How many staff work for your garden?* 您的植物园有多少员工？
4	*Please describe your garden's organizational structure. How many departments does it have?* 请描述一下植物园里组织结构。有多少个部门？它们是哪些？
5	*Is there a parent organization or research institute governing your garden?* 是否有上级组织或研究机构管理您的植物园？
6	*What other institutional affiliations does your garden have (nationally, internationally, etc.)?* 您的植物园有没有什么其它隶属关系的机构（国内，国际，等等）？
7	*What are the chief research priorities of your garden?* 您的植物园里的首要研究重点是什么？
8	*What are the chief educational priorities of your garden?* 您的植物园里的首要教育内容是什么？
9	*How does your garden handle public outreach? What public programming/events for the public does your garden offer?* 请问您的植物园如何进行公众宣传？您的植物园为公众提供了哪些活动计划/项目?
10	*Does your garden engage in any ethnobotanical work? If so, is this ethnobotanical work conducted locally, regionally, or elsewhere?* 请问您的植物园有没有从事任何民族植物学的工作？如果有，是本地进行，区域内，或其它地方从事民族植物学工作？
11	*What is the annual visitation of your garden?* 每年您的植物园访客有多少？
a.	*What demographic data do you maintain on your visitation?* 您的植物园是怎样进行访客统计（是否含有年龄，性别，民族等信息）？
b.	*Do you know what portion of your visitors are visiting locally or are visiting from other regions of your province, other provinces, or from foreign countries?* 您知道植物园的访客中，哪些是来自本地，或者本省其它地方，或其它省，其它国家？
12	*What are the main collections priorities? Do you have a collections policy?* 您的植物园首选的植物是什么？有没有植物征集的政策？
a.	*Where do you primarily source your plants (locally, regionally, nationally, abroad)?* 您主要的植物来源是哪里（本地，地区内，国内，国外）？
13	*How many taxa do you maintain in your garden's collections?* 您的植物园内有多少种类群的植物？
a.	*How many orchid taxa are maintained in your collections?* 有多少种兰花类群？
b.	*How many regionally threatened species are maintained in your collections?* 有多少种地区内受威胁的植物？

Table A-13: [Chapter 5] Objectives & Targets of the Global Strategy for Plant Conservation (2011-2020).

Objective I: Plant diversity is well understood, documented and recognized.	
Target 1:	An online flora of all known plants.
Target 2:	An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action.
Target 3:	Information, research and associated outputs, and methods necessary to implement the Strategy developed and shared.
Objective II: Plant diversity is urgently and effectively conserved.	
Target 4:	At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration.
Target 5:	At least 75 per cent of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity.
Target 6:	At least 75 per cent of production lands in each sector managed sustainably, consistent with the conservation of plant diversity.
Target 7:	At least 75 per cent of known threatened plant species conserved in situ.
Target 8:	At least 75 per cent of threatened plant species in ex situ collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes.
Target 9:	70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge.
Target 10:	Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded.
Objective III: Plant diversity is used in a sustainable and equitable manner.	
Target 11:	No species of wild flora endangered by international trade.
Target 12:	All wild harvested plant-based products sourced sustainably.
Target 13:	Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care.
Objective VI: Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted.	
Target 14:	The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programmes.
Objective V: The capacities and public engagement necessary to implement the Strategy have been developed.	
Target 15:	The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy.
Target 16:	Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this Strategy.

Table A- 14: [Chapter 5] Rubric for Comprehensive Botanical Gardens.

Component	Detail	Rating				
1) Clearly defined mission.		1	2	3	4	5
2) Quality horticulture techniques and regular change-outs/redesign of seasonal ornamental displays		1	2	3	4	5
3) Public education program:		1	2	3	4	5
a.	Labeled plants		Y		N	
b.	Garden brochures and/or interpretative panels		Y		N	
c.	Short and/or long-term exhibits		Y		N	
d.	K-12 school programs; youth camps		Y		N	
e.	Undergraduate and/or graduate education		Y		N	
f.	Agricultural-extension resources		Y		N	
g.	Professional training courses		Y		N	
4) Research program:		1	2	3	4	5
a.	Horticulture techniques		Y		N	
b.	Breeding & propagation		Y		N	
c.	Botany: taxonomy, systematics, and evolution		Y		N	
d.	Conservation and/or ecological restoration		Y		N	
e.	Education and visitor service		Y		N	
f.	Invasive species control		Y		N	
g.	Ethnobotany		Y		N	
5) Conservation program:		1	2	3	4	5
a.	Biological (*ex situ*)		Y		N	
b.	Ecological conservation/restoration (*in situ*)		Y		N	
c.	Ethnobotanical, local cultural knowledge		Y		N	
d.	Agronomic and/or horticultural varieties		Y		N	
6) Collections accessions/management policy:		1	2	3	4	5
a.	Focus on local/regional flora		Y		N	
b.	Focus on rare/endangered		Y		N	
c.	Collects data on provenance		Y		N	
d.	Invasive species assessment/deaccession program		Y		N	
e.	Priority taxa clearly articulated		Y		N	
7) Marketing and public outreach program:		1	2	3	4	5
a.	Use of social media and regular website updates		Y		N	
b.	Use of traditional media and advertisements		Y		N	
c.	Local community patronage/outreach		Y		N	
d.	Domestic/International collaborations		Y		N	
e.	Domestic/International association memberships		Y		N	

APPENDIX B: SUPPLEMENTAL FIGURES

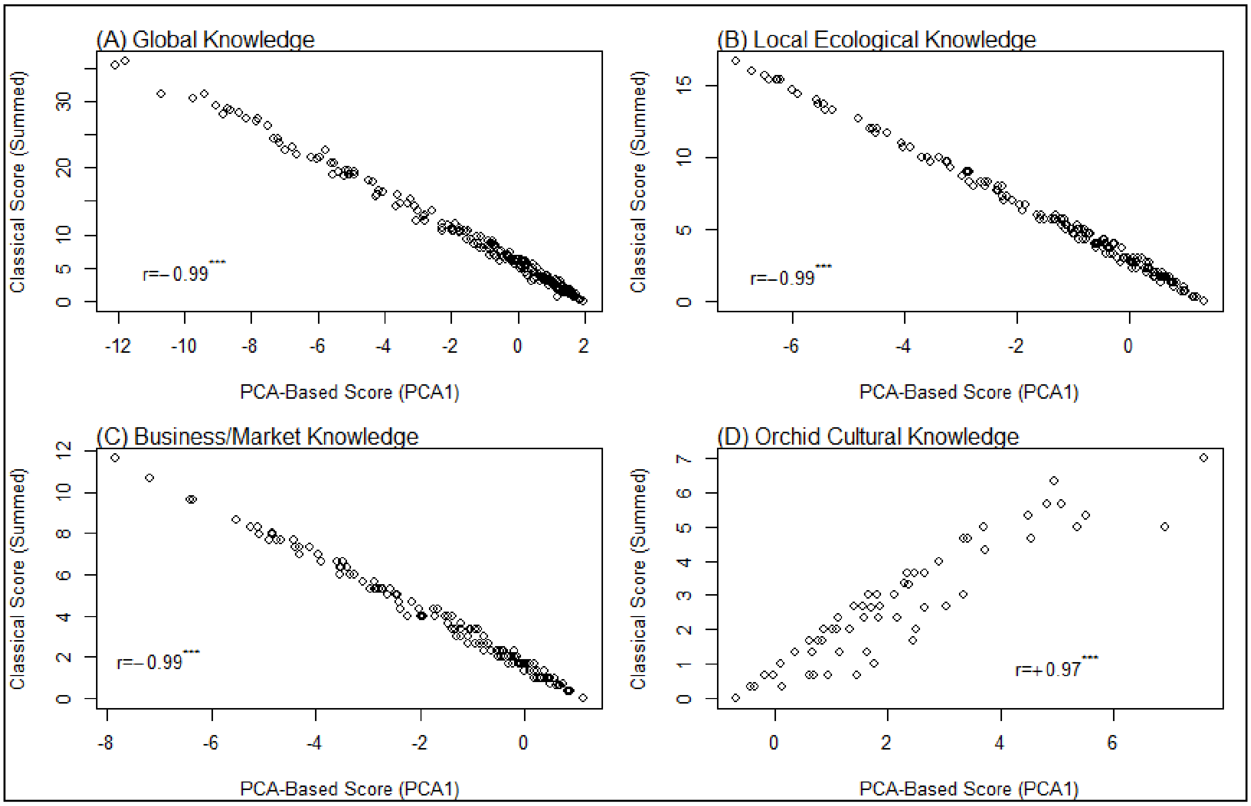

Figure B-1: [Chapter 2] Correlation between classical knowledge score analysis (summing the scores across individual questions) and principal component analysis (PCA). $r > 0.9$; Significance level: “***” = $p<0.001$.

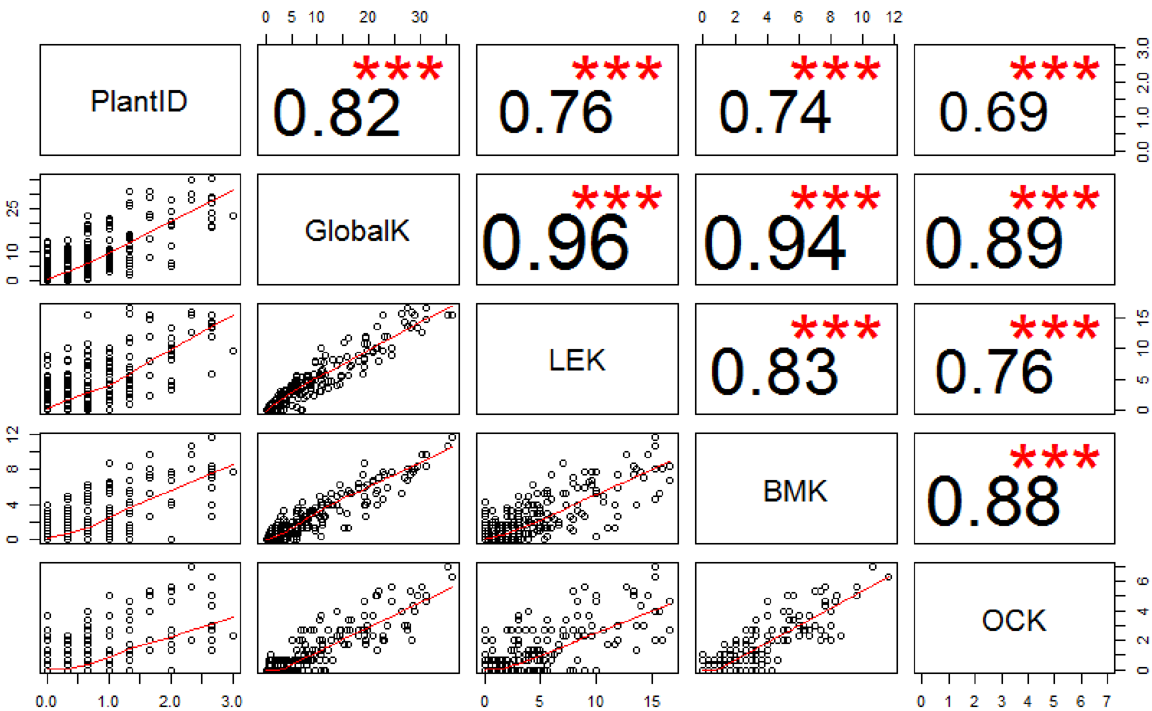

Figure B-2: [Chapter 2] Pairwise Spearman correlation between ability to correctly identify the plant (PlantID), global knowledge (GlobalK), local ecological knowledge (LEK), business/market knowledge (BMK), and traditional Han orchid cultural knowledge (OCK). Significance levels: "***" = p<0.001, "**" = p<0.01, "*" = p<0.05, and "ns" =not significant.

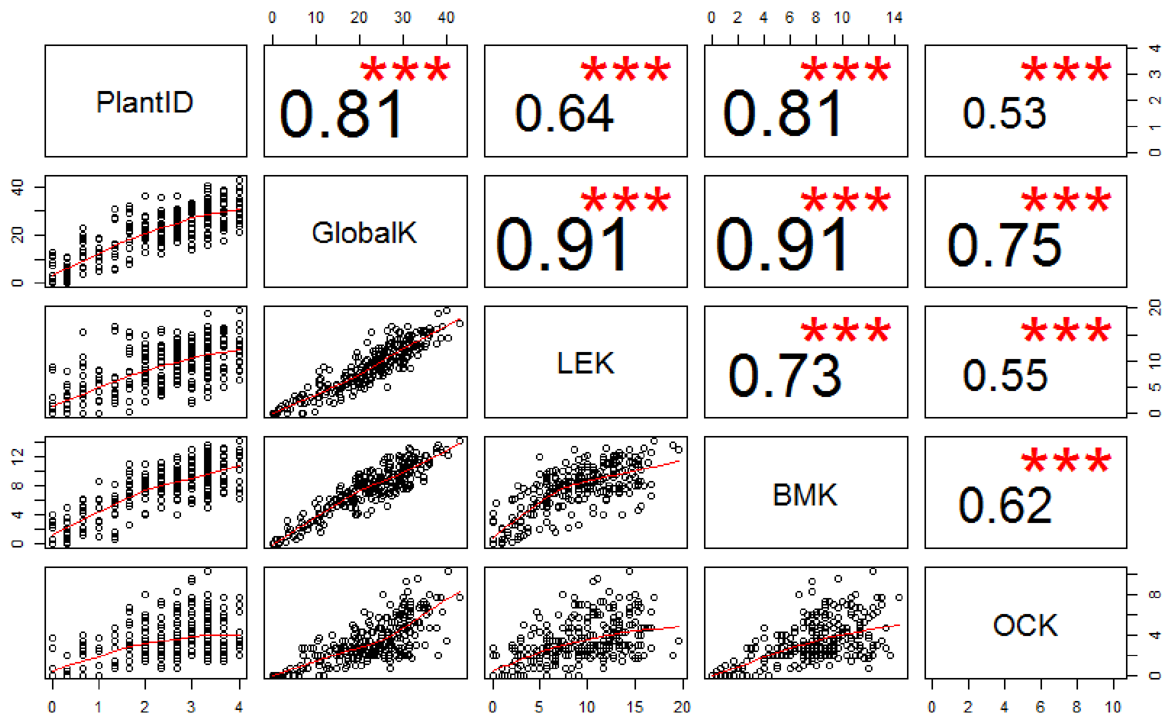

Figure B-3: [Chapter 3] Pairwise Spearman correlation between ability to correctly identify the plant (PlantID), global knowledge (GlobalK), local ecological knowledge (LEK), business/market knowledge (BMK), and traditional orchid cultural knowledge (OCK). Significance level: "***" = p<0.001.

APPENDIX C: DESCRIPTIONS OF CHINESE BOTANICAL GARDEN CASE STUDIES

6.2. Sichuan Case Studies

6.2.1. Chengdu Botanical Garden

Founded in 1983, opening to the public in 1985, and merging in 1987 with the Chengdu Institute of Landscape Architecture, **Chengdu Botanical Garden** (CBG, 成都市植物园) is the oldest BG in Sichuan Province. As a municipal BG, operating under the administration of the Chengdu Forestry and Landscape Administration Bureau, CBG is primarily focused on ornamental plants suitable for growing in urban environments. Encompassing approximately 105 acres, the gardens today are severely space limited, being completely landlocked by urban development. Receiving about 400,000 visitors per year, CBG remains the most visited of Sichuan's three BG, though overall visitation has been declining in recent years. CBG's mission is to promote public science education and plant domestication for urban environments, with the goals of greening city life, being a beautiful landscape, and pursuing harmonious development between humans and nature in the city of Chengdu.

CBG primarily seeks to address environmental, conservation, and invasive species challenges by increasing public awareness of these concerns through its public education program. To promote science education, approximately 100 CBG education department volunteers, trained by education department staff, go to local primary and secondary schools, as well as local community groups, to provide instruction on environmental issues, plant ecology, and human health. Volunteers are encouraged to lead educational tours of the grounds based on their own interests, and previous tours have included bird appreciation and invasive species walks. CBG also hosts field trips organized by the schools themselves. Within the gardens, science and technology activities are offered weekly in the 6400 m^2 plant science museum, with occasional educational programs on other topics, with seasonal garden-wide events like the annual spring and autumn flower exhibitions. To assist with the identification, monitoring, and control of destructive agricultural pests, CBG founded the "Chengdu Garden Plant Pests Early

Warning and Control Center" (成都市园林植物有害生物预警及控制中心), which has five dedicated staff persons who monitor the surrounding areas, provide community consultation services, and issue regular bulletins on the garden's website regarding home and garden plant pests and diseases.

In line with its mission, the CBG collections focus is on ornamental plants and shade trees suitable for thriving in the harsh urban environments of large Chinese cities like Chengdu, Beijing, and Shanghai. No preference is given to origin of the plants, but, due to severe space limitations of the gardens, if a species or cultivar is not ornamentally valuable or rare, CBG will not collect it. As of autumn, 2015, CBG's collections include more than 2,000 species and cultivars representing 774 genera in 170 families, with 72 varieties of plants specifically bred for excellence in urban environments. Priority is given to the families Magnoliaceae, Lauraceae, Fagaceae, Theaceae, Caprifoliaceae, Malvaceae, Rosaceae, Oleaceae, as well as conifers and *Rhododendron*, with more than 20 cultivars of the city flower *Hibiscus mutabilis* (芙蓉), and more than 200 hollyhock (*Alcea rosea*) cultivars. The collection includes >70 rare plants listed on the Chinese Red List, such as *Davidia involucrata*, *Cyathea spinulosa*, *Metasequoia glypotstroboides*, *Taiwania flousiana*, and *Taxus chinensis.* Although Sichuan Province has a separate list of endangered plants, CBG has chosen to prioritize the national red list.

6.2.2. Emei Mountain Botanical Garden

Emei Mountain Biological Resources Experimental Station (峨眉山生物资源实验站), known informally as **Emei Mountain Botanical Garden** (EBG, 峨嵋山植物园), was jointly established in 1984 by the Sichuan Provincial Academy of Natural Resource Sciences and the Emei County Government. Being located in the transitional zone between the Sichuan Basin and the eastern Himalayan highlands, Mt. Emei is one of the most biologically diverse mountains in all of China, with approximately 3,200 plant species in 242 families, >100 endemic species, and 31 of these listed as nationally protected (UNESCO 2017). Consequently, in 2004, EBG was designated by the provincial government as the key repository and exchange platform for the *ex situ* conservation and research of Sichuan's plant resources. Despite its small size (<9 acres open to the public), EBG annually receives approximately 20,000 visitors.

EBG's public education program consists of three components: 1) scientific research, 2) science application and promulgation, and 3) hosting the visiting public. EBG staff teach specialized seminars in local primary and secondary schools promoting natural science to help the students (~10,000/year) learn about and appreciate nature, as well as the importance of conservation. Local universities utilize the site for some of their coursework, with EBG providing the location for field courses in botany, ecology, and horticulture. Due to its unique collection of native plants, EBG regularly hosts visiting scholars (>50/year), who stay at an on-site hotel while utilizing EBG's living collections and small herbarium for research. For the visiting public, EBG has installed >30 interpretive panels throughout the property, describing key plant collections, as well as local plant diversity, ecology, and importance of conservation. Though EBG does not maintain its own website, it has pages on its parent organizations' websites, as well as listings on CUBG's and BGCI's websites. Due to the small size of the garden and concern for the security of its valuable collections, EBG does not actively promote tourism, but they are open to the public and welcome visitors who learn of their gardens.

EBG's mission is focused on the research and conservation of the diverse flora of Mt. Emei and its surrounding environs, particularly focused on collecting rare, endangered, and medicinally valuable taxa as in *Dendrobium*, *Paris*, and *Magnolia*. The national government and BGCI provided EBG with funds to assist with conservation of Mt. Emei's unique *Magnolia* species. In keeping with its mission, EBG does not introduce any plants from abroad. The collections include >2,400 total taxa, with >70 orchid species and >100 rare and endangered species from Southwest China. Due to EBG's small size and the great need to conserve the extremely diverse flora of greater Sichuan, EBG is collaborating with Sichuan Desheng Group Cultural Tourism Investment Co., Ltd. to establish a new BG nearby in Emei City called Sichuan Botanical Garden. In contrast to EBG's <9 acres, the new garden will consist of <1,300 acres, with plans to develop ten specialty gardens, including rare and endangered plants (with a goal of collecting >300 endangered plants), *Magnolia*, *Camellia*, *Actinidia*, bamboo, cherished trees, ferns and shade plants, a medicinal plant garden, bonsai garden, and a garden to represent the unique diversification of flora on Mt. Emei.

6.2.3. West China Subalpine Botanical Garden

West China Subalpine BG (WCBG, 华西亚高山植物园) is a small CAS-affiliated garden located in a rural, mountainous area in the northwestern outskirts of Chengdu (within the county-level Dujiangyan City). WCBG was founded by Prof. Minghong Chen in 1986 as a satellite field location of Beijing Botanical Garden, CAS. After participating in the Qinghai-Tibetan Plateau Hengduan Mountain Comprehensive Scientific Investigation (1981-1984), Chen recognized the scientific value of Southwest China's diverse flora for understanding the floristic relationship between the northern and southern hemispheres. Returning to his hometown, Dujiangyan, Chen found a high elevation location near Longchi suitable for conserving *Rhododendron* and established the Longchi Field Station. In 1988, the Dujiangyan City People's Government and the CAS Institute of Botany (IOB) in Beijing, signed an agreement to officially establish the West China Wild Plant Protection Experiment Center, being renamed WCBG in 1992. In 2001, WCBG was recognized as the National Rhododendron Garden of China.

Although the Longchi site was ideal for high-elevation *Rhododendron* species, it had proven quite challenging over-time to function as a BG due to its remoteness and logistical difficulties. Then, during the 2008 Sichuan Earthquake, the garden's facilities, infrastructure, and approach roads were completely destroyed. Consequently, governance of the gardens was transferred from Beijing Botanical Garden, CAS, to BBG's parent organization, the IOB, and plans were made to establish a second site, closer to town. In 2011, construction on the second site (Yutang Base) was completed and operations at both locations became synchronized. In total, the WCBG now encompasses 137 acres, with 104 acres at Longchi Base and 33 acres at Yutang Base. Offices and support staff are located at Yutang Base, and workers who care for the Longchi Base collections rotate shifts 2 weeks on and 2 weeks off.

As its facilities remain closed to the public, WCBG conducts science education programs in Dujiangyan City's primary and secondary schools. These programs focus on environmental protection, conservation of plant species diversity, and activities to better appreciate plants, such as pressing specimens and using leaves to produce art. The CAS science experts at WCBG also give lectures and coordinate science exhibitions on some campuses. For college students, WCBG hosts activities on how to do soil analyses, with field investigations at Longchi Base. On-site visits are only ~300 people per year, but the school activities reach >3,000 students each year.

Though the founding mission of WCBG was the conservation of *Rhododendron* as well as rare and endangered plants from the Hengduan Mountains Biodiversity Hotspot, over time, as their work with *Rhododendron* became more difficult, the focus shifted increasingly to *Rhododendron*. Two-thirds of global *Rhododendron* species are distributed in China, primarily in the Southwest Chinese provinces of Sichuan, Yunnan, Tibet, Guangxi, and Guizhou, as well as Chongqing, Hubei, and Hunan, and many of these can only flourish in specialized microclimates at high elevations. WCBG's current mission is to collect and conserve all Chinese *Rhododendron* species, as well as to conduct research on species conservation and domestication. WCBG hopes in the future to also collect foreign *Rhododendron* and artificial hybrids of horticultural value (at the Yutang Base). WCBG does continue to cultivate some locally rare and endangered plants in its collections, including *Davidia involucrata*, *Cercidiphyllum japonicum*, *Tetracentron sinense*, and *Primula* spp., but their wild-collection priority is solely *Rhododendron*. In total, WCBG's collections include >1,000 taxa, with >420 species of *Rhododendron* and 12 species of endangered *Rhododendron* from Sichuan and Yunnan provinces.

6.3. Non-Sichuan Case Studies

6.3.1. Kunming Botanical Garden

Founded in 1938, **Kunming Botanical Garden** (KBG, 昆明植物园) is a constituent unit of the Kunming Institute of Botany (KIB), CAS. Located on the Yunnan-Guizhou Plateau in the capital of Yunnan Province, which is China's most biologically and ethnically diverse jurisdiction, KBG and KIB have been at the forefront of biocultural diversity conservation work for decades. As a CAS research institute, KIB offers masters and doctoral degrees in many disciplines, including ethnobotany and environmental natural resource management. In 1995, faculty of KIB, led by Dr. Shengji Pei, founded the non-profit Center for Biodiversity and Indigenous Knowledge (CBIK) in Kunming, and KIB continues to be a leader in ethnobotanical research in China. As a comprehensive BG, KBG promotes the multidisciplinary study of plants, for the purposes of scientific research, conservation and sustainable use of plant resources, horticulture, and popular plant science education.

Despite the age of the BG and its plant collections, KBG only recently formulated a cohesive plant collections policy. Most of its oldest collections were gathered to support individual research projects at KIB, so their provenance and other pertinent collections information was not recorded or otherwise lost. Today, however, all new accessions include data on the number of specimens collected, the location, the environmental conditions, neighboring plants, soil type, etc. since it is now recognized that without these data, a BG's collection has minimal scientific or conservation value. This recent prioritization of systematic collections management has altered how the garden views its collections. KBG's collections policy is now primarily concerned with the native flora of the Yunnan-Guizhou Plateau and the southern Hengduan Mountains region, and, according to its "3E Policy," focused on collecting plants that are endemic, endangered, and/or economically important. According to KBG's director, Dr. Weibang Sun, "no botanical garden can do everything. We just focus on the Yunnan Plateau, but the Yunnan Plateau has more than five thousand species of plants, and about half of these are endemic to China. There are just too many interesting species for us to collect, so we must prioritize" (personal communication 2015).

In 2001, in cooperation with the Royal BG, Edinburgh (RBGE), KIB established the Lijiang Alpine BG (LABG, 丽江高山植物园) within the Hengduan Mountains ecoregion to help conserve the hotspot's fragile, endangered alpine flora. LABG is located just south of Lijiang's Jade Dragon Snow Mountain (elev. 5,596m), and consists of 708 acres, ranging in elevation between approximately 2,600 and 4,300 meters, conserving more than 2,300 species of native plants. Originally functioning more as an ecological field station than a BG, leaders of RBGE and KBG have recently drafted short-term and long-term plans of development for LABG to further its research and conservation capabilities.

KBG sees it as their responsibility to help the discipline of horticulture develop more professionally across China. Since 2012, on behalf of CUBG, KBG has hosted an annual 2-week horticulture technique-focused training course for BG staff from across China. More than 100 students from approximately 40 Chinese BG and other public horticulture institutions have completed the course, acquiring advanced professional gardening and technical horticulture training. Of these, 12 outstanding students were selected to also go to RBGE for further study and professional development. High quality horticulture is thus a distinct priority at KBG, since unhealthy plants cannot survive in the long term, and visitors to the garden intuitively recognize well-maintained collections regardless of their knowledge of horticulture. Thus, a well-maintained and aesthetically-pleasing landscape is critical to build local community support and leverage the scientific knowledge developed at KIB. This is also one reason why KBG recently redesigned and expanded its glasshouse facilities, to incorporate a larger conservatory complex. One interviewee explained that though visitors from other regions and other countries want to see local plants, most local people want to see exotic, foreign plants, so KBG, in addition to its primary collections of native species, also includes tropical and alpine plants in its temperature-controlled display conservatories. Nevertheless, the conservation mission runs throughout the conservatories as well, with one glasshouse dedicated to KBG's yellow *Camellia* collection, and a new one planned to house endangered plants in KBG's Plant Species of Extremely Small Populations (PSESP) collections, such as *Acer yangbiense* and *Magnolia sinica*, being grown with the goal of eventual reintroduction into the wild.

KBG actively seeks to reach out to its local community to fulfill its mission to increase awareness of issues related to environmental degradation, conservation, and sustainable resource use. KBG's Education Department develops all brochures, interpretive panels, and educational exhibits in its Plant Science Exhibition Hall. It also regularly hosts educational lectures and short courses for the local community, with the goal of educating the public on issues related to plant diversity, ecology, and environmental protection. In some cases, the CAS gives the KBG Education Department specific requests to develop educational materials on a particular topic, for a particular audience, and they research and plan these activities accordingly. But in all cases, the staff design educational materials and courses based on the needs of each audience. For example, some activities are targeted towards high school students, but others target pre-school and kindergarten students (4-6 years old) with their parents. One interviewee explained in reference to primary school visits, "we tell them this plant is this or that plant is that, but when they return, they tell *us* what is what." The department sees education not just as conveying knowledge, but also as inspiring people to marvel at plants. For example, one Education

Department interviewee explained, “there may be a lot of people who can recognize trees or grass, but they do not understand that there are many stories behind each plant. It is our job to research these stories and help explain them to the public in a fascinating way. If no one explains with words, the people just think all plants are the same. But after hearing stories, they realize how interesting and important plants are.” In addition to KBG, science education is also a major focus of two other KIB research units that work closely with KBG: the Kunming Herbarium (with >1,400,000 vouchers, including >700 type specimens) and the Germplasm Bank of Wild Species (China’s largest seed bank).

6.3.2. Shanghai Chen Shan Botanical Garden

The site of **Shanghai Chen Shan Botanical Garden** (CSBG, 上海辰山植物园), within Songjiang District in the suburban western outskirts of China’s largest city, was a stone quarry from the 1940s to 1990s that hollowed out what was formerly a large hill. With the rapid urbanization of Shanghai following China’s economic reforms in the 1980s, the city government became concerned with the declining urban environmental quality, decreasing green spaces, and threats to local biodiversity. Recognizing that the city’s first BG, Shanghai BG (SBG, 上海植物园, founded in 1974) was landlocked and unable by itself to fully address the environmental education, horticulture, and conservation needs of the city, the municipal government began to conceive of a new BG in 2005. Construction began in 2007, and CSBG was fully open to the public by early 2011. It is a cooperation between the Shanghai Municipal People’s Government (Shanghai Greening and City Administration Bureau), the CAS, and the State Forestry Administration. CSBG is a comprehensive BG with strong research, horticulture, education, and conservation programs, whose mission is “to conserve plants in Eastern China, discover sustainable ways of using them, and share our knowledge and enthusiasm with the public.”

With the assistance of management and staff from SBG, CSBG’s collections policy became one of the first in China to focus primarily on a Chinese regional flora (in this case, East China). The policy has three main collections objectives: research/conservation, education, and horticulture. 1) For research/conservation purposes, CSBG first prioritizes collecting rare and endangered species, especially those native to six provinces in East China (Anhui, Fujian, Jiangsu, Jiangxi, Shandong, and Zhejiang) as well as Shanghai City. CSBG is the official platform for the PSESP conservation program for these provinces. For research/conservation, CSBG also prioritizes collecting plants with economic potential, such as high oil content, medicinal potential, and environmental remediation abilities (such as *Salix* spp.). 2) For education, CSBG prioritizes those species that typify every climate zone as well as those species with "flashy" or unique morphologies or have interesting "stories to tell," that are useful for publicity or as teaching aids (such as *Victoria*, *Amorphophallus*, insectivorous plants, succulents, and Orchidaceae). 3) The horticultural priorities are those species that are ornamental and suitable for both indoor (conservatory) and outdoor display in Shanghai. In total, there are 21 collections priorities across these three core objectives, with the overall goal of "making the future more sustainable."

CSBG is not a research institution directly under the jurisdiction of the CAS, but instead hosts a unit of the CAS within itself, called the Shanghai Chen Shan Plant Science Research Center, CAS. This unit has three core research priorities, including: horticulture, botany, and biotechnology, with two or three research groups within each, and facilities include laboratories for morphology, tissue culture, genetics, phytochemistry, and plant physiology. CSBG hosts an annual 2-week training course on behalf of CUBG that is targeted towards training BG professionals on the topic of plant taxonomy and identification. CSBG has a 4,000 m^2 research and production greenhouse to support its operations and is actively involved with agricultural extension services for the local community. Due to its extensive connections with the public, CSBG has started to utilize web platforms to allow the public to input science data for them, like the Citizen Science movement in the United States. For example, if the researchers or collections managers are looking for a particular plant, they put out a request on these platforms, and users input location data and other pertinent information to assist the CSBG researchers. Sometimes it takes only a few minutes to locate wild populations of a targeted plant.

Education is a major focus of CSBG. With the vast majority of its approximately 900,000 annual visitors coming from Shanghai proper, the director of CSBG (Dr. Yonghong Hu) believes that educating the youth is one of the primary responsibilities for the garden. He explained that there is a noticeable gap between the plant knowledge of Shanghai's parents, many of whom used to be farmers or moved to Shanghai from rural areas, with that of the youth, who have essentially no understanding of plants. He has instituted a major push within the garden to encourage more home gardening throughout the city, teaching youth to grow their own vegetables and flowers, and become inspired by the diversity of the plant world. He believes this is especially important due to the urban youth's decreasing access to plants in their daily lives, not only due to the urban environment, but also due to modern lifestyles, with busy schedules and great academic pressure from teachers and schools inhibiting opportunities for young people to explore nature (personal communication 2015).

With over 300 cultural institutions (parks, zoos, gardens, museums, etc.) within Shanghai, and each K-12 student only having two field trip opportunities per school year (decided by the schools), there is great competition within Shanghai for quality of service and educational value at each institution. Although the CSBG Education Department staff can arrange educational activities, guides, and other programs for school groups that contact them in advance, few schools or teachers ever do. Consequently, CSBG actively reaches out to parents directly to help them see the value of bringing their children to the gardens. For example, CSBG advertises with local and national family organizations, each having hundreds of thousands of members, which in turn organize groups of parents and children to attend short courses hosted at the garden on various plant-related and environmental science topics. CSBG provides the resources, teachers, and venue, and each family pays about 10 元 ($1.50)/course. CSBG also offers a popular activity to the family organization members called "Fantastic Night" ("辰山奇妙夜"), which is a 2-day, overnight, summer camp in which 40-50 children (ages 6-12) stay in the Education Department head house of the gardens and participate in many hands-on, educational activities such as field sketching, painting with leaves, mini-lab experiments, and feeding the farm animals on site. What many children often find most enjoyable is being able to see the gardens at night and draw whatever most interests them. The garden hosts ~20 camps throughout July and August each year, with each student paying about 400 元 ($60.00). Since these camps are offered in cooperation with the family organizations, only one education department staff member must attend, with the family organizations providing 4-5 adults to staff the camps. Every child that attends receives a certificate from the sponsoring organization.

CSBG's Education Department also employs visitor surveys to tailor their educational offerings to the needs and interests of the visiting public. The Education Department utilizes an extensive network of about 500 student volunteers, recruited from the 8 nearby universities in Songjiang District, to staff the surveys and educational activities. Each major activity has 50-60 student volunteers (aged 18-22) who are trained and overseen by Education Department staff. For example, CSBG offers mobile educational carts that rotate through the gardens during weekends and holidays with various plant-related educational activities. They also staff a "Tropical Plants Pavilion" near the conservatory, with educational games designed and managed by the department's staff and volunteers. The garden also has a children's garden with a tree house, fountains, and many interesting plants that are variously scented, shaped, and textured to engage the children's senses, encourage exploration, and inspire the kids to want to come back and learn more. The Education Department realized that all schools throughout Shanghai use the same textbooks and therefore learn about the same plants, but few students have ever actually seen these plants in person. Since these plants were already growing at CSBG, the Education Department began developing a walking tour and interpretive panels to help introduce these plants to the visitors and help the students connect the school lessons to real life. These types of practical education-related programs are very attractive to parents too, who believe they will help their children to test better on exams if they have a personal connection to the plants.

6.3.3. Xishuangbanna Tropical Botanical Garden

Located in rural Xishuangbanna Dai Autonomous Prefecture in the far south of Yunnan Province, **Xishuangbanna Tropical Botanical Garden** (XTBG, 西双版纳热带植物园) is an influential and highly regarded comprehensive BG. It is one of only three CAS-affiliated BG that functions as a research institution on its own right, directly under the CAS, rather than being subordinate to another institute (in addition to South China BG in Guangdong and Wuhan BG in Hubei). As such, XTBG is a graduate degree-granting institution with a large research faculty that conducts extensive botanical, conservation, ecological, environmental, and ethnobotanical research, even incorporating the local minority people's culture into its conservation and education programs. XTBG was originally founded by the renowned Chinese botanist Xitao Cai in 1959 as a satellite tropical forest field station of KIB. Between 1978-1987, the field station became the independent Yunnan Institute of Tropical Botany, before joining again with KIB in 1988. In 1997, upon separation from KIB and merger with Kunming Institute of Ecology, XTBG became a stand-alone tropical BG directly under control of the CAS. Dr. Shengji Pei, the institution's second director (1981-1986) is considered the founder of ethnobotany in China, introducing it as a discipline first to XTBG and later to KIB. The current director of XTBG, Dr. Jin Chen, is the founding chairman of the CUBG, and XTBG hosts the CUBG secretariat.

The mission of XTBG is to promote the advancement of science and environmental conservation through the implementation of collaborative multi-disciplinary research programs, horticultural exhibitions, and public education of tropical botany. In line with its mission, XTBG's education program is wide-ranging and international in scope. As a CAS research institute, XTBG has a tremendous research output, publishing around 200 scholarly papers annually, with three-quarters of these in high-impact international journals. XTBG has more than 30 research groups organized into three laboratories: 1) Key Laboratory of Tropical Forest Ecology, 2) Key Laboratory of Tropical Plant Resources and Sustainable Use, and 3) Center for Integrative Conservation. There are approximately 90 full-time research faculty holding PhDs, with 18 additional foreign adjunct faculty; 76 graduate faculty instruct 136 master's students, 91 doctoral students, and 28 post-doctoral students (including 21 foreign students, as of 2015). Graduate education is focused on two disciplines for student recruitment: ecology and botany (with many sub disciplines, including ethnobotany, conservation, and ecological restoration). Each year XTBG hosts a six-week advanced field course on tropical ecology with students from Asia, Africa, and South America. XTBG is also one of three Chinese BG to offer specialized professional training courses on behalf of CUBG for BG staff. XTBG hosts two of these two-week courses, one on environmental education research and another tailored to BG directors.

XTBG is well-connected with its local community, hosting short courses and seminars for local primary and secondary school children, providing special training courses for teachers, and hosting undergraduate students for short-term programs. Each year, XTBG also offers residential summer and winter camps for middle and high school students from large cities across China, who learn about tropical ecology, botany, and conduct their own research projects (reaching several thousand students/year). The garden hosts an annual bird watching festival (in

January), orchid festival, nighttime botanical garden tours, as well as special educational programs during Chinese New Year and National Day holidays. Building upon its legacy of ethnobotanical research and its location within a minority-majority prefecture, XTBG hires local Dai women to serve as garden docents. This docent program introduces all XTBG visitors to both the biodiversity and cultural diversity of Xishuangbanna Dai Autonomous Prefecture.

In 1998, XTBG founded the Tropical Rain Forest Ethnobotany Museum on its grounds. As a museum within a botanical garden, it has two main educational focuses: 1) promoting knowledge about the tropical rain forest biodiversity, unique ecology, and importance of conservation, and 2) introducing the 13 unique minority nationality cultures of Xishuangbanna to the visiting public. The museum was built to also serve as a venue for XTBG's broader educational programs, and the museum trains all garden docents (so far teaching >500 Dai women about their own traditional culture). During summer holidays, the museum also holds a special program called the "little docent program," which trains local primary and middle school students as docents for a month, teaching them how to explain the museum, unique cultures of Xishuangbanna, and tropical rainforest ecology. When the students return to school, they must give presentations on their experiences, and the museum staff explain that these "little docents" become passionate champions for conservation and cultural traditions within their own communities. The museum also hosts lectures from XTBG research scientists and rainforest experts that are open to the general visiting public.

XTBG's 2,780 acre grounds (including ~620 acres of well-preserved primary tropical rainforest) make it the second-largest BG in all of China. Its collections house >13,000 species of plants in 35 living collections. XTBG's high standards for horticulture and beautiful landscape have earned it a 5A rating for tourism, which is the highest level awarded in China (one of only 100 5A locations in the entire country). XTBG is also a leader in ecological restoration and afforestation in China, being a member of the ERA and maintaining three ecological field stations throughout the province: 1) Xishuangbanna Tropical Rainforest Station, 2) Ailao Subtropical Forest Station, and 3) Yuanjiang Savanah Ecosystem Station. In 2013, XTBG implanted a new program called the "Zero Extinction Project," which seeks to conserve all threatened species in Xishuangbanna so that no new species go extinct. Due to the diversity of ecosystems in Yunnan Province, and the inability to grow all of Yunnan's threatened species in Xishuangbanna's tropical climate, XTBG is currently working to establish a satellite BG in collaboration with the Jingdong County People's Government, called the Jingdong Subtropical Botanical Garden (景东亚热带植物园), which will cover ~2,142 acres to conserve Fagaceae, Lauraceae, Magnoliaceae, Moraceae, Rosaceae, Theaceae, and other subtropical-temperate families with large species diversity in Yunnan.

BIBLIOGRAPHY

Akopian JA (2010) Conservation of Native Plant Diversity at the Yerevan Botanic Garden, Armenia. 65:663–669.

Albuquerque UP, Soldati GT, Sieber SS, et al (2011) The Use of Plants in the Medical System of the Fulni-ô People (NE Brazil): A Perspective on Age and Gender. J Ethnopharmacol 133:866–873. doi: 10.1016/j.jep.2010.11.021

APGA (2017a) What is a Public Garden? American Public Gardens Association. https://publicgardens.org/about-public-gardens/what-public-garden.

APGA (2017b) How Do I Get Official Botanical Garden status? American Public Gardens Association. https://publicgardens.org/acquiring-botanical-garden-status.

ArbNet (2017) About the Register. Morton Register. http://www.arbnet.org/about-register.

Attané I, Courbage Y (2000) Transitional Stages and Identity Boundaries: The Case of Ethnic Minorities in China. Popul Environ 21:257–280. doi: 10.1007/BF02436131

Barnes ML, Lynham J, Kalberg K, Leung P (2016) Social networks and environmental outcomes. Proc Natl Acad Sci 113:6466–6471. doi: 10.1073/pnas.1523245113

Barton K (2013) MuMIn: Multi-Model Inference.

Bensky D, Gamble A, Kaptchuk TJ, et al (1993) Chinese Herbal Medicine: Materia Medica/ compiled and translated by Dan Bensky and Andrew Gamble, with Ted Kaptchuk; illustrations adapted by Lilian Lai Bensky., Rev. ed. Eastland Press, Seattle, Wash.

Benz BF, Cevallos JE, Santana FM, et al (2000) Losing knowledge about plant use in the Sierra de Manantlan Biosphere Reserve, Mexico. Econ Bot 54:183–191.

Bernard HR (2011) Research Methods in Anthropology: Qualitative and Quantitative Approaches. Rowman Altamira

BGCI (2017) Mission and Strategy. Botanic Gardens Conservation International. https://www.bgci.org/about-us/mission/.

BGCI (2016) Annual Member's Review 2016. Botanic Gardens Conservation International.

BGCI (2012) Ecological Restoration Alliance. Botanic Gardens Conservation International. https://www.bgci.org/plant-conservation/era/.

Bian Y, Breiger R, Davis D, Galaskiewicz J (2005) Occupation, Class, and Social Networks in Urban China. Soc Forces 83:1443–1468.

Birkinshaw C, II PPL, Raharimampionona J, Aronson J (2013) Supporting Target 4 of the Global Strategy for Plant Conservation by Integrating Ecological Restoration into the Missouri Botanical Garden's Conservation Program in Madagascar. Ann Missouri Bot Gard 99:139–146. doi: 10.3417/2012002

Bodin Ö, Crona B, Ernstson H (2006) Social Networks in Natural Resource Management: What is There to Learn from a Structural Perspective. Ecol Soc 11:r2.

Bodin Ö, Ramirez-Sanchez S, Ernstson H, Prell C (2011) A Social Relational Approach to Natural Resource Governance. In: Bodin Ö, Prell C (eds) Social Networks and Natural Resource Management: Uncovering the Social Fabric of Environmental Governance. Cambridge University Press, Cambridge, pp 3–28

Bodin Ö, Tengö M (2012) Disentangling intangible social-ecological systems. Glob Environ Chang 22:430–439. doi: 10.1016/j.gloenvcha.2012.01.005

Borgatti SP, Everett MG, Freeman LC (2002) Ucinet for Windows: Software for Social Network Analysis.

Brandt R, Mathez-Stiefel S-L, Lachmuth S, et al (2013) Knowledge and Valuation of Andean Agroforestry Species: The Role of Sex, Age, and Migration Among Members of A Rural Community in Bolivia. J Ethnobiol Ethnomed 9:83. doi: 10.1186/1746-4269-9-83

Bretschneider E (1882) Notes on Chinese Botany from Native and Western Sources. In: Botanicon sinicum (Part I). Trubner, London :,

Bretschneider E (1895) Notes on Chinese Botany from Native and Western Sources: Botanical Investigations into the Materia Medica of the Ancient Chinese. In: Botanicon Sinicum (Part III). Trubner, Shanghai,

Burnham KP, Anderson DR, Huyvaert KP (2011) AIC Model Selection and Multimodel Inference in Behavioral Ecology: Some Background, Observations, and Comparisons. Behav Ecol Sociobiol 65:23–35. doi: 10.1007/s00265-010-1029-6

Butts CT (2008) Social network analysis: A methodological introduction. Asian J Soc Psychol 11:13–41. doi: 10.1111/j.1467-839X.2007.00241.x

Carlson TJ (2001) Language, Ethnobotanical Knowledge, and Tropical Public Health. In: Maffi L (ed) On Biological Diversity: Linking Language, Knowledge, and the Environment. Smithsonian Institution Press, Washington, DC, USA, pp 489–502

Chen J, Cannon CH, Hu H (2009a) Tropical Botanical Gardens: At the in situ Ecosystem Management Frontier. Trends Plant Sci 14:584–589. doi: http://dx.doi.org/10.1016/j.tplants.2009.08.010

Chen S, Tang T (1982) A General Review of the Orchid Flora of China. In: Arditti J (ed) Orchid Biology: Reviews and Perspectives. Comstock, Ithaca, NY, pp 39–81

Chen X, Liu Z, Zhu G, et al (2009b) Orchidaceae. In: Wu Z, Raven PH, Hong D (eds) Flora of China. Beijing: Science Press & St. Louis: Missouri Botanical Garden Press,

Chen X, Luo Y (2003) Advances in Some Plant Groups in China: A Retrospect and Prospect of Orchidology in China. Acta Bot Sin 45:2–20.

Cocks M (2006) Biocultural Diversity: Moving Beyond the Realm of “Indigenous” and “Local” People. Hum. Ecol. 34:185–200.

Cocks ML, Wiersum F (2014) Reappraising the Concept of Biocultural Diversity: A Perspective from South Africa. Hum Ecol 42:727–737. doi: 10.1007/s10745-014-9681-5

Conference of the Parties (2011) The Targets 2011-2020.

Cozzolino S, Noce ME, Musacchio A, Widmer A (2003) Variation at a Chloroplast Minisatellite Locus Reveals the Signature of Habitat Fragmentation and Genetic Bottlenecks in the Rare Orchid Anacamptis palustris (Orchidaceae). Am J Bot 90:1681–1687. doi: 10.3732/ajb.90.12.1681

Crane PR, Hopper SD, Raven PH, Stevenson DW (2009) Plant Science Research in Botanic Gardens. Trends Plant Sci 14:575–577. doi: http://dx.doi.org/10.1016/j.tplants.2009.09.007

Creswell JW (2003) Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 2nd edn. Sage Publications, Thousand Oaks, CA

Crona B, Bodin Ö (2006) What You Know is Who You Know? Communication Patterns Among Resource Users as a Prerequisite for Co-management. Ecol Soc 11:7. doi: 10.1038/nature09798

CUBG (2017) About Us: Chinese Union of Botanical Gardens. http://www.cubg.cn/aboutus.html#Aboutus.

Cunningham AB (2001) Applied Ethnobotany: People, Wild Plant use and Conservation. People and Plant Conservation Manual. Earthscan

Daubmann K (2002) Community Relations at Public Gardens: Issues, Causes and Responses. University of Delaware

Davis A, Wagner JR (2003) Who Knows? On the Importance of Identifying "Experts" When Researching Local Ecological Knowledge. Hum Ecol 31:463–489. doi: 10.2307/4603485

Dawson W, Mndolwa AS, Burslem DFRP, Hulme PE (2008) Assessing the Risks of Plant invasions Arising from Collections in Tropical Botanical Gardens. Biodivers Conserv 17:1979–1995. doi: 10.1007/s10531-008-9345-0

Day B (1984) Publicity for Botanic Gardens, Arboretums and Horticultural Organizations. University of Delaware

Dolinar EM (1987) The Economic Impact of a Public Garden on its Community: A Case Study of Phipps Conservatory, Pittsburgh, Pennsylvania. University of Delaware

Donaldson JS (2009) Botanic Gardens Science for Conservation and Global Change. Trends Plant Sci 14:608–613. doi: http://dx.doi.org/10.1016/j.tplants.2009.08.008

Du Puy D, Cribb P (2007) The Genus Cymbidium. Kew Publishing, Richmond, Surrey, UK

Dunn CP (2008) Biocultural Diversity Should Be A Priority for Conservation. Nature 456:315. doi: 10.1038/456315a

Dwyer A (2011) Tools and Techniques for Endangered-Language Assessment and Revitalization. Vitality Viability Minor Lang 1–20.

Enright NJ, Cao KF (2010) Plant ecology in China. Plant Ecol 209:181–187. doi: 10.2307/40666614

ERA (2017) Members. Ecological Restoration Alliance of Botanic Gardens.

http://www.erabg.org/members/.

Ferrari S, Cribari-Neto F (2004) Beta Regression for Modelling Rates and Proportions. J Appl Stat 31:799–815. doi: 10.1080/0266476042000214501

Frank O (2002) Using Centrality Modeling in Network Surveys. Soc Networks 24:385–394. doi: 10.1016/S0378-8733(02)00014-X

Furusawa T (2009) Changing Ethnobotanical Knowledge of the Roviana People, Solomon Islands: Quantitative Approaches to its Correlation with Modernization. Hum Ecol 37:147–159. doi: 10.1007/s10745-009-9223-8

Gandolfo ES, Hanazaki N (2014) Distribution of Local Plant Knowledge in a Recently Urbanized Area (Campeche District, Florianopolis, Brazil). Urban Ecosyst. 1–11.

Gavin MC, Solomon JN, Blank SG (2010) Measuring and Monitoring Illegal Use of Natural Resources. Conserv Biol 24:89–100. doi: 10.1111/j.1523-1739.2009.01387.x

Goody J (1993) The “Four Gentlemen of Flowers” in China. In: The Culture of Flowers. Cambridge University Press, Cambridge, pp 347–386

Granovetter M (1983) The Strength of Weak Ties: A Network Theory Revisited. Sociol Theory 1:201–233. doi: 10.2307/202051

Grueber CE, Nakagawa S, Laws RJ, Jamieson IG (2011) Multimodel Inference in Ecology and Evolution: Challenges and Solutions. J Evol Biol 24:699–711. doi: 10.1111/j.1420-9101.2010.02210.x

Hackney Blackwell A (2013) Botanical Gardens: Driving Plant Conservation Law. Kentucky J Equine, Agric Nat Resour 1–32. doi: 10.1525/sp.2007.54.1.23.

Hakkenberg C (2008) Biodiversity and Sacred Sites: Vernacular Conservation Practices in Northwest Yunnan, China. World Views Environ Cult Relig 12:74–90. doi: 10.1163/156853508X276842

Hallwass G, Lopes PF, Juras AA, Silvano RAM (2013) Fishers’ Knowledge Identifies Environmental Changes and Fish Abundance Trends in Impounded Tropical Rivers. Ecol Appl 23:392–407. doi: 10.1890/12-0429.1

Hanazaki N, Herbst DF, Marques MS, Vandebroek I (2013) Evidence of the Shifting Baseline Syndrome in Ethnobotanical Research. J Ethnobiol Ethnomed 9:75. doi: 10.1186/1746-4269-9-75

Hardwick KA, Fiedler P, Lee LC, et al (2011) The Role of Botanic Gardens in the Science and Practice of Ecological Restoration. Conserv Biol 25:265–275. doi: 10.1111/j.1523-1739.2010.01632.x

Harrell S (1990) Ethnicity, Local Interests, and the State: Yi Communities in Southwest China. Comp Stud Soc Hist 32:515. doi: 10.1017/S0010417500016613

He H, Chen J (2012) Educational and enjoyment benefits of visitor education centers at botanical gardens. Biol Conserv 149:103–112. doi: 10.1016/j.biocon.2012.01.048

Hedean SE (2005) Conservation, As Part of a Garden’s Mission, Promotes Organizational

Practices That Conserve Biodiversity. University of Delaware

Heikkila E, Xu Y (2014) Seven Prototypical Chinese Cities. Urban Stud 51:827–847. doi: 10.1177/0042098013492231

Hew CS (2001) Ancient Chinese Orchid Cultivation: A Fresh Look at an Age-Old Practice. Sci Hortic (Amsterdam) 87:1–10. doi: 10.1016/S0304-4238(00)00137-0

Hopkins A (2011) Use of Network Centrality Measures to Explain Individual Levels of Herbal Remedy Cultural Competence among the Yucatec Maya in Tabi, Mexico. Field methods 23:307–328. doi: 10.1038/jid.2014.371

Hulme PE (2011a) Addressing the Threat to Biodiversity from Botanic Gardens. Trends Ecol Evol 26:168–174. doi: 10.1016/j.tree.2011.01.005

Hulme PE (2011b) Botanic Garden Benefits Do Not Repudiate Risks: A Reply to Sharrock et al. Trends Ecol Evol 26:434–435. doi: 10.1016/j.tree.2011.06.005

Hulme PE (2015) Resolving Whether Botanic Gardens Are on the Road to Conservation or a Pathway for Plant Invasions. Conserv Biol 29:816–824. doi: 10.1111/cobi.12426

Jinxiu W, Hongmao L, Huabin H, Lei G (2004) Participatory Approach for Rapid Assessment of Plant Diversity Through a Folk Classification System in a Tropical Rainforest: Case Study in Xishuangbanna, China. Conserv Biol 18:1139–1142. doi: 10.1111/j.1523-1739.2004.00075.x

Johnson A (2013) Environmental Justice Advocacy Within Public Horticulture Institutions.

Kightley EP, Reyes-García V, Demps K, et al (2016) Measuring Traditional Ecological Knowledge: Does Knowledge Mean Skill? Tsimane'Amazonian Panel Study (Tsimane'Amazonian Panel Study Working Paper, 57)

Lauer M, Albert S, Aswani S, et al (2012) Globalization, Pacific Islands, and the paradox of resilience.

Lauer M, Matera J (2016) Who detects ecological change after catastrophic events? Indigenous knowledge, social networks, and situated practices. Hum Ecol 44:33–46. doi: 10.1007/s10745-016-9811-3

Levin Stevenson S (2013) Rooted in the Community: Tools for Engagement at Public Gardens. University of Delaware

Li D-Z, Pritchard HW (2009) The Science and Economics of ex situ Plant Conservation. Trends Pant Sci 14:614–621. doi: http://dx.doi.org/10.1016/j.tplants.2009.09.005

Li X, Li J (1997) The Tanaka-Kaiyong Line-An Important Floristic Line for the Study of the Flora of East Asia. Ann Missouri Bot Gard 84:888–892.

Lin LH (2011) Cultural and Organizational Antecedents of Guanxi: The Chinese Cases. J Bus Ethics 99:441–451. doi: 10.1007/s10551-010-0662-3

Ling C (2014) Orchid Conservation Messaging in Public Gardens. University of Delaware

Liu H, Luo Y, Liu H (2010) Studies of Mycorrhizal Fungi of Chinese Orchids and Their Role in

Orchid Conservation in China—A Review. Bot Rev 76:241–262. doi: 10.1007/s12229-010-9045-9

Liu H, Luo YB, Heinen J, et al (2014) Eat Your Orchid and Have it Too: A Potentially New Conservation Formula for Chinese Epiphytic Medicinal Orchids. Biodivers Conserv 23:1215–1228. doi: 10.1007/s10531-014-0661-2

Liu Q, Chen J, Corlett RT, et al (2015) Orchid conservation in the biodiversity hotspot of southwestern China. Conserv Biol 29:1563–1572. doi: 10.1111/cobi.12584

Lizarralde M (2001) Biodiversity and Loss of Indigenous Languages and Knowledge in South America. In: Maffi L (ed) On Biological Diversity: Linking Language, Knowledge, and the Environment. Smithsonian Institution Press, Washington, DC, USA, pp 265–281

Loh J, Harmon D (2005) A Global Index of Biocultural Diversity. Ecol Indic 5:231–241. doi: 10.1016/j.ecolind.2005.02.005

Luo Y, Jia J, Wang C (2003) A General Review of the Conservation Status of Chinese Orchids. Chinese Biodivers 11:70–77.

Ma R (2011) Social Relations (Guanxi): A Chinese Approach to Interpersonal Communication. China Media Res 7:25–33.

Maffi L (2005) Linguistic, Cultural, and Biological Diversity. Annu Rev Anthropol 34:599–617. doi: 10.1146/annurev.anthro.34.081804.120437

Maffi L (2004) Maintaining and Restoring Biocultural Diversity: The Evolution of A Role for Ethnobiology. In: Carlson TJS, Maffi L (eds) Ethnobotany and Conservation of Biocultural Diversity. The New York Botanical Garden Press, Bronx, pp 9–35

Maffi L (2001) Introduction: On the Interdependence of Biological and Cultural Diversity. In: Maffi L (ed) On Biological Diversity: Linking Language, Knowledge, and the Environment. Smithsonian Institution Press, Washington, DC, USA, pp 1–50

Mathez-Stiefel SL, Brandt R, Lachmuth S, Rist S (2012) Are the Young Less Knowledgeable? Local Knowledge of Natural Remedies and Its Transformations in the Andean Highlands. Hum Ecol 40:909–930. doi: 10.1007/s10745-012-9520-5

Maunder M (2008) Beyond the Greenhouse. Nature 455:596–597. doi: 10.1038/455596a

Maunder M, Lyte B, Dransfield J, Baker W (2001) The Conservation Value of Botanic Garden Palm Collections. Biol Conserv 98:259–271. doi: http://dx.doi.org/10.1016/S0006-3207(00)00160-9

Mazerolle M (2006) Improving Data Analysis in Herpetology: Using Akaike's Information Criterion (AIC) to Assess the Strength of Biological Hypotheses. Amphibia-Reptilia 27:169–180. doi: 10.1163/156853806777239922

Mbaru EK, Barnes ML (2017) Key players in conservation diffusion: Using social network analysis to identify critical injection points. Biol Conserv 210:222–232. doi: 10.1016/j.biocon.2017.03.031

McMillen H (2012) Ethnobotanical Knowledge Transmission and Evolution: The Case of

Medicinal Markets in Tanga, Tanzania1. Econ Bot 66:121–131. doi: 10.1007/s12231-012-9201-8

McMillen HL, Ticktin T, Friedlander A, et al (2014) Small Islands, Valuable Insights: Systems of Customary Resource Use and Resilience to Climate Change in the Pacific. Ecol Soc. doi: http://dx.doi.org/10.5751/ES-06937-190444

Miller B, Conway W, Reading RP, et al (2004) Evaluating the Conservation Mission of Zoos, Aquariums, Botanical Gardens, and Natural History Museums. Conserv Biol 18:86–93. doi: 10.1111/j.1523-1739.2004.00181.x

Mishler BD (2001) Biodiversity and the Loss of Lineages. In: Maffi L (ed) On Biological Diversity: Linking Language, Knowledge, and the Environment. Smithsonian Institution Press, Washington, DC, USA, pp 71–81

Moore JL, Manne L, Brooks T, et al (2002) The Distribution of Cultural and Biological Diversity in Africa. Proc Biol Sci 269:1645–1653. doi: 10.1098/rspb.2002.2075

Mühlhäusler P (2001) Ecolinguistics, Linguistic Diversity, Ecological Diversity. In: Maffi L (ed) On Biological Diversity: Linking Language, Knowledge, and the Environment. Smithsonian Institution Press, Washington, DC, USA, pp 133–144

Müller-Schwarze NK (2006) Antes and Hoy Día: Plant Knowledge and Categorization as Adaptations to Life in Panama in the Twenty-First Century. Econ Bot 60:321–334.

Naughton-Treves L, Holland MB, Brandon K (2005) The Role of Protected Areas in Conserving Biodiversity and Sustaining Local Livelihoods. Annu Rev Environ Resour 30:219–252. doi: 10.1146/annurev.energy.30.050504.164507

Oldfield SF (2009) Botanic Gardens and the Conservation of Tree Species. Trends Plant Sci 14:581–583. doi: 10.1016/j.tplants.2009.08.013

Pauly D (1995) Anecdotes and the Shifting Baseline Syndrome of Fisheries. Trends Ecol. Evol. 10:430.

Peery MZ, Kirby R, Reid BN, et al (2012) Reliability of Genetic Bottleneck Tests for Detecting Recent Population Declines. Mol Ecol 21:3403–3418. doi: 10.1111/j.1365-294X.2012.05635.x

Pei S (1984) Botanical Gardens in China. University of Hawaii Press, Honolulu

Pepper JG (1978) Planning the Development of Living Plant Collections in Botanic Gardens and Arboretums. University of Delaware

Perner H, Luo Y (2007) Orchids of Huanglong (黄龙兰花). Huanglong National Park, Sichuan

Prell C (2012) Social network analysis: History, theory and methodology. Sage

Prell C, Hubacek K, Quinn C, Reed M (2008) "Who"s in the Network?' When Stakeholders Influence Data Analysis. Syst Pract Action Res 21:443–458. doi: 10.1007/s11213-008-9105-9

Pretty J, Adams B, Berkes F, et al (2009) The Intersections of Biological Diversity and Cultural

Diversity: Towards Integration. Conserv Soc 7:100. doi: 10.4103/0972-4923.58642

Qiu J (2009) Where the rubber meets the garden. Nature 457:246–247.

QSR International (2016) NVivo 11 Plus for Windows.

R Core Team (2016) R: A Language and Environment for Statistical Computing.

Reyes-García V, Guèze M, Luz AC, et al (2013) Evidence of Traditional Knowledge Loss Among a Contemporary Indigenous Society. Evol Hum Behav 34:249–257. doi: 10.1016/j.evolhumbehav.2013.03.002

Reyes-García V, Martí N, McDade T, et al (2007a) Concepts and Methods in Studies Measuring Individual Ethnobotanical Knowledge. J Ethnobiol 27:182–203. doi: 10.2993/0278-0771(2007)27[182:CAMISM]2.0.CO;2

Reyes-García V, Vadez V, Huanca T, et al (2007b) Economic Development and Local Ecological Knowledge: A Deadlock? Data From a Native Amazonian Society. Hum Ecol 35:371–377.

Reyes-García V, Vadez V, Tanner S, et al (2006) Evaluating Indices of Traditional Ecological Knowledge: A Methodological Contribution. J Ethnobiol Ethnomed 2:21. doi: 10.1186/1746-4269-2-21

Riswan S, Yamada I (2006) A Note on the Progress of Biodiversity Research in Indonesia. Tropics 15:249–258.

Romney AK, Weller SC, Batchelder WH (1986) Culture as Consensus: A Theory of Culture and Informant Accuracy. Am Anthropol 88:313–338. doi: 10.1525/aa.1986.88.2.02a00020

Rudyj ES (1988) International Cooperation Among Botanic Gardens: The Concept of Establishing Agreements. University of Delaware

Schwetz G (1996) Regional Interpretation Linking Our Natural and Cultural Identities. University of Delaware

Seaton P, Kendon JP, Pritchard HW, et al (2013) Orchid Conservation: The Next Ten Years. Lankesteriana 13:93–101.

Seaton PT, Hu H, Perner H, Pritchard HW (2010) Ex Situ Conservation of Orchids in a Warming World. Bot Rev 76:193–203. doi: 10.2307/40792834

Seyler B (2009) Sino-American Botanical Exchange: Encouraging Greater Botanical Collaboration Through A Mutually Beneficial Staff Exchange Program. University of Delaware

Seyler B, Lyons R (2011) Sino-American Botanical Exchange: Characteristics of Success and Lessons Learnt.

Sharrock SL (2011) The Biodiversity Benefits of Botanic Gardens. Trends Ecol Evol 26:433. doi: 10.1016/j.tree.2011.05.008

Shen X, Li S, Chen N, et al (2012) Does Science Replace Traditions? Correlates Between Traditional Tibetan Culture and Local Bird Diversity in Southwest China. Biol Conserv

145:160–170. doi: 10.1016/j.biocon.2011.10.027

Shenton J, Ross N, Kohut M, Waxman S (2011) Maya Folk Botany and Knowledge Devolution: Modernization and Intra-Community Variability in the Acquisition of Folkbotanical Knowledge. Ethos 39:349–367. doi: 10.1111/j.1548-1352.2011.01197.x

Smith EA (2001) On the Coevolution of Cultural, Linguistic, and Biological Diversity. In: Maffi L (ed) On Biological Diversity: Linking Language, Knowledge, and the Environment. Smithsonian Institution Press, Washington, DC, USA, pp 95–117

Souto T, Ticktin T (2012) Understanding Interrelationships Among Predictors (Age, Gender, and Origin) of Local Ecological Knowledge. Econ Bot 66:149–164. doi: 10.1007/s12231-012-9194-3

Srithi K, Balslev H, Wangpakapattanawong P, et al (2009) Medicinal Plant Knowledge and Its Erosion Among the Mien (Yao) in Northern Thailand. J Ethnopharmacol 123:335–342. doi: 10.1016/j.jep.2009.02.035

Stepp JR, Cervone S, Castaneda H, et al (2004) Development of a GIS for Global Biocultural Diversity. Policy Matters 13:267–270. doi: Policy Matters

Sutherland WJ (2003) Parallel Extinction Risk and Global Distribution of Languages and Species. Nature 423:276–279. doi: 10.1038/nature01607

Swarts ND, Dixon KW (2009) Perspectives on Orchid Conservation in Botanic Gardens. Trends Plant Sci 14:590–598. doi: 10.1016/j.tplants.2009.07.008

Teoh E-S (2005) Orchids of Asia. Marshall Cavendish, Singapore

The Plant List (2013) About: The Plant List. Version 1.1. www.theplantlist.org/1.1/about/.

Torres-Avilez W, Medeiros PM de, Albuquerque UP (2016) Effect of Gender on the Knowledge of Medicinal Plants: Systematic Review and Meta-Analysis. Evidence-Based Complement Altern Med. doi: 10.1155/2016/6592363

Tu J, Chen Y, Ye G, Chen G (2005) The Upper Min River Basin: A Key Ethno-Cultural Corridor in China. Mt Res Dev 25:25–29. doi: 10.2307/3674365

Tunnicliffe SD (2001) Talking About Plants --Comments of Primary School Groups Looking at Plant Exhibits in a Botanical Garden. J. Biol. Educ. 36:27–34.

Turvey ST, Barrett LA, Hao Y, et al (2010) Rapidly Shifting Baselines in Yangtze Fishing Communities and Local Memory of Extinct Species. Conserv Biol 24:778–787. doi: 10.2307/40603293

U.S. Fish & Wildlife Service (2017) The U.S. Plant Rescue Center Program. https://nctc.fws.gov/resources/knowledge-resources/IA_Pubs/plant_rescue03.pdf.

UN Department of Economic and Social Affairs (2015) World Urbanization Prospects: The 2014 Revision. New York

United Nations Department of Economic and Social Affairs Population Division (2014) Annual Percentage of Population at Mid-Year Residing in Urban Areas by Major Area, Region and Country, 1950-2050. New York

USBG (2017) Plant Conservation. In: United States Bot. Gard. https://www.usbg.gov/plant-conservation.

Valente TW (1996) Social Network Thresholds in the Diffusion of Innovations. Soc Networks 18:69–89. doi: http://dx.doi.org/10.1016/0378-8733(95)00256-1

Vandebroek I, Balick MJ (2012) Globalization and Loss of Plant Knowledge: Challenging the Paradigm. PLoS One. doi: 10.1371/journal.pone.0037643

Voeks RA, Leony A (2004) Forgetting the Forest: Assessing Medicinal Plant Erosion in Eastern Brazil. Econ Bot 58:94–106. doi: 10.1663/0013-0001(2004)58[S294:FTFAMP]2.0.CO;2

Wasserman S, Faust K (1994) Social Network Analysis: Methods and Applications. Cambridge University Press

Waylen K (2006) Botanic Gardens: Using Biodiversity to Improve Human Wellbeing. Med Plant Conserv 12:4–6.

Wen X (2008) The Importance of Botanic Gardens in Chinese Cities.

Wilcox KN, Duin BA (1994) Indigenous Cultural and Biological Diversity: Overlapping Values of Latin American Ecoregions. Cult. Surviv. Q. Mag. 18:

Wyman D (1960) How to Establish an Arboretum or Botanical Garden. Arnoldia 20:69–83.

Wyse Jackson P, Kennedy K (2009) The Global Strategy for Plant Conservation: A Challenge and Opportunity for the International Community. Trends Plant Sci 14:578–580. doi: 10.1016/j.tplants.2009.08.011

Xu Z, Jiang H, Ye D, Liu E (2010) The Wild Orchids of Yunnan. Yunnan Publishing Group Corporation; Yunnan Science & Technology Press

Yang Z, Dong Y, Gao L, et al (2005) The Distribution of Y Chromosome Haplogroups in the Nationalities from Yunnan Province of China. Ann Hum Biol 32:80–87. doi: 10.1080/03014460400027557

Zarger RK, Stepp JR (2004) Persistence of Botanical Knowledge Among Tzeltal Maya Children. Curr Anthropol 45:413–418. doi: 10.1086/420908

Zhang K, Woan TS, Li J, et al (2014) Shifting Baselines on a Tropical Forest Frontier: Extirpations Drive Declines in Local Ecological Knowledge. PLoS One 9:e86598. doi: 10.1371/journal.pone.0086598

Zhang KH, Song S (2003) Rural-urban migration and urbanization in China: Evidence from time-series and cross-section analyses. China Econ Rev 14:386–400. doi: 10.1016/j.chieco.2003.09.018

Zhang Z, Yan Y, Tian Y, et al (2015) Distribution and Conservation of Orchid Species Richness in China. Biol Conserv 181:64–72. doi: 10.1016/j.biocon.2014.10.026

Zhao G, Tian Y, Tang Z, et al (2014) Distribution of terrestrial national nature reserves in relation to human activities and natural environments in China. Biodivers Sci 21:658–665. doi: 10.3724/SP.J.1003.2013.08048

Zhao S, Zhou D, Zhu C, et al (2015) Spatial and Temporal Dimensions of Urban Expansion in China. Environ Sci Technol 49:9600–9609. doi: 10.1021/acs.est.5b00065

Zhou X, Cheng Z, Liu Q, et al (2016) An Updated Checklist of Orchidaceae for China, With Two New National Records. Magnolia Press, Auckland, New Zealand