THE STATUS AND FUTURE OF ORCHID CONSERVATION IN NORTH AMERICA[1]

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Abstract

The status and trends of issues related to the conservation of orchids native to the United States, Canada, and Greenland are considered. We focus on nine of the 16 Targets of the Global Strategy for Plant Conservation (GSPC). The first two targets, which all other targets rely upon, appear to have been adequately achieved, in addition to Target 11. Limited progress has been made on six other GSPC targets. Three case studies of efforts to conserve the native threatened orchids, *Platanthera leucophaea* (Nutt.) Lindl., *Isotria medeoloides* (Pursh) Raf., and *Tolumnia bahamensis* (Nash) Braem, are presented to demonstrate the difficulties as well as the issues associated with effective conservation. We describe our efforts to establish an international program to conserve all native orchids in the United States and Canada. The North American Orchid Conservation Center (NAOCC) is an internationally focused effort that is based on public-private partnerships. The goal of NAOCC is to conserve the genetic diversity of all native orchids through efforts to develop an international collection of seeds and orchid fungi. The NAOCC also focuses on the cultivation of all native orchids in an international network of botanic gardens, and they partner with private and public landowners to develop techniques to conserve and restore all native orchid species.

Key words: Endangered species, Global Strategy for Plant Conservation (GSPC), North American Orchid Conservation Center (NAOCC), Orchidaceae, restoration.

Beautiful, diverse, and often bearing large and showy flowers, orchids are an ancient plant family that has evolved an amazing array of bizarre flower types, unique pollination syndromes, and complex symbiotic interactions with animals and fungi. In the plant world, orchids reign supreme as about 10% of all flowering plant species are members of the Orchidaceae. No other plant family can match the peculiar array of evolutionary features that orchids collectively possess. Along with the Asteraceae, the Orchidaceae has more species, estimated to be between 20,000 and 35,000 taxa (Cribb et al., 2003), than any other family of flowering plants, and individual orchid species are often rare in nature, occurring in restricted and specific niches and habitats. Collectors prize orchids for their seemingly infinite variety of showy flowers; scientists have long been fascinated by the relationships between the plants and their pollinators and other symbionts.

Today, orchids have taken on even greater significance. Due to their interconnectedness with the species around them, orchids, highly sensitive to habitat change, are among the first casualties from environmental degradation. Most orchid genera contain threatened or endangered species (Swarts & Dixon, 2009). Orchids are found throughout North America, and many of the approximately 210 species found north of Mexico are threatened, endangered, or extirpated in at least part of their ranges because of habitat loss and alteration. Most North American orchids are terrestrial. Globally, terrestrial orchids make up only one third of orchid species with the other two thirds being epiphytes and lithophytes. However, terrestrial herbaceous perennials are disproportionately represented in the extinct plant species listed by The World Conservation Union (IUCN, 1999). Consequently, terrestrial orchids are likely subject to a greater extinction risk than epiphytes, particularly in response to current climate changes.

Much of orchids' sensitivity to habitat change likely can be traced to their dependence on two, often

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very specific, types of symbiotic associations. Orchids' relationships with specific pollinators have been a subject of interest since before Darwin, but more recently orchid dependence on mycorrhizal fungi has also received substantial research attention (Waterman & Bidartondo, 2008). Identification of the fungi on which orchids depend requires DNA sequencing and analysis, but it is clear at this point that some orchids are dependent upon fungi that are free living in the soil, while others associate with fungi that are also connected to other plants, especially trees. As habitats change, the fungal community changes, and orchids may lose fungi upon which they depend for their survival.

As popular, desirable, and charismatic subjects for cultivation, orchids face another serious threat. Like precious gems, the most unique and rare orchids are sought by the most enthusiastic collectors. As word spreads about the location of a rare orchid, more and more demand is placed on already fragile populations. Unfortunately, without efforts to cultivate the symbiotic fungi, most of these plants are doomed in cultivation. Due to the combination of habitat loss and poaching, many orchid species, which were once widespread, are now found in small, ecologically fragile, fragmented populations. The majority of orchids are represented globally by tropical epiphytes, but temperate zone terrestrials make up a significant proportion (approximately 28%; Gravendeel et al., 2004) and conservation of terrestrial species has proven to be especially challenging (e.g., Stewart & Hicks, 2010). No orchid has ever been delisted, though one, *Isotria medeoloides* (Pursh) Raf., was upgraded from endangered to threatened in 1994 (U.S. Fish and Wildlife Service, 1994) after extensive directed searching uncovered new populations. A comprehensive holistic approach to species conservation has to be fully realized in conservation and restoration plans.

The orchid flora of North America represents an important scientific challenge for conservation biologists. Unlike many other plant species, where significant efforts are often employed to cultivate and reintroduce rare plants and to store germplasm, the majority of organizations that identify and protect orchids on public and private lands rely solely on habitat conservation for management. This conservation strategy has largely been dictated by the unique aspects of orchid biology that make them not amenable to standard plant conservation techniques. We propose a model of centralized but integrated orchid conservation that can provide one-stop shopping for agencies and organizations responsible for and actively participating in efforts to conserve native orchids.

We begin by identifying successes and major gaps in conservation strategies for North American native orchids by addressing nine of the 16 targets of the 2011–2020 Global Strategy for Plant Conservation (GSPC) in relation to the conservation of orchid species native to the United States, Canada, and Greenland. GSPC targets 4, 5, 6, 9, 10, 12, and 13 do not apply directly to native North American orchid species. We then propose a centralized North American Orchid Conservation Center (NAOCC) that addresses each deficiency.

Global Strategy of Plant Conservation Targets

target 1, an online flora of all known plants

A total of 210 orchid species are native to the United States, Canada, and Greenland (see Table 1), including one described as recently as 2007, as *Platanthera yosemitensis* Colwell, Sheviak & P. E. Moore (Colwell et al., 2007). The novel orchid list is a compilation of species from Kartesz (1994), the Flora of North America (Romero-González et al., 2002), Brown (2009), and NatureServe Explorer (NatureServe, 2011), and each name is accepted by The Plant List (<http://www.thePlantList.org>) and the World Checklist of Selected Plant Families (WCSP, 2011). Additionally, 135 orchid species are native to Puerto Rico and the Virgin Islands (Acevedo-Rodríguez & Strong, 2007), but of these species only those that extend into the mainland are treated here.

The 210 described species (Table 1) are distributed among 66 genera (Table 2), with 49 genera (74%) represented by only one or two species and a few genera being represented by more than three species (e.g., *Platanthera* Rich. with 35 species, *Spiranthes* Rich. with 23 species). While there are always questions of whether taxa should be split or lumped and questions about the treatment of hybrids, relationships between most genera in the Orchidaceae are well established (e.g., Górniak et al., 2010).

Native orchid species are found in all 50 states within the United States and all 10 provinces and three territories of Canada. On average, there are 40 native species per state, with Hawaii having the fewest native species (three) and Florida with the most (106). Other species-rich areas include the states along the East Coast associated with the Appalachian Mountains, especially North Carolina (67 species), Virginia (59 species), and New York (57 species). Of the Canadian provinces, Prince Edward Island and Ontario have an especially diverse orchid assemblage (59 and 58 species, respectively). All

Table 1. The 210 native orchid species of the United States, Canada, and Greenland, including conservation assessments, legal protections, and the number of botanic gardens holding ex situ collections. This list is a compilation of species from Kartesz (1994), the Flora of North America (Romero-González et al., 2002), Brown (2009), and NatureServe Explorer (NatureServe, 2011).

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Anoectochilus sandvicensis Lindl.	G3; S3	Vulnerable				1
Aplectrum hyemale (Muhl. ex Willd.) Nutt.	G5; SH, S1-S5, SNR			Endangered		11
Arethusa bulbosa L.	G4; SX, SH, S1-S4, SNR			Endangered		0
Basiphyllaea corallicola (Small) Ames	G2; S1			Endangered		0
Beloglottis costaricensis (Rchb. f.) Schltr.	G4; S1*			Endangered		0
Bletia patula Hook.	G4; SH					5
Bletia purpurea (Lam.) DC.	G5; S3			Threatened		17
Brassia caudata (L.) Lindl.	G3; SX			Endangered		37
Bulbophyllum pachyrachis (A. Rich.) Griseb.	G4; SX					0
Calopogon barbatus (Walter) Ames	G4; S1-S3, SNR					1
Calopogon multiflorus Lindl.	G2; SH, S1-S3			Endangered		0
Calopogon oklahomensis D. H. Goldman	G3; SH, S1, S2, SNR					0
Calopogon pallidus Chapm.	G4; S1-S5, SNR					2
Calopogon tuberosus (L.) Britton, Sterns & Poggenb.	G5; SX, S1-S4, SNR			Endangered		16
Calypso bulbosa (L.) Oakes	G5; SH, S1-S5, SNR			Endangered		8
Camaridium vestitum (Sw.) Lindl.	G4; S1*					5*
Campylocentrum pachyrrhizum (Rchb. f.) Rolfe	G4; S1			Endangered		1
Cephalanthera austiniae (A. Gray) A. Heller	G4; S2, S3, SNR				Threatened	1
Cleistesiopsis bifaria (Fernald) Pansarin & F. Barros	G4; S1-S4, SNR*					3*
Cleistesiopsis divaricata (L.) Pansarin & F. Barros	G4; SX, S1, S3, S4, SNR*			Endangered*		1
Cleistesiopsis oricamporum P. M. Br.	GNR; S2					0
Corallorhiza bentleyi Freudenst.	G1; S1					0
Corallorhiza maculata (Raf.) Raf.	G5; SH, S1-S4, SNR			Endangered		12
Corallorhiza mertensiana Bong.	G4; S2, S3, S5, SU, SNR					1
Corallorhiza odontorhiza (Willd.) Nutt.	G5; SH, S1-S5, SNR			Endangered		2
Corallorhiza striata Lindl.	G5; SH, S1-S4, SNR			Endangered		0
Corallorhiza trifida Châtel.	G5; S1-S5, SNR			Endangered		2
Corallorhiza wisteriana Conrad	G5; SX, SH, S1-S5, SNR			Endangered		2
Cranichis muscosa Sw.	G4; S1			Endangered		2
Cyclopogon cranichoides (Griseb.) Schltr.	G4; SNR*					0
Cyclopogon elatus (Sw.) Schltr.	G4; SH*			Endangered		4*
Cypripedium acaule Aiton	G5; S1, S3-S5, SNR			Endangered		22

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Cypripedium arietinum R. Br.	G3; SH, S1-S3			Endangered		1
Cypripedium californicum A. Gray	G3; S3					7
Cypripedium candidum Muhl. ex Willd.	G4; SX, SH, S1-S3, SNR			Endangered	Endangered	10
Cypripedium fasciculatum Kellogg ex S. Watson	G4; S1-S3					2
Cypripedium guttatum Sw.	G5; S2, SNR					7
Cypripedium kentuckiense C. F. Reed	G3; S1-S3			Endangered		14
Cypripedium montanum Douglas ex Lindl.	G4; S1-S4, SNR					3
Cypripedium parviflorum Salisb.	G5; SH, S1-S4, SNR			Endangered		12
Cypripedium passerinum Richardson	G4; S1-S4, SNR					2
Cypripedium reginae Walter	G4; SX, S1-S4, SU, SNR, SNA			Endangered		33
Cypripedium yatabeanum Makino	G4; SNR*					1
Cyrtopodium punctatum (L.) Lindl.	G5; S1			Endangered		22
Dactylorhiza aristata (Fisch. ex Lindl.) Soó	G4; S4					0
Dactylorhiza viridis (L.) R. M. Bateman, Pridgeon & M. W. Chase	G5; SX, SH, S1-S5, SNR*			Endangered		11*
Dendrophylax lindenii (Lindl.) Benth. ex Rolfe	G3; S2*			Endangered		7*
Dendrophylax porrectus (Rchb. f.) Carlsward & Whitten	GU; SNR*					0
Dichromanthus cinnabarinus (La Llave & Lex.) Garay	G5; SNR*					2
Dichromanthus michuacanus (La Llave & Lex.) Salazar & Soto Arenas	G4; S3, SNR*					0
Eltroplectris calcarata (Sw.) Garay & H. R. Sweet	G4; S1			Endangered		1
Encyclia tampensis (Lindl.) Small	G4; SNR					23
Epidendrum amphistomum A. Rich.	GNR; S3			Endangered		0
Epidendrum anceps Jacq.						10
Epidendrum blancheanum Urb.	G4; SX			Endangered*		1*
Epidendrum floridense Hágsater						5
Epidendrum magnoliae Muhl.	G4; S2, S3, SNR*					4*
Epidendrum nocturnum Jacq.	G4; S2			Endangered		25
Epidendrum rigidum Jacq.	G4; S3			Endangered		19
Epidendrum strobiliferum Rchb. f.	G4; S1			Endangered		1
Epipactis gigantea Douglas ex Hook.	G4; S1-S3, SU, SNR				Special Concern	37
Eulophia alta (L.) Fawc. & Rendle	G4; S4					6
Eulophia ecristata (Fernald) Ames	G2; S1, S2*			Endangered		0

Table 1. Continued.

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Galeandra beyrichii Rchb. f.	G4; SNR					0
Galeandra bicarinata G. A. Romero & P. M. Br.	G1; S1			Endangered		0
Galearis spectabilis (L.) Raf.	G5; S1-S5, SNR			Endangered		4
Goodyera oblongifolia Raf.	G5; S1-S5, SNR			Endangered		9
Goodyera pubescens (Willd.) R. Br.	G5; S1-S5, SNR			Endangered		27
Goodyera repens (L.) R. Br.	G5; SH, S1-S5, SNR			Endangered		14
Goodyera tesselata Lodd.	G5; SX, SH, S1-S5, SU, SNR			Endangered		3
Govenia floridana P. M. Br.				Endangered		0
Habenaria distans Griseb.	G5; S1			Endangered		1
Habenaria floribunda Lindl.	G4; SNR*					2*
Habenaria quinqueseta (Michx.) Sw.	G4; S1, SNR					1
Habenaria repens Nutt.	G5; S1-S3, SNR					4
Hammarbya paludosa (L.) Kuntze	G4; S1-S3, SNR*			Endangered*		2
Heterotaxis sessilis (Sw.) F. Barros	G4; S1*					18*
Hexalectris grandiflora (A. Rich. & Galeotti) L. O. Williams	G4; S2					2
Hexalectris nitida L. O. Williams	G3; S1, S3			Endangered		2
Hexalectris revoluta Correll	G1; S1, SNR					0
Hexalectris spicata (Walter) Barnhart	G5; SH, S1-S4, SNR			Endangered		3
Hexalectris warnockii Ames & Correll	G2; S1, S2					0
Ionopsis utricularioides (Sw.) Lindl.	G4; S1			Endangered		10
Isotria medeoloides (Pursh) Raf.	G2; SX, SH, S1, S2		Threatened	Endangered	Endangered	1
Isotria verticillata (Muehl. ex Willd.) Raf.	G5; SX, S1-S5, SNR			Endangered	Endangered	5
Lepanthopsis melanantha (Rchb. f.) Ames	G3; SH			Endangered		1
Liparis hawaiensis H. Mann	G3; S3					3
Liparis liliifolia (L.) Rich. ex Lindl.	G5; SX, S1-S5, SNR			Endangered	Endangered	4
Liparis loeselii (L.) Rich.	G5; SX, SH, S1-S5, SNR			Endangered		8
Liparis nervosa (Thunb.) Lindl.	G4; S2			Endangered*		10
Macradenia lutescens R. Br.	G4; SH			Endangered		0
Malaxis abieticola Salazar & Soto Arenas	G4; S1, S3*					0
Malaxis bayardii Fernald	G1; SH, S1, SU			Endangered		0
Malaxis brachystachys (Rchb. f.) Kuntze	G4; S3, S4*					0
Malaxis macrostachya (Lex.) Kuntze	G4; SNR, SNA					3*
Malaxis monophyllos (L.) Sw.	G4; SH, S1-S4, SNR*			Endangered*		1
Malaxis porphyrea (Ridl.) Kuntze	G4; S2, SNR					0

Table 1. Continued.

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Malaxis spicata Sw.	G4; S1-S3, SNR					0
Malaxis unifolia Michx.	G5; S1-S5, SX, SNR			Endangered		2
Malaxis wendtii Salazar	G2; S1					0
Mesadenus lucayanus (Britton) Schltr.	G4; S1, S2*			Endangered		1*
Microthelys rubrocallosa (B. L. Rob. & Greenm.) Garay	GNR; S1					0
Neottia auriculata (Wiegand) Szlach.	G3; S1-S3, SNR*			Endangered		0
Neottia banksiana (Lindl.) Rchb. f.	G4; S1-S4, SNR*					4*
Neottia bifolia (Raf.) Baumbach	G4; S1-S4, SNR*			Endangered*		5*
Neottia borealis (Morong) Szlach.	G4; SH, S1-S4, SNR*					0
Neottia convallarioides (Sw.) Rich.	G5; S1-S4, SNR*					0
Neottia cordata (L.) Rich.	G5; SH, S1-S5, SNR*			Endangered*		1
Neottia smallii (Wiegand) Szlach.	G4; S1-S4*			Endangered*		0
Oncidium ensatum Lindl.	GNR; S1			Endangered*		9*
Pelexia adnata (Sw.) Poit. ex Rich.	G5; S1			Endangered		1
Peristylus holochila (Hillebr.) N. Hallé	G1; S1*		Endangered*			3*
Piperia candida Rand. Morgan & Ackerman	G3; S2, S3, SNR					0
Piperia colemanii Rand.Morgan & Glic.	G3; S3					0
Piperia cooperi (S. Watson) Rydb.	G4; S3					0
Piperia dilatata (Pursh) Szlach. & Rutk.	G5; SH, S1-S5, SU, SNR*					5*
Piperia elegans (Lindl.) Rydb.	G4; S3, S4, SNR					1
Piperia elongata Rydb.	G4; S3, S4, SNR					0
Piperia leptopetala Rydb.	G3; S3					0
Piperia transversa Suksd.	G4; S3, S4, SNR					0
Piperia unalascensis (Spreng.) Rydb.	G5; S1-S5, SNR					0
Piperia yadonii Rand. Morgan & Ackerman	G2; S2		Endangered			0
Platanthera aquilonis Sheviak	G5; SX, S1-S5, SU, SNR					3
Platanthera blephariglottis (Willd.) Lindl.	G4; S1-S4, SNR			Endangered		4
Platanthera brevifolia (Greene) Senghas	G4; SNR					0
Platanthera chapmanii (Small) Luer	G2; S1, SH, SNR					1
Platanthera chorisiana (Cham.) Rchb. f.	G3; S2-S4			Threatened		2
Platanthera ciliaris (L.) Lindl.	G5; SX, SH, S1-S4, SNR			Endangered		5
Platanthera clavellata (Michx.) Luer	G5; SH, S1-S5, SU, SNR					2
Platanthera convallariifolia (Fisch. ex Lindl.) Lindl.						0

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Platanthera cristata (Michx.) Lindl.	G5; S1-S4, SX, SNR			Endangered		0
Platanthera flava (L.) Lindl.	G4; SX, S1-S4, SU, SNR			Endangered		1
Platanthera grandiflora (Bigelow) Lindl.	G5; SX, S1-S4, SNR			Endangered		3
Platanthera hookeri (Torr.) Lindl.	G4; SX, S1-S4, SH, SNR			Endangered		2
Platanthera huronensis Lindl.	G5; S1-S5, SU, SNR*					3
Platanthera hyperborea (L.) Lindl.	G5; S4			Endangered		5
Platanthera integra (Nutt.) A. Gray ex L. C. Beck	G3; S1-S3, SNR			Endangered		0
Platanthera integrilabia (Correll) Luer	G2; SH, S1-S3, SU		Candidate	Endangered		1
Platanthera lacera (Michx.) G. Don	G5; S1-S5, SNR					7
Platanthera leucophaea (Nutt.) Lindl.	G2; SX, SH, S1, S2		Threatened	Endangered	Endangered	2
Platanthera limosa Lindl.	G4; S4, SNR					0
Platanthera nivea (Nutt.) Luer	G5; SH, S1-S3, SNR			Endangered		1
Platanthera obtusata (Banks ex Pursh) Lindl.	G5; S1-S5, SNR			Vulnerable		1
Platanthera orbiculata (Pursh) Lindl.	G5; SX, SH, S1-S4, SNR			Endangered		1
Platanthera pallida P. M. Br.	GNA; SU, SNA, SNR*					0
Platanthera peramoena A. Gray	G5; SX, S1-S4, SNR			Endangered		1
Platanthera praeclara Sheviak & M. L. Bowles	G3; SH, S1-S3	Endangered	Threatened	Endangered	Endangered	1
Platanthera psycodes (L.) Lindl.	G5; SX, SH, S1-S5, SNR			Endangered		2
Platanthera purpurascens (Rydb.) Sheviak & W. F. Jenn.						0
Platanthera rotundifolia (Banks ex Pursh) Lindl.	G5; SX, SH, S1-S5, SNR*			Endangered*		1
Platanthera shriveri P. M. Br.	G1; S1, SNR					0
Platanthera sparsiflora (S. Watson) Schltr.	G4; S1, SNR			Sensitive		0
Platanthera stricta Lindl.	G5; S1-S5, SNR					4*
Platanthera tescamnis Sheviak & W. F. Jenn.						0
Platanthera tipuloides (L. f.) Lindl.	G4; S2					0
Platanthera yosemitensis Colwell, Sheviak & P. E. Moore	G2; S2					0
Platanthera zothecina (L. C. Higgins & S. L. Welsh) Kartesz & Gandhi	G2; S1, S2					0
Platythelys querceticola (Lindl.) Garay	G4; S1, SNR					0
Platythelys sagraeana (A. Rich.) Garay						0
Pogonia ophioglossoides (L.) Ker Gawl.	G5; SX, SU, S1-S5, SNR			Endangered		17
Polystachya concreta (Jacq.) Garay & H. R. Sweet	G4; S3			Endangered		13
Ponthieva brittoniae Ames	G3; S1			Endangered		1

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Ponthieva racemosa (Walter) C. Mohr	G4; S1-S3, SNR			Endangered		4
Prescottia oligantha (Sw.) Lindl.	G4; S1					1
Prosthechea boothiana (Lindl.) W. E. Higgins	G4; S1*					6*
Prosthechea cochleata (L.) W. E. Higgins	G4; S3*					65*
Prosthechea pygmaea (Hook.) W. E. Higgins	G4; S1*			Endangered		9*
Pseudorchis albida (L.) Á. Löve & D. Löve	G5; S3, SNR*					3
Sacoila lanceolata (Aubl.) Garay	G4; S3*			Threatened*		8*
Sacoila squamulosa (Kunth) Garay						0
Schiedeella arizonica P. M. Br.	GNR; S3, S4, SNR					0
Schiedeella confusa (Garay) Espejo & López-Ferr.	G3; SNR*					0
Spiranthes brevilabris Lindl.	G1; S1, SNR			Endangered		0
Spiranthes casei Catling & Cruise	G4; S1-S4, SNR			Endangered		0
Spiranthes cernua (L.) Rich.	G5; S1-S5, SU, SNR			Vulnerable		28
Spiranthes delitescens Sheviak	G1; S1		Endangered	Endangered		1
Spiranthes diluvialis Sheviak	G2; S1, S2		Threatened	Endangered		5
Spiranthes eatonii Ames ex P. M. Br.	G3; SH, S1-S3, SNR					0
Spiranthes infernalis Sheviak	G1; S1					0
Spiranthes lacera (Raf.) Raf.	G5; S1-S5, SNR			Threatened		5
Spiranthes laciniata (Small) Ames	G4; S1-S4, SU, SNR			Endangered		0
Spiranthes longilabris Lindl.	G3; SH, S1-S3, SNR			Threatened		0
Spiranthes lucida (H. H. Eaton) Ames	G5; SX, SH, S1-S5, SNR			Endangered		2
Spiranthes magnicamporum Sheviak	G4; SX, S1-S4, SNR			Endangered		2
Spiranthes ochroleuca (Rydb.) Rydb.	G4; SH, S1-S3, S5, SNR			Endangered		2
Spiranthes odorata (Nutt.) Lindl.	G5; SH, S1-S4, SU, SNR			Endangered		15
Spiranthes ovalis Lindl.	G5; SH, S1-S5, SNR			Endangered		3
Spiranthes parksii Correll	G3; S3		Endangered	Endangered		2
Spiranthes porrifolia Lindl.	G4; S1, S2, S4, SNR			Sensitive		3
Spiranthes praecox (Walter) S. Watson	G5; SH, S1-S4, SU					1
Spiranthes romanzoffiana Cham.	G5; SH, S1-S5, SU, SNR			Endangered		5
Spiranthes sylvatica P. M. Br.	GNR; S1					0
Spiranthes torta (Thunb.) Garay & H. R. Sweet	G4; S1*			Endangered		0
Spiranthes tuberosa Raf.	G5; SH, S1-S5, SNR			Endangered		4
Spiranthes vernalis Engelm. & A. Gray	G5; S1-S5, SNR			Endangered		5
Stelis gelida (Lindl.) Pridgeon & M. W. Chase	G5; S1*			Endangered*		3
Tipularia discolor (Pursh) Nutt.	G4; S1, S3-S5, SNR			Endangered		15

Table 1. Continued.

Species	NatureServe conservation status ranks[a]	IUCN 2011 Red List[b]	U.S. Endangered Species Act[c]	U.S. State conservation listing[d]	Canada's Species At Risk Act[e]	Number of botanic gardens where present[f]
Tolumnia bahamensis (Nash ex Britton & Millsp.) Braem	G3; S1			Endangered		5
Trichocentrum undulatum (Sw.) Ackerman & M. W. Chase	G4; S1*			Endangered*		1
Triphora amazonica Schltr.				Endangered		0
Triphora craigheadii Luer	G1; S1			Endangered		0
Triphora gentianoides (Sw.) Nutt. ex Ames & Schltr.	G4; SNR					0
Triphora trianthophora (Sw.) Rydb.	G3; SH, S1-S3, SNR			Endangered	Endangered	0
Triphora yucatanensis Ames	G1; S1					0
Tropidia polystachya (Sw.) Ames	G4; S1			Endangered		1
Vanilla barbellata Rchb. f.	G4; S2			Endangered		7
Vanilla dilloniana Correll	G3; SNR			Endangered		5
Vanilla inodora Schiede						1
Vanilla mexicana Mill.	G3; S1			Endangered		2
Vanilla phaeantha Rchb. f.	G4; S1			Endangered		8

* Listed in original publication under a synonymous name.

[a] Conservation assessments by NatureServe correspond to Global threats: G1 = Critically Imperiled, G2 = Imperiled, G3 = Vulnerable, G4 = Apparently Secure, G5 = Secure, GU = Unrankable, GNR = Not Yet Ranked, GNA = Not Applicable. Subnational threats follow similar values (S1 to S5, etc.), but apply at the state or provincial levels. NatureServe rankings are available through <http://www.natureserve.org/explorer>.

[b] International Union for Conservation of Nature and Natural Resources (IUCN), 2011.

[c] Endangered Species Act (ESA), 1973; U.S. Government Printing Office, 2012.

[d] U.S. State listing is at the highest level of protection among all states listed, as reported by the USDA PLANTS Database (USDA, NRCS, 2012).

[e] Species at Risk Act (SARA), 2002.

[f] The number of botanic gardens where the orchid species is conserved or present, according to Botanical Gardens Conservation International (2012).

Table 2. Species distribution among listed orchid genera in Table 1.

Genus	Species #	Percent of total species
Platanthera Rich.	35	16.7%
Spiranthes Rich.	23	11.0%
Cypripedium L.	12	5.7%
Piperia Rydb.	10	4.8%
Malaxis Sol. ex Sw.	9	4.3%
Epidendrum L.	8	3.8%
Corallorhiza Gagnebin	7	3.3%
Neottia Guett.	7	3.3%
Calopogon R. Br.	5	2.4%
Hexalectris Raf.	5	2.4%
Triphora Nutt.	5	2.4%
Vanilla Mill.	5	2.4%
Goodyera R. Br.	4	1.9%
Habenaria Willd.	4	1.9%
Liparis Rich.	4	1.9%
Cleistesiopsis Pansarin & F. Barros	3	1.4%
Prosthechea Knowles & Westc.	3	1.4%
Bletia Ruiz & Pav.	2	1%
Cyclopogon C. Presl	2	1%
Dactylorhiza Neck. ex Nevski	2	1%
Dendrophylax Rchb. f.	2	1%
Dichromanthus Garay	2	1%
Eulophia R. Br. ex Lindl.	2	1%
Galeandra Lindl.	2	1%
Isotria Raf.	2	1%
Platythelys Garay	2	1%
Ponthieva R. Br.	2	1%
Sacoila Raf.	2	1%
Schiedeella Schltr.	2	1%
Anoectochilus Blume	1	0.5%
Aplectrum Blume	1	0.5%
Arethusa L.	1	0.5%
Basiphyllaea Schltr.	1	0.5%
Beloglottis Schltr.	1	0.5%
Brassia R. Br.	1	0.5%
Bulbophyllum Thouars	1	0.5%
Calypso Salisb.	1	0.5%
Camaridium Lindl.	1	0.5%
Campylocentrum Benth.	1	0.5%
Cephalanthera Rich.	1	0.5%
Cranichis Sw.	1	0.5%
Cyrtopodium R. Br.	1	0.5%
Eltroplectris Raf.	1	0.5%
Encyclia Hook.	1	0.5%
Epipactis Zinn	1	0.5%
Galearis Raf.	1	0.5%
Govenia Lindl.	1	0.5%
Hammarbya Kuntze	1	0.5%
Heterotaxis Lindl.	1	0.5%
Ionopsis Kunth	1	0.5%
Lepanthopsis Ames	1	0.5%
Macradenia R. Br.	1	0.5%
Mesadenus Schltr.	1	0.5%
Microthelys Garay	1	0.5%
Oncidium Sw.	1	0.5%
Pelexia Poit. ex Lindl.	1	0.5%
Peristylus Blume	1	0.5%
Pogonia Juss.	1	0.5%
Polystachya Hook.	1	0.5%
Prescottia Lindl.	1	0.5%
Pseudorchis Ség.	1	0.5%
Stelis Sw.	1	0.5%
Tipularia Nutt.	1	0.5%
Tolumnia Raf.	1	0.5%
Trichocentrum Poepp. & Endl.	1	0.5%
Tropidia Lindl.	1	0.5%

state and provincial species numbers are according to the NatureServe Explorer (NatureServe, 2011). Three species are endemic to California, as *Piperia colemanii* Rand. Morgan & Glic., *P. yadonii* Rand. Morgan & Ackerman, and *Platanthera yosemitensis*, and three to Hawaii, as *Anoectochilus sandvicensis* Lindl., *Liparis hawaiensis* H. Mann, and *Peristylus holochila* (Hillebr.) N. Hallé. Two orchid species are endemic to Florida, *Govenia floridana* P. M. Br. and *Triphora craigheadii* Luer; one species is endemic, each to three states, with *Spiranthes delitescens* Sheviak in Arizona, *S. infernalis* Sheviak in Nevada, and *S. parksii* Correll in Texas.

TARGET 2, AN ASSESSMENT OF THE CONSERVATION STATUS OF ALL KNOWN PLANT SPECIES, AS FAR AS POSSIBLE, TO GUIDE CONSERVATION ACTION

Only two North American orchids have been assessed by the International Union for Conservation of Nature and Natural Resources (IUCN) and are listed as threatened on the 2011 IUCN Red List of Threatened Species (IUCN, 2011): *Anoectochilus sandvicensis* as Vulnerable (or VU), and *Platanthera praeclara* Sheviak & M. L. Bowles, as Endangered (or EN).

The U.S. Endangered Species Act (ESA; 1973; U.S. Government Printing Office, 2012) federally lists the four endangered species *Piperia yadonii*, *Peristylus holochila* [≡ *Platanthera holochila* (Hillebr.) Kraenzl.], *Spiranthes delitescens*, and *S. parksii*, as well as the four threatened species as *Isotria medeoloides*, *Platanthera leucophaea* (Nutt.) Lindl., *P. praeclara*, and *S. diluvialis* Sheviak, and the one candidate species, *Platanthera integrilabia* (Correll) Luer. At the state level, 57% (119 species) are protected as endangered, threatened, vulnerable, or sensitive in at least one state (cf. Table 1).

The Canadian Species at Risk Act (SARA; 2002) lists seven endangered orchid species, as *Cypripedi-*

um candidum Muhl. ex Willd., *Isotria medeoloides*, *I. verticillata* (Muhl. ex Willd.) Raf., *Liparis liliifolia* (L.) Rich. ex Lindl., *Platanthera leucophaea*, *P. praeclara*, and *Triphora trianthophora* (Sw.) Rydb. Further, one threatened species, *Cephalanthera austiniae* (A. Gray) A. Heller, is included, as well as one species that is noted of special concern for conservation, *Epipactis gigantea* Douglas ex Hook. (cf. Table 1).

All but 10 species of the 210 orchid names included in Table 1 have been assessed by NatureServe (2011), with 24% (50 species) listed as globally threatened. Of these 50 threatened species, 11 were assessed at the global scale as critically imperiled (G1), 13 are imperiled (G2), and 26 are vulnerable (G3; cf. Table 1). For subnational assessments by NatureServe, 14% (30 species) are presumed to be extirpated from at least one state or province, and an overlapping 23% (48 species) are possibly extirpated from at least one state or province. Also at the subnational level, 84% (176 species) are variably threatened (ranging from S1 or critically imperiled, S2 or imperiled, or S3 or vulnerable) in at least one state or province. In all cases, where an orchid had been extirpated in one or more states, it was also threatened or endangered in at least one other state.

TARGET 3, INFORMATION, RESEARCH AND ASSOCIATED OUTPUTS, AND METHODS NECESSARY TO IMPLEMENT THE STRATEGY DEVELOPED AND SHARED

As indicated by Stewart (2008), much of the information on conservation and reintroduction of orchids has been published in the "gray" literature and obtained from unreplicated efforts that are rarely designed as scientific studies to obtain statistically significant data. Academic research occasionally addresses aspects of orchid biology, but rarely includes the whole process from basic biology to application for conservation or reintroduction (e.g., Kindlmann et al., 2002; Dixon et al., 2003). Replicated assessment of conservation is sorely lacking. There are three major areas of orchid biology that urgently need additional research: (1) identification of fungi associated with nearly all orchids, (2) understanding of how those fungi contribute to seed germination in situ and in vitro, and (3) how to maximize survival of cultured seedlings or plants.

Seed banking alone cannot successfully preserve orchids, because using the seeds to eventually cultivate and restore plants in nature requires that appropriate mycorrhizal fungi are present, especially at the orchid's protocorm stage. Identifying, maintaining, and establishing the symbiotic fungi needed for orchid seed germination is technically difficult and requires specialized equipment (Liu et al., 2010; Seaton et al., 2010; Stewart & Hicks, 2010). However problematic, this is essential for propagation and establishment of self-sustaining populations. Few organizations have the capacity to handle these unique aspects of orchid biology, placing cultivation and reintroduction beyond the abilities of nearly all conservation agencies. Scientific research has made substantial progress in overcoming these difficult aspects of orchid ecology, but additional efforts are needed on all key elements of orchid life histories that must be understood if we are to successfully support conservation, reintroduction, and propagation efforts for native orchids. The techniques being developed by scientists are still, and likely will remain, beyond the capacity of most conservation agencies, and there exists no current network for scientific researchers either to support conservation program managers or to communicate with commercial or private growers and garden enthusiasts who would benefit from a more complete understanding of all aspects of orchid growth, cultivation, and conservation.

TARGET 7, AT LEAST 75% OF KNOWN THREATENED PLANT SPECIES CONSERVED IN SITU

When considering the proportion of threatened orchids that are conserved in situ, it is important to distinguish between species that are considered globally threatened and the majority of orchids that are threatened within a portion of their ranges. Conserved in situ means "that biologically viable populations of these species occur in at least one protected area or the species is effectively managed outside the protected area network, e.g., as part of a management plan" according to a recent GSPC Plant Conservation Report (Convention on Biological Diversity [CBD], 2009: 23–24). As previously outlined (cf. Table 1), of the 50 globally threatened (i.e., ranked G1, G2, or G3 by NatureServe) orchid species, only eight are protected under the ESA and one additional species, *Triphora trianthophora*, under Canada's SARA. An additional 22 species are protected at the state or province level. Taken together, a total of 62% (31 of 50 species, cf. Table 1) of native orchid species assessed as threatened are thus conserved in situ (i.e., have legal protection), which is far below the goal of Target 7. It is noteworthy that six of the 10 globally imperiled or critically imperiled species (G1 or G2) that currently have no protection at the federal or state level have only recently been described, suggesting that accurate identification and species delimitation have hampered attempts at species protection.

Beyond recognition of the need to protect orchid taxa is the degree to which protection is actually accomplished. The level of protection provided by state or federal protected status depends on both the number and distribution of plants on protected land and also on the knowledge of the species' biology needed to determine whether protection is adequate. A number of protected reserves in the United States and Canada focus to some degree on orchids or on habitats with disproportionately many orchids. One such example is the Bruce Peninsula National Park in Ontario, which supports 43 of the orchid species native to Canada that will be threatened as a result of climate change (Suffling & Scott, 2002). The heart of the Niagara Escarpment Biosphere Reserve includes the Bruce Peninsula National Park, a Nature Conservancy Preserve, and First Nations lands, all of which share knowledge about species at risk. The stated park goal is to maintain viable populations of all native species in situ, and there is a program underway to report on the condition of all SARA species, including trends in populations and the factors that contribute to their condition.

Attributing population trends to particular factors highlights the importance of in-depth understanding of species biology for accomplishing effective conservation. Most endangered orchids in North America have had at least some investigation of population genetic structure, and this has been used to understand connectivity between populations and to determine the contribution of outlying populations to species integrity. For example, Wallace (2003) found that *Platanthera leucophaea* was a predominantly outcrossing species and that inbreeding depression, especially in small populations, suppressed seed viability. These results suggested that larger, more diverse and outcrossing populations were needed to support population genetic variability in the current fragmented landscape. This white-fringed orchid historically was distributed from Missouri and Iowa to Ontario with disjunct populations in Maine, New Jersey, and Virginia (Bowles et al., 2005). The current distribution is, however, much reduced and few populations are self-sustaining.

Also important to consider are critical issues of land management. Many terrestrial orchids are pioneer species and cannot compete with overgrown habitat. One prime example is the Green Swamp Preserve of southeastern North Carolina in Brunswick and Columbus counties. Originally established to protect the habitat of the Venus fly trap (*Dionaea muscipula* J. Ellis, Droseraceae), a great variety of orchids, including species of *Calopogon* R. Br., *Platanthera*, and *Cleistes* Rich. ex Lindl., exist in the preserve. The reserve's 17,424 acres are owned and managed by The Nature Conservancy, and its longleaf pine savannas must be periodically subjected to prescribed burns to keep the habitat prime for the smaller, herbaceous species that would be otherwise crowded out by succession.

In contrast, other woodland species, such as *Cypripedium acaule* Aiton, *C. fasciculatum* Kellogg ex S. Watson, *C. montanum* Douglas ex Lindl., and *C. reginae* Walter, have ecological strategies and dependencies based both on edaphic constancy and occasional disturbance of their environments. For example, even though *C. fasciculatum* and *C. montanum* grow sympatrically in old growth forest, there is evidence that *C. montanum* needs occasional disturbances, such as fire or tree-felling and thinning, to create open, sunnier areas in which they will bloom and set seed more freely. Its sympatric relative, *C. fasciculatum*, conversely seems to be inhibited by burns and other such disturbances. Therefore, it becomes increasingly important to investigate the individual ecological complexities of each individual species if comprehensive management plans are to be created.

Understanding what factors influence population dynamics is critical for understanding how species will respond to warming global temperatures. With orchids, this uncertainty may be compounded by considering the other species on which they depend. Some orchids may be limited by the availability of pollinators. For example, the deceptive orchid *Cyrtopodium punctatum* (L.) Lindl. depends on oil-gathering *Centris* bees for pollination. These bees rely on other flowering plants, especially *Byrsonima lucida* (Sw.) DC. (Malpighiaceae), for the oils they collect. This led Pemberton and Liu (2008) to suggest that *B. lucida*, which is almost completely absent from the areas where the few remaining native orchid populations of *C. punctatum* persist, be planted in the vicinity of orchids to attract and support the bees that pollinate both taxa. Such activities may also be needed to support the interaction between orchids and their pollinators in the face of climate change. In particular, Liu et al. (2010) suggested that warming temperatures in southwestern China are differentially affecting pollinator and orchid phenologies such that availability of pollinators and orchid flowering may be increasingly out of synchronization. Effects of climate change on orchid mycorrhizal fungi are completely unknown, reflecting that very little is known about what factors drive the distribution and abundance of nearly all fungi. Because of this, conservation of fungi must be largely accomplished through habitat conservation.

TARGET 8, AT LEAST 75% OF THREATENED PLANT SPECIES IN EX SITU COLLECTIONS, PREFERABLY IN THE COUNTRY OF ORIGIN, AND AT LEAST 20% AVAILABLE FOR RECOVERY AND RESTORATION PROGRAMS

The Botanical Gardens Conservation International's (BGCI; 2012) Plant Search database shows that 66% (139 species) of native North American orchids are found in ex situ collections in botanical institutions around the world (Table 1). Each of these species is reported from an average of six botanic gardens, but more than 25% (36 species) are reported from a single botanic garden only. The species most prevalent is *Prosthechea cochleata* (L.) W. E. Higgins [≡ *Encyclia cochleata* (L.) Dressler], a species easily propagated (Pugh-Jones, 2009), which is reported from 65 botanic gardens. Only two of 11 species ranked G1 by NatureServe are found in any botanic garden collection, being *Peristylus holochila* at three gardens and *Spiranthes delitescens* at one institution. Five of 13 species ranked G2 are represented in botanic gardens, but only two are reported from more than one garden (two and five gardens, *Platanthera leucophaea* and *S. diluvialis*, respectively). It is highly unlikely that any of these ex situ collections represents a genetically representative sample of the species.

The major method likely to preserve species genetic variation is seed banking, as storing many genetically distinct orchid seeds requires very little space. Accomplishing such genetically representative conservation is a major goal of the project Orchid Seed Stores for Sustainable Use (OSSSU; Seaton et al., 2010). This project is initially focusing on hotspots of orchid diversity but is also beginning to work with groups within North America to organize locations and organizations for genetically representative orchid seed storage. The Center for Plant Conservation (CPC; <http://www.centerforplantconservation.org>) maintains seed collections for eight orchid species, two of which are ranked G1 (*Peristylus holochila* and *Spiranthes delitescens*), three G2 (*Isotria medeoloides*, *Platanthera leucophaea*, and *S. diluvialis*), and three G3 (*Cypripedium kentuckiense* C. F. Reed, *Platanthera praeclara*, and *S. parksii*). These species are specifically directed to be available for conservation and restoration activities, so this would suggest that seeds of 16% (eight of 50) of threatened North American orchid species are available for conservation and restoration, though the extent to which their collections are genetically representative is unclear.

One shortcoming of seed storage for orchids is that all orchids are dependent on or benefit from mycorrhizal fungi for seed germination and all species are dependent on fungi for protocorm growth. While fungal requirements can sometimes be overcome under specialized conditions in the laboratory, there is little question that under natural conditions fungi are required for orchid recruitment and long-term survival of populations. Many orchids require specific fungi at all life history stages (e.g., McCormick et al., 2004), while other more generalist orchids use fungi from one or a few families (e.g., Shefferson et al., 2010). As a result, effective ex situ conservation of orchids will require not just seed banking, but also maintenance of required mycorrhizal fungi. This goal is still far from being accomplished. One of the central difficulties has been to simply identify the needed fungi. Most orchid mycorrhizal fungi rarely produce spores and so were known only from the anamorphic stage for many years. Now they can be identified largely by DNA sequencing. This rarity of spore production, coupled with inconspicuous and morphologically depauperate sporulating bodies, has resulted in a poorly defined taxonomy of these cryptic fungi (e.g., Swarts & Dixon, 2009); DNA sequences rarely match the taxonomically described species. Furthermore, with few spores produced, the fungi that an orchid needs can rarely be stored as spores and so must be maintained as active cultures. However, some researchers have been testing methods for storing fungal cultures in liquid nitrogen (Batty et al., 2001). If these methods prove successful, then conservation of genetically representative collections of mycorrhizal fungi may become more common.

As yet there are relatively few orchid mycorrhizal fungi in culture. The University of Alberta Mycological Herbarium's (UAMH; <http://www.uamh.devonian.ualberta.ca>) culture collection currently maintains 113 fungal cultures obtained from 37 orchid species. The Smithsonian Environmental Research Center (SERC) currently maintains more than 400 fungal isolates in culture from more than 40 native orchid species (D. F. Whigham, M. K. McCormick & J. P. O'Neill, pers. comm.). The American Type Culture Collection (ATCC) maintains 30 isolates from 13 orchid species (<http://www.atcc.org>). Other scattered fungal cultures exist in laboratories around the country where orchid research is conducted, but the maintenance of these collections is often uncertain. Most of the existing collections focus on saprotrophic *Tulasnella* J. Schröt. and *Ceratobasidium* D. P. Rogers fungi, while many orchids rely on fungi that form ectomycorrhizal associations with other plants. These fungi are often difficult to culture and many cannot be grown without a photosynthetic host, often a tree, making them very difficult to establish or maintain in culture. Even when fungi are available in culture, however, their role in facilitating seed germination is far from certain.

Germination requirements for seven of 11 G1-ranked and five of 13 G2-ranked orchids have yet to be studied (Stewart & Hicks, 2010). One threatened orchid (*Isotria medeoloides*) has so far proven completely recalcitrant in culture or in the field. Of the 11 G1- and G2-ranked orchids for which some level of germination success has been obtained, two have had only limited asymbiotic success and only five have been germinated symbiotically. Symbiotic germination has not been reported for the other six of these 11 species. Symbiotic germination is expected to be the method that leads to seedlings best able to survive reintroduction and also provides a method for co-introducing needed fungi and orchids (e.g., Stewart, 2008).

Few well-documented orchid reintroductions exist. Often reintroductions occur in one location at one time and either succeed or fail without providing information about what may have been suboptimal or may increase success in the future (Stewart, 2008). Two examples of reintroductions designed as studies are outlined by Stewart (2008). Elements of another reintroduction are described by Zettler and Piskin (2011). All three studies were designed to assess effectiveness of introduction into different habitats, but only one utilized symbiotic seedlings because fungi were not available for the other two species. In two of the three studies, survival was highest in sites that already had the target orchid species. In the third study, reintroduction was only attempted in sites with the target species so existing plants could act as sources for mycorrhizal colonization of the transplants. This suggests that mycorrhizal colonization may be critical for reintroduction success. No mention of pollinator availability was made in these three studies.

TARGET 11, NO SPECIES OF WILD FLORA ENDANGERED BY INTERNATIONAL TRADE

The United States and Canada are both parties to The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; <http://www.cites.org>), the lead coordinating agency for the implementation, monitoring, and review of Target 11. All orchid species are listed in CITES appendix II, thus preventing the endangerment of North American orchids by over-exploitation caused by international trade. Artificially propagated plants, hybrids, plant parts, products, or derivatives, with a few exceptions, require permits or certificates to import, export, or re-export orchid species across international lines. However, the smuggling of wild orchids remains a problem (Phelps et al., 2010).

TARGET 14, THE IMPORTANCE OF PLANT DIVERSITY AND THE NEED FOR ITS CONSERVATION INCORPORATED INTO COMMUNICATION, EDUCATION, AND PUBLIC AWARENESS PROGRAM

As environmental awareness matures and enters the digital age, several organizations previously limited to spreading their messages slowly though periodicals and mailings have found much broader and enthusiastic younger audiences. One example is the Native Orchid Conference (<http://tech.groups.yahoo.com/group/nativeorchidconference/>) that has become the "go to" place for information about native orchid species and access to experts, photographs, ecology, phenology, and field information to any interested party. It is particularly useful to the public, who may not otherwise have access to or might be intimidated by scientific publications.

Botanical institutions nationwide, such as the Smithsonian Institution and the U.S. Botanic Garden (USBG), provide a type of outreach through conservation messages that regularly appear in exhibits, particularly annual orchid exhibits, and are viewed by their many visitors. In addition, speakers from these institutions regularly travel around the country discussing conservation values to likely interested parties at orchid societies and special events across North America. These efforts, however, are not sufficient. Considerably more could, and should, be done to raise public awareness about the importance of North American native orchid species.

TARGET 15, THE NUMBER OF TRAINED PEOPLE WORKING WITH APPROPRIATE FACILITIES SUFFICIENT ACCORDING TO NATIONAL NEEDS, TO ACHIEVE THE TARGETS OF THIS STRATEGY

Without a centralized organization focusing on North American orchids, it is difficult to assess how many trained individuals work on the in situ and ex situ conservation of orchid species. Kramer et al. (2010) report on a U.S. survey that revealed a major decline in botanical courses and degree programs at universities and colleges nationwide, as well as a deficiency of botanists at U.S. government agencies. With fewer college graduates entering the botanical workforce and many government botanists retiring in the coming years, it will be difficult to increase the number of trained people working on orchid taxonomy and conservation.

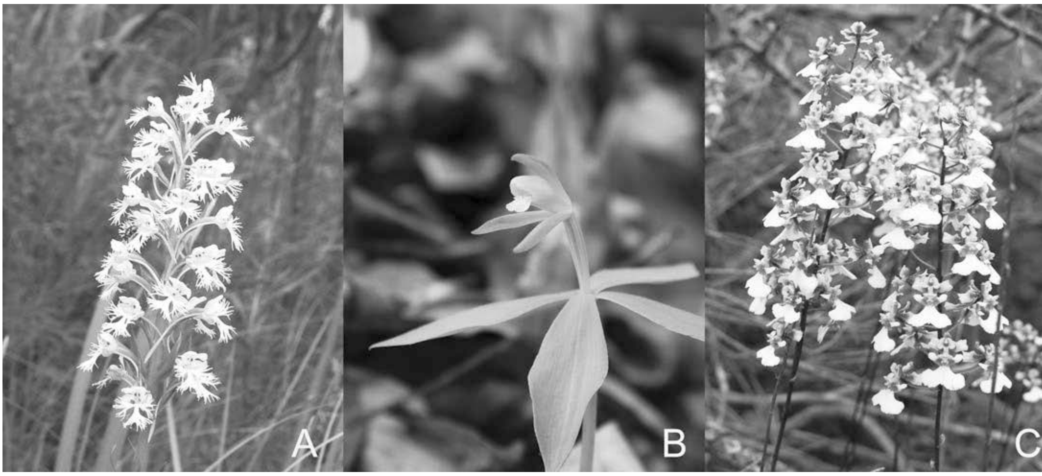

Figure 1. Three endangered orchid species. —A. *Platanthera leucophaea* (Nutt.) Lindl. (photo by Timothy Bell). —B. *Isotria medeoloides* (Pursh) Raf. (photo by Melissa McCormick). —C. *Tolumnia bahamensis* (Nash) Braem. (photo by Matt Richards).

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

The CPC is a successful network of botanic institutions dedicated to preventing the extinction of U.S. native plants by ensuring that ex situ material is available for restoration and recovery efforts. Orchids, however, are unique in that effective ex situ conservation of orchids requires not just seed banking, but also maintenance of cultures of required mycorrhizal fungi. A network of partnerships focusing exclusively on the needs of orchids is necessary.

Three Case Studies

As described throughout this manuscript, effective conservation of any orchid species is a complex undertaking that includes a wide range of variables from long-term storage and maintenance of collections of materials (e.g., seeds and mycorrhizal fungi) that would be required for cultivation and propagation to the establishment and maintenance of habitats that support the long-term success of orchid populations. For many of the reasons described above, we are unaware of any effort that has been fully successful in assuring the long-term survival of any native orchid species. There are, however, a few examples of the efforts that are necessary to build an information base, which can support further attempts to conserve all native orchid species.

Effective orchid conservation must integrate the understanding of existing and future environmental threats, taxonomic distinctiveness, numbers of individuals in populations, reproductive biology, ex situ propagation, and the maintenance of evolutionary processes influencing population distribution patterns. In order to do this, conservation must combine detailed experimentation directed at continued survival of the species both in situ and ex situ (Ramsay & Dixon, 2003). The integrated conservation strategy emphasizes the study of interactions among land conservation, biological management, research and propagation and reintroduction and habitat restoration (Hopper, 1997).

CASE 1

Platanthera leucophaea (Fig. 1A) is currently listed as federally threatened, under the ESA, and has declined in the United States by more than 70% from estimates provided by original county records. This decline has mainly been due to habitat loss. Most of the remaining 79 populations are small, these with fewer than 50 plants, and only 28% have adequate protection and management (U.S. Fish and Wildlife Service, 2007). Investigation of the orchid's genetics indicates that the species is primarily outcrossing and demonstrates significant inbreeding depression particularly prevalent in small populations (Wallace, 2003). Despite the low number of protected populations, the outlook for conservation of *P. leucophaea* is relatively good. Well-coordinated efforts to recover this species are currently in place and involve a network of scientists, private landowners, and volunteers (Zettler & Piskin, 2011). Fungi needed by *P. leucophaea* are known, and symbiotic germination is regularly accomplished in laboratory cultures, although successful transplantation of seedlings into natural populations has met with limited success (Zettler et al., 2005; Zettler & Piskin, 2011). Genetic surveys have found that even small populations of *P. leucophaea* may retain relatively high levels of genetic diversity (Holsinger & Wallace, 2004), potentially resulting in significant seed production and recruitment where habitat is available. This level of information about the species and the network of public and private agencies cooperating toward the orchid's conservation suggest that *P. leucophaea* has a strong potential for recovery.

CASE 2

In contrast to the favorable outlook for *Platanthera leucophaea*, *Isotria medeoloides* (Fig. 1B) is listed by NatureServe as imperiled (G2) in 14 (78%) of the 18 states and provinces in which it is still known to occur; the orchid is thought to be historical or extirpated in five states. Nowhere across its distributional range in eastern North America is *I. medeoloides* considered secure or common. The primary threat to its existence is destruction of its woodland habitat for development or forestry. The majority of its populations number fewer than 25 plants and are thus vulnerable to local extinction (U.S. Fish and Wildlife Service, 1994). Many of the extant populations, including some of the largest populations, occur on land protected by federal or state agencies or the U.S. military, and on this basis the plant might be considered well protected (U.S. Fish and Wildlife Service, 1994). Its preferred habitat conditions have also been identified (Sperduto & Congalton, 1996), and searching these habitat types allowed researchers to locate many new populations in the late 1990s. However, the plant's biology throughout much of its range is defined by many small, ephemeral populations that make it quite difficult to target areas to protect. Additionally, long periods of dormancy, common in many terrestrial orchids, are characteristic of the lifecycle of this species, making it difficult to assess population sizes or even plant presence (Mehrhoff, 1989).

Ongoing management experiments of *Isotria medeoloides* are beginning to reveal a management technique, tree thinning, which can benefit local populations (e.g., Brumback et al., 2011). The fungi needed by this orchid have recently been identified (M. K. McCormick, unpubl. data), but they have so far been resistant to culture in the laboratory. Seed germination, either symbiotic or asymbiotic, has never been accomplished either in the field or in the laboratory, yet based on population demographic studies (Mehrhoff, 1989) and preliminary genetic analyses (M. K. McCormick, unpubl. data), recruitment from seed is critically important to both population persistence and also the founding of new populations. This suggests that this species, many of whose extant populations are relatively well protected, is sufficiently poorly understood and that its maintenance in the face of a changing climate is a serious concern.

CASE 3

An additional case study involved returning a semiepiphytic species, *Tolumnia bahamensis* (Nash ex Britton & Millsp.) Braem (Fig. 1C), to reasonably pristine habitat, where ostensibly all the other pieces of the ecological puzzle remain. In this case, suitable unspoiled, historical habitat in Jonathan Dickinson State Park in southern Florida was assessed and the few extant plants of *T. bahamensis* were cross-pollinated and grown ex situ at Atlanta Botanical Garden. With most of the host plants and presumably mycorrhizal fungi intact in the orchid's preferred environment, reintroduction has initially been successful. These types of enrichment reintroductions should be attempted whenever suitable protected habitat is available. This underscores the need for a holistic approach to orchid conservation in which entire habitats and ecosystems are sought to be preserved whenever possible (Jonathan Dickinson State Park, 2011).

THE FUTURE OF ORCHID CONSERVATION

International efforts such as CITES have focused on the illegal trade of orchids and many organizations have been established to cultivate, market, and enjoy orchids, but there is no one national organization that focuses on their conservation and restoration. Neither is there one entity devoted to educating the public about the evolutionary and ecological importance of orchids. Organizations (e.g., federal agencies and the U.S. military) that are mandated to identify and protect orchids on public lands have been involved in research on relatively few species (see examples above), and they rely mostly on habitat conservation for management. While habitat management is important, ecological attributes of orchids (e.g., the obligatory relationships between orchids and fungi at critical life history stages) dictate that habitat management alone will not result in orchid conservation or restoration. Every U.S. state lists at least one orchid species that is rare or threatened and most states list multiple orchid species. There is, however, little coordination among states and no one organization that can provide answers to basic questions that would guide effective management plans. Private land-management conservation groups (e.g., The

Nature Conservancy) face a similar dilemma. Perhaps most important, the public has little recognition of the diversity and importance of orchids and there is no central organization that focuses on orchids as an important aspect of education and outreach to the public.

We propose a possible solution to the lack of coordination and the pooling of resources to focus on the more than 200 native orchids listed within the United States and Canada. The NAOCC (http://northamericanorchidcenter.org) is the first internationally focused public–private effort to support the conservation, cultivation, and restoration of native orchid species. NAOCC began as a collaborative effort between the SERC, Smithsonian Gardens, Department of Botany at the National Museum of Natural History (NMNH), Exhibits and Park Management Department of the National Zoological Park (NZP), and USBG. Other government agencies, botanic gardens, and public and private landowners are joining the collaboration. NAOCC launched in 2012 and the network that will support the effort will be developed over approximately 10 years.

The NAOCC's mission is to conserve the native orchid heritage of the United States and Canada through preservation, restoration, and cultivation of native orchids and to convey the importance of NAOCC to the public through innovative educational programs. The goals of NAOCC are to:

- Develop an international seed bank collection, in collaboration with the CPC, that will be representative of the genetic diversity of all North American orchid species.
- Develop an international collection of fungi representative of the genetic diversity of mycorrhizal fungi required by native orchids.
- Develop techniques to conserve the genetic diversity of all native orchids by cultivating them in an international network of botanic gardens and arboretums.
- Use seed and mycorrhizal fungal banks to develop techniques for restoring, conserving, cultivating, and restoring orchids in native habitats.
- Support efforts to conserve orchid populations through habitat conservation and restoration.
- Develop web-based materials that will provide up-to-date information on the ecology, conservation status, and techniques for the cultivation of North American orchids.

An initial goal of the network of botanic gardens is to grow and display all native orchids in the United States and Canada using an ecoregional approach. The primary partners play different yet integrated roles. NAOCC administration and research are based at the SERC, which provides research services to private and public organizations, and collaborates with the CPC and other affiliated organizations (e.g., Kew Gardens and the U.S. Bureau of Land Management's Seeds of Success program) to develop a genetically diverse seed bank for all native orchids. The seed collection will not only be used to assure the long-term survival of the germplasm of each species, but will also serve as a resource for material to support efforts to grow and cultivate all native orchids. SERC is collaborating with the partners of NAOCC to expand its collection of orchid mycorrhizal fungi to include fungi from all native orchids. SERC is also playing a lead role in developing a network of laboratories that provides services for the molecular analysis of orchid fungi. The Smithsonian's Department of Botany at the NMNH will focus on the development of a well-curated and complete herbarium-based orchid collection and will develop DNA barcodes for all North American orchids. NMNH will also develop a digital library of all North American orchids, including visual images of all species, and will actively partner with SERC and NAOCC to develop web-based technologies to provide up-to-date public access to orchid information. Smithsonian Gardens, the Exhibits and Park Management Department of the NZP, and the USBG will coordinate efforts to cultivate all orchids within the Washington ecoregion into their living collections, and they will collaborate with partner-gardens to develop and put into effect a plan to cultivate all 210 native orchids in a range of gardens across the United States and Canada. The Smithsonian and the USBG will also include exhibits about native orchids in their biannual orchid show.

Conclusion

Native orchids occur in every state in the United States and every Canadian province, and one or more species is listed as endangered or threatened in every state and province. As described above, national and international efforts have provided a degree of protection for native orchids, and there have been efforts to conserve and restore a small number of species. It is our view that progress toward the effective conservation of the numerous species that are listed as threatened or endangered will require a large-scale integrated effort to develop the knowledge base required to develop effective management strategies to assure the survival of the more than 200 species of native orchids. In establishing the NAOCC, our goal is to develop the resource base and integration of public and private organizations responsible for or interested in native orchids to ultimately assure the survival of all native orchid species. The success of NAOCC will require long-term commitments to obtain the financial support for the research, training, and education necessary to reach the organization's goal of conserving the genetic diversity of all native orchid species.

In addition to botanic gardens, research organizations, and private and public groups devoted to orchid conservation, the success of NAOCC will also require the establishment of a dynamic web site and associated web-based materials that will enlist the public in the effort. The ultimate success of NAOCC and its partner organizations is important for other reasons. While the orchid family is the most diverse family of flowering plants on earth, the number of species in the United States and Canada is relatively small, and conserving our native orchids would be a success that has never been obtained. Orchids are more than just beautiful flowers. They are an important component of North America's ecology, biological richness, and heritage, and they need greater protections than they currently receive. With so many uncertainties in the future due to habitat degradation, urban sprawl, and climate change, it is incumbent on organizations with the infrastructure necessary to guide and coordinate the efforts of the many individuals and organizations that have a stake in native orchid preservation. NAOCC seeks to be this important resource for North American orchid species and ultimately to serve as a model for similar conservation organizations in other parts of the world.

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