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**DNA Barcodes for the Cariceae (*Carex* & *Kobresia*,
Cyperaceae) of North America, North of Mexico**

Brianna Nicole Chouinard

Thesis submitted to the Faculty of Graduate and Postdoctoral Studies
University of Ottawa
in partial fulfillment of the requirements for the
M.Sc. degree in the Ottawa-Carleton Institute of Biology

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List of Abbreviations

AFLP – Amplified Fragment Length Polymorphisms

BLAST – Basic Local Alignment Search Tool

BOLD – Barcode of Life Data Systems

CCDB – Canadian Centre for DNA barcoding

CBOL – Canadian Barcode of Life

COSEWIC – Committee on the Status of Endangered Wildlife in Canada

FNA – Flora of North America

PCR – Polymerase Chain Reaction

PWG – Plant Working Group

USFWS - United States' Fish and Wildlife Service

UPGMA – Unweighted Pair Group Method with Arithmetic mean

Abstract

The Cariceae (*Carex* & *Kobresia*; Cyperaceae) account for ca. 10% of Canada's native vascular plants, yet diversity within the tribe is overlooked due to its taxonomically-difficult floral morphology. DNA barcoding is a useful tool for identifying animals and the technique is currently being adapted for use in plants. This thesis develops a reference barcode database for the Cariceae of North America, north of Mexico, using the chloroplast gene *matK*. A species resolution rate of 39% is reported, although when broken down into political regions, this can increase to 75%. Unknown tissue samples from across North America were then identified using this reference database; 50% of these were identified to a single species matching the morphological identification, and 50% were identified to a group of taxa containing the correct identification. An ecogeographical regional database for the Arctic Archipelago was also challenged with 230 unknown samples and identified 98% to a single species.

Résumé

La tribu Cariceae (*Carex* et *Kobresia*; Cyperaceae) représente environ 10% de la flore vasculaire canadienne. Pourtant, sa diversité est souvent sous-estimée car sa complexité florale pose des problèmes taxonomiques. La méthode des code barres ADN sert à identifier génétiquement des espèces d'animaux et présentement est appliquée aux plantes, aussi. On présente ici une base de données des code barres des espèces de Cariceae au nord du Mexique, basée sur le gène *matK* du chloroplaste. On a distingué 39% des espèces, ou 75% en traitant séparément les régions politiques. Utilisant notre base de données, on a ensuite identifié 50% des échantillons de matière végétale inconnus, venant des régions nord-américaines, à une espèce correspondante à la description morphologique. On a identifié chacun du reste à un taxon qui comprend une telle espèce. Enfin, on a testé 230 spécimens inconnus contre une base de données écogéographique régionale de l'archipel arctique, en identifiant 98% au niveau de l'espèce.

Statement of Contributions

Chapter Two (Appendices B and C)

I am the lead author. This chapter will be published in combination with Chapter three with RFC Naczi and JR Starr as coauthors. Roughly half the populations were provided by Robert FC Naczi. I conducted DNA extraction, and *matK* amplification with assistance from Carmén Fletcher, Jeff Graham, and Alex MacPhail. Approximately 90% of all sequencing was done at the Canadian Centre for DNA Barcoding.

Chapter Three

I am lead author. I conducted DNA extraction and *matK* amplification with assistance from Anna Ginter and Veronic Pruneau. Unknown samples were provided by John Nelson from the University of South Carolina, Robert Kraul from the University of Nebraska, Theodore Cochrane from the University of Wisconsin, Micheal Oldham from the Ministry of Natural Resources, Ontario, Jacques Cayouette from Agriculture and Agri-Food Canada (Ottawa), Bruce Ford from the University of Manitoba, and Peter Ball from the University of Toronto at Mississauga. All samples were processed by Root Gorelick at Carleton University to remove potential bias during sample processing.

Chapter Four

I am lead author. This chapter will be published with JM Saarela and JR Starr as coauthors. The reference database was previously established by Jessica Le Clerc-Blain (*Mol. Ecol. Res.*, 10(1):69–91.) and the ‘unknown’ samples were collected during two expeditions to the arctic: first, a western expedition attended by L. J. Gillespie, J. M. Saarela, L. L. Consaul, and R. D. Bull from the Canadian Museum of Nature; and an eastern expedition attended by J. R. Starr and students enrolled in the Students on Ice program (<http://www.studentsonice.com/>). I conducted DNA extraction and *matK* amplification and sequencing with assistance from Anna Ginter and Veronic Pruneau.

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Foremost, I would like to thank Dr. Julian Starr, my supervisor, for his contributions of experience, advice, and patience throughout the course of this enormous project. I would also like to thank Drs. Root Gorelick and Stéphane Aris-Brosou, for their assistance and advice as part of my thesis committee. Special thanks to Dr. Gorelick for accepting and processing the unknown samples used in Chapter Three. This project could not have been accomplished without the strong foundation provided by specimens collected and curated at the University of Delaware State Herbarium (DOV) by Dr. Robert Naczi, now at the New York Botanical Gardens (NY). Critical specimens which bridged taxonomic gaps were also graciously supplied by Drs. Bruce Ford, Tony Reznicek, Leo Bruederle, and Peter Ball, as well as Michael Oldham, Barbara Wilson, and the *Carex* Working Group.

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To all the students and volunteers in the lab: Paul Sokolof, Jessica Le Clerc-Blain, Carmen Fletcher and Jeff Graham, Alex MacPhail, Anna Ginter, Veronic Pruneau, Daniela Gambarotta, Wayne Sawtell, and Michel Paradis, thank you for making my time in that little windowless room as bright and cheerful as possible and for your immeasurable and varied contributions to this project.

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Finally, last but not least, I would like to acknowledge all the herbaria listed below from which I solicited loans. A project on this scale could never have been accomplished without the dedicated work of their curators, collectors, and volunteers.

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Chapter 1 - Introduction

“Sedges have edges
Reeds are round
Grasses are hollow
Right to the ground”

-Anonymous

The sedge genus *Carex* L. (Cyperaceae Juss.) is one of the largest plant genera on Earth with approximately 2 150 species worldwide (Reznicek 1990). Alone, it accounts for ca. 10% of Canada’s native vascular plant flora (Scoggan 1978). The region described by the Flora of North America (FNA), which is all of North America, north of Mexico and including Greenland, contains 480 *Carex* species (Ball & Reznicek 2002), making it the second most diverse region in the world after China (488 spp.; Dai & Liang 2000). It is one of the few truly cosmopolitan plant genera (Good 1974) with individual species representing a curiously large array of biogeographical patterns (e.g., Ball 1990) and occurring in a wide variety of habitats from desert to tropical rainforest to across the Arctic, where it is an important member of the ecosystem due to its diversity (Aiken *et al.* 1999) and forage value (e.g., Jeffries *et al.* 2004). Although the genus does have limited ethnobotanical use (Simpson 2008), it remains economically important either indirectly as a forage plant for both wild and domestic animals or as a consequence of its many weedy species in North America (Bryson & Carter 2008).

Carex is a member of the sedge tribe Cariceae Kunth ex. Dumort., which contains three other genera: *Uncinia* Pers., *Schoenoxiphium* Nees, and *Kobresia* Willd. (Starr & Ford 2009). Of these, only *Kobresia* is present in North America with three species (Ball 2002).

Members of tribe Cariceae are distinguished by their evolutionarily reduced, monoecious flowers and the presence of a sac-like modified bract, called a perigynium or utricle, subtending the female flower. In *Carex*, the margins of the perigynia are completely fused, with a pore at the apex to allow the stigmas to emerge, whereas in *Kobresia*, the margins of the perigynia are only partially fused (Fig.1.1; Ball *et al.* 2002).

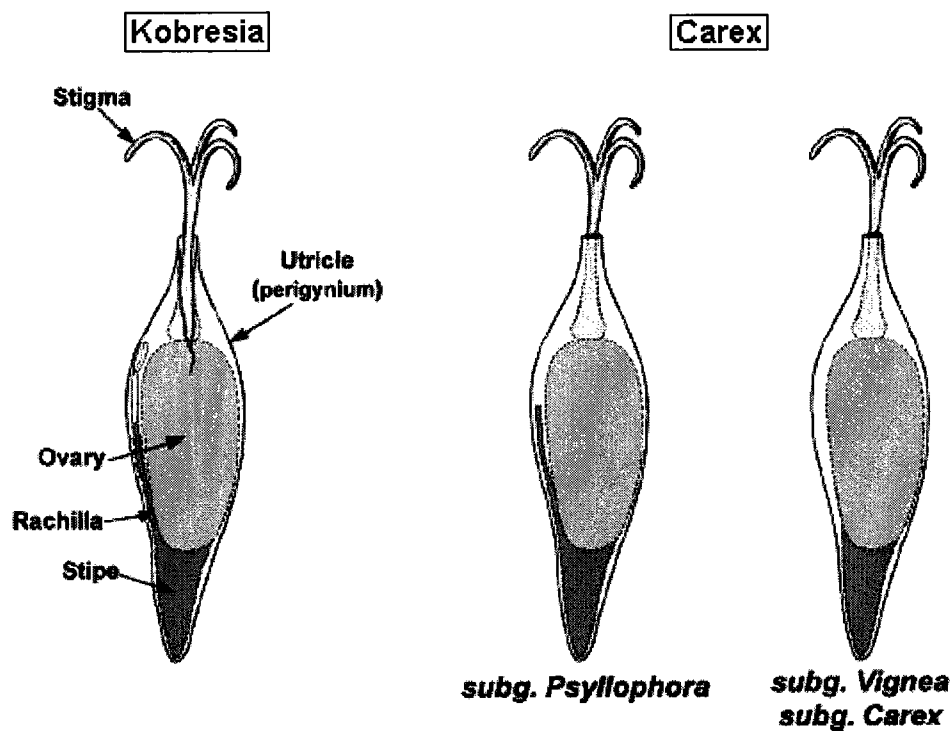


Figure 1.1: Perigynial features of *Kobresia* and the three subgenera of *Carex* found in the FNA region (Modified from Starr *et al.* 2004).

Morphological characteristics of the perigynia, such as their dimensions, colouration, texture, venation, etc., are essential for the separation of species within each genus; if the plants are not collected when the perigynia are mature, identification can be difficult or even impossible (Naczi & Bryson 2002). In addition to floral characters, ecological, vegetative,

anatomical and micromorphological characteristics may also be useful for species identification and circumscription in conjunction with limited reproductive characters (Reznicek & Catling 1986; Starr & Ford 2001; Dean & Ashton 2008).

Whichever set of morphological characters are used to accurately identify a sedge, it is necessary to have a good microscope, prior experience with the group (Catling *et al.* 1990), and at times, multiple reproductively mature collections (Naczi & Bryson 2002). Even when all of these conditions are met, identification can take a significant amount of time due to the length of the dichotomous keys for the Cariceae. For instance, the key for Canadian *Carex* species is a daunting 39 pages in Scoggan (1978), and species keys and descriptions cover 319 pages in the Flora of North America (2002). Misidentification of species is common, even in large herbaria where extensive representative collections are available to confirm species identification (Molina *et al.* 2008).

Due to the difficulties posed by their reduced floral morphology, Cariceae diversity is often overlooked by non-taxonomists (i.e. Koch *et al.* 2000; Fuchs & Haselwandter 2004). This is a detriment to studies involving members of the tribe as *Carex* species are excellent indicators of microhabitats and can thus provide environmental clues (Busch & Losch 1999; Gignac *et al.* 2004; Waterway *et al.* 2009). It would therefore be beneficial to develop a means of identification that is not solely dependent on experience, equipment, and the quality of the unknown *Carex* specimens. As the number of Cariceae specialists are few compared to its diversity, cosmopolitan distribution, and economic and ecological importance, any method that could facilitate and improve the accuracy of Cariceae identifications would be a significant for both scientists and the general public alike.

DNA sequences from small, standardized regions of an organism's genome have been used as a method of identification in fungi since the early 1990s (Bruns *et al.* 1991), but the concept was not extended to the animal kingdom until researchers at the University of Guelph demonstrated the discriminatory power of a 648 base pair portion of the mitochondrial cytochrome C oxidase 1 (CO1) gene in Lepidoptera (Hebert *et al.* 2003a). Eager supporters (Charles & Godfray 2002; Tautz *et al.* 2003; Janzen 2005) and staunch detractors (Will & Rubinoff 2004; Ebach & Holdrege 2005a; Will *et al.* 2005) of DNA barcoding have helped elucidate its potential limits and benefits, with many authors concerned about the integration of morphological and molecular taxonomy (Rubinoff 2006; Sundberg *et al.* 2010). However, in these early stages of DNA barcoding when databases are being established for all birds (2 942 species barcoded; <http://www.barcodingbirds.org/>), fish (7 225 species barcoded, <http://www.fishbol.org/>), lepidopterans (36 870 species barcoded; <http://www.lepbarcoding.org/>), and polar fauna (6 952 species barcoded; <http://www.polarbarcoding.org/>), accurately linking barcode sequences to specific taxa depends heavily on the presence of a well-established morphological taxonomy. Only after a database has been well established for a particular group of organisms can barcoding be used as a tool to help revise its taxonomy (Hebert *et al.* 2004; Ebach & Holdrege 2005b; Emery *et al.* 2009).

In order to solidify the relationship between specimen and sequence, and to ensure the quality and accuracy of the database by minimizing misidentifications through complete disclosure, the Canadian Centre for DNA barcoding maintains the Barcode of Life Data Systems (BOLD; <http://www.barcodinglife.org/>; Ratnasingham & Hebert 2007). For each sequence in the database, label information and photos are available for the collection from

which the DNA was isolated, as well as the trace files from which the sequence was read, enabling suspicious entries to be tracked down and confirmed. As of this writing, 65 898 formally described species with barcode sequences have been added to BOLD.

It is important to note that there are a few groups for which CO1 does not provide enough variation to act as a barcode, for example, the grasshoppers of New Zealand (Trewick 2008) and some groups of Cnidarians (Hebert et al 2003b). In the case of the Cnidarians, an addition region (16S ribosomal DNA) has been shown to provide sufficient resolution as part of a multi-locus barcode solution (Sinniger *et al.* 2008). Conversely, in some groups there is enough variation in CO1 to allow the use of 'minibarcodes', 100bp regions which are capable of providing accurate identification (Hajibabaei *et al.* 2006). These minibarcodes are especially useful in the barcoding of historical specimens, where the whole 648bp CO1 barcoding region is not easily amplifiable due to DNA degradation.

One of the most exciting aspects of DNA barcoding is its ability to reveal cryptic species. In the most dramatic example of this, barcoding aided in the discovery of several hundred overlooked Lepidopteran species in Costa Rica, most of which were then confirmed as unique species due to subtle morphological or even ecological characteristics (Janzen *et al.* 2009). A survey of red algae, a taxonomically difficult group due to phenotypic plasticity and alternation of heteromorphic generations, present in the Canadian flora has reportedly found approximately 70 new species so far (G. W. Saunders, unpublished data; Saunders 2008).

Unfortunately for plants, the mitochondrial genome does not undergo the same rate of substitution as it does in animals (Wolfe *et al.* 1987), except in a few plant groups (*Plantago* sp., Cho *et al.* 2004; *Pelargonium* sp., Bakker *et al.* 2000) and is subject to wide

variations in size, gene order, and content (Palmer *et al.* 2000; Adams & Palmer 2003). In addition, flowering plants demonstrate evolutionarily-frequent horizontal transfer of mitochondrial genes between distantly-related species, a phenomenon which is considered rare in the nuclear and chloroplast genomes and which could pose problems for a mtDNA-based plant barcode (Bergthorsson *et al.* 2003).

The chloroplast genome, like the animal mitochondrial genome, has a conserved gene order and a high copy number in each cell, meaning it is easier to obtain DNA and sequences for chloroplast genes using universal primers than for nuclear or mitochondrial genes in plants. Chloroplast genes evolve at a slower rate than nuclear genes (Wolfe *et al.* 1987), but nuclear genes are problematic as plants are capable of maintaining multiple divergent copies of the same nuclear gene (Rapini *et al.* 2006). As well, amplifying and sequencing single-copy or low-copy nuclear genes as barcode sequences is technically difficult, especially in old or degraded samples (e.g., Cowan *et al.* 2006) due to the simple fact that they are few in number within each cell.

By early 2007, the Consortium for the Barcode of Life (CBOL) Plant Working Group had posted a list of primer pairs for chloroplast regions determined to be good potential plant DNA barcodes (<http://www.kew.org/barcoding/update.html>), focusing on the coding regions *matK*, *rpoB*, *rpoC1*, *rbcL* and the non-coding *trnH-psbA* spacer (Kress & Erickson 2007; Chase *et al.* 2007). The effectiveness of these regions has since been assessed in a number of different plant groups with mixed results (e.g.,: Cycadales, Sass *et al.* 2007; Myristicaceae, Newmaster *et al.* 2008; Orchidaceae, Lahaye *et al.* 2008; *Crocus* sp., Seberg & Petersen 2009). Ideally, a DNA barcode would be easily amplifiable from any plant group using universal primers and would display a high amount of interspecific

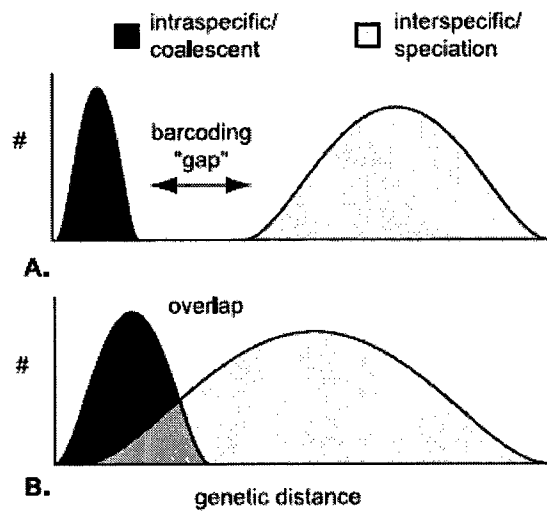


Figure 1.2 Schematic of the Inferred Barcoding Gap. (A) Ideal situation with discrete distributions and no overlap in inter- versus intraspecific sequence divergence. (B) An alternative situation with significant overlap and no gap. From Meyer & Paulay (2005).

variation while maintaining low intraspecific variation, visible as a barcoding “gap” (Fig. 1.2). The larger the gap, the less likely a specimen will be misidentified using DNA barcodes. As in the case of CO1, the ideal plant DNA barcode would also be a single region but due to the relatively slow genetic evolution of chloroplast genes it is generally accepted that multiple loci will be necessary to represent a comprehensive plant DNA barcode system.

It is my intention, through the course of this thesis, to determine whether DNA barcodes demonstrate utility as an alternate or additional method of identification within the Cariceae, and if so, to what extent DNA barcodes can be applied.

The Cariceae are an ideal group for DNA barcoding, due to their biological diversity and ecological importance, particularly in North America, and the difficulties in accurately identifying members of the tribe due to their reduced floral morphology. When this project

began in 2007, there was no decision as to which regions would represent the standardized plant DNA barcodes. At the time, there were very few published studies evaluating the effectiveness of the six proposed regions, and no consensus as to which regions provided the greatest resolution. Therefore, before a barcode database could be established, it was first necessary to evaluate which regions would be most effective within the Cariceae.

A pilot study was conducted including only members of three *Carex* sections, sections *Griseae* (L. H. Bailey) Kük., *Phyllostachyae* Tuckerm. ex Kük., and *Deweyanae* (Tuckerm. ex Mack.) Mack., each of which represents some of the taxonomically best known sections in the tribe (Naczi *et al.* 1998; Starr & Ford 2001; Naczi & Ford 2001; Naczi & Bryson 2002; Naczi *et al.* 2002) in addition to representing three of the four major lineages in *Carex* (subg. *Carex*, subg. *Psyllophora*, subg. *Vignea*, respectively) as reported in recent phylogenetic studies (Waterway *et al.* 2009; Starr & Ford 2009). These sections were chosen to ensure that any incongruities in the data would reflect an issue in the barcoding technique and not result from taxonomic error. Three samples were collected from each species, representing as much of the geographic range of each taxon as possible. For example, where species X occurs across Canada, samples would be taken from British Columbia, Manitoba or Ontario, and Newfoundland.

For each sample, *matK*, *rpoB*, *rpoC1*, *rbcL*, and the intergenic spacer *psbA-trnH* were amplified using the primers proposed by the CBOL plant working group. The results were published and are submitted as Appendix A, but as they pertain closely to the rest of this thesis, they are briefly presented below.

The *psbA-trnH* spacer is absent from Table 1.1 as it was only amplifiable in sect. *Griseae*, indicating a very limited utility with the proposed universal primers. This

noncoding region is problematic in monocots as it often contains a copy of *rps19*, expanding the size of the region up to and over 1000 bp and making it difficult to amplify and sequence without the use of internal primers. In addition, the *psbA-trnH* spacer varied so much in size and sequence within sect. *Griseae* that it was sometimes difficult to determine whether the proper region had been amplified. For all of these reasons, it is not an ideal barcode region in the Cariceae. Although the *rbcL* coding region was amplifiable in some taxa using the universal primers, no clean sequences were obtained and so it is absent from Table 1.1 as well.

Table 1.1: Barcoding utility of three partial chloroplast gene sequences in *Carex*. Only individuals with data for the single locus or multiple loci examined were included in the analysis (from Starr *et al.* 2009)

	Species resolvable (≥ 2 individuals)	Species resolved as single groups	Species resolved with $\geq 70\%$ BS
<i>matK</i>	30	17 (57%)	10 (33%)
<i>rpoB</i>	32	3 (9%)	1 (3%)
<i>rpoC1</i>	33	3 (9%)	1 (3%)
<i>matK</i> + <i>rpoB</i>	29	17 (59%)	11 (38%)
<i>matK</i> + <i>rpoC1</i>	30	18 (60%)	11 (37%)
<i>rpoB</i> + <i>rpoC1</i>	30	5 (17%)	3 (10%)
<i>matK</i> + <i>rpoB</i> + <i>rpoC1</i>	29	17(59%)	11 (38%)

As seen in Table 1.1, as a single locus *matK* provides the highest amount (57%) of species resolution with only minor increases when combined with *rpoC1*. *matK* was also the second easiest region to amplify, which is an important quality when assessing potential barcodes (Meyer & Paulay 2005). A species resolution rate of 57% may appear low when compared to rates observed in animal DNA barcoding studies (e.g. 96.5%, Meiklejohn *et al.* 2009; 93%, Ward *et al.* 2009) but it has been noted that using the currently proposed chloroplast markers, resolution rates in plants plateau around 70% (Fazekas *et al.* 2009).

Marginal increases in support were seen with the inclusion of *rpoCl*, but not enough to warrant the expenses of time and money. It was therefore decided to proceed with *matK* as a sole DNA barcode for the Cariceae. It is important to note that when this decision was reached there was no agreement within the barcoding community as to which regions should be selected as standard plant barcodes.

Chapter 2 outlines the establishment of a reliable DNA barcode database for the Cariceae of North America, based on 815 bp of the chloroplast gene *matK*. Chapter 3 assesses the ability of this database to accurately identify unknown tissue samples submitted by Caricologists (scientists that study the tribe Cariceae) across North America, and emulates the series of events that would occur with unknown samples being sent to a barcoding facility for routine identification. The identities of the unknown samples are determined first from a database of reference sequences representing all taxa present in North America. Second, in order to determine whether arbitrary political boundaries can be used to increase identification accuracy, the unknown sequences are compared to smaller databases containing only taxa known to occur in the same state or province from which the sample was collected.

The final chapter takes an ecogeographical approach to regional DNA barcoding and compares a selection of unknown samples collected from the Canadian Arctic to a barcode database established by fellow researchers at the Canadian Museum of Nature for Cariceae taxa occurring in the Arctic Archipelago as defined by Aiken et al. (1999). By including only taxa that occur in this specific ecoregion, many closely-related sister species are removed and so the identification accuracy is expected to increase.

Chapter 2 - Establishing a DNA barcode database for North American Cariceae, north of Mexico

2.1 Introduction

Until recently, the Cariceae were not well studied. It is reported that between 1955 and 1965, only two papers were published in the Canadian Journal of Botany regarding *Carex*, with a doubling of publications every 10 years thereafter (Catling *et al.* 1990). The Web of Science (an online academic service managed by Thomson Reuters) reports 30 published papers directly concerning *Carex* in 2008, and 29 in 2009. While the Cariceae remain poorly studied on a species level due to the sheer size of the group and the relatively small number of Caricologists, considerable progress has been made towards elucidating the larger phylogenetic groups through molecular studies (e.g., Starr *et al.* 1999; Yen & Olmstead 2000; Roalson *et al.* 2001). It is the goal of this chapter to describe the population of a database of *matK* reference sequences for all 530 *Carex* and *Kobresia* species and subspecies in the Flora of North America and to evaluate the efficacy of DNA barcoding in resolving each of these taxa.

Barcoding studies have a number of criticisms in common. The first common criticism is of incomplete taxonomic sampling (Will & Rubinoff 2004; Moritz & Cicero 2004; Meyer & Paulay 2005; Cowan *et al.* 2006). Poor taxonomic sampling will exclude many closely-related sister species and result in an abnormally high resolution rate, as is seen in regional studies (e.g., Kress *et al.* 2005; LeHaye *et al.* 2008; Le Clerc-Blain *et al.* 2009). A second criticism, closely related to the first, is that there is not enough sampling within each taxonomic group (Meyer & Paulay 2005). By only sampling one individual for each taxon, each taxon is only assigned one sequence. This could pose a problem if a field

or lab error has occurred or if there is a taxonomic problem, resulting in an incorrect sequence being linked to a particular taxon and ultimately, misidentification for all future instances of that taxon using DNA barcodes. Therefore, although the potential for recovering putative new species in relatively unstudied Cariceae sections is exciting, it could prove to be a disadvantage for establishing an initial database. An accurate taxonomy is vital to assign accurate sequences for each taxon (Emery *et al.* 2009) and the presence of cryptic taxa could skew interspecific and intraspecific resolution rates. However, as each taxon in this study will be represented by three separate collections, it will be possible to identify unique sequences, provided that at least two of the three sequences are identical or nearly identical. Ideally, more than three individuals per taxon would be sampled but due to monetary and time constraints, increased sampling for all taxa is not possible.

In addition, given that some *Carex* species have fragmented distributions, resulting in distinct and isolated populations (e.g. *Carex stylosa* C. A. Meyer, *Carex ovalis* Good.), while others are extremely widespread, covering the continent uninterrupted from coast to coast (e.g. *Carex leptalea* Wahl., *Carex brevior* (Dewey) Mack. Ex Lunell), it is very likely that there will be some degree of intraspecific variation which will be represented in the database as multiple sequences for some taxa.

To address both of these criticisms, this study will aim to include each specific and subspecific taxonomic group in the Cariceae of the Flora of North America, which was recently revised in 2002, with multiple individuals for each taxon collected from locations as geographically disparate as possible to capture any intraspecific variation. Mexico is not included in this study as its Cariceae diversity is poorly understood and because it would not be possible to conduct the broad sampling outlined in this sampling protocol.

2.2 Methods and materials

2.2.1 Sample collection

To ensure the collection of as many specific and subspecific taxonomic groups in the Cariceae as possible, the FNA was used as a checklist. The flora includes 528 taxa of *Carex* and *Kobresia*; in addition, two species which have been described since the flora was published in 2002, *Carex reznicekii* Werier and *Carex klamathensis* B.L. Wilson & Janeway, have been included.

For each taxon, the goal was to sample three individuals representing as much of its geographic distribution as possible, based on the distributions described in the FNA. This would mean that the database would ideally contain $3 \times 530 = 1590$ total *matK* sequences. Ideally, more individuals would be sampled but this study was limited by time and money and three collections should at least offer some idea of the potential intraspecific variation. In order to obtain these geographically disparate samples, it was necessary to contact herbaria across North America with specific lists of taxa. Fortunately, many herbaria have catalogued their collections and provide searchable online inventories, and so these herbaria were preferentially contacted for loans. It was decided, based on preliminary extraction runs, that no voucher in excess of 35 years would be sampled unless absolutely necessary, due to the increased likelihood of low DNA yield and quality. When available, sequences were obtained from recently collected plants whose leaves were dried in silica gel.

For each sample, a series of photographs was taken (Fig. 2.1) which allowed for verification of the collection's identity without requiring the physical presence of the voucher. The first photo taken was of the entire voucher, with a scale in view (A). The next

set of photos was taken of the label(s), with a numbered microcentrifuge tube in view to link the specimen and sampling number (B). The final set of photos taken were close-ups of features of interest, usually the inflorescences as various minute characters of the reduced flowers are critical for accurate identification (C). In addition to the photo set, one or two mature perigynia were collected where available. Micromorphological characteristics of silica bodies present on the achene within the perigynium have been used to differentiate closely related sister species in the past (Standley 1985; Starr & Ford 2001). Therefore, the micromorphology of silica bodies from these collected perigynia can be examined to help confirm and resolve putative misidentifications and quickly recognize cryptic new species. Unfortunately, due to time constraints, this examination was not possible.

After the photographs were taken and the perigynia removed, a maximum of 3 cm x 1 cm of leaf tissue was collected from each specimen, where its removal would not reduce the scientific value of the specimen or affect any characters critical for identification. When a voucher contained multiple plants, the plant that was sampled was indicated with an arrow in pencil, as a voucher will sometimes contain multiple taxa. The collected tissue was placed in the microcentrifuge tube that was photographed with the labels of that specimen, and the tube was not reopened until it was time to extract the DNA from the tissue.

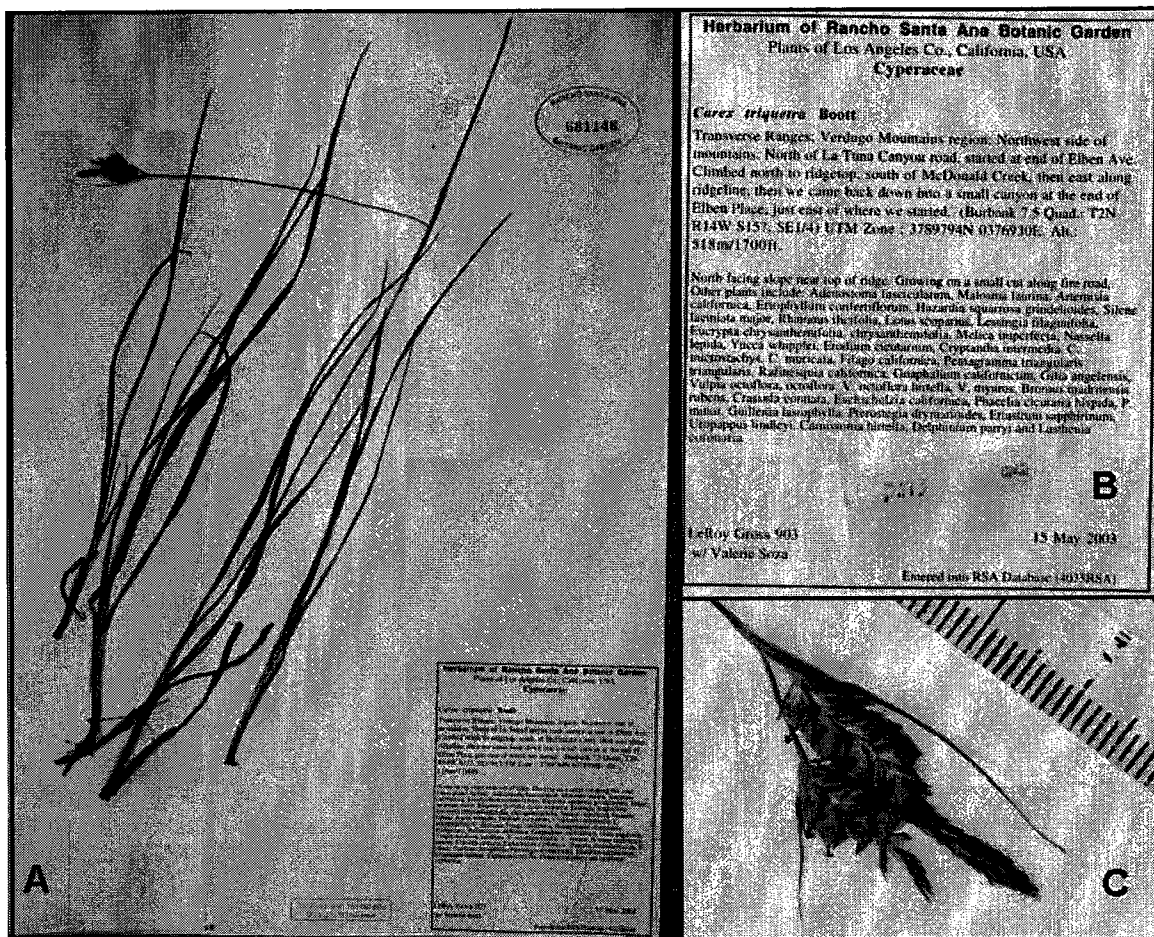


Figure 2.1: A selection of photos from a sample photo set conducted prior to tissue sampling for DNA barcoding. The first photos are of the whole voucher, unsampled (A) followed by a photo of the label information (B) and photos of structures of interest, usually the inflorescence (C).

2.2.2 DNA extraction

DNA extraction was accomplished based on the silica-column-based approach of Alexander *et al.* (2007). A short study was first conducted to identify any variables in the protocol that could be modified to increase DNA recovery and quality rates. These experiments demonstrated that a 7 M guanidine hydrochloride binding buffer with 17% ethanol increased DNA yield and quality as compared to the 2 M aqueous binding buffer

used by Alexander *et al.* (2007). The 7 M buffer also resulted in DNA that provided more effective PCR amplification of the barcoding sequence *matK*. DNA yield and quality for all extractions was assessed by electrophoresis on a 1.25% agarose gel and photographed.

2.2.3 Amplification of *matK*

The primers used for amplification were suggested by the CBOL Plant Working Group phase 2 evaluation and their efficacy was verified in the pilot study by Starr *et al.* (2009): *matK2.1F* (5' CCTATCCATCTGGAAATCTTAG 3') and *matK5R* (5' GTTCTAGCACAAGAAAGTCG 3'). Reactions were run with a final volume of 15µL containing the following components: 1x PCR buffer (Sigma, P2317), 0.05mM of each dNTP, 0.25 µM of each primer, 2.5mM MgCl₂, 1.33 mg bovine serum albumin, 20-50 ng of template DNA, and 2.5 U of JumpStart *Taq* DNA Polymerase (Sigma, D4184). Amplification occurred with the following thermocycler program: 95°C for 60s for initial denaturing; then 35 cycles of 95°C for 45s, 45°C for 45s for primer annealing, 72°C for 45s for primer extension; finally, 72°C for 90s as a final extension step. The PCR product was examined by electrophoresis on a 1.25% agarose gel to check for amplicon quality and quantity, then photographed.

2.2.4 Sequencing

Sequencing was conducted in two separate locations. The majority of sequences (approximately 95%) were obtained by sending 5 µL of unpurified PCR product to the Canadian Centre for DNA Barcoding (CCDB) where sequencing was done with the same primers used for amplification according to the Centre's standardized protocol (Ivanova & Grainger 2009).

The remaining sequences were obtained at the Canadian Museum of Nature. Dideoxy terminator cycle sequencing reactions were carried out using *matK*2.1F and *matK*5R and a BigDye terminator kit according to the manufacturer's protocols (Applied Biosystems, Foster City, CA). Termination products were passed through an Applied Biosystems 3100-Avant Genetic Analyzer to obtain DNA sequences. These sequences were then aligned and edited using Sequencher versions 4.7 and 4.8 (Gene Codes Corporation, Ann Arbor, MI, USA).

2.2.5 Analysis

Phylogenetic Analysis Using Parsimony (*and other methods) (PAUP*, Swofford 2002) was used to construct UPGMA trees, given that plant barcoding studies that have used this method (Lahaye *et al.* 2008; Newmaster *et al.* 2008; Le Clerc-Blain *et al.* 2009) have found that UPGMA trees provide more resolution than the NJ trees typically used in animal barcoding studies (e.g., Clare *et al.* 2007; Kerr *et al.* 2007; Hubert *et al.* 2008). The K2P model was used, as is recommended by CBOL in their Guidelines for Non-CO1 Selection document available at <http://www.barcoding.si.edu/protocols.html>. More robust phylogenetic reconstruction methods such as parsimony, Bayesian, and maximum likelihood analysis were not used to generate trees as the goal of this research was not to explore phylogenetic relationships but to examine the maximum ability of *matK* to resolve species. These methods also require considerable time for tree construction which is presently prohibitive for routine database queries as emulated in this study.

All trees were rooted using *matK* sequences for *Eriophorum vaginatum* L., *Scirpus polystachyus* Vahl, and *Carex siderosticta* Hance as they have been shown to be sister to all other Cariceae (Waterway *et al.* 2009; Starr & Ford 2009). Resulting trees were viewed using Dendroscope (Hudson *et al.* 2007). The number of monophyletic subgeneric taxa on each tree was counted, where a taxon was only counted as monophyletic if it had more than one sequence available and if all of its members formed a discrete cluster containing no other taxa.

TAXONDNA (Meyer *et al.* 2006) was used to generate intra- and inter-specific pairwise comparisons to tally base pair variation and to determine the presence or absence of a barcoding ‘gap’ (Meyer & Paulay 2005). Collections which appeared to be misidentified, either because they occurred in the wrong section or because there was significant conspecific divergence, were investigated and either maintained if they could conceivably be correct, renamed if they were misidentified, or removed if their discrepancy could be explained by lab error. The barcoding gap was assessed statistically using the non-parametric Mann-Whitney U-test in SYSTAT version 13.

SYSTAT was also used to assess significant correlation between taxon resolution and section size, as well as between taxon resolution and taxon diversity.

2.3 Results

2.3.1 Sample collection

Voucher details for all collections sampled and sequenced in this study are given in Appendix B. Overall, 1 510 tissue samples were gathered. The majority of the specimens (867 or 57%) were collected from the herbarium at Delaware State University (DOV), which was previously curated by Dr. Robert F. C. Naczi who specialises in *Carex* taxonomy and systematics. This ensured that a large number of the specimens used in this study would be properly identified. For these specimens, the photo sets I obtained at DOV were critical as it was not feasible to request a specimen loan of that size.

The remainder of the specimens were obtained from 56 different herbaria and individuals across the continent.

2.3.2 *matK* amplification and sequencing success rates

In the pilot study, *matK* was strongly amplified in 77% of the samples (Appendix A). Unfortunately, the 1 510 samples in this study demonstrated only a 54% PCR success rate at the conditions listed above. Prior to this study, few amplification failures were noted in fresh tissue and so the decrease in sequencing success for this study is likely a reflection of the quality of DNA that was recovered from herbarium specimens as there were very few taxa (*Carex gholsonii*, *C. gigantea*, *C. granularis*, *C. kraliana*, *C. microdonta*, *C. ormostachya*, *C. scabrata*, *C. tenax*, and *C. vesicaria*) that consistently resisted amplification. To increase amplification success, the primers were redesigned slightly to provide more specific binding at priming sites:

matK2.1F_J (5' CCTGTCCATTTTGAAATCTTAG 3')

matK5R_J (5' GTTTTAGCACACGAAAGTCG 3').

Bases in bold represent bp changes from *matK2.1F* and *matK5R*. When the new primers produced weak bands, a touchdown thermocycler program proved to be efficacious: 1 pretreatment cycle of 94°C for 120s, followed by 10 cycles of 94°C for 30s denaturation, 55°C for 60s for primer annealing (increasing by 1°C each cycle), and 72°C for 90s for primer extension. This was followed by 40 cycles of 94°C for 30s, 45°C for 60s, and 72°C for 90s, with a final extension step at 72°C for 4 minutes.

Although *matK5R_J* was suitable for amplification, it did not produce clean sequencing results. It was therefore necessary to generate yet another set of primers, this time internal, for sequencing: *matKFalt* (5' GATATCAAGGTAAAGCTATT 3') and *matKR* (5' TGGCAATATTATTTTCATT 3').

Ultimately, only two samples were not amplifiable, both due to poor quality DNA, and 14 were not sequenced. None of the 14 samples that were not sequenceable were from the same taxon and the sequencing failure was likely due to technical error. All verified sequences were deposited in GenBank (www.ncbi.nlm.nih.gov/genbank/) and BOLD (barcodinglife.org).

2.3.3 Utility of *matK* in resolving the Cariceae on a continental scale

A UPGMA tree (Appendix C) containing all *matK* sequences was constructed and examined for sequences that might be incorrectly identified to species, either because they did not cluster within their taxon, section or clade, or for sequences that were the only instance of their taxon. The corresponding collections for these sequences were reidentified morphologically. Sequences were then removed from the database for two main reasons: first, if the sequence discrepancy could be explained by experimental error (for instance, if

the erroneous sequence matched a taxon whose sample was in a neighbouring well); or second, if the sequence appeared to be erroneous but it was impossible to confirm the identity of the collection, either because the collection was immature or overly mature, or because the sample had been submitted to me without a photo set. In total, 34 (2.3%) sequences were removed, and 68 (4.6%) were found to be mistakenly identified. After all the identifications were confirmed, the distribution of the 1 460 samples across the 530 Cariceae taxa was examined and is summarized in Table 2.1. Overall, there were only 14 species and subspecies occurring in the FNA region for which no sequences were obtained.

With the erroneous sequences removed, the tree contains three major groups corresponding to the traditional circumscription of subgenera *Carex*, *Vignea*, and *Psyllophora*, with considerable sectional mixing within each clade.

Table 2.1: The number of individuals sequenced per taxon for all 530 Cariceae taxa currently recognized in the Flora of North America region.

	Sequences per taxon (#)			Taxa (#)
	≥ 3	2	1	
	324	136	56	14

Table 2.2: Barcoding utility of *matK* and character statistics

Aligned length (bp)	821
Variable Characters	401
Parsimony Informative Characters	323
Total Species	516
Species with >1 collection	460
Resolved species	182
	(39.6%)

Figure 2.2 demonstrates the absence of a ‘barcoding gap’ between inter- and intraspecific sequence variation based on pairwise comparisons. It is important to note that both inter- and intraspecific comparisons have been converted into percentages in order to view both datasets simultaneously, as the intraspecific percentages are based on approximately 4 300 pairwise comparisons while the interspecific percentages are based on more than two million pairwise comparisons.

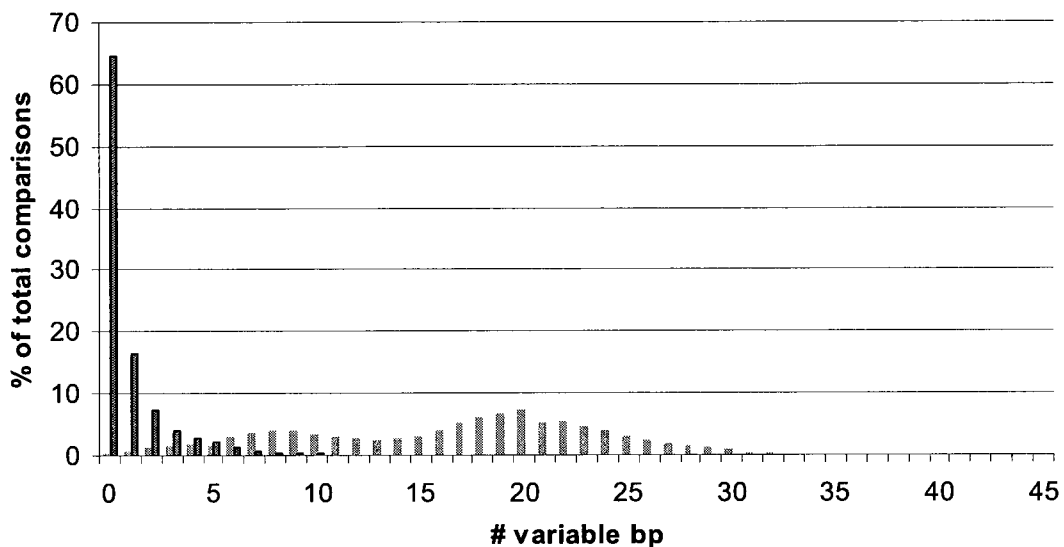


Figure 2.2: The number of variable base pairs from each pairwise sequence comparison between and among species. The darker series represents intraspecific sequence comparisons and the lighter-coloured series represents interspecific sequence comparisons. Note that there are interspecific pairwise comparisons exhibiting up to 45 variable base pairs but that their proportion is so low they are not visible.

This dataset shows visible overlap between inter- and intra-specific comparisons but the Mann-Whitney U test indicates the two data sets are from unique distributions ($p = 0.000$). In order to conduct this test, it was necessary to randomly sample the interspecific dataset using Microsoft Excel.

Finally, in order to determine whether there were certain sections which had comparatively low resolution rates, the resolved and unresolved taxa were sorted into their respective sections and the percentage of species resolution within each section was calculated. This data is summarized in Fig. 2.3. The data was transformed to show a more linear distribution and, based only on sections with more than 10 members, Pearson's coefficient was determined to be -0.585 ($p = 0.045$) indicating a relationship between section size and section resolution.

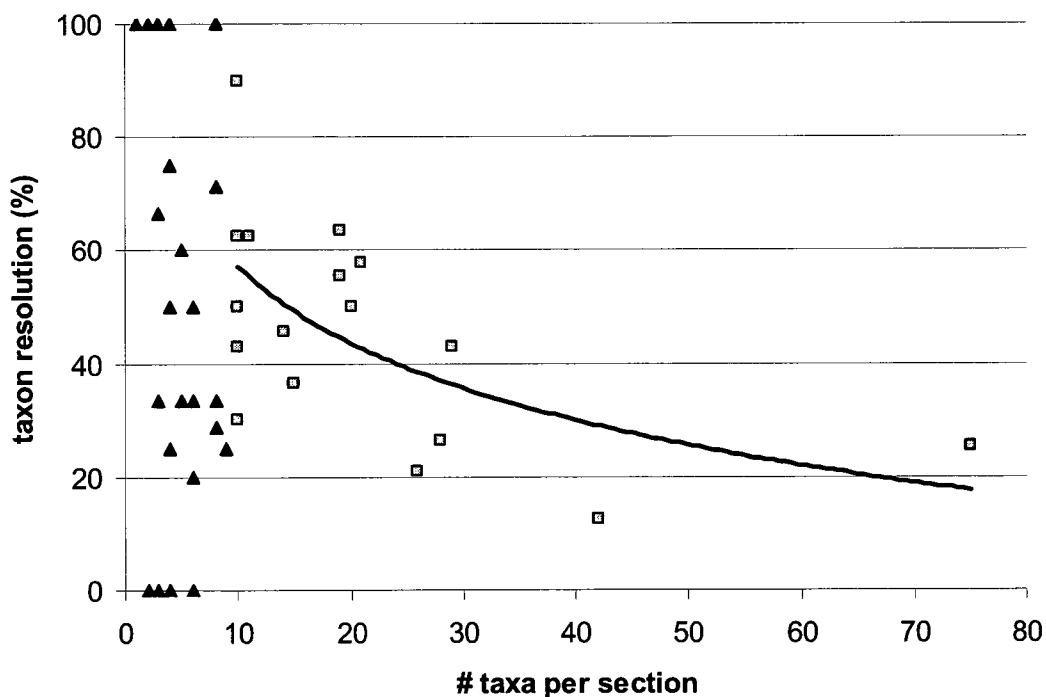


Figure 2.3: Taxon resolution (%) compared to the number of taxa in each section. Sixty-five sections are represented. Triangles represent sections with fewer than 10 members, while squares represent sections with 10 or more members. The logarithmic regression line is based only on sections with more than 10 members ($R^2 = 0.30$).

2.3.4 Utility of *matK* in resolving the Cariceae on a regional scale

Regional analyses based on FNA political boundaries were used to determine whether this approach could increase Cariceae resolution over the 39.6% noted in Table 2.2. Twenty-four regional *matK* databases were generated, one for each of the thirteen provinces and territories in Canada, as well as for the following American states: Texas (TX), Montana (MT), California (CA), Florida (FL), Wisconsin (WI), New Hampshire (NH), Nebraska (NE), New Mexico (NM), North Carolina (NC), South Carolina (SC), and Pennsylvania (PA). Many of these states were chosen based on their geographical position in order to capture as much taxonomic diversity as possible (as opposed to selecting adjacent states which will have similar floras), but some were chosen for having some of the highest (PA, 170 taxa; NC, 164 taxa) and lowest (NM, 50 taxa; FL, 71 taxa; NE, 73 taxa) amounts of Cariceae diversity. UPGMA trees were created for each dataset; the resolution was tallied and is summarized in Fig. 2.4.

In every regional situation, taxon resolution increased over the 39.6% for the entire FNA region. The greatest increase (75.61% species resolution) was noted for New Mexico, which contained only 41 taxa with more than one individual. The data was transformed to show a linear relationship and Pearson's coefficient was calculated to be -0.619 ($p = 0.001$ from a t-test), indicating a significant relationship between the number of taxa present in a database and the transformed taxon resolution. Each region was also evaluated for the presence of a barcoding gap, but none were found (data not provided).

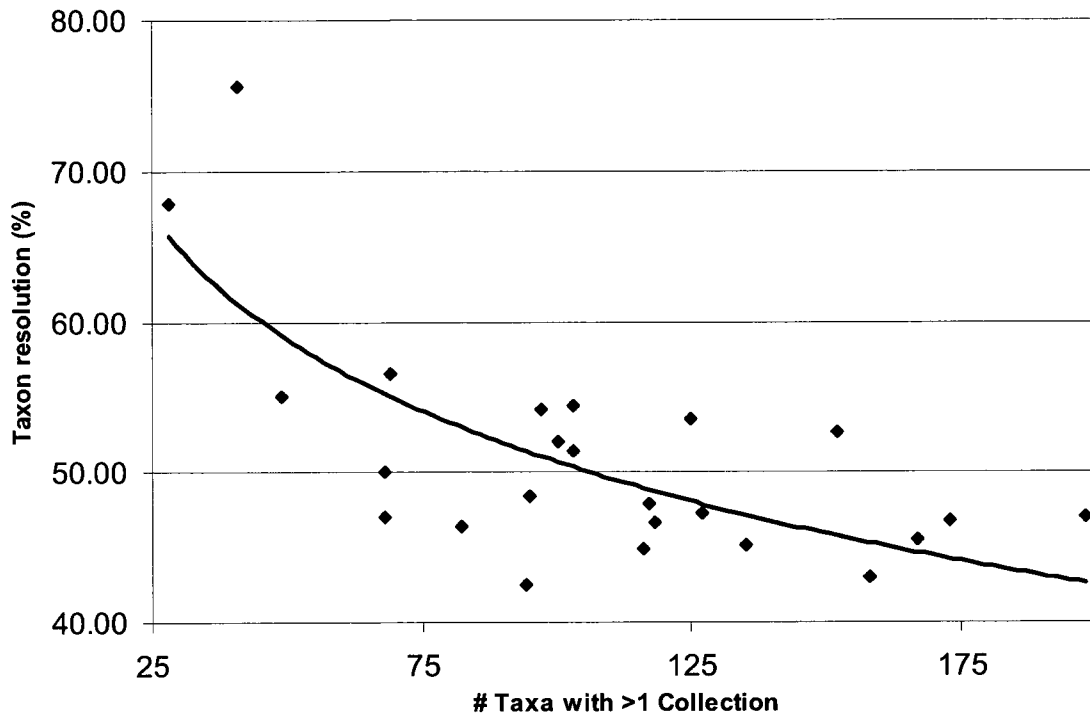


Figure 2.4: Taxon Resolution (%) based on 24 regional *matK* databases ($R^2 = 0.5321$).

2.3.5 Utility of *matK* in resolving taxa to general groups without considering taxon monophyly

Instead of resolving each unknown specimen to a single taxon, barcoding could also be used to reduce the number of possible identifications of an unknown specimen to a small number of poly- or paraphyletic taxa that could then be distinguished from one another using a short key. It is important to note that this does not take into account whether all individuals for a particular taxon group together. To examine this possibility, the number of taxa present in each polytomy was counted and is presented in Table 2.3.

Table 2.3: The number of taxa present in each cluster observed in UPGMA trees constructed from *matK* sequences for Cariceae taxa occurring in North America (NA), as well as Cariceae taxa present in seven selected states and provinces. Where only one taxon is present in a cluster, those individuals can be identified to a single species using DNA barcoding.

	taxa present in polytomy (% occurrence)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	21
NA	66	19	7.5	1.9	1.3	1.3	0.3	0.3	0.6	0.6	0	0.3	0	0	0.3	0.3
AB	73	16	8.2	0	0	0	1	1	0	0	0	0	0	0	0	0
QC	72	20	2.1	2.8	1.4	0.7	0	0.7	0	0	0	0	0	0	0	0
NC	79	5.4	9	2.7	1.8	0.9	0	0.9	0	0	0	0	0	0	0	0
SC	77	10	6.8	4.5	0	1.1	0	0	0	0	0	0	0	0	0	0
SK	73	22	2.2	0	1.1	2.2	0	0	0	0	0	0	0	0	0	0
NM	82	16	0	2.3	0	0	0	0	0	0	0	0	0	0	0	0
CA	75	15	4.5	1.8	0	1.8	1.8	0	0	0	0	0	0	0	0	0

Using this technique, 66% of the observed groups contain sequences unique to a single taxon in the UPGMA tree constructed from the complete North American dataset. The number of groups which can be identified to species is highest in NM, with 82%. The large polytomy containing 21 taxa present in the complete North American dataset is reduced to 4-8 taxa using regional datasets.

2.4 Discussion

2.4.1 Amplification and sequencing success

There were a few difficulties encountered while amplifying and sequencing *matK* for the database. Some of these issues were due in part to the quality of the sampled tissue. In some cases, it was necessary to sample leaves from collections that were a very pale green, a less than ideal situation when trying to amplify and sequence chloroplast regions. At other times, it was necessary to sample collections considerably older than 35 years (there are a

number of sequences from tissue as old as 1950) in order to capture as much of the geographic distribution of a taxon as possible.

After all the sequences had been collected for this study, a new set of primers was put forward by the CBOL Plant Working Group (2009) that amplify a region shorter on the 5' end of the amplicon sequenced herein by 3 base pairs and 25 bp longer on the 3' end. Because the extra 25 bp region mostly consists of the relatively conserved 22 bp site where one of the primers used to generate this database should bind, it is unlikely it would provide much additional resolution to this dataset. Most importantly, because the sequences in this study contain 97% of the PWG's recommended barcoding region (CBOL PWG 2009), they will still be useful as reference barcodes.

Despite the minor troubles with amplification, only 16 out of 1 510 sequences (1%) were not recovered. With the new primers described above, it might be possible to amplify and sequence *matK* for 14 of these 16 samples, as their extracted DNA appears to be of reasonable quality and quantity.

2.4.2 A 39% resolution rate

The low resolution rate observed in this study is not entirely unexpected. From the start of this project, I have reported increasingly lower numbers as taxonomic gaps were filled (57%, Starr *et al.* 2009; 31%, Chouinard *et al.* 2008), and based on other plant barcoding studies, it was not expected that the resolution overall should be any higher than 70% using the currently proposed chloroplast regions (Fazekas *et al.* 2009). However, it was not expected that the resolution would settle at so low a number, and as more sequences are added to the database it will likely drop even further. This low resolution rate can be visualized by Fig. 2.2, which demonstrates considerable overlap between the number of

variable basepairs in intraspecific pairwise comparisons and interspecific pairwise comparisons, and therefore the complete absence of a barcoding gap. If there is considerable overlap between the inter- and intra-specific comparisons, there is an increased chance of misidentification and a lower resolution rate, as is seen in the case of the Cariceae.

The regional animal barcoding studies examined by Meyer and Paulay (2005) show the presence of a barcoding gap and note that it tends to disappear with increased taxonomic and geographic sampling. If the number of taxa and samples included in this dataset are reduced, however, there remains no visible barcoding gap even in the regions with the smallest amount of Cariceae diversity (New Mexico with 41 taxa). It therefore seems entirely possible that *matK* will only fully resolve Cariceae species when extremely low amounts of taxonomic diversity are considered.

Funk and Olmland (2003) described a number of possible causes of low species resolution in phylogenetic studies, including faulty taxonomy and hybridization, two explanations which are also applicable to barcoding studies. These shall be explored as they apply to this study, in addition to the effects of extensive taxonomic and geographic sampling.

2.4.3 The effects of extensive taxonomic sampling on species resolution

The low species resolution observed in this study illustrates how important it is for barcoding studies to include all sister taxa, as these will help elucidate the limits of a region's discriminatory power and reduce the number of false positives. Many closely-related taxa included in this study are indistinguishable from one another using only *matK* sequences, and account for the greatest reduction in resolution rates. This phenomenon is

best exemplified by the case of section *Ovales* Kunth, a primarily North American group, with 72 species recognized in the flora and 85 species recognized worldwide (Mastrogiuseppe *et al.* 2002).

Ovales is the largest North American *Carex* section and it is one of the most complex and difficult sections in the genus as a whole, due in part to its high diversity. The *Ovales* key in the Flora of North America is 13 pages long, and identification can quickly be misled if the specimen being identified does not have absolutely mature perigynia (B. Chouinard, pers. obs.). In the North American *matK* UPGMA tree, 21 members of *Ovales* form the largest polytomy observed (Fig. 2.5), a fact that could be the result of species radiations occurring at faster rates than mutations in *matK* (Hipp *et al.* 2006). Amplified Fragment Length Polymorphism (AFLP) studies in the section have recovered high resolution rates (Hipp *et al.* 2007), but unfortunately, the technique is not as cost-effective and as universally-applicable as the current barcoding system necessitates. These studies do suggest, though, that current *Ovales* species are well circumscribed taxa and not the result of excessive splitting.

Other large sections exhibiting low resolution rates are *Phacocystis* Dumort. (12% resolution) with 25 taxa (Standley *et al.* 2002), *Phaestoglochin* Dumort. (21%) with 26 taxa (Ball 2002), and *Acrocystis* Dumort. (26%) with 28 taxa (Crins & Rettig 2002). Previous studies in *Acrocystis* have noted several species that appear to be para- and poly-phyletic, and for this reason and others, high resolution rates have never been achieved within the section by sequencing nuclear or chloroplast regions (Roalson *et al.* 2001, Roalson & Friar 2004). Significant taxonomic issues within *Acrocystis* have been elucidated in particular by Roalson and Friar (2004), including hybridization, cryptic species, difficult taxonomic

characters, and reluctantly, the possibility of splitting; all may contribute to the lack of resolution in this group.

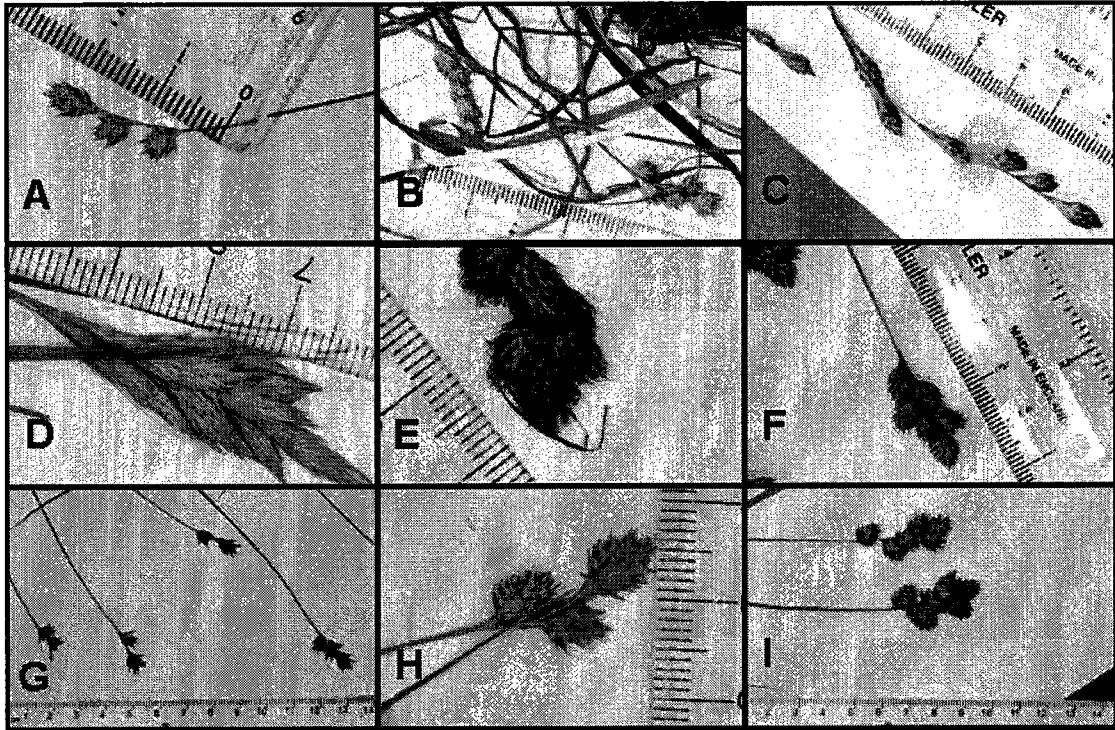


Figure 2.5: Inflorescence variation among nine of the twenty-one *Ovales* taxa which form the largest polytomy on the UPGMA tree. A) *Carex shinnerii*; B) *Carex normalis*; C) *Carex silicea*; D) *Carex muskingumensis*; E) *Carex oronensis*; F) *Carex tinctoria*; G) *Carex hyalina*; H) *Carex merritt-fernaldii*; I) *Carex missouriensis*

As in *Ovales*, AFLP studies within section *Phacocystis* recovered high resolution rates (e.g. 100% [7sp.], Nakamatte & Lye 2007), but in the *matK* UPGMA tree, *Phacocystis* species appear mostly in large polytomies. This apparent lack of resolution is likely due to the fact that the section has one of the highest rates of hybridization (Cayouette & Catling 1992) and so this dataset might contain unrecognized hybrids. A few stabilized hybrids are recognized as species in this section, such as *Carex salina* Wahl. (Standley 1998), which emerges in this study at two different clusters corresponding to its two putative parent

species within UPGMA trees (Cayouette & Catling 1992). The inclusion of hybrids in this study and its effects on resolution will be expanded upon later in this discussion.

North American members of *Phaestoglochin* have not been the focus of intensive study on a sectional level, but the section has been shown to be unnatural in molecular studies that examined Cariceae phylogeny (Ford *et al.* 2006, Waterway & Starr 2007). Four members of *Phaestoglochin* (*C. hookerana* Dewey, *C. hoodii* Boott, *C. occidentalis* L.H. Bailey, and *C. vallicola* Dewey) appear in a large polytomy with taxa from other sections, while other *Phaestoglochin* members cluster together in polytomies of various sizes, scattered around the tree within subgenus *Vignea*. This suggests that the sectional limits of *Phaestoglochin* warrant further study.

As seen in Fig. 2.3, there are several very small sections like *Foetidae* Tuck. ex Bailey (4 taxa), *Inflatae* Kük. (3 taxa), and *Bicolores* Tuck. ex Bailey (4 taxa) which show very low resolution rates. This is due to their size: having one unresolved taxon in a section with only two taxa results in a rapid 50% decrease. Because these smaller sections are less robust, they were not included in the regression line.

Interestingly, each of the three sections that were used in the preliminary study, *Griseae* (20 taxa), *Deweyanae* (8 taxa), and *Phyllostachyae* (10 taxa), showed resolution rates of 50% and above. These sections were specifically chosen for the initial test as their taxa have all been very well characterized morphologically, micromorphologically, and anatomically in recent years (Crins *et al.* 2002; Naczi & Bryson 2002; Naczi 2002) and this extensive examination might account for their relatively high barcoding success rates.

2.4.4 The effects of extensive geographic sampling on species resolution

In addition to the large number of closely-related taxa that negatively affect resolution rates, there are a number of taxa which express high amounts of intraspecific variation across their geographic range. This variation was well-examined in *Carex aquatilis* Wahl. and *Carex lenticularis* Mich. in a comparative study of eastern and western populations by Dragon & Barrington (2009). The extensive variation detected herein suggests that some of these taxa may in fact represent multiple cryptic species, and so should be investigated for any corresponding morphological variation. For instance, *Carex leptalea*, which occurs in every state and province across North America, emerges as a distinct monophyletic group yet within that group sequences from east and west coasts differ by up to 7 bps, an extraordinary amount. Another example is *Carex granularis* Muhl. ex. Will, which occurs in eastern and central North America. Again, all members of this taxon emerge as a monophyletic group and yet there are sequence divergences of up to 4 bps. Additional sampling to fill in the geographic gaps between collections for these taxa would help elucidate genetic drift within their distributions.

2.4.5 The effects of misidentified collections on species resolution

Another way in which species resolution is reduced is by the inclusion of misidentified specimens. In some cases, this misidentification can be due to simple errors in determination, which are usually easily remedied. In other cases, these errors can be explained by the presence of hybrids with characters that appear similar enough to one of their parent species to pass for one of them or by the inclusion of cryptic species.

Only 66 of the collections in this study were determined to be misidentified, 20 of which belonged to section *Ovales*, which, as previously mentioned, is a taxonomically difficult section. It is entirely possible there are additional unrecognized identifications within the section as they are extremely difficult to accurately identify. The second largest group of misidentifications consisted of 8 members of *Racemosae* G. Don which are only distinguishable with careful observation of the perigynia and pistillate scales. The remainder of the misidentifications were spread among 23 other sections.

2.4.6 The effects of cryptic hybrids and species on species resolution

The effects of stable hybrid species have already been briefly discussed, as in the case of *C. salina*, but it is possible that unrecognized hybrids have been inadvertently included in this study. Many hybrids are sterile in which case they could be easily identified and removed from the dataset, but none were noted in this study. Cayouette and Catling (1992) noted the highest levels of hybridization in *Phacocystis*, *Ceratocystis* Dumort., *Paludosae* G. Don, *Glareosae* G. Don, and *Vesicariae* Hueffel. *Phacocystis* has already been discussed as having one of the lowest resolution rates, though hybrids are not the sole cause. The other four sections listed as having high rates of hybridization demonstrated species resolution rates of 50%, 45%, 50%, and 55%, respectively, which are average for sectional resolution. It is therefore unlikely that hybridization played a significant role in reducing species resolution in this study.

Finally, one of the most exciting aspects of barcoding is its ability to uncover previously unrecognized species (Smith *et al.* 2009, Janzen *et al.* 2009). It is generally accepted that new species should not be described solely by virtue of their barcode, based on a specified cut-off point (e.g., Dasmahapatra *et al.* 2009; Emery *et al.* 2009). This is

especially true for this dataset as there is little variation overall and setting a cut-off point would result in many well-established taxa being lumped together. However, there are sequences in this dataset which are unique and which might suggest the presence of cryptic species. For instance, one of the four collections of *Carex texensis* Torrey ex L. H. Bailey appears on its own due to one transition and five transversions, and far removed from the other three collections which emerge otherwise as a monophyletic group. *Carex triangularis* Boeckeler as well has one individual out of three that appears distinctly on its own due to three transitions. In both these cases, which are only two of many (see also *Carex aestivalis* M.A. Curtis Ex. A. Gray, *Carex capitata* L., *Carex crinita* Lamarck var. *brevicrinis* Fern., *Carex dasycarpa* Muhl., *Carex debilis* Mich. var. *rudgei* L. H. Bailey, *Carex deflexa* Hornemann, *Carex glaucescens* Elliott, *Carex hystericina* Muhl. Ex Will., *Carex laxiculmis* Schweinitz var. *copulata* (L.H. Bailey) Fern., *Carex lemmonii* W. Boott, *Carex lenticularis* Michaux var. *dolia* (M. E. Jones) L. A. Standley, *Carex macloviana* D'Urville, *Carex mendocinensis* Olney ex W. Boott, *Carex nigromarginata* Schweinitz, *Carex pellita* Will., *Carex phaeocephala* Piper, *Carex tenuiflora* Wahl., *Carex turbinata* Liebmann, *Carex venusta* Dewey, *Carex vestita* Will.), the odd collection(s) appear unique from the other members of its taxon and do not group with any other taxa.

There is great potential for barcoding to quickly point taxonomists towards potential new species (e.g. Ragupathy *et al.* 2009). To show the benefit of careful sectional examination and the potential number of cryptic species, consider the case of *Phyllostachyae*, a section that doubled in size due to thorough investigation (for example: Catling *et al.* 1993; Ford & Naczi 2001; Saarela & Ford 2001). Few of the remaining 71

sections within the Cariceae of North America have been subjected to similar scrutiny and it is hoped that DNA barcoding will bring to light previously unrecognized taxonomic issues within these groups.

2.4.7 A regional barcoding system for the Cariceae

It seems resolution could be greatly increased, from 39% to as high as 75%, if taxa from a specific region are considered during a barcode database search. These results are similar to reported increases in species resolution when comparing non-regional (Fazekas *et al.* 2009) and regional (Lahaye *et al.* 2008; Le Clerc-Blain *et al.* 2009) barcoding studies. The main challenge with a regional barcoding system is ensuring that knowledge of the local flora is kept up-to-date and in line with the sequence database: failure to add new taxa to a regional database that already contains taxa with similar sequences would result in a serious reduction in barcoding utility.

In addition, it might be beneficial to generate regional databases that are tailored to specific habitats. Including species that only occur in a specific habitat could remove more sister species and hence further improve database accuracy over the arbitrary political regions used here. Especially in large provinces like Ontario, which covers a wide range of latitude and longitude, it would be more sensible to divide the area into smaller regions based on common biotic and abiotic factors. For instance, Marshall and Schut (2009), using data from Agriculture and Agri-Food Canada and Environment Canada, assembled a series of maps which divide Canada into 15 ecozones, 52 ecoprovinces, 194 ecoregions, and 1021 ecodistricts. It is possible that at one of these eco-regional levels, barcoding would achieve high levels of resolution. However, this approach would require a continued and significant effort to ensure regions are kept up-to-date in terms of their Cariceae flora.

Even if regional barcoding does not achieve resolution rates of 100%, it still is a very useful tool in conjunction with morphological identification. With regional barcoding, the 21-species polytomy of *Ovales* species can be reduced to 8 taxa or fewer, sometimes grouping species that are easily separated by morphology and enabling the use of a considerably shorter dichotomous key. If regional barcodes can bring an unidentified organism down to two or three potential taxonomic names, rather than 530, Cariceae identification would require a significantly smaller investment of time and money for non-taxonomists. Moreover, if those two or three options could be distinguished vegetatively, it would enable accurate identification of tissue even when the plant could not otherwise be identified.

2.4.8 Implications for conservation efforts

There are seven Cariceae taxa that are recognized by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the United States Fish and Wildlife Service (USFWS) as endangered or threatened (Table 2.4). With these designations, it is illegal to damage or remove these plants, or to damage or destroy their habitat (Species at Risk Act, 2002; Endangered Species Act 1973). Using the complete database of *matK* sequences, three taxa clearly resolve as independent groups, three do not, and one has not been included in this study. Twelve other narrow endemics (species that occur in a limited geographic area), *C. brysonii* Naczi, *C. aboriginum* M. E. Jones, *C. harfordii* Mack., *C. hirtissima* W. Boott, *C. tompkinsii* J. T. Howell, *C. turbinata* Liebmann, *C. congdonii* L. H. Bailey, *C. sartwelliana* Olney, *C. heterostachya* Bunge, *C. triquetra* Boott, *C. obispoensis* Stacey, and *C. endlichii* Kük also resolve in unique groups. However, if we consider a regional approach, *Carex specuicola* and *Carex juniperorum* form unique clusters in half of

their ranges, where *C. specuicola* can be distinguished in Arizona but not Utah, and *C. juniperorum* can be distinguished in Ontario and Virginia but not Ohio and Kentucky. Barcoding could thus be a very effective tool for conservation of these species, as it would allow for population monitoring (e.g. Rowntree *et al.* 2009) and possibly aid in the discovery of new populations without the need for harvesting the whole plant. It could also be used to quickly identify plants that are being shipped over national borders to stop illegal poaching and trafficking, or to trace the movement of populations due to habitat changes such as those brought about by global warming (Carlsson & Callaghan 1994; Hassol 2004).

Table 2.4: Protected Cariceae taxa as recognized by COSEWIC and USFWS and their ability to resolve as unique species clusters using a North American *matK* DNA barcoding database. Asterisks indicate species resolution using regional databases. *Carex albida* was not sampled.

Taxon	Status	Agency	Resolved?
<i>Carex lupuliformis</i>	Endangered	COSEWIC	N
<i>Carex tumulicola</i>	Endangered	COSEWIC	Y
<i>Carex juniperorum</i>	Endangered	COSEWIC	N*
<i>Carex albida</i>	Endangered	USFWS	N/A
<i>Carex lutea</i>	Endangered	USFWS	Y
<i>Carex sabulosa</i>	Threatened	COSEWIC	Y
<i>Carex specuicola</i>	Threatened	USFWS	N*

2.4.9 Phylogenetic utility of *matK*

Although it is out of the scope of this thesis, it should be noted that these *matK* sequences have some utility as a phylogenetic marker. In Starr *et al.* (2009), it was shown that *matK* was able to resolve as many species as the commonly used nrDNA internal transcribed spacer (ITS) region (Roalson *et al.* 2001; Hendrichs *et al.* 2004; Ford *et al.* 2006), at least for section *Phyllostachyae* where comparable data was available for all species. If parsimony, Bayesian, and maximum likelihood trees were constructed, this

dataset would represent the largest phylogenetic study conducted in the Cyperaceae, including nearly every taxonomic unit recognized in North America. Such a tree could provide baseline information for a wide array of directed studies in sections or groups whose relationships are poorly described, and help elucidate our understanding of Cariceae evolution.

2.5 Conclusions

In this study, 1 460 *matK* sequences were generated, representing 516 of the 530 (97%) described Cariceae taxa in North America, and constituting the foundation of a Cariceae DNA Barcode database. Each time the database is used, sequences are added to it, increasing its accuracy and making it a more reliable tool for identifying North American *Carex* and *Kobresia* species. Eventually, as the barcoding movement takes hold, it will perhaps even expand to include substantial numbers of taxa in other countries and continents.

Following the recommendation of CBOL's plant working group, *rbcL* will likely be added to *matK* to act as a multilocus barcode. The chloroplast gene *rbcL* has been used in Cyperaceae studies in the past to elucidate tribal and generic relationships (Muasya *et al.* 1998; Simpson *et al.* 2007), as well as relationships in *Cyperus* L. (Muasya *et al.* 2001), but never specifically in the Cariceae. It is doubtful that *rbcL* will provide much additional resolution to some of the larger polytomies seen in the *matK* tree as the region demonstrated very low discriminatory power in the Cariceae of the Canadian Arctic Archipelago (Le Clerc-Blain *et al.* 2009), an ecogeographic region whose few species are, with few exceptions, distantly related. In addition, it has been shown that *rbcL* in general is not as variable in monocots as it is in other plant groups (Newmaster *et al.* 2006). As there are

significant amounts of DNA left for each of the taxa used in this study, the only impediment to establishing an *rbcl* database sister to this one will be the cost of sequencing.

Currently, the CCDB is in the process of establishing a high-throughput protocol for plant barcoding, which would accept large amounts of tissue samples and return equally large numbers of sequences, similar to their animal barcoding services. Once this is up and running, it will open up Cariceae identification to scientists and the public alike and allow caricologists to devote their time to the more challenging tasks of taxonomic investigation.

Chapter 3 - Assessing the ability of DNA barcodes to identify unknown collections from across the Flora of North America region

3.1 Introduction

With an initial *matK* barcoding database established, the next step is testing its effectiveness for identifying a series of unknown samples. This practical test of a database's utility has never been done in any plant barcoding study.

In animals, DNA barcoding databases are established enough to allow researchers to utilize them in a number of interesting ways. For instance, barcodes are currently being used to check the identification of market fish (Wong & Hanner 2008), to identify pests at various life stages (Ball & Armstrong 2006), and to identify ectomycorrhizal fungi (using ITS instead of CO1) (Tendersoo *et al.* 2009). In each of these cases, accurate identification is obtained from small fragments of tissue that would be impossible, or at least very difficult, to identify using traditional means. Similar applications for plant DNA barcodes might include confirming the ingredients in herbal medicines (Cowan *et al.* 2006), establishing forage patterns for herbivores (Bradley 2007), or simply assisting in any of a wide variety of ecological problems (Valentini *et al.* 2008).

To evaluate the utility and accuracy of using DNA barcodes for identifying Cariceae taxa, caricologists across North America were asked to send in small quantities of tissue from collections known to be accurately identified. This test essentially mimics the process that would occur in a large barcoding facility, where only small quantities of unknown tissue are submitted and identifications are returned.

The success rate of this system will be evaluated first by comparing the unknown sequences to the entire North American reference database and then again by comparing the unknown sequences to smaller regional reference databases using political boundaries.

3.2 *Methods and materials*

3.2.1 Sample collection

Twenty-five caricologists across North America were asked to each submit five to ten tissue samples from collections made in the last 35 years that were still green in appearance, and which the submitters were confident were correctly identified. In order to remove any potential bias, samples were received and processed by a third party (Dr. Root Gorelick at Carleton University), who transferred each sample to a new, standardized ziplock bag and assigned to each a tracking number. Only then were they passed on to the lab for processing.

3.2.2 DNA extraction and amplification and sequencing of *matK*

Extraction was conducted as in chapter two. The primers used for amplification were *matK2.1F_J* and *matK5R_J* using the touchdown program outlined in Chapter two. Sequencing was conducted at the Canadian Museum of Nature using the primers *matKR* and *matKFalt* due to the problems with sequencing encountered with amplification primers as noted before.

3.2.3 Identification of unknowns

Two separate methods were used to compare unknown sequences to those in the database. In the first method, a UPGMA tree was created using the unknown sample sequences and sequences from the *matK* database developed in Chapter 2. As before, a K2P model was used. The identity of the unknown specimens was based on which reference sequences clustered with each unknown sequence in the tree. In cases where the unknown sequences did not perfectly match any reference sequences, the closest match in the tree was taken as the identity.

The second method was a local BLASTn search of the *matK* database using the unknown sequence as a query. All reference sequences that matched the unknown sequence with an E-value of 0 were noted. If there was no complete match, the closest match was recorded as was the number and position of divergent base pairs. It should be noted that while using a BLAST search, identifications based on incomplete sequences should be applied with caution (Koski & Golding 2001). These two methods were chosen as they are similar to the identification methods used by BOLD and therefore would approximate the same identifications BOLD would return in a practical setting.

Both methods were first applied with a *matK* database containing all the sequences for North America Cariceae. All potential identifications were recorded. Next, Dr. Gorelick provided the state or province from which each sample was collected, and each unknown was compared to a regional database containing only taxa that occur in their region. These potential identifications were recorded as well.

Once the morphological identification was revealed, all sequences were deposited in GenBank (www.ncbi.nlm.nih.gov/genbank/) and BOLD (barcodinglife.org).

3.3 Results

3.3.1 Sample collection

Forty-five samples from seven different researchers were received, including John Nelson from the University of South Carolina, Robert Kraul from the University of Nebraska, Theodore Cochrane from the University of Wisconsin, Micheal Oldham from the Ministry of Natural Resources, Ontario, Jacques Cayouette from Agriculture and Agri-Food Canada (Ottawa), Bruce Ford from the University of Manitoba, and Peter Ball from the University of Toronto at Mississauga.

3.3.2 DNA extraction and *matK* amplification, and sequencing success rates

All 45 extractions were successful. Amplification of *matK* was not successful on the first pass in one of these, but the remaining 44 were successfully amplified in a single attempt and sequenced.

3.3.3 Identification using UPGMA trees and BLAST

There was one unknown that did not perfectly match any sequences in the database; it differed from a *C. douglasii* sequence by one base pair and so this identification was accepted. It grouped with *C. douglasii* on the tree.

When the DNA barcoding identifications were checked against the morphological identifications, two discrepancies were observed. In both cases, each unknown unambiguously matched only one reference sequence.

In each instance where a group of sequences was reached as a result for an unknown, the group contained the correct taxonomic name for the unknown sample.

Table 3.1: Number of reference sequence matches for each unknown sample based on tree- and algorithm-based analyses of full and regional databases. The full database contains all *matK* sequences for FNA Cariceae while the regional databases are composed of taxa known to occur in the same state or province as the unidentified collection. Note that with the exception of two samples (one later found to be part of a mixed collection and one whose identity could not be confirmed due to the loss of the voucher), all clusters contained the correct taxonomic name.

Potential taxonomic names for each unknown sample	Occurance			
	Full database		Regional Database	
	UPGMA	BLAST	UPGMA	BLAST
1	20	19	26	26
2	8	8	8	9
3	2	3	3	2
4	1	1	2	2
5	0	0	2	3
6	1	1	1	1
7	0	0	1	0
8	3	3	1	1
9	4	5	0	0
10	0	0	0	0
11	1	0	0	0
12	0	0	0	0
13	0	0	0	0
14	1	1	0	0
19	0	3	0	0
20	0	0	0	0
21	3	0	0	0

3.4 Discussion

Acquiring *matK* sequences from these tissue samples was accomplished easily and successfully. Provided that the tissue is no older than 35 years and is green, the extraction, amplification, and sequencing protocols presented herein are very effective, with only one sample of 45 not generating a clear sequence. As most people would be submitting recently collected tissue for identification, and given that the tissue was properly dried, a future DNA barcoding facility should have no trouble obtaining data from field collections.

The most accurate identifications were achieved using regional datasets, with similar results for both the tree-based and BLAST search methods. If the database is well-populated for a particular area, it would be faster to use BLAST simply because the results can be obtained quickly without the labourious task of having to look through a tree, even though this is made considerably easier on BOLD by showing only the local topology for the unknown and highlighting the sequence in question. However, in cases where the unknown sequence does not perfectly match any reference sequences, either due to infraspecific variation or a missing reference taxon, it would be better to use a tree-based method for identification in order to match the unknown to the nearest neighbour.

Although there were a number of collections that were never reduced to a single species name, applying a regional database considerably reduced the number of taxa in each species group, the most noticeable case being in section *Ovales* where twenty-one possible species names were reduced to eight. At this point, with only eight species names, a short key could be effective in completing the identification.

Two collections were 'misidentified' using DNA barcoding, and so the submitter was contacted to confirm their identities. For the first, a sample identified as *Carex flava*

using DNA barcoding was morphologically identified as *Carex cryptolepis*. When the voucher was re-examined, it was found that two of the three plants present on the voucher were indeed *Carex flava*, while the third plant was *Carex cryptolepis*. It could not be determined which plant was actually sampled for submission but it was admitted by the submitter that *Carex flava* was not expected to occur in the location the voucher was collected for ecological reasons, and so the possibility was not considered during identification. Because the two taxa look so similar, the unexpected diversity was easily overlooked using morphological identification. DNA barcoding would not be subject to such bias, and would hopefully reduce the number of such errors.

The second 'misidentified' collection could not be confirmed as the voucher from which the sample was taken could not be recovered.

3.5 Conclusions

Using a regional approach, 25 of 43 (58%) unknown collections were identified to a single taxon, not including the collection whose identity could not be confirmed as the voucher was misplaced. The remaining 18 (42%) were identified to a group of taxa, where each group contained the correct identification. To complete the identification of these grouped taxa it would be necessary to use a key. However, rather than using a dichotomous key with terminology unfamiliar to the general public, a Delta (<http://delta-intkey.com/>) or a Lucid key (<http://www.lucidcentral.com/>) could be created. In a Delta key, the user selects which characters they wish to use for identification until a taxon name is reached, while Lucid keys rely heavily on photographs to guide a non-technical user through difficult terminology.

Although it will still be necessary to obtain the services of an experienced taxonomist for the more challenging collections where the specimen might be too immature or degraded to complete the identification, DNA barcoding is a demonstrably useful tool to aid in the rapid identification of Cariceae species. It is important to note that the utility of DNA barcoding is derived from the hard work of taxonomists and naturalists in describing the characters and geographic limits of these species, and that their continued research is critical for improving barcoding efficiency. By enabling a barcode system, these researchers will not need to spend time on routine identifications and will be rewarded with a new source of information for Cariceae distribution, ecology, and phylogeny as the database is used and expanded.

Chapter 4 - Assessing the ability of DNA Barcodes to identify unknown collections from a clearly defined ecogeographic region: the Canadian Arctic Archipelago

4.1 Introduction

The Cariceae comprise approximately 11% of all vascular plant species in the Canadian Arctic Archipelago, an area that includes the islands of the Northwest Territories east of 127°W, the islands of Nunavut north of 60°N, including Southampton Island, White and Caribou Islands, Coats Island, Bencas Island, Digges and Mansel islands, and Akpotok Island in Ungava Bay, as defined by Aiken *et al.* (1999). Expeditions to these regions are expensive and due to the narrow growing season and seasonal fluctuations in climate, collections are often immature or over-mature which makes them particularly difficult to identify, especially in the case of sedges (Larter & Nagy 2001). Furthermore, as the cost of shipping materials to and from the arctic is high, being able to assess biodiversity from a large collection of small tissue samples rather than from a collection of whole plants would greatly reduce the collection weight and hopefully permit greater non-destructive sampling of the arctic flora. Accurate and complete cataloguing of these northern ecosystems becomes an important goal when considering potential changes in these environments due to climate change (Hassol 2004; Sturm *et al.* 2005; Wipf *et al.* 2009). DNA barcoding could possibly provide a quick, accurate, and economical means to achieve this goal across this vast region.

A *matK* database for the Cariceae of the Arctic Archipelago has already been established by Le Clerc-Blain *et al.* (2009). The purpose of this chapter is to test the ability of this regional database, which reported a species resolution rate of 100%, to identify a

series of “unknown” tissue collections. The collections used here were from two different expeditions, one to the western Arctic, and one to the eastern Arctic. By using samples from opposite ends of the Arctic Archipelago, the effectiveness of this regional database can be assessed from the limits of its latitudinal range and elucidate potential intraspecific variation. As the *matK* database established for this region does not contain all the taxa known to be present, this test might demonstrate how DNA barcoding can recognize ‘new’ taxa, which is a major goal of DNA barcoding.

4.2 Methods and materials

4.2.1 Sample collection

All the unknowns used in this study are from two different expeditions to the Arctic. The western expedition occurred from late June to late July in 2008 and was attended by L. J. Gillespie, J. M. Saarela, L. L. Consaul, and R. D. Bull from the Canadian Museum of Nature. The eastern expedition occurred in August 2009 and was attended by J. R. Starr and students enrolled in the Students on Ice program (<http://www.studentsonice.com/>).

Whole plants representing each unknown from both expeditions are housed at CAN. Tissue samples from each plant were put into Ziploc bags with silica gel when the plants were harvested in order to dry the tissue quickly and thus provide high quality DNA for extraction. The identities of the samples and their collection localities within the Canadian Arctic Archipelago were determined morphologically by the collectors but were kept unknown to me to reduce potential bias.

4.2.2 DNA extraction and *matK* amplification and sequencing

Extraction was conducted as in Chapter 2. The primers used for amplification of *matK* were *matK2.1F_J* and *matK5R_J*, and PCR was conducted using the touchdown program listed in Chapter 2. Sequencing was conducted at the Canadian Museum of Nature using the primers *matKR* and *matKFalt* and the protocols described in Chapter 2.

4.2.3 Analysis

Identification was accomplished using both the tree-based and algorithmic methods presented in Chapter two. The reference database used in this study was established by Le Clerc-Blain *et al.* (2009) and contains *matK* sequences from across the Arctic Archipelago. In cases where a BLAST search returned no exact sequence match, the closest match was taken as identification and the number of variable base pairs was noted. In these instances, the unknown was also compared to the North American reference database.

In cases where the barcode identification did not match the morphological identification, the collection was reassessed morphologically to determine whether the collection had been misidentified.

Once the morphological identification was revealed and compared to the barcode identification, all sequences were deposited in GenBank (www.ncbi.nlm.nih.gov/genbank/) and BOLD (barcodinglife.org).

4.3 Results

4.3.1 *matK* amplification and sequencing success rates

In the end, 244 collections were sampled: 101 from the eastern expedition and 143 from the western expedition. For each of these 244 collections, *matK* amplification was only attempted once. No amplification attempts failed completely, but three samples (1.2%) produced weak bands from PCR and so sequencing was not attempted. The remaining 241 amplifications were put forward for sequencing, and of these, only 11 (4.5%) did not produce a clear signal in both directions.

4.3.2 Identification using UPGMA trees and BLAST

Of the 230 unknown collections assayed, 198 had *matK* sequences which perfectly matched reference sequences, while 32 specimens had no exact sequence match. Of these 32, 15 collections had sequences that differed by 1 or 2 base pairs and were assigned the correct identification by both tree- and algorithm-based methods. The remaining 17 collections did not have direct matches in the database but formed three distinct groups with consistently variable base pairs amongst each group. Each of these 15 sequences was compared to the North American database; one of these groups, which was morphologically identified as *Carex ursina*, perfectly matched a *C. ursina* reference sequence from the Yukon in the North American database. The two remaining groups, which were identified as *Carex microglochis* and *Carex vaginata*, did not match any of the reference sequences in the North American database.

Of the 198 collections with *matK* sequences that perfectly matched reference sequences in the Arctic Archipelago database, 16 had barcode identifications that did not

match the morphological identifications. Two of these were likely due to a lab error, as the barcode identifications matched the identifications of immediately adjacent sample numbers. In another case, when the morphological identification was being confirmed, two different species were noted in the collection; one species matched the morphological identification while the other matched the barcode identification. Another collection was not mature and so its morphological identification could not be confirmed. Three other collections were morphologically identified as *Carex subspathacea* but were barcoded to *Carex aquatilis*. The Canadian Arctic Archipelago reference database did not contain any instances of *C. subspathacea* and because the two species have identical *matK* sequences the identification was mistakenly applied. The remaining nine collections (3.9% of all barcoded unknowns) were found to be morphologically misidentified. With all issues resolved, DNA barcoding successfully assigned 95% of the unknown tissue samples to a single species, and the remaining 5% (11 collections) to a species complex including *C. subspathacea* and *C. aquatilis*.

4.4 Discussion

A number of issues arose during the course of this study that elucidate the limitations of both DNA barcoding and morphologic identification systems, as discussed below.

4.4.1 Barcode misidentification due to taxa not present in the reference database

Four taxa were absent from the Arctic Archipelago reference database (*Carex microglochin*, *Carex subspathacea*, *Carex ursina*, and *Carex vaginata*) due to difficulties in obtaining either recent collections or acceptable DNA extractions from herbarium material

(Le Clerc-Blain *et al.* 2009) and do not represent new species to the area (Aiken *et al.* 1999). By examining the UPGMA tree, the presence of these four taxa was immediately obvious as they formed four distinct and unidentified groups which were easy to pick out visually. Using BLAST, the four distinct groups were only truly evident as groups when their base pair variances were compared, but individually they were all distinct as they had no exact sequence matches. In this regard, a tree-based approach appears to be more suitable when dealing with sequences that do not already appear in the database as they allow a researcher to quickly identify groups that represent potentially new species while identifying potential sister species for these groups at the same time.

Two of these taxa, *C. microglochin* and *C. vaginata*, did not match sequences in the North American database either. For *C. microglochin*, there is only one reference sequence and it is from Norway as no North American specimens were available. This geographic isolation is a likely explanation as to why the sample sequences and the reference sequence do not match. In the case of *C. vaginata*, there are two reference sequences, one from Newfoundland and one from the Yukon, both of which differ by 9 bp from one another and by 17 bp from the sample sequences. This variation might be simply due to the wide geographic area covered by all of the collections but is very curious nonetheless.

4.4.2 Misidentification due to multiple taxa in a single collection

One particular problem arose when a collection appeared to have two different species on the voucher. Most specimens in the collection were morphologically identified as *Carex scirpoidea*, but a single specimen appeared to be more morphologically similar to *Carex vaginata*, which matches the barcode identification. Since it is impossible to say which plant(s) were actually sampled, it is impossible to determine whether the barcode

identification is in error or not. It is, however, a good example of how easily diversity can go unrecognized in mixed populations containing different species with similar appearances. One other case of this was noted wherein *Carex nardina* grew in a mixed population with *Kobresia myosuroides*. In this instance, however, the two genera were recognized and separated both by morphologic and barcode identifications.

4.4.3 Misidentification due to immature collections

In one case, a specimen was collected that was immature. This is an ideal situation for barcoding, where a specimen cannot otherwise be accurately identified using morphologic means. Unfortunately, because the specimen lacks the characteristics that would be present at maturity, it is not possible to accurately say if the barcode identification is correct. Once the database becomes more populated, it will become useful in situations like these where collections are otherwise impossible to identify.

4.4.4 Morphological misidentification

Of the 230 barcoded collections, nine (3.9%) collections were found to be morphologically misidentified by trained taxonomists. In all cases, the two possible identifications were very similar looking taxa and so misidentification occurred very easily, especially when the collections were not perfectly mature.

This misidentification rate is very similar to the rate noted in chapter two (4.6%), although it is difficult to determine whether this is a coincidence or not. Different taxonomists will have varying amounts of success depending on how much prior experience they have with the species and sections being examined and as tempting as it is to assign an inherent rate of misidentification using morphological means, it would not be appropriate.

4.5 Conclusions

As was noted in Le Clerc-Blain *et al.* (2009), there are a number of taxa that occur in the Arctic Archipelago which are not represented in the Arctic Archipelago reference database. Completing this database with new sequences and with sequences from the North American dataset established in Chapter 2 will increase its utility and avoid issues which occurred due to absent reference sequences.

In the end, 95% of the unknown collections in this study were successfully identified to a single species using DNA barcoding. The remaining 5% were identified to a species complex of *Carex subspathacea* and *Carex aquatilis*, which can be clearly distinguished from one another by the width of their leaves (Standley *et al.* 2002). Even though barcoding cannot distinguish between the two taxa, it should be possible for anyone with a ruler to complete the identification.

Chapter 5 - Future work and conclusions

Due to their extremely reduced floral morphology and difficult taxonomy, the Cariceae are largely ignored by scientists and the public alike. With the establishment of a DNA barcode database for the Cariceae based on the chloroplast region *matK*, a new tool is available to facilitate accurate identification of *Carex* and *Kobresia* that does not rely on years of expertise, freeing taxonomists from the routine and time-consuming tasks of identification. It should be noted that no other plant barcoding study has been attempted on this scale, both in terms of the number of included taxa and the number of sequences collected, and that this represents a significant step towards barcoding the flora of Canada and the flora of North America (ca. 10% and 3% of the native flora respectively).

Although it was demonstrated in Chapter 2 that the reference database containing all North American species of *Carex* and *Kobresia* only provides 39% species resolution, it is demonstrated in Chapter 3 that by reducing the number of reference sequences to contain only those taxa that occur in a particular political region, the resolution can increase to as high as 75%. Furthermore, as each political region covers a wide variety of habitats and ecoregions, by further reducing the number of reference sequences to only encompass those taxa that occur in a specific environment, such as the Canadian Arctic Archipelago, species resolution can increase to 95%, as seen in Chapter 4.

With only 30 Cariceae species, the Canadian Arctic Archipelago is comparable to Nunavut (28 spp.) but shows a 27% increase in species resolution. This difference is likely due to the fact that the 28 species occurring in Nunavut exist over a wide range of habitats, from tundra to taiga, allowing the inclusion of closely-related sister species which typically are not found in the same habitat. It would be worthwhile to determine whether additional

ecoregional databases exhibit similar increases in species resolution. This would be a considerable task, however, and would require constant maintenance by taxonomists and naturalists to ensure they are kept current and relevant, if such a system is adopted.

Even when an unknown sample cannot be assigned to a single species using DNA barcodes, it is always assigned to a small group of possible identifications, especially when regional datasets are used. In order to complete the identification, it would be necessary to develop a set of keys specific to taxonomic groups recovered through DNA barcoding, which are not necessarily closely-related. As these taxa will not always be close relatives, there is the possibility they might be distinguished by characters that are not necessarily dependent on perigynial morphology, enabling identification even when the specimen is under- or overmature. Lucid keys in particular would likely be most effective for use in the Cariceae as they provide visual cues to guide the user through unfamiliar terminology.

In addition to assisting in the identification of unknown samples, DNA barcodes will also enable researchers to elucidate evolutionary and taxonomic problems within this poorly-understood group by indicating areas which should be the focus of directed study. The preliminary study evaluating the efficacy of barcodes in *Carex* compared the utility of *matK* as a phylogenetic marker and found it functions better than the standard nuclear ITS region (Starr *et al.* 2009), which is often used to reconstruct Cariceae phylogenies. The presence of one stabilized hybrid, recognized as *Carex salina*, in two locations on the UPGMA tree corresponding to its two putative parents indicates multiple speciation events for that hybrid. With the expansion of the database through use, and the inevitable inclusion of further known and unknown hybrids, this database could help further our understanding of the evolution of hybrids.

Furthermore, the potential for recovery of previously unrecognized Cariceae diversity is very high using DNA barcodes. There are a number of taxa identified in Chapter 2 which appear to be unique, and again, though their thorough investigation was not within the scope of this research, it is possible that a few will eventually be recognized as distinct taxa. As the database is expanded, these instances will occur more frequently and be easier to recognize.

The Canadian Centre for DNA Barcoding (CCDB) is in the process of establishing automated high-throughput protocols for plant regions, as are currently in place for CO1, which would greatly reduce the chance occurrence of lab errors. With this system in place, anyone interested in doing so will be able to submit small tissue fragments to assist accurate identification of members of the Cariceae, based on the reference sequences developed through this research.

Appendix A. The pilot study conducted in order to determine which of the five proposed plant barcoding loci (*rpoC1*, *rpoB*, *matK*, *rbcL*, *psbA-trnH*) would provide the most resolution within the Cariceae, either singly or as part of a multilocus barcode.

Starr, JR, Naczi, RFC, Chouinard BN (2009) Plant DNA barcodes and species resolution in sedges (*Carex*, Cyperaceae). *Molecular Ecology Resources*, 9(Suppl. 1):151-163.

Phylogeny and Evolution in Cariceae (Cyperaceae): Current Knowledge and Future Directions

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Abstract The goal of this study was to review the impact of DNA sequence analyses on our understanding of Cariceae phylogeny, classification and evolution. To explore character evolution, 105 taxa from four different studies were included in an nrDNA ITS + ETS 1f analysis of all recognized genera (*Carex*, *Cymophyllus*, *Kobresia*, *Schoenoxiphium*, *Uncinia*) and *Carex* subgenera (*Carex*, *Psyllophora*, *Vignea*, *Vigneastra*). As in previous analyses, four major Cariceae clades were recovered: (1) a “Core *Carex* Clade” (subg. *Carex*, *Vigneastra*, *Psyllophora* p.p.); (2) A “*Vignea* Clade” (subg. *Vignea*, *Psyllophora* p.p.); (3) a “*Schoenoxiphium* Clade” (*Schoenoxiphium*, subg. *Psyllophora* p.p.), and (4) a “Core Unispicate Clade” (*Uncinia*, *Kobresia*, subg. *Psyllophora* p.p.). All studies provide strong support (86–100% BS) for the Core *Carex* and *Vignea* Clades, but only weak to moderate support (<50%–78% BS) for the Core Unispicate and *Schoenoxiphium* Clades. The relationships of these groups are unresolved. Studies suggest that *Carex* is either paraphyletic with respect to all Cariceae genera or to all genera except *Schoenoxiphium*. *Kobresia* is a grade, but *Uncinia* and possibly *Schoenoxiphium* are monophyletic. The monotypic *Cymophyllus* is indistinct from *Carex* subg. *Psyllophora* species. Character analyses indicate that inflorescence proliferation and reduction have occurred in all major clades, and that the Cariceae’s unisexual flowers have evolved from perfect flowers. The ancestor to Cariceae possessed a multispicate inflorescence with cladoprophylls and female spikelets with tristigmatic gynoecea and closed utricles. This morphology is most similar to extant *Carex* subg. *Carex* species, which contradicts the nearly unanimous assumption that the highly compound inflorescences of *Schoenoxiphium* are primitive. Since taxonomic sampling and statistical support for phylogenies have generally been poor, we advocate the temporary maintenance of the four traditional *Carex* subgenera with androgynous unispicate species placed within subg. *Psyllophora* and dioecious and gynaeandrous unispicate species distributed amongst subgenera *Carex* and *Vignea*. A collective effort focused on developing new nuclear markers, on increasing taxonomic and geographic sampling, and on studying development within the context of phylogeny, is needed to develop a phylogenetic classification of Cariceae.

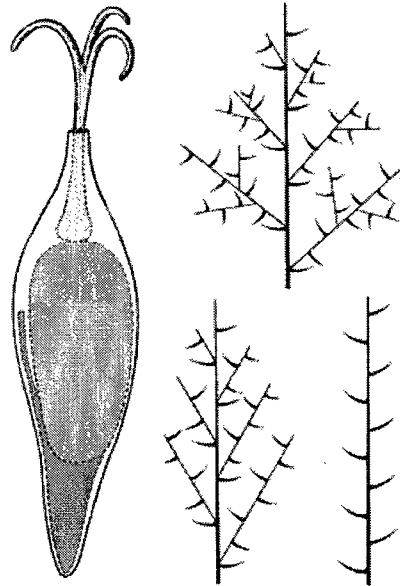
Keywords Cariceae Phylogeny · Classification · Evolution

Introduction

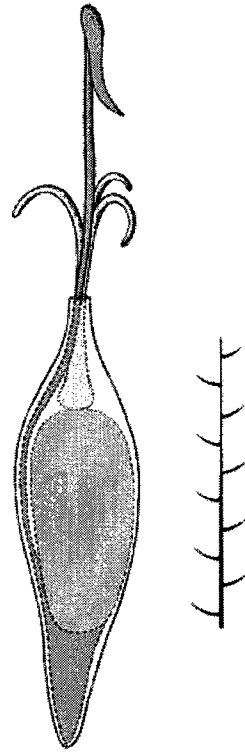
The Cyperaceae (5,000 spp., 109 genera, 14 tribes; Goetghebeur, 1998) is a cosmopolitan clade (Jones et al., 2007) of mainly anemophilous, herbaceous plants that is the third largest monocot family after orchids and grasses. Even within such a remarkable family, tribe Cariceae Pax stands out for its extraordinary diversity (2,150 spp.; Goetghebeur, 1998), extensive aneuploidy ($n=6-56$; Davies, 1956), varied habitats (prairies to rain forests) and diverse biogeographic patterns (e.g., Gondwanan, Amphiatlantic, Bipolar; Raymond, 1951; Croizat, 1952). The tribe is also notable because it is clearly monophyletic (Muasya et al., 1998, 2000; Starr et al., 2006) and easily separated from all other Cyperaceae by naked unisexual flowers where the female is surrounded by a sac-like prophyll known as a utricle or perigynium (Fig. 1). The above characteristics would seem to make Cariceae an ideal model for studying the evolution of biodiversity, but factors such as its high species diversity and reduced morphology have confounded traditional attempts to create a phylogenetic classification of the group (e.g., Kükenthal, 1909; Kreczetovicz, 1936; Nelmes, 1951, 1952; Savile & Calder, 1953).

Despite the well-marked nature of the tribe, the circumscription of genera (*Carex* L., *Cymophyllus* Mack., *Kobresia* Willd., *Schoenoxiphium* Nees, *Uncinia* Pers.) and infrageneric groups has been contentious with many taxa possessing a mixture of features. Traditionally, genera have been distinguished on the basis of differences in the morphology of the utricle and rachilla (i.e., the pistillate spikelet; Fig. 1), the latter interpreted as the continuation of the axis that bears a single female flower. *Carex*, *Cymophyllus*, and *Uncinia* are characterized by completely closed utricles (Fig. 1). *Cymophyllus* (1 sp.) is distinguished by its unique leaf morphology, short rachillae and white, solitary androgynous spikes. *Uncinia* (ca. 60 spp.) is characterized by an elongate rachilla, which is exsert from the utricle and bent like a hook. *Carex* (ca. 2,000 spp.) usually has multiple, non-white spikes and reduced rachillae that lack a hook (Reznicek, 1990). In contrast to these genera, *Kobresia* (ca. 50 spp.) and *Schoenoxiphium* (ca. 17 spp.) have open utricles with well-developed rachillae that bear male flowers at their termini (Fig. 1). Inflorescences are often highly compound (>1 lateral order), the consequence of proliferation of both rachillae and inflorescence axes. *Kobresia* and *Schoenoxiphium* are primarily distinguished on the basis of rachilla morphology and geography (northern hemisphere vs. predominantly South African). Past hypotheses regarding primitive and derived characters states in Cariceae are based on the assumption that compound inflorescences, composed of androgynous peduncled spikes, are primitive. For this

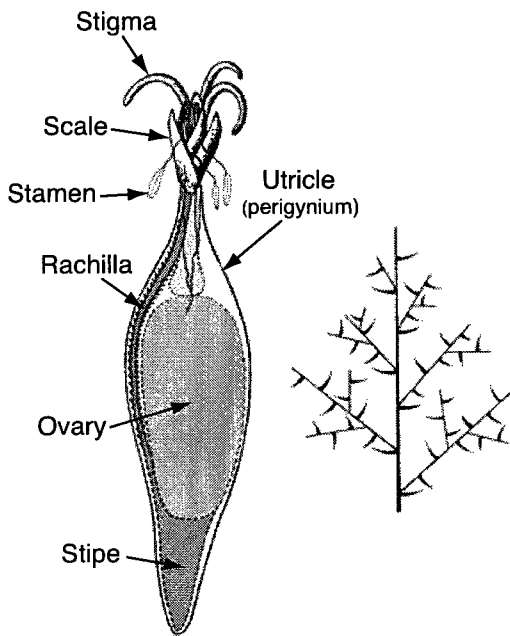
Fig. 1 Cariceae generic circumscription. For each genus, typical spikelet morphologies are portrayed next to a stylised representation of their inflorescences [highly compound (>1 lateral order), multispicate and/or unispicate]. Note that the female spikelets in *Schoenoxiphium* and *Kobresia* have open utricles (i.e., not fused to apex) and rachillae that typically have male flowers at their apex, whereas *Uncinia* and *Carex* have closed utricles and sterile rachillae (i.e., when present). *Schoenoxiphium* can be distinguished from *Kobresia* by flattened rachillae with scabrous or ciliate margins that possess more highly developed male apices. *Uncinia* is separated from *Carex* by hooked rachillae exsert from the utricle. *Cymophyllus* has a similar spikelet and inflorescence morphology to unispicate *Carex*. Note that rachillae may be present or absent in all *Carex* subgenera. Modified from Starr et al. (2008)



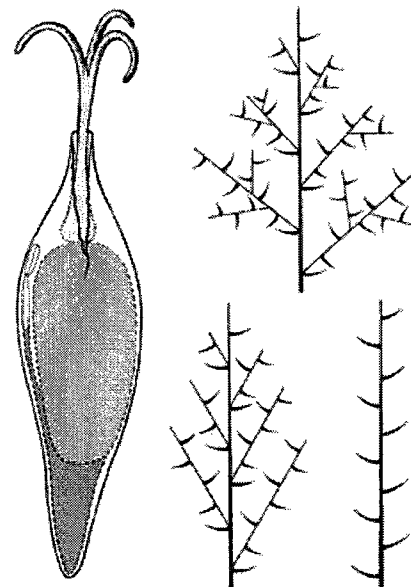
Carex



Uncinia



Schoenoxiphium



Kobresia

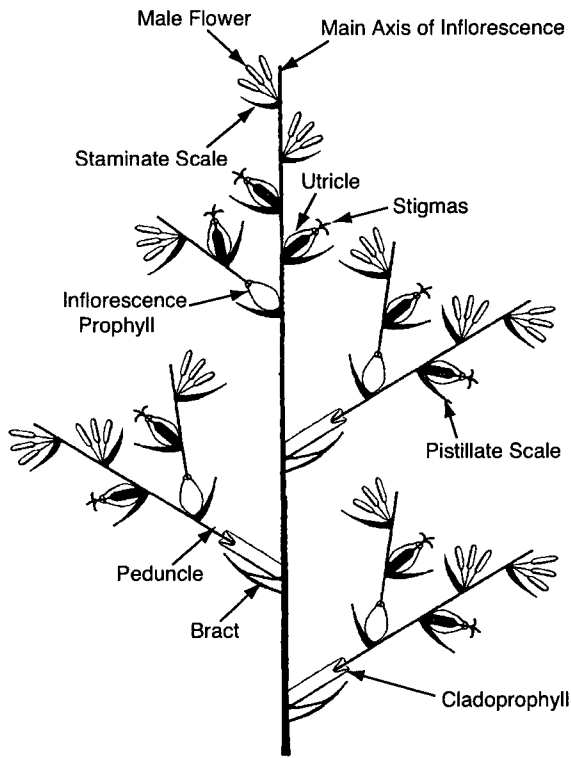
reason, *Kobresia* and *Schoenoxiphium* are usually considered the least derived members of the tribe (Reznicek, 1990).

Owing to its size and variability, *Carex* has a particularly complex infrageneric taxonomy. In the only comprehensive monograph of the genus, Kükenthal (1909) divided *Carex* into four subgenera (Fig. 2): (1) *Vigneastra* (Tuck.) Kük. [= *Indocarex* (Baill.) Kük. in Engl.; highly compound bisexual spikes with the peduncles of the primary axes subtended by cladoprophylls, but with secondary and tertiary floral aggregations associated with utricle-like inflorescence prophylls]; (2) *Carex* (mostly tristigmatic flowers, peduncled unisexual spikes with the peduncle of at least the lowest spike subtended by a scale-like or ocreiform cladoprophyll); (3) *Vignea* (P. Beauv. ex Lestib. f.) Perterm. (sessile bisexual spikes, usually distigmatic flowers, no prophylls, setaceous bracts); and (4) *Psyllophora* (Degl.) Peterm. (= *Primocarex* Kük. in Engl.; solitary, terminal spikes) (Reznicek, 1990). Subgenus *Vigneastra*, with its highly compound inflorescences, is regarded as being derived from a *Kobresia*- or *Schoenoxiphium*-like ancestor and is usually considered ancestral for the genus (but see Reznicek, 1990).

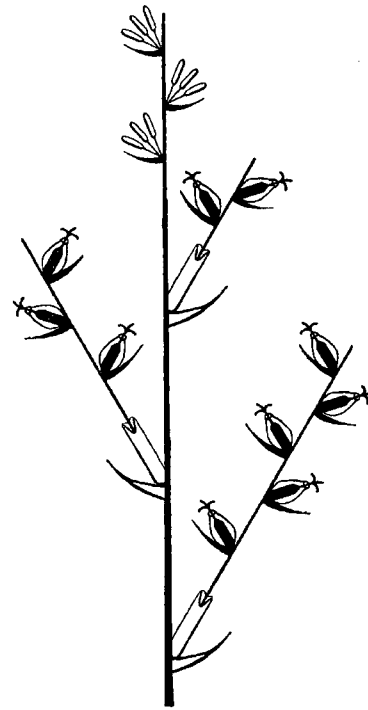
Significant variation, approaching the extremes found in the tribe as a whole, occurs within most *Carex* subgenera. For example, the highly compound inflorescences of subgenera *Vignea* p.p., *Carex* p.p. and *Vigneastra*, are similar to those found in *Schoenoxiphium* or *Kobresia* p.p., while the reduced unispicate inflorescences of subgenera *Carex* p.p. and *Psyllophora*, approach the morphology of *Uncinia*, *Cymophyllus* and *Kobresia* p.p. Although many authors consider Kükenthal's (1909) classification as unnatural, his taxonomy is generally maintained because of its utility for organizing gross morphological types and because of the lack of any widely accepted alternatives (e.g., Raymond, 1959; Chater, 1980; Jermy et al., 1982; Kukkonen, 1978; Kukkonen & Toivonen, 1988; Egorova, 1999).

The goal of this study is to review the impact of recent DNA sequence analyses on our understanding of Cariceae phylogeny, classification and evolution. To explore character evolution we performed an nrDNA ITS + ETS 1f analysis of taxa selectively chosen from four different studies (Starr et al., 2004, 2008; Ford et al., 2006; Waterway & Starr, 2007) to represent both "typical" variation within major taxa and taxa that have played important roles in past phylogenetic scenarios. The trees from our analyses were then manipulated to reflect unique topologies among the major Cariceae clades seen in previous phylogenetic analyses to determine what effect they would have on our inference of character evolution. This gave us an insight into the origin of the caricoid flower and the evolution of some of the most important traits used in generic and subgeneric circumscription. Based on our topologies and those of previous studies, past morphological evidence, and the results of our character analyses, we also make recommendations for future Cariceae research and classification.

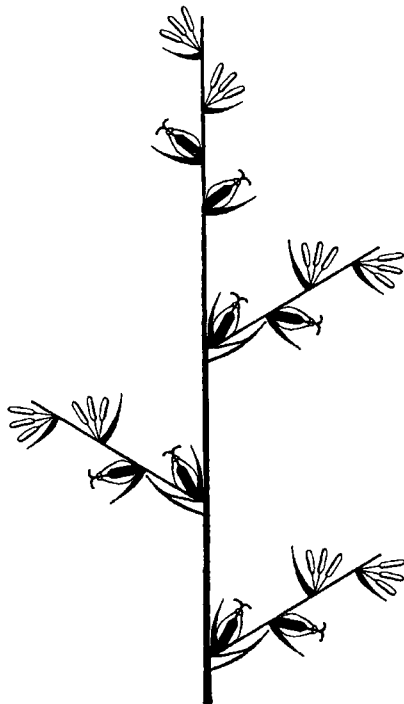
Fig. 2 *Carex* subgeneric circumscription based on Kükenthal (1909) (see "Introduction" for details). Note that subg. *Vigneastra* is distinguished from all other subgenera by the presence of peduncled, bisexual spikes (androgynous) with cladoprophylls and inflorescence prophylls; subg. *Carex* by peduncled, predominately unisexual spikes (lateral females, terminal males) with cladoprophylls; subg. *Vignea* by typically sessile, bisexual spikes (androgynous or gynaeandrous), two stigmas, and the absence of cladoprophylls, and subg. *Psyllophora* by a unispicate inflorescence. Reprinted from Starr et al. (2008)



subg. *Vigneastra*



subg. *Carex*



subg. *Vigneae*



subg. *Psyllophora*

Materials and Methods

Phylogenetic Analyses

All ITS and ETS 1f sequences from the 52 taxa used in the previous study by Starr et al. (2004) were included in analyses, in addition to a further 53 taxa selected from the analyses of Starr et al. (2008), Ford et al. (2006), and Waterway and Starr (2007). ITS and ETS 1f sequences for the unusual *Carex* subg. *Vignea* species *C. baldensis* L. were generated for this study using the PCR primers, and DNA amplification and sequencing techniques described in Starr et al. (2003, 2004). Sequences for both these regions are available from GenBank by using accession numbers EF363120 (ITS) and EF363121 (ETS 1f). The taxa and taxonomy used in this analysis are given in Table 1. The aligned matrices for all analyses, including scored characters for indels and morphology can be obtained from TreeBASE (<http://www.treebase.org/>).

Sequences were initially aligned with Clustal X (Thompson et al., 1997) and then adjusted manually using parsimony as an objective criterion to choose between potential alignments (Starr et al., 2004). Characters 71–100, 137–140, 203–206, 239–242, 269–281, and 1107–1111 were excluded from all analyses due to alignment ambiguity or the presence of sequence repeats. Insertion/deletions (indels) were scored in GapCoder (Young & Healy, 2003) using the ‘simple’ gapcoding method of Simmons and Ochoterena (2000). These indels were only used in parsimony analyses.

Tree searches were performed using parsimony and Bayesian methods. For both methods *Eriophorum vaginatum* and *Scirpus polystachyus* were placed in the outgroup based on previous molecular analyses that strongly suggest these taxa are sister to Cariceae (Muasya et al., 1998; Starr et al., 2006; Simpson et al., 2007). Parsimony analyses were conducted in PAUP* 4.0b10 (Swofford, 2003) using heuristic searches and a random addition sequence of taxa for 2,000 replicates with the MULTREES option on. Support for internal branches was assessed via the bootstrap (BS; Felsenstein, 1985) using a simple addition sequence for 10,000 replicates with the MULTREES option off (DeBry & Olmstead, 2000). Clade support was subjectively described (strong, weak, etc.) according to the scheme used by Starr et al. (2004) which is based on explicit intervals in BS values. Posterior probabilities (PP, see below) were not considered when describing clade support.

Bayesian analyses were performed in MrBayes 3.0b4 (Huelsenbeck & Ronquist, 2001). The posterior tree distribution was estimated via a Metropolis-coupled Markov Chain Monte Carlo (MC³) run of 1,000,000 generations with a tree sampled every 100th generation from one (the “cold” chain) of four simultaneously run Markov chains. A general-time-reversible (GTR) model incorporating a gamma distribution (*G*) and invariant sites (*I*) was enforced during the running of the chain. The model was chosen using MrModeltest 1.1b (J. A. A. Nylander, Uppsala University). A plot of log-likelihoods versus generation number was used to determine the point where the chain levelled off and began to fluctuate around a stable value (i.e., the stationary phase). Trees sampled prior to the stationary phase were discarded. To assess whether enough generations had been run to reach convergence and to determine whether sufficient mixing of the chain had occurred to

Table 1 Classification and Voucher Data for Cariceae Taxa Used in ITS and ETS 1f Analyses*Carex* L.

subg. *Carex* sect. *Abditispicae* G. A. Wheeler, *C. collumanthus* (Steyerm.) Mora, Colombia: Arauca, Sierra Nevada del Cocuy, Cleef 8875, (NY) (AY241987, AY241988); sect. *Acrocystis* Dumort., *C. albicans* Willd., USA: Arkansas, Scott Co., Ford 9440 & Naczi, (WIN) (AF027439, AF027478, AY241986); sect. *Depauperatae* Meinsh., *C. depauperata* Curt. ex With., UK: England, Surrey, Rich 01, (OXF) (AY241984, AY241985); sect. *Fecundae* Kük. in Engl., *Carex fecunda* Steud., Bolivia: La Paz, Inquisivi, 1–4 km SW of Quime, Lewis 38074, (MICH) DQ115170, DQ115171; sect. *Griseae* (L. H. Bailey) Kük., *C. hitchcockiana* Dewey, Canada: Quebec, Ile Perrot, Waterway 2001.082, (MTMG) [AY757614, AY757675]; sect. *Hallerianae* (Ascherson & Graebner) Rouy, *C. tenax* Dewey, U.S.A.: Louisiana, Natchitoches Co., P. Hyatt 10401, (MTMG) [AY757610, AY757671]; sect. *Hymenochlaenae* (Drejer) L. H. Bailey, *C. cherokeensis* Schwein., USA: Florida, Holmes Co., Waterway 2000.044, (MTMG) [AY757619, AY757680], *C. misera* Buck., USA: North Carolina, Jackson Co., Waterway 2002.021, (MTMG) [AY757607, AY757668], *C. sylvatica* Huds., SWITZERLAND: forest near Basal, Lechowicz s. n., (MTMG) [AY757599, AY757660]; sect. *Laxiflorae* (Kunth) Mack., *C. blanda* Dewey, Canada: Ontario, Peterborough Co., Bakowsky 96–176, (WIN) (AF027445, AF027484, AY241983); sect. *Lupulinae* J. Carey, *C. grayi* J. Carey, USA: Illinois, Jackson Co., Waterway 98.036, (MTMG) [AY757580, AY757642], *C. lupulina* Willd., Canada: Quebec, Hull, Lac Leary, Waterway 97.127, (MTMG) [AY757576, AY757638]; sect. *Paniceae* G. Don, *C. livida* (Wahl.) Willd., USA: New Jersey, Burlington Co., Waterway 98.078, (MTMG) [AY757628, AY757688], *C. vaginata* Tausch, Canada: Labrador, ca. 12 km E of Schefferville, Waterway 97.085, (MTMG), [AY757629, AY757689]; sect. *Phacocystis* Dumort., *C. aquatilis* Lam., Canada: Quebec, Lac St. Francois, Y. Bérubé 99.009, (MTMG) [AY757590, AY757651], *C. crinita* Wahl., Canada: Quebec, Vaudreuil, Waterway 99.002, (MTMG) [AY757589, AY757650], *C. nigra* (L.) Reichard, France: Col du Luitel, Playford 9807 et al., (FHO) (AY241989, AY241990); sect. *Phyllostachyae* Tuckerm. ex Kük., *C. backii* Boott, Canada: Ontario, Niagara R. M., Ball s.n., (WIN) (AF027411, AF027453, AY241968), *Carex cordillerana* Saarela & B. A. Ford, USA: Utah, Salt Lake Co., 12 mi SE of Salt Lake City, Naczi 3433 & Thieret, (WIN) DQ115132, DQ115133; sect. *Porocystis* Dumort., *C. swanii* (Fern.) Mack. USA: Illinois, Pope Co., Waterway 98.024, (MTMG) [AY757603, AY757530]; sect. *Racemosae* G. Don, *C. mertensii* J.D. Prescott, USA: Washington, Chelan Co., Waterway 97.054, (MTMG) [AY757592, AY757653]; sect. *Rostrales* Meinsh., *C. folliculata* L., USA, New Jersey, Burlington Co., Waterway 98.094, (MTMG) [AY757601, AY757662]; sect. *Squarrosae* J. Carey, *C. squarrosa* L., USA: Illinois, Pope Co., Waterway 98.020, (MTMG) [AY757587, AY757648], *C. typhina* Michx., USA: South Carolina, Manchester State Forest, Waterway 2000.016, (MTMG) [AY757588, AY757649]

subg. *Psyllophora* (Degl.) Peterm. (= subg. *Primocarex* Kük.) sect. *Aciculares* (Kük.) G.A. Wheeler, *C. acicularis* Boott, New Zealand: Fiordland, Southland Land District, Ford 113/98, (FHO) (AY242012, AY242013); *C. vallis-pulchrae* Phil., Argentina: Tierra del Fuego, Laegaard 13290, (AAU) (AY012619, AY012620); sect. *Capituligerae* Kük., *Carex capitata* L., Canada: Manitoba, Twin Lakes, ca. 20 km E of Churchill, Ford 02379 et al., (WIN) DQ115118, DQ115281; sect. *Caryotheca* V. Krecz. ex Egor., *C. phyllostachys* C.A. Meyer, Turkey: Prov. Adana, Bahçe District, Davis & Hedge D. 26885, (BM 000059251) (AY242016, AY242017); sect. *Dornera* Heuff., *C. nigricans* C.A. Meyer, Canada: British Columbia, Mount Revelstoke, Ford 9720, (WIN) (AY242042, AY242043); *C. pyrenaica* Wahlenb., New Zealand: Fiordland, Southland Land District, Ford 104/98, (FHO) AY244528, AY244529; sect. *Filifoliae* (Tuckerm.) Mack., *C. filifolia* Nutt., Canada: Manitoba, Lauder Sand Hills, Punter & Punter s. n., (WIN) (AF027433, AF027473) AY244530; sect. *Firmiculmes* (Kük.) Mack., *C. geyeri* Boott, USA: Montana, Cascade Co., Starr MT96039, (WIN) (AF027434, AF027474) AY244527; sect. *Junciformes* (Boeck.) Kük., *C. aphylla* Kunth, Argentina: Prov. Rio Negro, Laegaard 13496, (AAU) (AY242014, AY242015); sect. *Leptocephalae* L.H. Bailey, *C. leptalea* Wahlenb., Canada: Alberta, 2 km NE of Manly Comer, Starr 96014 et al., (WIN) (AY241979, AY241980); sect. *Leucoglochis* Dumort., *C. microglochis* Wahlenb., (1) Ecuador: Prov. Chimborazo, Molau, Eriksen & Klitgaard 2329, (GB) AY244519, AY244520; (2) UK: Scotland, Meall Greigh, Starr 98017 & Scott, (FHO) AY244517, AY244518; *C. parva* Nees, China: Yunnan, Diqing Prefecture, Aldén et al. s.n., K.E.G. No. 1252, (E) AY244523, AY244524; *C. pauciflora* Lightf., France: Col du Luitel, Playford 9806 et al., (FHO) (AY242040, AY242041); sect. *Longespicatae* Kük., *C. monostachya* A. Rich., Kenya: Muasya 1052, (K) (AY241977, AY241978); sect. *Nardinae* (Tuckerm.) Mack., *C. nardina* Fries, USA: Wyoming, Big Horn Co., Starr et al. WY96134, (FHO) (AY241973, AY241974); sect. *Obtusatae* (Tuckerm.) Mack., *C. obtusata* Lilj., Canada: Manitoba, Portage Sand Hills, Ford 9601 et al., (WIN) (AY241981, AY241982); sect. *Physoglochis* Dumort., *C. dioica* L., UK: Scotland, Ben Lawers Visitor's Centre, Starr 98015 & Scott, (FHO) (AY241999, AY242000); sect. *Psyllophora* (Degl.) Koch, *C. pulicaris* L., UK: England, Yorkshire Dales National Park, Starr 98001 & Scott, (FHO) (AY242018, AY242019); sect. *Rupestres* (Tuckerm.) Meinsh., *C. rupestris* All., FRANCE: Col du Galibier, Playford 9801 et al., (FHO) AY244521,

Table 1 (continued)

- AY244522; sect. *Scirpinae* (Tuckerm.) Kük., *C. scirpoidea* Michx., Canada: Alberta, Jasper National Park, Bayer AB-96010 et al., (WIN) (AF027447, AF027486, AY241991).
- subg. *Vignea* (P. Beauv. ex Lestib. f.) Peterm. sect. *Ammoglochin* Dumort. subsect. *Herporrhizae* (O. Lang) Kük., *C. arenaria*⁴ L., UK: Scotland, Lunan Bay Sand Dunes, Starr 98020 & Scott, (FHO) (AY242003, AY242004), *Carex brizoides* L., Germany: Bayern, ca. 55 km E of Nürnberg, ca. 3 km SW of Kirchentumbach, Spellenberg 11575 & Mahrt, (MICH) DQ115108, DQ115109, *Carex praecox* Schreb., Russia: Kalmykia, ca. 15 km SW of Elista, Skvortsov s.n. & Kostina, (MO) DQ115248, DQ115249, subsect. *Siccatae* Carey, *Carex siccata* Dewey, Canada: Manitoba, ca. 1.5 km N of town of Falcon Lake, Naczi 9862 & Ford, (DOV) DQ115274, DQ115275; sect. *Baldenses* Kük., *C. baldensis* L., Switzerland: Montreaux (cultivated by A. A. Reznicek), Reznicek 8250, (MICH) EF363120, EF363121; sect. *Curvulae* Tuckerm. ex Kük., *C. curvula* All., France: Col du Galibier, Playford 9803 et al., (FHO) (AY242030, AY242031); sect. *Divisae*, H. Christ ex Kük. in Engl., *Carex douglasii* Boott in Hook., USA: Colorado, Park Co., Pike National Forest, Kenosha Pass, Ford 99252 et al., (WIN) DQ115156, DQ115157; sect. *Deweyanae* (Tuckerm. ex Mack.) Mack., *C. deweyana* Schw., Canada: Alberta, Edmonton, Starr 96007, (WIN) (AF027437, AF027476, AY242007); sect. *Gibbae* Kük. in Engl., *Carex gibba* Wahlenb., China: Hunan, Li Ling, Da Lin County, Liu 6741, (MO) DQ115174, DQ115175; sect. *Glareosae* Don in Loudon, *Carex mackenziei* V. I. Krecz. in Kom. et al., Canada: Manitoba, Churchill area, Zbiegniewicz 83-253, (WIN) DQ115208, DQ115209; sect. *Heleoglochin* Dumort., *Carex decomposita* Muhl., USA: Delaware, New Castle Co., ca. 3 mi S of Middletown, Naczi 9313 et al., (DOV); DQ115140, DQ115141, *Carex paniculata* L., SPAIN: Almeria, Rio de Ohanes, Pallares s.n., (DOV) DQ115236, DQ115237; sect. *Macrocephalae* Kük. in Engl., *Carex kobomugi* Ohwi, USA: Delaware, Sussex Co., ca. 2.5 mi S of Dewey Beach, Naczi 9459 & McAvoy, (DOV, WIN) DQ115194, DQ115195, *Carex macrocephala* Willd. ex Spreng., Canada: British Columbia, Tsawwassen, Boundary Bay Regional Park, Ford 9715, (WIN) DQ115210, DQ115211; sect. *Multiflorae* (J. Carey) Kük. in Engl., *Carex vulpinoidea* Michx., USA: Kentucky, Monroe Co., SE of Tomkinsville, along the W side of route 216, along McFarland Creek, Ford 9872 & Naczi, (WIN) DQ115308, DQ115309; sect. *Ovales* Kunth, *Carex cristatella* Britton in Britton & A. Brown, USA: Michigan, Monroe Co., ca. 3 mi ENE of Petersburg, Naczi 8277, (DOV) DQ115134, DQ115135; sect. *Phaestoglochin* Dumort., *Carex aggregata* Mack., USA: Kentucky, Monroe Co., SE of Tomkinsville, along the W side of route 216, along McFarland Creek, 23 May 1998, Ford 9874 & Naczi, (WIN) DQ115084, DQ115085, *Carex hoodii* Boott in Hook., Canada: Alberta, Castle Special Management Area of the Rocky Mountain Forest Reserve, N side of the Carbondale River, Ford 00120 & Saarela, (WIN) DQ115178, DQ115179; sect. *Phleoideae* Meinsh., *Carex albata* Boott ex Franch., Sav. Japan: Honshu, Toyama, Fukumitsu-cho, Nishi-tonami-gun, Tsugaru 17287, (MO) DQ115086, DQ115087; sect. *Remotae* (Aschers.) C.B. Clarke, *C. remota* L., UK: England, Yorkshire Dales National Park, Starr 98022 & Scott, (FHO) (AY242001, AY242002); sect. *Stellulatae* (Kunth) Christ, *C. echinata* Murray, UK: Scotland, Sròn Dha Murchdi, Starr 98009 & Scott, (FHO) (AY242005, AY242006), *Carex exilis* Dewey, USA: Maine, Hancock Co., Corea Heath, ca. 1 mi NW of Corea, Reznicek 9150, (MICH) DQ115168, DQ115169; sect. *Vulpinae* (Heuff.) H. Christ, *Carex conferta* Hochst. ex A. Rich. var. *lycurus* (K. Schum.) K. A. Lye, Zimbabwe: Vumba Mountains, Toozes swamp, Browning 562, (MICH) DQ115128, DQ115129, *Carex crus-corvi* Shuttl. in Kunze, USA: Mississippi, Warren Co., 2.8 mi N Yazoo River Crossing of Hwy. 61, Bryson 5877, (WIN) DQ115136, DQ115137, *Carex neurophora* Mack. in Abrams & R. S. Ferris, U. S. A.: Oregon, Baker Co., S side of Anthony Lake, Wallowa-Whitman National Forest, Wilson 7476 et al., (MICH) DQ115224, DQ115225, *Carex otrubae* Podp., UK: England, Oxfordshire, Oxford, Starr 98023, (WIN) DQ115226, DQ115227
- subg. *Vigneastra* (Tuck.) Kük. (= subg. *Indocarex* (Baill.) Kük.) sect. *Baccantes* (T. Koyama) P.C. Li, *C. baccans* Nees, Taiwan: Wu Lai, Taipei, Yen 078, (WTU) (AF027449, AF027488, AY241994); sect. *Indicae* Tuckerm., *C. cruciata* Wahlenb., Malaysia: Mulu National Park, Sarawak, Yen 075, (WTU) (AF027450, AF027489, AY241995); *C. echinocloe* Kunze, Kenya: Muasya 1051, (K) (AY241992, AY241993); *C. filicina* Nees, Taiwan: Yang Ming Shan National Park, Da Tun Shan, Yen 0076, (WTU) (AY241996, AY241997); sect. *Polystachyae* Tuckerm., *C. polystachya* Sw., Belize: Cayo District, Jones 11275 & Wipff, (MICH) (AF027448, AF027487, AY241998)
- Cymophyllus* Mack.
*C. fraserianus*⁵ (Ker-Gawler) Kartesz & Gandhi, USA: Tennessee, Blount Co., along road to Cades Cove, Sharp s.n., (cultivated at K), Starr 98024 ex RBG Kew, (FHO) (AY241969, AY241970)
- Kobresia* Willd.
subg. *Compositae* (C. B. Clarke) Kukkonen, *K. curticeps* (C. B. Clarke) Kük., INDIA: Sikkim, East District, Long & Noltie s.n., E.E.N.S. No. 73, (E) (AY242044, AY242045); *K. laxa* Nees, INDIA: Sikkim, North District, Long & Noltie s.n., E.E.N.S. No. 211, (E) (AY241975, AY241976)
- subg. *Kobresia* sect. *Hemicarex* (Benth.) C. B. Clarke, *K. esenbeckii* (Kunth) Noltie, India: Sikkim, West

Table 1 (continued)

District, Bikbari, Long *et al. s.n.*, *E.S.I.K. No. 335*, (E) (AY242032, AY242033); *K. nepalensis* (Nees) Kük., INDIA: Sikkim, North District, Long & Noltie, *E.E.N.S. No. 291*, (E) (AY242034, AY242035); sect. *Kobresia*, *K. myosuroides* (Vill.) Fiori, FRANCE: Col du Galibier, Playford 9804 *et al.*, (FHO) (AY242036, AY242037); *K. schoenoides* (C.A. Meyer) Steud., INDIA: Sikkim, West District, Chhopta, *E.S.I.K. No. 647*, (E) (AY242038, AY242039); *K. simpliciuscula*[§] (Wahlenb.) Mack., Canada: British Columbia, Emerald Lake, Ford 9710, (FHO) (AY241971, AY241972)

Schoenoxiphium Nees
S. ecklonii Nees, South Africa: Cape Province, George-Knysna, Baard 128, (PRE) (AY242024, AY242025); *S. filiforme* Kük., South Africa: Eastern Cape, Drakensbergs, Phillipson 666, (PRE) (AY242020, AY242021); *S. lanceum*[§] (Thunb.) Kük., South Africa: Cape Province, Stellenbosch, McDonald 829, (PRE) (AY242028, AY242029); *S. lehmannii* (Nees) Steud., South Africa: Natal Province, Ngoye Forest Reserve, Williams 1007, (PRE) (AY242026, AY242027); *S. sparteum* (Wahlenb.) C. B. Clarke, South Africa: Orange Free State, Ladybrand, De Lange FA 57, (PRE) (AY242022, AY242023)

Uncinia Pers.
 subg. *Uncinia* (= *Eu-Uncinia* Kük.)
 sect. *Platyandrae* C. B. Clarke ser. *Hamatae* Hamlin, *U. hamata* (Swartz) Urban, Ecuador: Prov. Pichincha, N face of Pichincha, Starr 99032 & Amigo, (FHO) (AY012664, AY012665); ser. *Macrotrichae* Hamlin, *U. ecuadorensis* G. A. Wheeler & Goetghebeur, Ecuador: Prov. Cotacachi, S face of Nevado Cotacachi, Starr 99020 & Amigo, (FHO) (AY012661, AY012662); *U. erinacea* (Cav.) Pers., Chile: Isla Grande de Chiloé, Parque Nacional de Chiloé, Vann 9804, (FHO) AY244531, AY244532; ser. *Trichocarpae* Hamlin, *U. multifaria* Nees ex Boott, in Hook. f., Chile: Isla Grande de Chiloé, P. N. de Chiloé, Vann 9803, (FHO) (AY012667, AY012668); *U. phleoides* (Cav.) Pers., Chile: Isla Grande de Chiloé, P. N. de Chiloé, Vann 9801, (FHO) (AY012670, AY012671)
 sect. *Uncinia* (= *Stenandrae* C. B. Clarke) ser. *Compactae* Hamlin, *U. flaccida* S. T. Blake, Australia: Australian Capital Territory, Southern Slope of Mt. Murray, Gilmour 6604, (CANB) (AY012643, AY012644); ser. *Graciles* Hamlin, *U. banksii* Boott, New Zealand: North Island, Auckland Ecological Region, Cameron 7510, (AK) (AY012634, AY012635); *U. subsacculata* G. A. Wheeler & Goetghebeur, Ecuador: Prov. Pichincha, N face of Pichincha, Starr 99035 & Amigo, (FHO) (AY012652, AY012653); *U. tenuis* Poeppig ex Kunth, Ecuador: Prov. Imbabura, Cerro Blanco, Øllgaard 98225, (AAU) (AY012658, AY012659); ser. *Leptostachyae* Hamlin, *U. leptostachya* Raoul, New Zealand: Otago Land District, Otago Peninsula, Enright *s.n.*, (CHR 505712) (AY012631, AY012632); ser. *Macrolepidae* Hamlin, *U. macrolepis* Decne., Ecuador: Prov. Pichincha/Napo, Volcan Antisana, Starr 99028 & Amigo, (FHO) AY244535, AY244536; *U. triquetra* Kük., (1) Argentina: Tierra del Fuego, Cerro Huehupen, Laegaard 13233, (AAU) AY244542; (2) Chile: Laguna el Parrillar, Costa E., Pisano 3.917, (RNG) AY244541; ser. *Ripariae* Hamlin, *U. laxiflora* Petrie, New Zealand: Wellington Land District, Ruahine Ranges, Bellingham 789, (CHR) (AY012622, AY012623)
 subg. *Hemihamatae* (Hamlin) Kukkonen (=subg. *Pseudocarex* Kük., nom. illegit.), *U. kingii* Boott, Chile: Isla Hoste, Pisano 5530, (GH) AY244525, AY244526

Outgroups
Eriophorum vaginatum L., UK: England, Starr 98007 and Scott, (FHO) (AY242008, AY242009); *Scirpus polystachyus* F. Muell., Australia: New South Wales, Wilson *s.n.* (MWC 5927) (K) (AY242010, AY242011)

Ingroup taxa are arranged in alphabetical order to series, with outgroup taxa placed last. Generic delimitation follows Kükenthal (1909) and Ball *et al.* (2002). Subgeneric circumscription adheres to Kükenthal (1909), Kukkonen (1967) and Zhang (2001), whilst sections follow Kükenthal (1909), Wheeler (1989), Egorova (1999), Dai and Liang (2000), Zhang (2001) and Ball and Reznicek (2002). The series of *Uncinia* are circumscribed as in Hamlin (1958, 1959) except for sect. *Platyandrae* C. B. Clarke ser. *Trichocarpae* Hamlin which includes *Uncinia multifaria* Nees ex Boott (see Starr *et al.* 2003). Individuals sampled from the same species are numbered (1) and (2). Note that the ITS and ETS 1f sequences of *U. triquetra* were combined from two separate individuals. The type species for Cariceae genera (Goetghebeur, 1986; Nicolson 1992) and *Carex* subgenera (Egorova, 1999) included in the analysis are marked respectively by (§) and (‡). GenBank numbers in parentheses represent sequences from Starr *et al.* (1999, 2003, 2004). GenBank numbers in brackets represent sequences from Waterway and Starr (2007). All remaining GenBank numbers are from Ford *et al.* (2006) or Starr *et al.* (2008). Herbarium acronyms follow Holmgren *et al.* (1990).

provide reliable parameter estimates, three further independent analyses using the same initial parameters as above were conducted. Convergence and mixing were assessed by a comparison of likelihood values, the mean and variance of model parameters, and the topologies of 50% majority rule consensus trees that were generated via the “sumt contype = allcompat” command (i.e., with all compatible partitions). The final Bayesian topology used in character analyses also used the “sumt contype = allcompat” command to generate a consensus of all trees sampled from the stationary phase of the four independent Bayesian analyses conducted. Estimates of branch lengths on this consensus were determined from the mean branch lengths of all summarized trees.

Character Evolution

The history of character change was inferred in Mesquite 1.06 (Maddison & Maddison, 2005) for six of the most important characters used in Cariceae classification using the Bayesian “allcompat” topology and the criteria of parsimony and maximum likelihood (ML; all characters were treated as unordered). For parsimony reconstructions, the major Cariceae clades in the Bayesian consensus were rearranged manually in Mesquite to reflect unique parsimony, ML or Bayesian topologies that were recovered in either Yen and Olmstead (2000a, b), Roalson et al. (2001), Starr et al. (2004, 2008), Waterway and Starr (2007), or the present parsimony and Bayesian analyses. Only topologies that resolved all four major Cariceae clades were used. These rearrangements were done to determine how the conclusions drawn on character evolution in this study would be affected by the topologies of previous analyses. ML reconstructions were performed under a Markov k-state 1 parameter model (Mk1) of character evolution. For interpretive purposes, likelihood reconstructions were reported as proportional likelihoods (pL) adding up to 1. Nodal support for one character state over another was considered significant if reconstructions differed by two or more log-likelihood units (Edwards, 1972; Pagel, 1999; significant support is denoted by $*pL$ in “Results”). Multiple states were reported for binary characters where neither state was supported at a node and for multistate characters where at least two states were significantly different from a third, but not from each other. All ingroup and outgroup taxa were scored for the following characters (see Figs. 1 and 2): (1) Gross Inflorescence Structure (unispicate, 0; occasionally unispicate, 1; multispicate, 2; highly compound, 3); (2) Degree of Utricle Fusion (closed, 0; open, 1); (3) Spikelet Sexuality (one-flowered pistillate, 0; bisexual, but monoecious, 1; perfect, 2); (4) Stigma Number (three, 0; two, 1); (5) Cladoprophylls (present, 0; absent, 1); (6) Inflorescence Prophylls (present, 0; absent, 1). Character 1 can be difficult to score because some Cariceae species (e.g., *Carex exilis*, *C. curvula*) are not strictly unispicate or multispicate. Highly compound inflorescences were defined as those possessing more than one lateral order. All *Kobresia* and *Schoenoxiphium* species were treated as possessing open utricles with bisexual spikelets, except for *K. nepalensis* and *K. esenbeckii* whose pistillate spikelets are strictly one-flowered (Noltie, 1994). It should be noted, however, that considerable variability in characters 2 and 3 may be observed not only between, but even within, the inflorescences of *Kobresia* and *Schoenoxiphium* species (Clarke, 1883; Noltie,

1994). Since utricles are unique to Cariceae, character 2 could not be scored for outgroup taxa. Following Reznicek (1990), cladoprophylls are defined as the tubular structures found at the bases of the first lateral order of a lateral inflorescence unit (i.e., spike), whereas inflorescence prophylls are utricle-like structures, often possessing a fertile, female flower that are seen at the bases of second lateral order spikes and above as seen in *Carex* subg. *Vigneastra* (Fig. 2). Although *C. baldensis* and *C. gibba* possess utricle-like prophylls that typically possess a fertile, female flower like subg. *Vigneastra* species, both taxa were scored as present for cladoprophylls because the prophyll is found at the base of the first lateral order on the inflorescence. In general, the presence/absence of cladoprophylls for all species in this analysis could not be directly scored due to a lack of material. Unfortunately, such gaps in the dataset cannot be filled from monographic works since the presence/absence and morphology of cladoprophylls has not been consistently described for all infrageneric taxa. Although we recognize that errors in scoring may have been made, for the purposes of this study, all unispicate taxa (i.e., *Uncinia*, *Carex* subg. *Psyllophora*, *Kobresia* p.p., and *Carex* sect. *Phyllostachyae*) were scored as cladoprophylls absent and all multispicate taxa were scored as cladoprophylls present, including *Carex* sect. *Ammoglochin* subsect. *Herporrhizae* (*C. arenaria*, *C. brizoides*, and *C. praecox*), which is the only *Carex* subg. *Vigneae* taxon besides *C. gibba* known to possess cladoprophylls (Ford et al., 2006). Since the genus *Schoenoxiphium* possesses prophylls that are often utricle-like and fertile at the base of the first, second and above lateral orders (Kukkonen, 1983), all strictly multispicate species from this genus were scored as possessing both cladoprophylls and inflorescence prophylls. These characters were not scored for *S. filiforme* (often unispicate) because of a lack of material.

Results

Phylogenetic Analysis

The aligned matrix of ITS and ETS 1f sequences including 176 indels for 105 taxa produced 1,396 aligned characters of which 89 were excluded, and 629 were parsimony informative. Parsimony searches found 75 trees, 3,927 steps long (CI=0.34; RI=0.68). Because the strict consensus was largely similar to Bayesian results, only a summary of the relationships of the major Cariceae clades is presented for parsimony (Fig. 3). A full description of the composition of these groups is given below.

For Bayesian analyses, plots of log-likelihood values versus generation number indicated that the stationary phase was reached after generation 110,100 (Markov chain 1), generation 143,200 (Markov chain 2), generation 256,900 (Markov chain 3), and generation 174,500 (Markov chain 4). All trees sampled prior to these generations were excluded from majority rule consensus trees as they were not sampled from the posterior distribution. Comparisons of likelihood values, estimates of model parameters and majority rule consensus trees suggested that convergence had been reached in all four Bayesian analyses. Therefore, all 33,157 trees sampled from the stationary phase of all four independent analyses were used to generate a

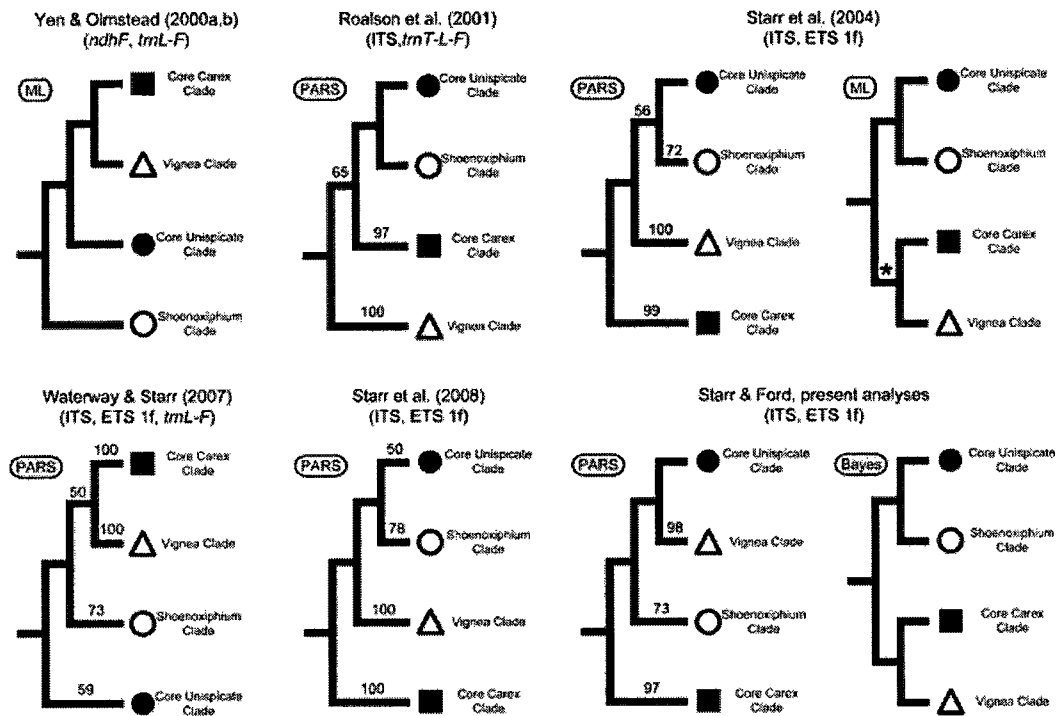
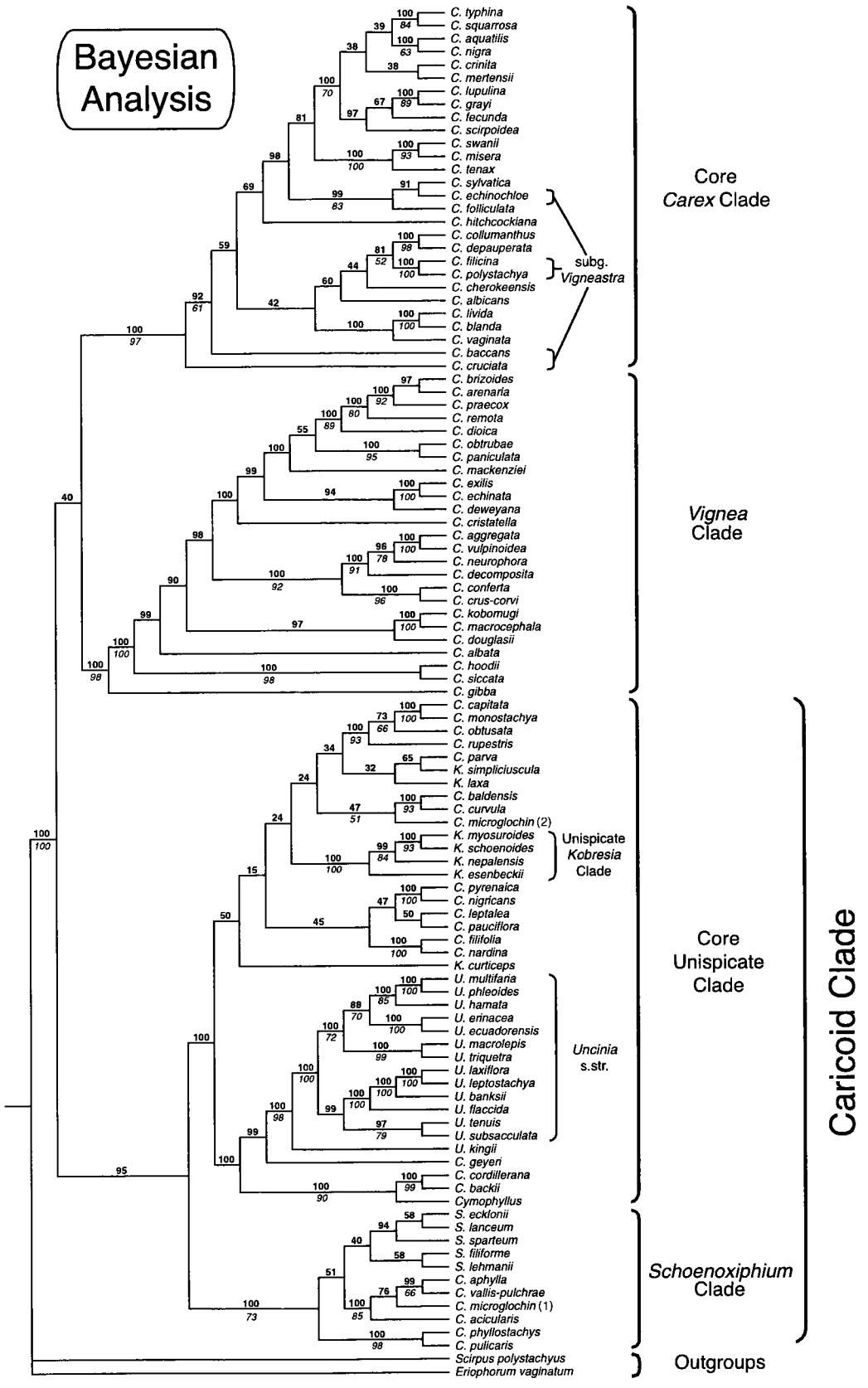


Fig. 3 Relationships of the four major Cariceae clades in all previous analyses where one or more species from each clade was sampled and all four clades were monophyletic. The criterion used to reconstruct phylogeny is abbreviated to the left of each topology (*PARS* parsimony; *ML* maximum likelihood; *Bayes* Bayesian analysis). *Abbreviations with darkened backgrounds* represent unique topologies that were used in character reconstructions. All bootstrap values were derived from parsimony analyses and are given above branches when previously reported. *Asterisks* above *ML* or *Bayesian* topologies represent branches whose lengths were not significantly different from zero. Summary topologies of the present parsimony (strict consensus) and Bayesian analyses are also given for comparison. The *Schoenoxiphium* Clade in Roalson et al. (2001) was represented by a single *Schoenoxiphium* species. The Bayesian analysis of Waterway and Starr (2007) is not depicted since it has the same topology as the Bayesian tree in the present analysis. The branch lengths for the *Core Carex* + *Vignea* clade and *Core Unispicate* Clade in Waterway and Starr (2007) were not significantly different from zero. Squares (*Core Carex* Clade), open triangles (*Vignea* Clade), closed circles (*Core Unispicate* Clade) and open circles (*Schoenoxiphium* Clade) are used to discern differences in topologies

50% majority rule consensus with all compatible groups in MrBayes (Fig. 4). This tree consists of four major Cariceae clades identical to those recovered in parsimony analyses: (1) A strongly supported “*Core Carex* Clade” (97% BS; 100% PP), containing typical multispicate and highly compound (*C. fecunda*) members of *Carex* subg. *Carex*, a dioecious unispicate member (*C. scirpoidea*) of *Carex* subg. *Psyllophora*, and species of *Carex* subg. *Vigneastra* (*C. echinochloe*, *C. filicina*, and *C. polystachya*) that are either variously placed within the clade or successively positioned as sister to all other clade members (*C. cruciata* and *C. baccans*); (2) a strongly supported “*Vignea* Clade” (98% BS; 100% PP) consisting of typical multispicate and highly compound (*C. crus-corvi*, *C. decomposita*, *C. paniculata*)

Fig. 4 Fifty percent majority-rule consensus with all compatible groups of 33,157 trees sampled from the posterior distribution under a GTR + G + I model of sequence evolution. *Numbers above branches* are posterior probabilities; *numbers below branches* are bootstrap values $\geq 50\%$. *Numbers in parentheses* after species epithets correspond to specific vouchers in Table 1. Except for *Cymophyllus*, generic names are abbreviated as follows: *C.* = *Carex*, *K.* = *Kobresia*, *S.* = *Schoenoxiphium*, *U.* = *Uncinia*

Bayesian Analysis



members of *Carex* subg. *Vignea*, a dioecious unispicate species of *Carex* subg. *Psyllophora* (*C. dioica*) and *C. gibba* (subg. *Vignea*), a tristigmatic species with cladophylls that is sister to the remainder of the clade; (3) a moderately supported “*Schoenoxiphium* Clade” (73% BS; 100% PP), consisting of a poorly supported but monophyletic *Schoenoxiphium* (<50% BS; 40% PP) and androgynous unispicate members of *Carex* subg. *Psyllophora* from Europe and South America; and (4) a poorly supported “Core Unispicate Clade” (<50% BS; 100% PP) that consists of the androgynous unispicate species of *Uncinia*, *Kobresia*, *Cymophyllus*, *Carex* subgenera *Carex* (i.e., sect. *Phyllostachyae*) and *Psyllophora* and multispicate species of *Carex* subg. *Vignea* (i.e., *Carex baldensis*) and *Kobresia*. Within the Core Unispicate Clade notable relationships include the strong support for an *Uncinia* s.str. clade (100% BS, 100% PP; Fig. 4) that is sister to *Uncinia kingii* (i.e., *Uncinia* s.l.; 98% BS, 100% PP); the nested position of *Cymophyllus* as sister to *Carex* sect. *Phyllostachyae* (*C. cordillerana* and *C. backii*; 90% BS, 100% PP); an unnatural *Kobresia*, but a strongly supported unispicate *Kobresia* clade (100% BS, 100% PP; Fig. 4), and a nested *C. baldensis* sister to another subg. *Vignea* species, *C. curvula* (93% BS, 100% PP). Notably, Ecuadorian and Scottish samples of *C. microglochin* are positioned in separate clades (Fig. 4).

The only potentially important differences between parsimony and Bayesian analyses lie in the relationships portrayed for the major Cariceae clades (cf. Figs. 3 and 4) and in the fact that *Schoenoxiphium* is paraphyletic in parsimony analyses but monophyletic in Bayesian analyses. These two topological differences are typical of comparisons between parsimony and model-based methods (i.e., ML/Bayesian analyses), although they have never been shown to be statistically significant (Starr et al., 2004, 2008; Waterway & Starr, 2007).

Character Evolution

The generalized topologies of the six trees used in character reconstructions are given in Fig. 3. Character 1, Gross Inflorescence Structure, had a ci of 0.11. For all topologies and reconstruction methods the ancestral character for the *Vignea* Clade is a multispicate inflorescence (**pL*=0.96). Within the *Vignea* Clade, the highly compound inflorescences of *Carex decomposita*, *C. crus-corvi*, and *C. paniculata* have all evolved independently. The dioecious unispicate condition seen in *C. dioica* and the often unispicate condition seen in *C. exilis* have evolved independently from monoecious multispicate ancestors. Either multispicate or highly compound inflorescences are ancestral for the Core *Carex* Clade, although ML reconstructions favour multispicate inflorescences as the more likely state for this node (**pL*=0.79 vs. **pL*=0.15). The dioecious unispicate *C. scirpoidea* evolved by reduction from a monoecious multispicate ancestor. The ancestral condition of the Caricoid Clade is most parsimoniously inferred to be unispicate on the topologies of Roalson et al. (2001), Starr et al. (2004), and in the present Bayesian analysis (PBA). ML reconstructions also suggest that unispicate inflorescences are the most likely ancestral state for this clade (unispicate **pL*=0.83 vs. multispicate **pL*=0.16). In those analyses where the *Schoenoxiphium* and Core Unispicate Clades are separate (Yen & Olmstead, 2000a, b; Waterway & Starr, 2007; present parsimony analysis or PPA), the ancestral state for both clades is ambiguous (multispicate/unispicate). The

root node for Cariceae is ambiguous in all topologies (multispicate/unispicate or multispicate/highly compound for PPA) except those of the PBA and the parsimony analysis of Starr et al. (2004) where it is multispicate. However, all studies have the ancestral state of multispicate at the Cariceae root node if the genus *Schoenoxiphium* is placed as sister to the androgynous unispicate species in its clade. Moreover, when this is done, all those studies that have a Core *Carex* + *Vignea* clade (Yen & Olmstead, 2000a, b; Starr et al., 2004; Waterway & Starr, 2007; PBA) also infer the multispicate condition as being ancestral for this group. ML reconstructions suggest that multispicate inflorescences are more likely ($*pL=0.67$) to be ancestral than unispicate inflorescences ($*pL=0.31$) at the Cariceae root node. Character 2, Utricle Fusion, had a ci of 0.20. Both character reconstruction methods suggest that closed utricles are ancestral at the Cariceae root node and for all of the major clades in the tribe ($*pL=1.00$). Character 3, Spikelet Sexuality, had a ci of 0.33. Perfect flowers are ancestral at the outgroup node in both parsimony and ML ($*pL=0.99$) reconstructions. Likewise, both methods indicate that unisexual spikelets are ancestral for both the Cariceae and for all the major clades in the tribe ($*pL=1.00$). Bisexual spikelets evolved multiple times and in parallel in *Schoenoxiphium* and *Kobresia*. Character 4, Stigma Number, had a ci of 0.08, with three stigmas being the ancestral character state for the tribe and all major Cariceae clades in parsimony and ML ($*pL=0.94-1.00$) reconstructions. Stigma losses have been frequent and have occurred in all major Cariceae lineages. Within the *Vignea* Clade the loss of a stigma distinguishes a large clade that includes all *Carex* subg. *Vignea* species except *Carex gibba* ($*pL=0.99$). Within this distigmatic clade a single reversion to the ancestral tristigmatic condition has occurred in *Carex* sect. *Macrocephalae* (*C. macrocephala* and *C. kobomugi*; $*pL=1.00$). Character 5, Cladoprophylls, had a ci of 0.06. Four of the six topologies examined place the presence of cladoprophylls as the most parsimonious ancestral state for the Cariceae (Roalson et al., 2001; Starr et al., 2004; PPA and PBA). However, if the genus *Schoenoxiphium* is placed as sister to the unispicate androgynous species in its clade, all topologies unambiguously place the presence of a cladoprophyll as ancestral for the tribe. In contrast, ML reconstructions suggest that cladoprophyll absence is more likely ($pL=0.61$) than presence ($pL=0.39$) at the Cariceae root node, although the difference was not significant. All topologies and methods infer cladoprophyll presence ($*pL=0.96$) as the most parsimonious ancestral state for the Core *Carex* Clade. Two topologies (Roalson et al., 2001 and PBA) also unambiguously place the presence of a cladoprophyll as ancestral for a *Vignea* + Core *Carex* Clade, although all other topologies are either ambiguous or consider the presence of a cladoprophyll in the *Vignea* Clade as an autapomorphy for *C. gibba* and a synapomorphy for *Carex* sect. *Ammoglochin* subsect. *Herporrhizae*. Likewise, ML reconstructions reflect the same ambiguity in the presence/absence of cladoprophylls in the *Vignea* + Core *Carex* (presence $pL=0.43$; absence $pL=0.57$) and *Vignea* Clades (presence $pL=0.43$; absence $pL=0.57$), whilst providing strong support for cladoprophyll presence as a synapomorphy for sect. *Ammoglochin* subsect. *Herporrhizae* ($*pL=0.99$). The scale-like cladoprophylls of subsect. *Herporrhizae* and the utricle-like prophylls of *C. baldensis* (Core Unispicate Clade) have evolved independently. The cladoprophylls in *Schoenoxiphium* have also evolved independently. Character 6, Inflorescence Prophylls, had a ci of 0.20. All topologies suggest that inflorescence prophylls

evolved from species that lacked them; the ancestral state at the Cariceae root node is the absence of inflorescence prophylls for both parsimony and ML (* $pL=1.00$) reconstructions. All topologies demonstrate that the inflorescence prophylls in *Schoenoxiphium* have evolved independently of those in *Carex* subg. *Vigneastra*. Although several species of subg. *Vigneastra* are seen near the base of the Core *Carex* Clade, parsimony reconstructions cannot resolve the ancestral state for this clade. In contrast, ML reconstructions indicate that the absence of inflorescence prophylls (* $pL=0.92$) is the ancestral state for this clade. Analyses suggest that the inflorescence prophylls of *C. echinochloe*, *C. filicina* and *C. polystachya* are examples of parallelism.

Discussion

The Major Clades of Tribe Cariceae: Circumscription and Relationships

Although Cariceae studies have differed considerably in their taxonomic (27 taxa in Yen & Olmstead, 2000b vs. 101 in Roalson et al., 2001) and geographic sampling (36.1% of taxa were of North American or European origin in Starr et al., 2008 vs. 82.5% in Waterway & Starr, 2007), all analyses have recovered the same four major clades recognized by Starr et al. (2004). To facilitate discussions on tribal phylogeny and to avoid the inconsistent practice of characterising clades by numbers or letters (e.g., Roalson et al., 2001; Starr et al., 2004, 2008), Waterway and Starr (2007) named these four clades according to the most distinctive element in each group; i.e., the “Core *Carex*”, “*Vignea*”, “Core Unispicate”, and “*Schoenoxiphium*” Clades (see Results for detailed clade composition). The latter two clades were further described as the “Caricoid” Clade (Waterway & Starr, 2007) to convey the idea that their morphology was different from the “typical” *Carex*-like features seen in the Core *Carex* and *Vignea* Clades.

In agreement with traditional views (e.g., Koyama 1962; Smith & Faulkner, 1976; Reznicek, 1990), molecular phylogenies strongly indicate that the Core *Carex* and *Vignea* Clades are monophyletic (Fig. 3). In contrast, the Core Unispicate and *Schoenoxiphium* Clades have received only moderate support from molecular data (Fig. 3), and the seemingly odd placement of both highly compound and multispicate *Kobresia* and *Schoenoxiphium* amongst androgynous unispicate taxa (*Uncinia*, *Kobresia*, *Cymophyllus*, *Carex* subgenera *Psyllophora* and *Carex* p.p.) appears to defy a morphological definition for these groups. The significant morphological gap that separates the multispicate and unispicate taxa of these clades could be due to an ancient origin followed by extinction, although a clearer explanation may appear when relationships are better resolved by increased character and taxonomic sampling.

Although all four major Cariceae clades have appeared in those analyses that have sampled at least one individual from each group, relationships amongst these clades have not been stable. Six different topologies have been presented in molecular studies, and no group consisting of two or more major Cariceae clades has received more than 65% BS (Fig. 3). Moreover, differences in topology are often seen between parsimony and ML/Bayesian analyses within the same study (Yen & Olmstead, 2000a; Starr et al., 2004; Waterway & Starr, 2007). The majority of

topologies favour a Caricoid Clade sister to a Core *Carex* + *Vigneia* Clade (Fig. 3), but until character sampling is increased, the relationships of the major Cariceae clades should be treated as unresolved.

There is also evidence to indicate that a fifth major clade may exist within the tribe. Recent work by Waterway et al. (2008) suggests that the East Asian *Carex* sect. *Siderostictae* Franch. ex Ohwi (subg. *Carex*), which includes species such as *C. siderosticta* Hance and *C. pachygyna* Franch. et Savat., may be sister to all remaining Cariceae. The implications of this discovery to our conclusions on tribal character evolution and to future tribal analyses are discussed in “Future work”.

Taxonomic Implications of Molecular Phylogenies

Generic Circumscription

The most significant molecular result for generic circumscription is that *Carex* as presently circumscribed is either paraphyletic with respect to all Cariceae genera (Roalson et al., 2001; Starr et al., 2004, 2008; Waterway & Starr, 2007; present analyses) or to all genera except *Schoenoxiphium* (Yen & Olmstead, 2000a, b). The implications of this result to future infratribal taxonomic name changes should be considered while assessing the conclusions drawn below.

Although no analysis has ever recovered a monophyletic *Kobresia*, *Schoenoxiphium* has been strongly supported (100% BS) in the analyses of Yen and Olmstead (2000a, b) and it has been grouped as monophyletic in several ML/Bayesian analyses (Starr et al., 2004, 2008; Waterway & Starr, 2007; PBA). Statistical tests conducted by Starr et al. (2004, 2008; nrDNA data only) suggested that the branch supporting *Schoenoxiphium* was not significantly different from zero. However, Waterway and Starr (2007), whose data also included cpDNA sequences like those of Yen and Olmstead (2000a, b), did find a significant difference and a >95% PP support for the clade. To date, only seven of the ca. 17 species of *Schoenoxiphium* have been sampled, and no study has included more than five taxa in a single analysis. Further taxonomic sampling is warranted, but current evidence suggests that *Schoenoxiphium* is a clade.

Molecular analyses have also rejected two long-held hypotheses of homology that would support a *Schoenoxiphium* + *Kobresia* clade (e.g., Koyama 1961; Kern 1974; Smith & Faulkner 1976), or a phylogenetic link between *Carex* subg. *Vigneastra* and *Schoenoxiphium* (Haines & Lye 1972, 1983; Smith & Faulkner, 1976; Reznicek 1990). The clear separation of *Schoenoxiphium* and *Kobresia* in all analyses is particularly interesting because of the strong conviction of numerous authors that these genera were morphologically indistinct (e.g., Nelmes 1951; Kern 1958, 1974; Koyama 1961; Smith & Faulkner, 1976). This example illustrates why Cariceae taxonomy can be so difficult because even these distantly related taxa cannot be easily separated on the basis of morphology. As with exemplary cases in *Uncinia* and major Cariceae groups like the Core Unispicate Clade, the separation of *Schoenoxiphium* and *Kobresia* represents one of several problems of cryptic morphology that have been identified by molecular analyses (Starr et al., 2004, 2008).

Uncinia s.str. (sensu Reznicek 1990) is a monophyletic group based on the strong support (99–100% BS) found in all previous molecular analyses (two to three spp.;

Yen & Olmstead, 2000a, b; Roalson et al., 2001; Waterway & Starr, 2007) including the recent study of Starr et al. (2008) that sampled over a third of the genus (24 spp.). This supports strong morphological evidence for the monophyly of this group (see Reznicek, 1990). However, molecular analyses also strongly indicate that *U. kingii* is sister to all other *Uncinia* (i.e., *Uncinia* s.l.), which contradicts its recent transfer to *Carex* sect. *Leucoglochin* (Reznicek, 1990) based partly on evidence that its hooks (formed by a bend in the rachilla) were not homologous to the hooks in *Uncinia* s. str. (formed by a retrorse inrolled scale). We suggest that while the hooks may be analogous, the bend in the rachilla where the hooks begin could provide a homologue for *Uncinia* s.l. (cf. Figs. 18, 20, 21 in Reznicek, 1990, and Figs. 5, 6 in Kukkonen, 1967).

The monotypic genus *Cymophyllus* with its closed white utricles, pendulous stamens, clavate stigmas, condensed, solitary spikes and unique strap-like leaves suggested to numerous authors that its origins were enigmatic (Kükenthal, 1909; Mackenzie, 1935; Kreczetovicz, 1936; Nelmes, 1952). Given that molecular analyses always place *Cymophyllus* in the Core Unispicate Clade, typically sister to androgynous unispicate *Carex*, and that all of its characteristics are seen in that clade except its strap-like leaves, we recommend that future systematic studies should refer to this taxon as *Carex fraseriana* Ker-Gawler.

Subgeneric and Sectional Circumscription

Of the four subgenera that are currently recognized in *Carex*, molecular analyses indicate that only subg. *Vignea* is largely monophyletic as traditionally circumscribed (Yen & Olmstead, 2000a, b; Roalson et al., 2001; Starr et al., 2004, 2008; Waterway & Starr, 2007; Ford et al., 2006; present analyses). This confirms the strong traditional evidence from morphology (e.g., Bailey, 1886; Koyama, 1962), anatomy (Le Cohu, 1967), and even smut host-parasite relationships (e.g., Nannfeldt, 1977) that *Carex* subg. *Vignea* is natural.

In contrast, there has been considerable debate over whether the large, and highly variable subg. *Carex* (ca. 1,400 spp.) and the small, mainly tropical subg. *Vigneastra* (ca. 100 spp.) are natural or should be merged due to seemingly transitional East Asian species from sections *Hymenochlaenae* (Holm, 1900; Ohwi, 1936; Koyama, 1962) and *Decorae* (Kük.) Ohwi (Raymond, 1959; Koyama, 1957, 1962). Molecular analyses indicate that these subgenera cannot be separated (Starr et al., 1999, 2004, 2008; Yen & Olmstead, 2000a; Roalson et al., 2001; Waterway & Starr, 2007; present analyses) and that neither group forms a clade as presently circumscribed (Starr et al., 1999, 2004, 2008; Yen & Olmstead, 2000a; Waterway & Starr, 2007; present analyses). Interestingly, most analyses position species of *Carex* subg. *Vigneastra* near the base of the Core *Carex* Clade (Starr et al., 1999, 2004, 2008; Waterway & Starr, 2007; present analyses), which is compatible with past arguments based on phytogeography (Kreczetovicz, 1936; Nelmes, 1951; Ball, 1990) and inflorescence structure (Kreczetovicz, 1936; Koyama, 1962; Smith & Faulkner, 1976) that subg. *Vigneastra* may retain the plesiomorphic characteristics of a wider subgenera *Vigneastra* + *Carex* + *Psyllophora* line. Although molecular analyses would indicate that subgenera *Carex* and *Vigneastra* are unnatural as circumscribed, no analysis has ever sampled more than five subg. *Vigneastra* species. Moreover,

only the recent analyses of Waterway and Starr (2007), which placed *C. cruciata* (subg. *Vigneastra*) as sister to all other Core *Carex* taxa, provides strong statistical evidence (92% BS) for merging the two. Like many of the results generated by molecular data, their final impact on tribal classification will depend upon further taxonomic and character sampling (see “Future work”).

As expected, all molecular analyses demonstrate that the unispicate *Carex* subg. *Psyllophora* is polyphyletic, a result that confirms the common belief that reduction has occurred along several different evolutionary lines in Cariceae (e.g., Kreczetovicz, 1936; Nelmes, 1952; Smith & Faulkner, 1976). Analyses indicate that dioecious unispicate *Carex* sections, such as *Physoglochin* and *Scirpinae*, which are traditionally placed in subg. *Psyllophora* (e.g., Kükenthal, 1909; Egorova, 1999; Dai & Liang, 2000), should now be distributed amongst the multispicate sections of subgenera *Carex* and *Vignea*. Likewise, those androgynous unispicate sections such as the *Capituligerae*, *Phyllostachyae*, *Leptocephalae*, etc., which have been variously attributed to subgenera *Carex* and *Vignea* in some treatments (e.g., Marie-Victorin, 1935; Koyama, 1962; Aiken, et al., 1999), should no longer be placed in these groups since it is clear that they are more closely related to *Uncinia*, *Kobresia*, and *Schoenoxiphium*. Because there is no satisfactory classification at present to recognize the Core Unispicate and *Schoenoxiphium* Clades, and support for these groups is still weak, we suggest that a practical solution for the interim would be to treat these sections as elements of *Carex* subg. *Psyllophora*. Although this subgenus remains unnatural, the placement of the androgynous unispicate sections in this group better reflects their true relationships than their assignment to either subg. *Carex* or *Vignea*.

Sections are the principle category used to organize the enormous diversity of *Carex*. When molecular studies have included multiple members of a section they have generally found that morphologically cohesive groups such as sections *Phyllostachyae*, *Stellulatae* and *Ovales* (Starr et al., 1999; Ford et al., 2006) have been monophyletic, whereas large groups suspected of being heterogeneous such as sections *Phacocystis* or *Phaestoglochin* (Waterway & Starr, 2007; Ford et al., 2006) are unnatural. *Carex* is divided into more than 130 sections worldwide (Egorova, 1999), and determining whether these groups are natural will constitute one of the more difficult challenges of the future (see “Future work”).

In *Uncinia*, molecular analyses suggest that the subgeneric and sectional classification of the genus is largely natural. Kükenthal’s (1909) division of the genus into subg. *Hemihamatae* (=subg. *Pseudocarex* Kük. nom. illegit.) for *U. kingii* and subg. *Uncinia* (=Eu-*Uncinia*) for Clarke’s (1883) sections *Platyandrae* and *Uncinia* almost directly reflects the pattern of relationships seen in molecular phylogenies (Starr et al., 2008). The only major difference is seen in the placement (72–86% BS; Starr et al., 2008; present analyses) of sect. *Uncinia* series *Macrolepidae* as sister to sect. *Platyandrae*. Even though this may seem like a straightforward result it creates a philosophical problem because the three discrete characters used by Clarke (1883) and Hamlin (1958, 1959) to distinguish section *Uncinia* from *Platyandrae* are plesiomorphic (respectively, filiform vs. dilated filaments, glabrous vs. hispid utricles, deciduous vs. persistent scales). A re-evaluation of morphology may reveal previously undetected homologies for sect. *Uncinia*, but this example highlights the general lack of discrete morphological apomorphies for tribal classification.

Recently Zhang (2001) proposed a new subgeneric and sectional classification for *Kobresia*. Although taxonomic sampling of *Kobresia* in all molecular studies has been poor (≤ 7 spp. per analysis), one consistent result is the strong support (100% BS) for the monophyly of an androgynous unispicate clade (Roalson et al., 2001; Starr et al., 2004, 2008; Waterway & Starr, 2007; Fig. 4). Molecular studies suggest that at least the unispicate species of subg. *Kobresia* sections *Kobresia* [e.g., *K. capillifolia* (Decne.) C. B. Clarke, *K. sibirica* (Turcz. Ex Ledeb.) Boeck., *K. myosuroides*, *K. schoenoides*] and *Hemicarex* (e.g., *K. esenbeckii*, *K. nepalensis*) should be recognized as a distinct taxonomic category. Other unispicate species such as *K. robusta* Maxim. (subg. *Kobresia* sect. *Psammotachys* Ivanova) and *K. macrantha* Boeck. [subg. *Blysmocarex* (N. A. Ivanova) S. R. Zhang] may also be a part of this clade.

The small African genus *Schoenoxiphium* remains a poorly studied group (Kukkonen, 1978, 1983). Although no infrageneric classification exists for the genus, its species can be divided into two distinct groups based on bracts short and sheathless vs. elongate and long-sheathing. Species in the latter group also tend to possess inflorescences that are lax and elongated (A. A. Reznicek, personal communication). Further study is required to determine whether these two groups could represent distinct lineages.

Character Evolution in Cariceae

The Origin of the Caricoid Unisexual Spikelet

Because of its distinctive utricle and unisexual flowers, circumscribing Cariceae has always been straightforward. In contrast, deciphering the phylogenetic origins of its atypical floral morphology has not been easy. Some authors have hypothesized that the Cariceae is a direct descendant of the unisexually-flowered Sclerieae Kunth ex Fenzl (Haines & Lye, 1972; Smith & Faulkner, 1976), the bisexually-flowered Hypolytreae Presl ex Fenzl (Smith & Faulkner, 1976), or that the similarities between Cariceae and Sclerieae are due to an independent descent from the bisexually-flowered Rhynchosporae Nees (Koyama, 1961). Molecular *rbcL* analyses (Muasya et al., 1998; Simpson et al., 2007) have consistently placed the Cariceae in a Dulichieae Rchb. ex J. Schultze-Motel + Scirpeae Kunth ex Dumort. p.p. + Cariceae clade and sister to the small Scirpeae genera *Eriophorum* (ca. 20 spp.) and *Scirpus* s.str. (ca. 20 spp.). However, statistical support for these relationships has been lacking and there is little traditional evidence in favour of such an alignment (anatomy, Kukkonen, 1967; smut host-parasite data, Savile, 1979, Kukkonen & Timonen, 1979). Nevertheless, recent chloroplast (*matK*, *ndhF*, *rbcL*) and nuclear (arginine decarboxylase) data strongly support a Dulichieae + Scirpeae p.p. + Cariceae clade (94% BS) with Cariceae sister to *Scirpus* s.str. and *Eriophorum* (90% BS; Starr et al., 2006). Our character analyses and the nested position of Cariceae amongst bisexually-flowered tribes (Dulicheae, Scirpeae) indicate that caricoid unisexual flowers evolved from perfect flowers. In addition, the close relationship of *Scirpus* s.str. and *Eriophorum* to Cariceae suggests that the tribe has undergone a relatively high diversification rate relative to its sister. Whether this could be due to the tribe's defining features (utricles, a separation of the sexes) or to other factors can only be speculated.

The Origin of the Major Groups in Cariceae

In general, Cyperaceae and Cariceae authors have focused on reduction as the principle means by which taxa evolve (e.g., Nelmès, 1952; Dahlgren et al., 1985). The broad consensus over the past 100 years is that starting from a *Schoenoxiphium*- or *Kobresia*-like ancestor with highly compound inflorescences subtended by cladoprophylls and composed of bisexual spikelets, open utricles, and tristigmatic pistils, each of the remaining Cariceae genera could be derived by reduction (see Reznicek, 1990; Starr et al., 2004). Likewise for *Carex*, the search for an ancestral group has centred on those taxa that have the most compound inflorescences. The most promising candidate has usually been *Carex* subg. *Vigneastra* (Reznicek, 1990), whose highly compound inflorescences could have generated subgenera *Carex* or *Vignea* by a series of simple losses (*Carex* = loss of inflorescence prophylls, specialization in sex of spikes, *Vignea* = loss of one stigma, prophylls, peduncles; e.g., Nelmès, 1951; Hamlin, 1959; Smith & Faulkner, 1976). In contrast, the ultimate example of reduction, the unispicate *Carex* subg. *Psyllophora*, was considered to be an unnatural collection of species derived independently from multiple *Carex* subgenera and/or Cariceae genera (e.g., Kreczetovicz, 1936; Nelmès, 1952; Smith & Faulkner, 1976; but see Savile & Calder, 1953). Alternatively, Reznicek (1990) proposed that the highly compound inflorescences of some *Carex* subg. *Vignea* or *Carex* sect. *Fecundae* species (the latter group with an admixture of subg. *Carex/Vignea* features; Reznicek, 1990, 1992) were the ancestral type from which subg. *Carex* was derived. The origin of subg. *Vigneastra* was uncertain.

Our analyses, which take into account all previous topologies seen in molecular analyses, suggest that for the characters examined, the ancestral condition in Cariceae is most similar to that seen in multispicate *Carex* subg. *Carex* species. In general, all the major Cariceae clades displayed both inflorescence proliferation and extreme reduction to the unispicate state, but the highly compound condition was consistently derived. Within the *Vignea* Clade, multispicate inflorescences were ancestral, with both the highly compound (e.g., *Carex decomposita*) and unispicate (e.g., *C. dioica*) conditions representing derived character states. In the Core *Carex* Clade, ambiguity was seen at the root node, but the position of *C. fecunda* and *C. scirpoidea* demonstrate that proliferation and reduction have also occurred in this clade. For the Caricoid Clades, the root node was either ambiguous or suggested that the ancestral condition was a unispicate inflorescence. Within these clades, analyses suggested that the multispicate or highly compound inflorescences of *Schoenoxiphium*, *Kobresia*, and *C. baldensis* have evolved in parallel from unispicate ancestors.

The phylogenetic position of *Carex baldensis* is particularly significant because it suggests that rachillae axes in fertile utricles have evolved into complete androgynous lateral spikes (Reznicek, 1990; Starr et al., 2004). In *Carex*, rachilla proliferation often produces androgynous lateral spikes in teratological specimens (Snell, 1936; Smith & Faulkner, 1976), and presumably these spikes could become genetically fixed if there was a selective advantage. In the case of *C. baldensis* this advantage would appear to be entomophily. The white, congested inflorescences of *C. baldensis* are strongly analogous to those seen in the entomophilous *Rhynchospora* Vahl sect. *Dichromena* (Michx.) Griseb. (see Thomas, 1984).

The implication that inflorescence proliferation and reduction could be a common and frequent mode of evolution in Cariceae largely explains the difficulty of determining relationships and homology across the tribe. Cariceae inflorescences are essentially repeated structures where all prophyll types are homologous (i.e., inflorescence prophylls, cladoprophylls, utricles), and scales are homologous to the bracts subtending lateral spikes (Snell, 1936; Smith & Faulkner, 1976). The lack of inflorescence prophylls and bracts in unispicate species is thus explained by the absence of more than one inflorescence axis. Because the strict sequence of bract → prophyll → female flower → axis (rachilla) is normally followed during development, proliferation or reduction across widely divergent clades is likely to produce similar structures that could be misinterpreted as homology.

All topologies suggest that the ancestral pistillate spikelet in Cariceae had three stigmas and that the loss of a stigma has occurred frequently during the evolution of the tribe. Other sedge genera such as *Schoenoplectus* (Rchb.) Palla and *Eleocharis* R. Br. also possess distigmatic and tristigmatic species (e.g., Ball et al., 2002) suggesting that stigma losses may be common throughout the family. In *Carex* subg. *Vignea*, only three species are tristigmatic. Whilst *C. gibba* retains the ancestral tristigmatic condition as sister to all other subg. *Vignea* taxa, the three stigmas in *C. macrocephala* and *C. kobomugi* (sect. *Macrocephalae*) appear to be the result of a reversal.

Most topologies suggest that cladoprophylls are ancestral for the Cariceae as would be expected given their presence in the outgroup and throughout the family (Blaser, 1944). All topologies resolve cladoprophylls as ancestral to the Core *Carex* Clade, but only two topologies unambiguously do so for the *Vignea* Clade; other topologies suggest ambiguity or consider cladoprophylls as an autapomorphy for *Carex gibba*. Given the position of *C. gibba* as sister to all other *Vignea* species, and its retention of the ancestral tristigmatic condition, we believe that the presence of cladoprophylls in this species is plesiomorphic. The nested positions of *Carex* sect. *Ammoglochin* subsect. *Herporrhizae* (*Vignea* Clade), *C. baldensis* (Core Unispicate Clade), and the genera *Schoenoxiphium* and *Kobresia* suggest that their cladoprophylls have evolved independently.

Not surprisingly, the absence of inflorescence prophylls appears to be the ancestral state for Cariceae. All topologies demonstrate that the inflorescence prophylls seen in *Schoenoxiphium* are not homologous to the inflorescence prophylls in *Carex* subg. *Vigneastra*. Although several species of subg. *Vigneastra* are seen at the base of the Core *Carex* Clade, the ancestral character state for this clade is unresolved. Nonetheless, the nested positions of *Carex echinochloe*, *C. filicina* and *C. polystachya* within the Core *Carex* Clade suggest that their inflorescence prophylls are not homologous to those of *C. cruciata* or *C. baccans*.

In summary, our analyses would suggest that cladoprophylls subtending multi-spicate inflorescences of strictly unisexual, tristigmatic pistillate spikelets with closed utricles are the ancestral characters for Cariceae. In extant groups, this combination of characters most closely resembles the morphology of multispicate species from *Carex* subg. *Carex*. Moreover, if sect. *Siderostictae*, which is currently placed in *Carex* subg. *Carex* and possesses this suite of characters, is confirmed as sister to all remaining Cariceae as Waterway et al. (2008) have proposed, it would strengthen this hypothesis.

Future Work

All analyses to date have recognized three (*Core Carex*, *Vignea*, Caricoid) or four (Caricoid = Core Unispicate + *Schoenoxiphium*) major clades within Cariceae. Our current level of understanding suggests that a sectional or species-level revision is possible for at least the *Vignea* Clade (ca. 300 spp.) because it would be easy to sample (17 of the 26 sections and more than half of all species are found in North America) and nearly a third of all *Vignea* species are found in sect. *Ovales* (ca. 90 spp.), a taxon that is clearly monophyletic (Hendrichs et al., 2004; Ford et al., 2006; Hipp, 2008). On the other hand, a revision of the Caricoid Clade will be faced with the problem of its phylogeography. *Uncinia* has a Gondwanan distribution, *Kobresia* ranges from North America through Eurasia, and the species of *Carex* subg. *Psyllophora* are widely scattered in high latitudinal or altitudinal habitats across six different continents. Although the total number of species in the Caricoid Clade is relatively small (ca. 215), such a distributional pattern will require considerable effort to clarify its systematics. Understanding phylogenetic relationships within the Core *Carex* Clade will continue to be our greatest challenge because of the large number of taxa (ca. 1,400 spp.) and cosmopolitan distribution of its species. The studies of Roalson et al. (2001) and Waterway and Starr (2007) represent strong beginnings. Also, the conclusion of Waterway et al. (2008) that *Carex* sect. *Siderostictae* is sister to all other Cariceae could have significant implications for polarizing characters and understanding evolution in the tribe.

The conclusion of Waterway et al. (2008) that the East Asian *Carex* sect. *Siderostictae* is sister to all remaining Cariceae not only has significant implications for polarizing characters and understanding evolution in the tribe, but it highlights the need for a more balanced sampling regime in future studies. No analysis has included more than 5% of Cariceae diversity; no Cariceae genus has been sampled for more than 40% of its species (i.e., *Uncinia*, 24 of ca. 60 spp.; Starr et al., 2008), and no *Carex* subgenus has been sampled for more than 7% of its diversity except subgenera *Psyllophora* (31% or 20 of ca. 65 spp.; present analyses) and *Vignea* (30% or 100 of ca. 300 spp.; Ford et al., 2006). On average, 60% of the taxa that have been sampled in molecular studies are from Europe or North America, whereas only 6% are from Eastern Asia. Although Cariceae diversity is high in Europe (182 spp., Chater, 1980) and North America (484 spp.; Ball et al., 2002), it is as high or higher in Eastern Asia (e.g., 203 spp. for Japan, Ohwi, 1965; 488 spp. of *Carex* for China, Dai & Liang, 2000). This is particularly significant when we consider that our analyses suggest that at least two of the four major Cariceae clades (i.e., *Vignea* and Core *Carex*) have East Asian species at their base. Asia contains many poorly studied and enigmatic groups including *Carex* sect. *Hemiscaposae* C. B. Clarke (subg. *Vigneastra*), which shares many of the features found in sect. *Siderostictae* (e.g., androgynous spikes, broad lanceolate leaves, lateral culms; Waterway et al., 2008), and *Carex* sect. *Hypolytroides* Nelmes (subg. *Vigneastra*) with its *Scleria*-like stems and corymbiform panicles similar to narrow-leaved *Hypolytrum* Rich. ex Pers. species (Nelmes, 1951, 1955; Raymond, 1959). Moreover, some East Asian sections, such as the *Hymenochlaenae* p.p. and *Decorae*, contain problematic species that blur the boundaries between traditionally recognized *Carex* subgenera (Holm, 1900; Ohwi, 1936; Koyama, 1957, 1962; Raymond, 1959). Knowing the

phylogenetic position of any of the above mentioned taxa could have important implications for our understanding of tribal classification and character evolution.

Central and South America also represent a region of great diversity (Mexico, ca. 100 spp., Reznicek, 1993; Mesoamerica, 44 spp., Chater, 1994; South America, ca. 200 spp., Wheeler, 1996) that has been very poorly sampled (but see Starr et al., 2004, 2008). Species such as *Carex david-smithii* Reznicek, *C. catamarcensis* Kük., and other undescribed taxa from the Andes, have all been considered critical to our understanding of evolutionary relationships in *Carex* but have yet to be included in phylogenetic analyses (see Reznicek, 1990, 1992; Ford et al., 2006). Just as the position of the New Caledonian genus *Amborella* Baill. as sister to all other angiosperms (Qiu et al., 1999; Mathews & Donoghue, 1999) came as a surprise after it was added to molecular analyses, it is clear that many further surprises await Cariceae analyses when taxonomic sampling becomes reflective not only of perceived morphological and taxonomic diversity, but also of geographic distribution.

Considerable effort has been made to understand Cariceae relationships and floral structures through the study of teratology, positional homology and inflorescence development (e.g., Smith, 1966; Smith & Faulkner, 1976; Timonen, 1998; Reznicek, 1990). These studies have focused on species that were meant to represent the structural diversity of Cariceae as reflected by Kükenthal's (1909) traditional generic and subgeneric classification. Unfortunately, this approach has been largely uninformative on the taxonomic limits and relationships of major Cariceae groups. A new and potentially more profitable method would be to select species on the basis of recent developments in phylogenetic research (Starr et al., 2004). For example, comparisons of the morphology and development of *Carex* sect. *Siderostictae*, *C. gibba* and *C. cruciata* to typical members of their sister groups could potentially clarify many questions on tribal homology and evolution. Moreover, a comparison of the morphology and development of the multispicate *C. curvula*, *C. baldensis*, and *C. supina* Wild. ex Wahlenb. to the strictly unispicate and highly compound *Kobresia* species of their clade (Roalson et al., 2001; Starr et al., 2004; present study) could also be informative. We believe that the clear separation of unispicate dioecious, paradioecious (see Starr et al., 2004) and gynaeandrous species (e.g., *Carex squarrosa*, *Carex exilis*, often unispicate; Ford et al., 2006; Waterway & Starr, 2007; present analyses) from androgynous unispicate taxa in all molecular analyses may signal a fundamental difference in inflorescence development between the Core *Carex* and *Vignea* Clades and the Core Unispicate and *Schoenoxiphium* Clades. It is notable that although androgyny is present throughout Cariceae, gynaeandry is only seen in the Core *Carex* and *Vignea* Clades.

Although we consider the four major clades described in this paper as "real", it cannot be discounted that the perceived congruence amongst studies may be due more to marker choice than accuracy. All five Cariceae analyses that have sequenced a nuclear marker have used the ITS region and four of these have also employed the linked ETS 1f region of nrDNA (Fig. 3). For analyses that have used chloroplast markers, whether alone or in combination with nrDNA data, all four have sequenced portions of the non-coding *trnT-L-F* region and two have sequenced the *ndhF* gene (Fig. 3). In addition, incongruence length difference tests (ILD; Farris et al., 1994) suggest that there may be some concerns with phylogenetic accuracy. With the exception of Yen and Olmstead (2000a, b) who compared chloroplast regions, all

Cariceae studies that have conducted ILD tests have found incongruence either between nuclear and chloroplast data (Roalson et al., 2001; Waterway & Starr, 2007) or between nrDNA partitions (Ford et al., 2006; Starr et al., 2004, 2008). Whether this may be due to paralogues, hybridization, or other sources of systematic error (e. g., G/C bias, long-branch attraction) is unclear, but the unexpected placement of multiple samples of *Carex microglochin* in separate nrDNA clades suggests that some form of error may be present (see Starr et al., 2008; Fig. 4). New genetic markers are needed, not simply from the linked and conserved chloroplast genome or the potentially problematic nrDNA locus (Alvarez & Wendel, 2003), but from low-copy nuclear genes that can provide independent phylogenetic estimates. Given the lack of a robust topology and the consistently low statistical support for many clades, future studies should not focus on trying to add more data from these loci, but to develop new nuclear markers.

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Appendix B. Voucher information for *Carex* and *Kobresia* taxa sampled in this study, arranged alphabetically by genus, section, and species. Following each entry, sample numbers and GenBank accession numbers are provided in parenthesis.

Carex L sect *Acrocystis* Dumortier, *C. albicans* Willd. ex Sprengel var *albicans*, (1) USA: MD, Dorchester Co, Apr 29 2005 *WM Knapp 1154* (DOV 054088)(B0070, GU172468); (2) USA: PA, Blair Co, Jun 09 2005 *RFC Naczi, SP Grund, WM Knapp, SV Parker, A Sabo 11066* (DOV 053073)(B0071, GU172469); (3) USA: KN, Brown Co, May 06 2002 *CA Morse 7665* (DOV 037575)(B0072, GU172467); *C. albicans* Willd. ex Sprengel var *australis* (LH Bailey) Rettig, (1) USA: TX, Smith Co, May 20 1999 *R Kral 88072* (DOV 046685)(B0073, GU172472); (2) USA: NC, Macon Co, May 27 1999 *PE Hyatt, S Hyatt 8611* (DOV 044980)(B0076, GU172471); (3) USA: MS, Lawrence Co, Apr 14 2005 *CT Bryson 20010* (DOV 047014)(B0083, GU172470); *C. albicans* Willd. ex Sprengel var *emmonsii* (Dewey ex Torrey) Rettig, (1) USA: MI, Manistee Co, Jun 19 2005 *AA Reznicek 11676* (DOV 054691)(B0078, GU172474); (2) USA: SC, Pickens Co, Apr 13 2004 *A Darr, L Lee, T Goforth 2115* (DOV 049387)(B0079, GU172475); (3) USA: DE, Sussex Co, Apr 21 2003 *RFC Naczi 9524* (DOV 035373)(B0080, GU172473); *C. brainerdii* Mack., (1) USA: CA, Butte Co, May 29 2005 *LP Janeway 8406* (DOV 055892)(B0142, GU172612); (2) USA: CA, Siskiyou Co, Jul 02 2006 *LP Janeway 8729* (DOV 060750)(B0841, GU172613); (3) USA: CA, Madera Co, Jul 27 2004 *RFC Naczi 10588* (DOV 050486)(B0847, GU172614); *C. brevicaulis* Mack., (1) USA: WA, Skagit Co, May 08 1989 *E Burnett, M Arnot 82* (WTU 317671)(B0966, GU172615); *C. communis* LH Bailey var *amplisquama* (FJ Hermann), (1) USA: SC, Pickens Co, Apr 17 2003 *A Darr, A B Pittman, P McMillon 1700* (USCH 89346)(B1151, GU172690); (2) USA: GA, Murray Co, May 05 1985 *JH Rettig 1288* (LSU 75301)(B1315, GU172689); *C. communis* LH Bailey var *communis*, (1) USA: NC, Ashe Co, May 17 2005 *DB Poindexter 05 249* (DOV 063071)(B0178, GU172691); (2) USA: ME, Penobscot Co, Jun 29 2002 *AA Reznicek, SA Reznicek 11342* (DOV 040458)(B0179, GU172693); (3) USA: SC, Pickens Co, Apr 13 2004 *A Darr, L Lee, T Goforth 2112* (DOV 049416)(B0469, GU172695); (4) USA: GA, Rabun Co, Jun 01 2003 *RFC Naczi 9722* (DOV 035391)(B0470, GU172692); (5) Canada: QC, Saint Vallier Jun 18 2000 *S Hay, J Labrecque, F Coursol 2000 07* (MT)(B0888, GU172694); *C. deflexa* Horne. var *boottii* LH Bailey, (1) USA: WY, Teton Co, Jul 05 1997

CA Morse, *IE Jordon 1795* (KANU 319981)(B1294, GU172761); (2) USA: MI, Summit Co, Aug 14 1986 *R Tallent 587* (MICH)(B1494, GU172762); *C. deflexa* Horne. var *deflexa*, (1) Canada: NL, Bonavista South Dist Jul 08 1996 *R Charest, L Brouillet 96 488* (MT)(B0897, GU172764); (2) Canada: NL, Whit Bay North Dist Aug 06 1991 *A Bouchard, S Hay, L Brouillet, M Jean 91298* (CAN 564373)(B1199, GU172763); (3) Canada: BC, Fording Riv Valley Aug 23 1996 *H Roemer, JL Penny 96462* (UBC 223806)(B1519, GU172760); *C. floridana* Schweinitz, (1) USA: FL, Seminole Co, Mar 19 2005 *WD Longbottom, DH Williams 5558* (DOV 048331)(B0288, GU172877); (2) USA: SC, Georgetown Co, Mar 29 2002 *JB Nelson 22440* (DOV 040376)(B0289, GU172878); (3) USA: AL, Tuscaloosa Co, Mar 15 2003 *R Kral 93615* (DOV 062042)(B0290, GU172876); *C. geophila* Mack., (1) USA: TX, Brewster Co, May 11 1992 *TF Wieboldt, A Wieboldt 8057* (DOV 021177)(B0322, GU172908); (2) USA: NM, Bernalillo Co, *D Castaner 10926* (DOV 039954)(B0323, GU172907); (3) USA: CO, Dolores Co, May 12 1996 *J Sanderson 1173* (COLO 460444)(B1091, GU172905); (4) USA: CO, Rio Blanco Co, May 25 1990 *RL Hartman, JP Vanderhorst, W Fertig 24788* (RM 683702)(B1271, GU172906); *C. globosa* Boott, (1) USA: CA, Santa Cruz Co, Jun 1 2002 *DW Taylor 18093* (DOV 023975)(B0302, GU172922); *C. inops* LH Bailey subsp *heliophila* (Mack.) Crins, (1) USA: CO, Jefferson Co, Jun 11 2003 *C Lea 3414* (DOV 047117)(B0350, GU173034); *C. inops* LH Bailey subsp *inops*, (1) USA: WA, Yakima Co, Jun 15 2001 *S Gage 7182* (WTU 352122)(B1001, GU173036); (2) USA: CA, Siskiyou Co, Jul 12 2002 *LP Janeway 7623* (CHSC 82806)(B1084, GU173035); (3) Canada: BC, Fraser Valley Apr 30 1994 *F Lomer* (UBC 208440)(B1394, GU173033); *C. lucorum* Willd. ex Link var *austrolucorum* Rettig, (1) USA: KY, Laurel Co, May 21 1998 *RFC Naczi, BA Ford 7146* (DOV 021364)(B0385, GU173138); (2) USA: VA, Smyth Co, Jun 13 2006 *CT Bryson, NB Bryson 21783* (DOV 057346)(B0386, GU173140); (3) USA: GA, Rabun Co, Jun 01 2003 *RFC Naczi 9723* (DOV 035245)(B0391, GU173137); (4) USA: TN, Sevier Co, Apr 30 2006 *LR Phillippe, PB Marcum, MJC Murphy, J Payne 38550* (ILLS 235345)(B1128, GU173139); *C. lucorum* Willd. ex Link var *lucorum*, (1) USA: MD, Cecil Co, May 16 2004 *J Ebert, J Holt* (DOV 046922)(B0387, GU173141); (2) USA: NC, Haywood Co, May 02 2005 *MA Feist, LR Phillippe, PB Marcum, PA Tessene, MJC Murphy 2916* (ILLS 236475)(B1129, GU173142); *C. nigromarginata* Schweinitz, (1) USA: AR, Nevada Co, Apr 16 1999 *R Kral 88225* (DOV

050418)(B0514, GU173291); (2) USA: AL, Jackson Co, May 19 2005 *RFC Naczi 10849* (DOV 049848)(B0515, GU173290); (3) USA: VA, Northhampton Co, Apr 21 2005 *W Knapp, CT Frye 1140* (DOV 054095)(B0516, GU173292); *C. novae-angliae* Schweinitz, (1) USA: ME, Oxford Co, Jun 30 2001 *AA Reznicek, SA Reznicek 11281* (DOV 041023)(B0453, GU173301); (2) USA: NY, Greene Co, Jul 03 2004 *RFC Naczi 10446* (DOV 053922)(B0454, GU173303); (3) USA: MN, Lake Co, Jun 20 2002 *WR Smith, MD Lee 29308* (WIS 215026)(B1171, GU173302); *C. peckii* Howe, (1) Canada: MB, 1.5 km N of town of Falcon Lk Jun 25 2003 *RFC Naczi, BA Ford 9857* (DOV 035416)(B0537, GU173370); (2) USA: AK, Fairbanks Quad Jun 18 1995 *M Duffy, R Lipkin, J Tande 95 102* (ALA 1136152)(B1018, GU173369); *C. pensylvanica* Lamarck in J Lamarck *et al.*, (1) Canada: MB, Souris Riv Wildlife Management Area Jun 26 2003 *RFC Naczi, BA Ford 9878* (DOV 036859)(B0565, GU173384); (2) USA: OK, Le Flore Co, May 26 2003 *RFC Naczi, BA Ford 9639* (DOV 037260)(B0566, GU173385); (3) USA: WA, Island Co, Apr 30 2004 *PW Dunwiddie PWD 34* (WTU 357732)(B0987, GU173386); *C. pityophila* Mack., (1) USA: NM, Torrance Co, May 20 1990 *D Castaner 10918* (DOV 039650)(B0588, GU173406); (2) USA: CO, Jefferson Co, Jun 11 2003 *C Lea 3413* (DOV 047116)(B0594, GU173404); (3) USA: NM, Rio Arriba Co, Jun 02 2002 *B Reif 9453* (UNM 108890)(B1223, GU173405); *C. reznicekii* Werier, (1) USA: VA, Accomack Co, Apr 18 1999 *WA McAvoy 4266* (DOV 028305)(B0604, GU173476); (2) USA: AL, Jackson Co, Apr 22 2002 *RFC Naczi 9034* (DOV 025816)(B0605, GU173474); (3) USA: NC, Macon Co, Apr 19 2004 *D Werier 2052* (DOV 059329)(B0606, GU173475); *C. rossii* Boott in Hooker, (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11506* (DOV 063463)(B0595, GU173486); (2) Canada: BC, Jun 27 2000 *BA Ford, JM Saarela 123* (DOV 022942)(B0610, GU173485); (3) Canada: BC, Gila Co, Apr 04 1992 *F Lomer 92 014* (UBC 215814)(B1215, GU173484); *C. serpenticola* Zika, (1) USA: OR, Curry Co, Jun 19 1997 *PF Zika, V Stansell 13170* (OSC 189228)(B1057, GU173556); (2) USA: CA, Del Norte Co, Apr 30 1997 *PF Zika 13068* (UC 1763993)(B1354, GU173555); *C. tonsa* (Fernald) EP Bicknell var *rugosperma* (Mack.) Crins, (1) Canada: MB, Whiteshell Provincial Pk Jun 12 1994 *BA Ford 94111* (DOV 022936)(B0750, GU173700); (2) USA: IL, Mason Co, May 10 2004 *D Busemeyer, JE Ebinger, W McClain, LR Phillippe 1677* (ILLS 228795)(B1130, GU173699); *C. tonsa* (Fernald) EP Bicknell var *tonsa*, (1) Canada: MB, 4 km N of town of W Hawk Lk Jun 25

2003 *RFC Naczi*, *BA Ford 9830* (DOV 000031)(B0710, GU173696); (2) USA: GA, Habersham Co, Mar 31 2000 *PE Hyatt 8986* (DOV 046874)(B0711, GU173695); (3) Canada: MB, N end of Moose Lk Jun 13 1994 *BA Ford, JR Starr, D Punter, E Punter 94128* (DOV 022932)(B0749, GU173701); (4) Canada: NL, Green Bay Dist Jul 25 1988 *A Bouchard, S Hay, L Brouillet 88219* (MT)(B0890, GU173697); (5) Canada: ON, Thunder Bay Dist May 26 1981 *CE Garton 19940* (CAN 471708)(B1498, GU173698); *C. turbinata* Liebmann, (1) USA: AZ, Cochise Co, Jul 27 2007 *S Pilversack, G Onder 95* (ASU 233553)(B1270, GU173734); (2) USA: AZ, Sierra de Alamos Apr 29 1994 *VW Steinmann 94 45* (UCR 84370)(B1364, GU173735); *C. umbellata* Schkuhr ex Willd., (1) USA: DE, Kent Co, Apr 22 2005 *RFC Naczi, JW Thieret 10772* (DOV 049080)(B0771, GU173741); (2) Canada: MB, Nopiming Provincial Pk Jun 19 2004 *BA Ford 418* (DOV 049821)(B0772, GU173742); (3) USA: OK, Bryan Co, Apr 20 1998 *PE Hyatt 7975* (DOV 025922)(B0773, GU173743).

Carex L sect *Albae* (Ascherson & Grabner) Kük in Engler, *C. eburnea* Boott in Hooker, (1) USA: MI, Menominee Co, Jul 18 1996 *VE McNeilus 96 580* (DOV 044967)(B0224, GU172811); (2) USA: OH, Adams Co, Apr 22 1998 *RFC Naczi 7085* (DOV 020810)(B0230, GU172813); (3) USA: WI, Door Co, Jul 03 2003 *N Harriman 21754* (DOV 039752)(B0249, GU172814); (4) USA: MT, Flathead Co, Jun 24 1998 *PF Zika 13451* (WTU 343054)(B0975, GU172812).

Carex L sect *Ammoglochin* Dumortier, *C. arenaria* L, (1) USA: DE, Sussex Co, Jul 23 2002 *RFC Naczi, WA McAvoy 9460* (DOV 023435)(B0115, GU172527); (2) USA: OR, Columbia Co, Jun 14 2003 *PF Zika 18478* (WTU 353605)(B0963, GU172528); *C. siccata* Dewey, (1) USA: CO, Eagle Co, Jul 19 1986 *D Castaner 9476* (DOV 039620)(B0292, GU173570); (2) USA: CO, Park Co, Jul 08 2004 *C Lea 3453* (DOV 046660)(B0623, GU173571); (3) Canada: MB, 14 km E of Richer Jun 25 2003 *RFC Naczi, BA Ford 9802* (DOV)(B0624, GU173572); (4) USA: NM, Santa Fe Co, Jun 10 1993 *GK Helmkamp, E Helmkamp 132* (UCR 123101)(B1253, GU173573); (5) Canada: ON, Renfrew Co, Jul 21 1999 *DF Brunton 14212* (CAN 585306)(B1464, GU173574).

Carex L sect *Anomalae* J Carey, *C. amplifolia* Boott in Hooker, (1) USA: NV, Washoe Co, Jul 22 2004 *RFC Naczi 10464* (DOV 050549)(B0097, GU172490); (2) USA: CA, Fresno Co, Jul 26 2004 *RFC Naczi 10556* (DOV)(B0865, GU172489); *C. scabrata* Schweinitz, (1) USA: GA, Lumpkin Co, May 17 2001 *L Kruse 01 145* (DOV 049310)(B0636, GU173510); (2) USA: ME, Hancock Co, Jun 30 2002 *AA Reznicek 11351* (DOV 040965)(B0637, GU173511); (3) USA: PA, Blair Co, Jun 09 2005 *RFC Naczi, SP Gruund, WM Knapp, SV Parker, A Sabo 11071* (DOV 053501)(B0638, GU173512).

Carex L sect *Aulocystis* Dumortier, *C. atrofusca* Schkuhr, (1) USA: AK, Kotzebue Quad Jul 05 2003 *CL Parker, AR Batten, R Elven, H Solstad 14441* (ALA 1115438)(B1047, GU172555); (2) Canada: ON, Kenora Co, Jul 06 2001 *MJ Oldham, DA Sutherland 26043* (TRTE 66026)(B1268, GU172556); *C. fissuricola* Mack., (1) USA: CA, Mono Co, Aug 05 2006 *RFC Naczi 11483* (DOV)(B0816, GU172868); (2) USA: ID, Lemhi Co, Jul 30 1990 *M Mancuso 310* (ID 107727)(B1511, GU172869); *C. fuliginosa* Schkuhr, (1) USA: AK, Killik Riv Quad Jul 26 2002 *CL Parker, BA Bennett, N Guldager 13178* (ALA 1130321)(B1020, GU172899); (2) USA: AK, Charley Riv Quad Jun 20 1996 *CL Parker, L Hasselbach 6319* (ALA 1125382)(B1044, GU172900); (3) Canada: NU, Qarlikturvik Valley Jul 11 2004 *B Tremblay 213 2004* (QFA 259923)(B1267, GU172901); *C. lemmonii* Boott, (1) USA: CA, Butte Co, Jul 23 2004 *L Ahart 11296* (DOV 048114)(B0411, GU173090); (2) USA: CO, Mariposa Co, Jun 30 2005 *A Colwell, D Grossenbacher, H Wanamaker NAD27* (UC 1861931)(B1499, GU173091); (3) USA: CA, Butte Co, Jul 23 2004 *L Ahart 11296* (CHSC 88156)(B1071, GU173089); *C. luzulifolia* Boott in S Watson, (1) USA: CA, Plumas Co, Jul 03 2004 *L Ahart, J Dittes, J Guardino, R Schlising 11156* (DOV 042355)(B0410, GU173153); (2) USA: CA, Nevada Co, Aug 04 2006 *RFC Naczi 11465* (DOV)(B0862, GU173154); *C. luzulina* Olney var *ablata* (LH Bailey) FJ Hermann, (1) USA: CA, Siskiyou Co, Sep 09 2003 *LP Janeway 7956* (CHSC 84711)(B1072, GU173155); (2) USA: WY, Teton Co, Jul 07 1994 *E Evert 27811* (RM 781834)(B1285, GU173156); *C. luzulina* Olney var *luzulina*, (1) USA: OR, Curry Co, Jul 22 1996 *V Stansell 3087* (DOV 020794)(B0477, GU173161); (2) USA: AK, Anchorage area Jul 27 2003 *AA Reznicek, J Delapp 11511* (DOV 041019)(B0478, GU173157); (3) USA: WA, Chelan Co, Jul 28 2006 *N Walker 06 20* (WTU 366896)(B1007, GU173162); (4) USA: CA, Tehama Co, Jun 12 2005 *LP Janeway*

8423 (JEPS 108564)(B1301, GU173159); (5) USA: NV, Washoe Co, Jul 29 1975 *A Tiehm 1780* (RENO 33612)(B1331, GU173160); (6) USA: CA, San Bernardino Mountains Jul 24 1994 *AC Sanders, P MacKay 15133* (UCR 49164)(B1356, GU173158); *C. petricosa* Dewey var *misandroides* (Fernald) B Boivin, (1) Canada: QC, Comté de Gaspé Ouest Jun 29 1995 *N Dignard 95 49* (QFA 111964)(B1388, GU173394); *C. petricosa* Dewey var *petricosa*, (1) USA: AK, Ambler Riv Quad Jul 20 1998 *CL Parker, R Lipkin 8137* (ALA 1136254)(B1037, GU173393); (2) Canada: YT, Bonnet Plume Drainage, Penguicula Lake Jul 11 2005 *BA Bennett, P Seccombe Hett, J Ryder, S Thompson, D Mahoney 05 0423* (MICH)(B1493, GU173395).

Carex L sect *Bicolores* (Tuck. ex Bailey) Rouy, *C. aurea* Nuttall, (1) USA: CA, Lake Co, May 30 2000 *LP Janeway 6762* (DOV 048079)(B0149B, GU172560); *C. bicolor* Allioni, (1) Canada: NL, St. Barbe South Jul 05 1999 *L Brouillet, J Maunder, D Ballam, L Lavers, A Marceau, M Burzynski, B Pollock, C Wentzel, M Anions LB 99 70* (MT)(B0900, 1138327)(B1015, GU172595); (3) Canada: AB, Jasper National Park Jul 28 2004 *BA Ford, AJ Gould 4224* (WIN 70903)(B1145, GU172594); *C. garberi* Fernald, (1) USA: AK, Nabesna C5 Quad Jun 24 2003 *MB Cook 4710* (ALA 1130415)(B1017, GU172902); (2) Canada: YT, Knorr Range Jul 09 2005 *BA Bennett, P Seccombe Hett, J Ryder 05 0343* (CAN 589247)(B1324, GU172904); (3) Canada: BC, Greater Vancouver Regional District May 28 1996 *F Lomer 96 22* (UBC 219156)(B1391, GU172903); *C. hassei* LH Bailey, (1) USA: CA, Tuolumne Co, May 17 2002 *DW Taylor 18061* (DOV 023309)(B0348, GU172961); (2) USA: CO, NORAD site Jun 22 1995 *T Kelso, J DuWaldt 95 1005* (COLO 457610)(B1107, GU172962); (3) USA: CA, Los Angeles Co, Jun 14 2000 *V Soza, L Moore 1011* (UCR 147792)(B1260, GU172960).

Carex L sect *Capituligerae* Kük., *C. capitata* L, (1) USA: CA, Nevada Co, Aug 03 2006 *RFC Naczi 11420* (DOV)(B0827, GU172658); (2) USSR: Taymya, Riv Pyasina Aug 21 1982 *UP Kozhevnikov Sn.* (CAN 490439)(B1429, GU172652); (3) Canada: BC, Pine Pass Quad Jul 12 1973 *GW Argus* (CAN 372267)(B1430, GU172653); (4) Canada: SK, Hwy #2 near Waskesiu Riv Jul 31 1992 *JH Hudson* (CAN 565528)(B1431, GU172654); (5) USA: AK, Healy Quadrangle county Aug 3 1964 *LA Viereck* (CAN 362141)(B1447,

GU172655); (6) Canada: SK, vicinity of Patterson Lake Jul 20 1963 *GW Argus* (CAN 282691)(B1448, GU172656); (7) Canada: AB, Banff National Park Jul 29 1960 *AE Parsild* (CAN 266077)(B1449, GU172657).

Carex L sect *Carex*, *C. atherodes* Sprengel, (1) USA: MI, Oscoda Co, Jul 17 2002 *AA Reznicek, FW Case, J Morgan, RR Comstock 11373* (DOV 040967)(B0106, GU172540); (2) Canada: MB, 26 km E Richer Jun 25 2003 *RFC Naczi, BA Ford 9810* (DOV 035521)(B0107, GU172539); (3) Canada: BC, Wells Gray Provincial Park Aug 21 2004 *C Bjork 9691* (UBC 223227)(B1242, GU172538); *C. hirta* L, (1) Austria: Niederosterreich, 10 km SW of Pottenstein Jul 20 2005 *RFC Naczi, JR Starr, BA Ford, J Thibault 11150* (DOV 053882)(B0328, GU172984); (2) USA: PA, Chester Co, Jun 19 2007 *RFC Naczi, J Holt, J Ebert, M Waterway 11898* (DOV 063495)(B0329, GU172986); (3) Canada: NB, St John Co, Jun 30 2001 *CS Blaney 3866* (UNB 57996)(B1166, GU172985); *C. laeviconica* Dewey, (1) Canada: MB, 1 km ESE of Treesbank Jun 26 2003 *RFC Naczi, BA Ford 9914* (DOV 036029)(B0371, GU173064); (2) USA: KN, Leavenworth Co, Jun 04 2003 *CA Morse 9455* (KANU 342643)(B1280, GU173063); *C. sheldonii* Mack., (1) USA: CA, Plumas Co, Aug 13 2007 *L Ahart, J Dittes, J Guardino 14464* (CHSC 97294)(B1086, GU173559); (2) USA: CA, Plumas Co, Jun 04 1992 *LP Janeway 4216* (CHSC 60504)(B1198, GU173560); (3) USA: ID, Adams Co, May 28 1999 *CR Bjork 4264* (ID 116308)(B1227, GU173561); *C. trichocarpa* Willd., (1) USA: DE, New Castle Co, Jun 21 2006 *WA McAvoy 6169* (DOV 063905)(B0726, GU173719); (2) USA: IL, McDonough Co, Jun 10 1996 *AA Reznicek, PE Rothrock, M Rothrock, SA Reznicek 10221* (DOV 024272)(B0727, GU173720); (3) Canada: ON, Simcoe Co, May 30 2003 *AA Reznicek, B Bowles 11476* (DOV 040968)(B0728, GU173721).

Carex L sect *Careyanae* Tuck. ex Kük. in Engler, *C. abscondita* Mack., (1) USA: MD, Kent Co, Jun 12 2005 *WD Longbottom 6131* (DOV 051296)(B0057, GU172447); (2) USA: MS, Tishomingo Co, May 29 2003 *CT Bryson, BA Ford, JR MacDonald, RFC Naczi, R Warren 19707* (DOV 057292)(B0058, GU172449); (3) USA: FL, Leon Co, Apr 07 2004 *LC Anderson 20913* (DOV 038861)(B0059, GU172448); *C. austrocaroliniana* LH Bailey, (1) USA: SC, Pickens Co, May 03 1989 *RFC Naczi 2086* (DOV 019531)(B0136, GU172569);

(2) USA: NC, McDowell Co, May 28 1987 *RFC Naczi 1662* (DOV 013067)(B0137, GU172568); (3) USA: NC, Swain Co, May 05 2005 *MJC Murphy, MA Feist, P Marcum, R Phillippe, G Spyreas, P Tessene 42* (ILLS 231629)(B1122, GU172567); (4) USA: TN, Roane Co, Apr 19 1995 *CT Bryson, V McNeilus 14778* (MISS 58072)(B1179, GU172570); *C. careyana* Torrey ex Dewey, (1) USA: KY, Lincoln Co, May 24 2005 *RFC Naczi 10949* (DOV)(B0798, GU172659); (2) USA: KY, Kenton Co, May 15 1999 *RFC Naczi 7848* (DOV)(B0799, GU172660); (3) USA: TN, Van Buren Co, May 17 2001 *C Fleming, B Wofford, D Smith, K Bowman FCF 323* (DOV)(B0814, GU172661); *C. cumberlandensis* Naczi Kral & Bryson, (1) USA: AR, Franklin Co, May 13 1989 *RFC Naczi 2155* (DOV 026777)(B0199, GU172732); (2) USA: KY, Wayne Co, May 20 1999 *RFC Naczi 7940* (DOV 027567)(B0200, GU172733); (3) USA: SC, Anderson Co, Apr 24 1998 *JF Townsend, L Waldrop, JE Fairey II 1659* (DOV 037975)(B0201, GU172734); *C. digitalis* Willd. var *digitalis*, (1) USA: KY, Laurel Co, May 29 1989 *RL Thompson, RL Jones 89 766* (DOV)(B0227, GU172784); (2) USA: DE, New Castle Co, Aug 13 2003 *WA McAvoy 5886* (DOV 040620)(B0233, GU172780); (3) USA: SC, Pickens Co, Jun 24 2003 *A Darr, AB Pittman, R Ahle, L Lee 1872* (DOV 047700)(B0234, GU172788); *C. digitalis* Willd. var *floridana* (LH Bailey) Naczi & Bryson, (1) USA: MS, Amite Co, Apr 27 2007 *CT Bryson, K Gordon, RFC Naczi, Mike Steele 22124* (DOV 062411)(B0225, GU172782); (2) USA: SC, Georgetown Co, Apr 10 1998 *JB Nelson W Furman Long 19035* (DOV 020750)(B0231, GU172783); (3) USA: FL, Leon Co, Apr 7 2004 *LC Anderson 20919* (DOV 038859)(B0236, GU172781); *C. digitalis* Willd. var *macropoda* Fernald, (1) USA: KY, Calloway Co, Apr 25 1999 *RL Thompson 99 66* (DOV 023705)(B0232, GU172786); (2) USA: MD, Worcester Co, May 31 2005 *WA McAvoy, F Hirst, R Wilson 6119* (DOV 054663)(B0235, GU172787); (3) USA: AR, Nevada Co, Apr 14 2001 *RD Thomas, H Young, C Doffitt 169264* (DOV 020992)(B0237, GU172785); *C. laxiculmis* Schweinitz var *copulata* (LH Bailey) Fernald, (1) USA: IL, Kane Co, May 24 2006 *MJC Murphy 1051* (ILLS 236096)(B1126, GU173077); (2) USA: TN, Sevier Co, Aug 23 1999 *LR Phillippe, DW Phillippe 30181* (ILLS 200881)(B1127, GU173078); (3) USA: VA, Giles Co, May 16 2002 *TF Wieboldt 10895* (VPI 100849)(B1248, GU173079); *C. laxiculmis* Schweinitz var *laxiculmis*, (1) USA: MD, Talbot Co, May 18 2006 *WD Longbottom 7314* (DOV 057638)(B0378, GU173080); (2) USA: PA, Potter Co, May 22 2004 *RFC Naczi 10323*

(DOV)(B0800, GU173081); (3) USA of America: VA, Prince Edward Co, Apr 30 2005 *RFC Naczi 10803* (DOV)(B0801, GU173082); (4) Canada: QC, Saint Vallier Jun 18 2000 *S Hay, J Labrecque, F Coursol 2000 06* (MT)(B0871, GU173083); *C. plantaginea* Lamarck in J Lamarck *et al.*, (1) USA: NY, Greene Co, Jul 03 2004 *RFC Naczi 10453* (DOV)(B0864, GU173409); (2) USA: TN, Scott Co, May 03 2001 *VE McNeilus 01 163* (LSU 106954)(B1286, GU173410); *C. playphylla* J Carey, (1) USA: MD, Washington Co, May 02 2006 *WD Longbottom, RD Redden, JD Saffer 7212* (DOV)(B0546, GU173411); (2) USA: PN, Bradford Co, May 21 2004 *RFC Naczi 10263* (DOV)(B0863, GU173412); (3) Canada: QC, MRC Argenteuil (MT)(B0873, GU173413).

Carex L sect *Ceratocystis* Dumortier, *C. cryptolepis* Mack., (1) USA: IL, Kane Co, May 17 2007 *MJC Murphy 2079* (ILLS 240042)(B1123, GU172730); (2) Canada: ON, Lanark Co, Aug 6 1988 *A Vogt 1302* (CAN 551689)(B1473, GU172731); *C. flava* L, (1) USA: VT, Orleans Co, Jul 12 1998 *AA Reznicek, SA Reznicek 10706* (DOV 022674)(B0287, GU172874); (2) Canada: NL, Notre Dame Bay Aug 08 2001 *C Hanel, N Djan Chekar CH010808 11* (MT)(B0881, GU172872); (3) USA: WA, Pend Oreille Co, Aug 12 2004 *PF Zika, F Weinmann, B Wilson, B Newhouse 19952* (WTU 364347)(B0995, GU172875); (4) Canada: QC, Anticosti Island Jul 25 1995 *P Grondin G9514 1* (QFA 122345)(B1389, GU172873); *C. hostiana* de Candolle, (1) Canada: NL, Port au Port Jul 13 1999 *R Charest, C Hanel, L Lavers Prov23 6* (MT)(B0903, GU173003); (2) Canada: QC, Anticosti Island Jul 30 1995 *N Dignard, L Couillard 95 331* (QFA 106487)(B1387, GU173004); (3) Canada: QC, Anticosti Island Aug 21 1991 *MJ Oldham 13215* (TRTE 52539)(B1506, GU173005); *C. lutea* LeBlond, (1) USA: NC, Pender Co, Apr 30 2003 *AS Weakley, RJ LeBlond 7220* (NCU 63296)(B1158, GU173152); *C. viridula* Michaux subsp *brachyrrhyncha* (Celakovsky) B Schmid, (1) Canada: QC, Saint Simon Jul 10 1970 *E Lepage 16451* (CAN 334651)(B1305, GU173782); *C. viridula* Michaux subsp *oedocarpa* (Andersson) B Schmid, (1) Canada: NS, Digby Co, Jul 23 1981 *WJ Crins 13532* (TRTE 34827)(B1341, GU173786); (2) Canada: NS, Cumberland Co, Jul 04 2002 *CS Blaney, RM Whittam 4572* (ACAD 019981)(B1383, GU173787); *C. viridula* Michaux subsp *viridula*, (1) USA: MI, Montmorency Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9456* (DOV 023851)(B0754, GU173784); (2) Canada: NL, Notre Dame Bay Jul 08 2001 *C Hanel, N*

Djan Chekar CH010808 17 (MT)(B0907, GU173785); (3) Canada: QC, Iles de la Madeleine Sep 12 2006 *M Blondeau IM06 040* (MT)(B0911, GU173788); (4) Canada: BC, Malahat Land District, Jun 06 2007 *P Henderson* (UBC 224761)(B1366, GU173781); *C. viridula* Michaux var *elator* (Schlechtendal) Crins, (1) Canada: NL, Gros Morne National Park, Jul 17 1972 *A Bouchard, SG Hay 72 356* (CAN 361898)(B1295, GU173783); (2) Canada: NL, S of Bellburns, Jul 20 1996 *PW Ball 96054* (TRTE)(B1296, GU173780); *C. viridula* Michaux var. *saxilittoralis* (Robertson) Crins, (1) Canada: NL, St Barbe N dist, Jul 23 2007 *LeBlond 6449* (COLO)(B1410, GU173789).

Carex L sect *Chlorostachyae* Tuck. ex Meinshausen, *C. capillaris* L, (1) Canada: NL, Northeast Coast Jul 21 2001 *C Hanel, N Djan Chekar, J Maunder CH010720 2* (MT)(B0874, GU172650); (2) Canada: NT, Wollaston Peninsula Jul 27 1982 *SA Edlund* (CAN 489228)(B1488, GU172651); *C. krausei* Boeckeler, (1) USA: AK, Tetlin National Wildlife Refuge Jun 07 2003 *BA Bennett, P Loomis 03 315* (ALA 1131268)(B1032, GU173059); *C. williamsii* Britton, (1) Canada: YT, Quartet Lake Jul 07 2005 *BA Bennett, P Seccombi Hett, S Thompson, D Mahoney 05 0190* (UBC 223019)(B1362, GU173800); (2) Canada: YT, Moose Channel, near YT/NWT border Jul 31 2006 *BA Bennet, MJ Oldham, CA Kennedy, P Seccombe Hett, DC Gordon 06 372* (UBC 224456)(B1517, GU173801).

Carex L sect *Chordorrhizae* (Heuffel) Meinshausen, *C. chordorrhiza* Ehrhart ex L, (1) USA: MI, Montgomery Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9454* (DOV 023867)(B0215, GU172683); (2) Canada: NL, St Barbe North Jul 27 1987 *S Hay, L Brouillet, I Saucier 87421* (MT)(B0915, GU172684); (3) Canada: BC, Okaloosa Co, Jul 31 1974 *VJ Krajina, J Pojar, C Parsons* (UBC 150100)(B1318, GU172682).

Carex L sect *Circinatae* Meinshausen, *C. anthoxanthea* J Presl & C Presl in CB Presl, (1) USA: WA, Olympic National Forest *AC Yen 246* (WTU 342098)(B0961, GU172499); (2) USA: AK, Goodnews Bay Quad Jun 16 2004 *CL Parker 15653* (ALA 1114587)(B1011, GU172497); (3) Canada: BC, Queen Charlotte Island Jul 23 2007 *JM Saarela, D Percy 1197* (CAN)(B1424, GU172498); *C. circinata* CA Meyer, (1) USA: AK, Seldovia Quad Jul 08 2003 *R Lipkin, B Rice, E Groth 39892* (ALA 1125263)(B1370, GU172685).

Carex L sect *Clandestinae* G Don in JC Loudon, *C. concinna* R Brown in J Franklin *et al.*, (1) Canada: NL, White Bay North Dist Jul 18 1987 *A Bouchard, S Hay, L Brouillet, I Saucier 87127* (CAN 545521)(B0950, GU172703); (2) USA: CO, Clear Crk Co, Aug 03 1994 *N Lederer 4400* (COLO 454925)(B1090, GU172702); *C. concinnoides* Mack., (1) USA: CA, Trinity Co, Jun 12 2002 *DW Taylor 18136* (JEPS 100190)(B1311, GU172704); (2) USA: ID, Bonner Co, Jun 21 2006 *P Brunsfeld, AJ Brumble, E Poor, L Stratford, D Craig 5194* (ID 141596)(B1510, GU172705); *C. pedunculata* Muhl. ex Willd., (1) Canada: MB, 1.5 m N of town of Falcon Lk Jun 25 2003 *RFC Naczi, BA Ford 9850* (DOV 037230)(B0539, GU173372); (2) USA: MD, Garrett Co, Jun 04 2005 *WD Longbottom, RFC Naczi, G Van Velsir 6029* (DOV 051234)(B0540, GU173373); (3) USA: MA, Hampshire Co, May 11 1999 *TM Zebryk 6085* (DOV 046246)(B0541, GU173371); (4) USA: AL, Winston Co, Apr 08 1978 *RR Haynes 6422* (UNA 2728)(B1237); *C. richardsonii* R Brown in J Franklin *et al.*, (1) USA: MD, Baltimore Co, Apr 28 2005 *WM Knapp 1149* (DOV)(B0613, GU173477); (2) USA: South Dakota, Custer Co, Jun 08 1993 *GE Larson 11028* (RM 603430)(B1274, GU173478).

Carex L sect *Collinsiae* (Mack.) Mack. in NL Britton *et al.*, *C. collinsii* Nuttall, (1) USA: DE, Sussex Co, May 31 1999 *RFC Naczi 8108* (DOV 035261)(B0209, GU172686); (2) USA: NC, Cumberland Co, May 18 2007 *RFC Naczi, BA Sorrie, EL Hoffman, WA McAvoy, K Sinclair, G Sinclair 11871* (DOV 063499)(B0216, GU172688); (3) USA: GA, Marion Co, Jul 22 2001 *BA Sorrie, R LeBlond 10778* (NCU 66902)(B1156, GU172687).

Carex L sect *Cyperoideae* G Don in JC Loudon, *C. sychnocephala* J Carey, (1) USA: MI, Oscoda Co, Jul 17 2002 *AA Reznicek, FW Case, J Morgan, RR Comstock 11374* (DOV 040989)(B0701, GU173658); (2) Canada: ON, Hamilton Wentworth Co, Aug 02 2002 *JS Pringle, CJ Rothfels CJR268* (TRTE 66756)(B1293, GU173659); (3) Canada: BC, Marble Canyon Campground Aug 06 1995 *F Lomer 95 148* (UBC 210737)(B1373, GU173657).

Carex L sect *Deweyanae* (Tuck. ex Mack.) Mack. in NL Britton *et al.*, *C. bolanderi* Olney, (1) USA: CA, Santa Clara Co, Jul 19 1993 *RFC Naczi 3293* (DOV)(B0811); (2) USA: CA,

Fresno Co, Jul 26 2004 *RFC Naczi 10553* (DOV)(B0812, GU172607); (3) USA: CA, Del Norte Col Jul 12 1993 *RFC Naczi 3261* (DOV)(B0813, FJ597188); (4) USA: WA, King Co, Aug 11 2001 *S Bagshaw, M Koehler, J Hall, SC Pechara 01 224* (WTU 351136)(B0965, GU172608); *C. bromoides* Schkuhr ex Willd. subsp *bromoides*, (1) USA: FL, Leon Co, Apr 07 2004 *LC Anderson 10920* (DOV 038479)(B0020, FJ597189); (2) USA: NY, Rockland Co, May 10 1995 *GC Tucker, J Focht, S Barbour 10495* (DOV 045833)(B0021, FJ597190); (3) USA: MD, Wicomico Co, Apr 17 2000 *C Lea 1323* (DOV)(B0022, FJ597191); *C. bromoides* Schkuhr ex Willd. subsp *montana* Naczi, (1) USA: NC, Avery Co, May 28 1987 *RFC Naczi 1657* (DOV 019517)(B0023, FJ597192); (2) USA: VA, Patrick Co, May 30 1987 *RFC Naczi 1671* (VPI 83855)(B1245, GU172622); *C. deweyana* Schweinitz var *collectanea* Fernald, (1) Canada: QC, Gaspesie *JR Starr, C Fletcher, J Graham 08 092* (CAN)(B1403, GU172773); (2) Canada: QC, Gaspesie *JR Starr, C Fletcher, J Graham 08 120* (CAN)(B1404, GU172774); (3) Canada: QC, Gaspesie *JR Starr, C Fletcher, J Graham 08 095* (CAN)(B1405, GU172775); *C. deweyana* Schweinitz var *deweyana*, (1) USA: PA, Bradford Co, May 21 2004 *RFC Naczi 10289* (DOV)(B0402, GU172771); (2) Canada: MB, Souris Riv Wildlife Management Area Jun 26 2003 *RFC Naczi, BA Ford 9881* (DOV)(B0421, GU172770); (3) Canada: BC, Little Fort Jun 30 2000 *BA Ford, JM Saarela 00148* (DOV)(B0422, GU172769); (4) USA: WA, Pend Oreille Co, Aug 12 2004 *PF Zika, F Weinmann, B Wilson, B Newhouse 19947* (WTU 364349)(B0972, GU172772); *C. infirmivervia* Naczi, (1) USA: CA, Fresno Co, Jul 26 2006 *RFC Naczi 10552* (DOV)(B0795, FJ597220); (2) USA of America: CA, Amador Co, Aug 06 2006 *RFC Naczi 11511* (DOV)(B0802, FJ597221); (3) USA: CA, Butte Co, Jul 23 2004 *RFC Naczi, LP Janeway 10500* (DOV)(B0803, FJ597222); (4) USA: WA, Pend Oreille Co, Aug 13 2004 *PF Zika, F Weinmann, B Wilson, B Newhouse 19962* (WTU 361936)(B1000, GU173032); *C. laeviculmis* Meinshausen, (1) USA: CA, Butte Co, Aug 03 2006 *LP Janeway, M Waterway, M Lechowicz 8824* (DOV 060586)(B0019, GU173066); (2) USA: CA, Del Norte Co, Jul 12 1993 *RFC Naczi 3263* (DOV)(B0024, FJ597228); (3) USA: CA, Butte Co, Jul 23 2004 *RFC Naczi, LP Janeway 10501* (DOV)(B0793, FJ597229); (4) USA: CA, Del Norte Co, Jul 11 1993 *RFC Naczi 3235* (DOV)(B0794, FJ597230); (5) Canada: BC, W of Smithers Jul 19 2007 *JM Saarela, D Percy 1096* (CAN)(B1422, GU173065); *C. leptopoda* Mack. in PA Rydberg, (1) USA: OR, Lane Co, Jun 23 1999 *SM Yelton 31* (DOV

046042)(B0025, GU173119); (2) Canada: BC, 16 km E of Salmo Jun 27 2000 *BA Ford, JM Saarela 134* (DOV)(B0796, FJ597234); (3) USA: OR, Benton Co, Jul 15 1993 *RFC Naczi 3289* (DOV 046042)(B0805, FJ597235).

Carex L sect *Dispermae* Ohwi, *C. disperma* Dewey, (1) USA: MI, Oscoda Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9426* (DOV 023493)(B0229, GU172795); (2) USA: CO, Jefferson Co, Jul 21 2003 *C Lea 3431* (DOV 046665)(B0238, GU172793); (3) USA: ME, Hancock Co, Jun 30 2003 *AA Reznicek 11487* (DOV 040970)(B0239, GU172794); (4) USA: AK, Big Delta Quad Jun 21 1995 *MDuffy, R Lipkin, J Tande 95 270* (ALA 1125748)(B1045, GU172792).

Carex L sect *Divisae* Christ ex Kük. in Engler, *C. divisa* Hudson, (1) USA: MD, St Mary's Co, May 17 1994 *CA Davis 2509* (MICH)(B1458, GU172798); (2) Spain: Seville, Andalusia May 15 2000 *J Solis, M Luceno 103JESOGA* (UPOS 001053)(B1505, GU172799); (3) USA: VA, Lancaster Co, *T Weldy 483* (WILLI 71592)(B1534, GU172800); *C. douglasii* Boott in Hooker, (1) USA: CA, Plumas Co, Jul 07 2001 *GK Helmkamp, E Helmkamp 6874* (UCR 123513)(B1249, GU172803); (2) USA: ID, Owyhee Co, Jun 12 1980 *D Henderson, C Wellner 5565* (CAN 497329)(B1529, GU172804); (3) Canada: SK, Dundurn CP Jun 28 1999 *JH Hudson 5398* (CAN 582656)(B1530, GU172805); *C. duriuscula* CA Meyer, (1) USA: AK, Fairbanks Quad Jul 07 1995 *M Reynolds 95 586* (ALA 1125845)(B1046, GU172806); *C. pansa* LH Bailey, (1) USA: OR, Coos Co, Jul 20 2006 *BL Wilson, K Mitchell 11903* (OSC 215850)(B1053, GU173361); (2) USA: CA, San Luis Obispo Co, Sep 03 1990 *G Helmkamp* (UCR 67025)(B1357, GU173360); *C. praegracilis* Boott, (1) USA: CA, Lassen Co, Jun 01 2005 *L Ahart, J Dittes 11879* (DOV 055897)(B0551, GU173424); (2) USA: ME, Penobscot Co, Jun 12 1992 *MJ Oldham 13794* (DOV 044969)(B0552, GU173426); (3) Canada: MB, 3.2 km E of Stuartburn Jun 28 2003 *RFC Naczi, BA Ford, CE Punter, CA Burchill 9941* (DOV 039082)(B0562, GU173425); *C. simulata* Mack., (1) USA: CA, Madera Co, Jul 27 2004 *RFC Naczi 10593* (DOV 055808)(B0678, GU173580); (2) USA: UT, Summit Co, Aug 05 2004 *RFC Naczi, WM Knapp 10698* (DOV 055353)(B0679, GU173581); (3) USA: WA, Klickitat Co, Jun 15 2001 *S Rodman 515* (WTU 351948)(B0981, GU173582).

Carex L sect *Dornera* Heuffel, *C. micropoda* CA Meyer, (1) USA: WA, Whatcom Co, Aug 03 2007 *K O'Neil, L Hickenbottom, P Zika, D Giblin 07 13* (WTU 368131)(B0991, GU173229); (2) USA: AK, Iliamna Quad Jul 29 2001 *P Caswell, A Jansen 01 400* (ALA 1119567)(B1025, GU173225); (3) USA: WY, Sublette Co, Aug 02 1994 *RL Hartman, T Cramer 49157A* (RM 625627)(B1264, GU173230); (4) USA, *L Bruederle 815200802* (COLO)(B1407, GU173226); (5) USA: *L Bruederle 814200801* (COLO)(B1408, GU173227); (6) Canada: BC, Hudson Bay Mt Rd, W of Smithers Jul 27 2007 *JM Saarela, D Percy 1327* (CAN)(B1426, GU173228); *C. nigricans* CA Meyer, (1) USA: ID, Shoshone Co, Jul 15 2003 *T Kemper 165* (DOV 047402)(B0513, GU173289); (2) USA: AK, Talkeetna Quad Jul 23 2002 *MDuffy MD02 112* (ALA 119565)(B1031, GU173287); (3) Canada: BC, Queen Charlotte Island Jul 24 2007 *JM Saarela, D Percy 1228* (CAN)(B1425, GU173288).

Carex L sect *Filifoliae* (Tuck.) Mack. in NL Britton *et al.*, *C. filifolia* Nuttall var *erostrata* Kük., (1) USA: CA, Plumas Co, Jun 14 2006 *LP Janeway, B Castro 8691* (DOV 055726)(B0259, GU172859); (2) USA: CA, Mono Co, Aug 07 1997 *SD White, E Read, G Hawkins, A Sears, S Weaver 5463* (UCR 109048)(B1365, GU172858); *C. filifolia* Nuttall var *filifolia*, (1) USA: NV, Elko Co, Jul 01 2004 *RFC Naczi, W Knapp 10668* (DOV 005)(B0247, GU172860); (2) USA: CA, Mono Co, Aug 05 2006 *RFC Naczi 11490* (DOV)(B0829, GU172857); (3) USA: AK, Valdez Quad Jul 08 1981 *AP Khokhryakov, BA Yurtsev, DF Murray 6201* (ALA 1130145)(B1035, GU172856); *C. oreocharis* Holm, (1) USA: CO, Jefferson Co, May 20 1997 *JK Nelson 548* (COLO 508213)(B1097, GU173330); (2) USA: AZ, Apache Co, Jul 28 1990 *LR Landrum, S Landrum, J Dietrich, M Dietrich 7126* (ASU 177390)(B1269, GU173328); (3) USA: *L Bruederle 627080110* (COLO)(B1406, GU173329).

Carex L sect *Firmiculmes* (Kük.) Mack. in NL Britton *et al.*, *C. geyeri* Boott, (1) Canada: AB, Rocky Mts Forest Reserve Jun 26 2000 *BA Ford, JM Saarela 00110* (DOV 021808)(B0324, GU172909); (2) USA: CA, Trinity Co, May 21 2002 *DW Taylor 18068* (DOV 023457)(B0325, GU172910); *C. multicaulis* LH Bailey, (1) USA: CA, Siskiyou Co,

Jun 19 1989 *D Castaner 10243* (DOV 039651)(B0486, GU173260); (2) USA: OR, Jackson Co, Jul 02 1996 *BL Wilson 8194* (OSC 184991)(B1065, GU173261); (3) USA: CA, Nevada Co, Jul 27 2007 *GK Helmkamp, E Helmkamp 12594* (UCR 189156)(B1259, GU173259); *C. tompkinsii* JT Howell, (1) USA: CA, Fresno Co, Jul 06 2003 *LP Janeway 7874* (DOV 042286)(B0738, GU173693); (2) USA: CA, Merced Co, Apr 25 2002 *DW Taylor 18011* (DOV 023311)(B0838, GU173694).

Carex L sect *Foetidae* (Tuck. ex Bailey) Kük. in Engler, *C. incurviformis* Mack in PA Rydberg, (1) USA: CO, Park Co, Aug 07 1998 *R Orthner, T Hogan, L Yeatts, D Yeatts 738* (COLO 500063)(B1116, GU173030); (2) Canada: BC, Peel/Blow Riv Delta Jul 08 1996 *GW Douglas, JL Penny, G Berg, T Antifeau 13162* (UBC 214741)(B1378, GU173029); (3) USA: CO, Park Co, Aug 09 1986 *R Tallent 517* (MICH)(B1495, GU173031); *C. perglobosa* Mack., (1) USA: CO, Clear Crk Co, Sep 19 2001 *L Yeatts, D Yeatts 4756* (COLO 500184)(B1196, GU173390); *C. vernacula* LH Bailey, (1) USA: CA, Tuolumne Co, Aug 05 2006 *RFC Naczi 11500* (DOV)(B0859, GU173765); (2) USA: CO, Saguache Co, Jul 31 1994 *L Yeatts 3612* (COLO 456092)(B1106, GU173766).

Carex L sect *Glareosae* G Don in JC Loudon, *C. arcta* Boott, (1) USA: AK, Just S of Smith Lk Aug 04 2003 *AA Reznicek, DF Murray 11538* (DOV 041015)(B0092, GU172519); (2) USA: MT, Lincoln Co, Aug 25 2000 *PE Hyatt 9643* (DOV 047190)(B0093, GU172520); (3) Canada: NB, Restigouche Co, Aug 10 1988 *HR Hinds 8977* (CAN 550248)(B0955, GU172521); *C. arctiformis* Mack. in Britton *et al.*, (1) Canada: BC, Vancouver Island Aug 07 1976 *A Ceska, O Ceska, H Roemer* (UBC 220956)(B1244, GU172526); *C. bonanzensis* Britton, (1) USA: AK, Circle Quad Nov 11 2005 *DV Person, A Larsen, J Spires 05DVP36* (ALA 1124246)(B1213, GU172609); (2) Canada: North West Territories, Inuvik Jul 17 1978 *F Fodor 1324* (UBC 167826)(B1214, GU172610); (3) Canada: YT, Vicinity of Mayo Jul 13 1967 *RT Porsild 816* (CAN)(B1497, GU172611); *C. brunnescens* (Persoon) Poir. subsp *brunnescens*, (1) USA: CA, Nevada Co, Jul 28 2004 *RFC Naczi 10618* (DOV 055146)(B0146, GU172625); (2) USA: AK, Kenai peninsula Aug 19 2005 *AA Reznicek 11717* (DOV 053266)(B0154, GU172623); (3) Canada: NL, Great Northern Peninsula Jul 26 2000 *L Brouillet, N Djan Chekar, T Ahit, C Wentzell LB 00 117* (MT)(B0882,

GU172624); *C. brunnescens* (Persoon) Poiret subsp. *sphaerostachya* (Tuck.) Kalela, (1) USA: WI, Wood Co, Jun 6 2003 *NA Harriman, TG Lammers 21718* (DOV 039639)(B0155, GU172628); (2) Canada: NL, Great Northern Peninsula Jul 20 2000 *L Brouillet, N Djan Chekar, T Ahit, L Lavers, C Wentzell LB 00 262* (MT)(B0883, GU172626); (3) Canada: ON, Thunder Bay Dist Jun 18 1970 *CE Garton 12971* (CAN 342984)(B1472, GU172627); *C. canescens* L subsp. *canescens*, (1) USA: DE, Sussex Co, Jul 6 2005 *WA McAvoy 6122* (DOV 054707)(B0192, GU172643); (2) USA: UT, Summit Co, Aug 5 2004 *RFC Naczi, WM Knapp 10692* (DOV 055063)(B0193, GU172649); (3) USA: CA, Nevada Co, Aug 9 2004 *L Ahart 11372* (DOV 047933)(B0194, GU172642); (4) Canada: NL, Bonavista South Dist Aug 13 1996 *R Charest 96 2831* (MT)(B0886, GU172644); (5) USA: WA, Chelan Co, Jun 29 2006 *B Smith 06 18* (WTU 366811)(B0968, GU172645); *C. canescens* L subsp. *disjuncta* (Fernald) Toivonen, (1) Canada: NL, Bonavista South Dist Aug 21 1997 *R Charest, L Brouillet, J Labrecque 97 3226* (MT)(B0879, GU172648); (2) Canada: NL, Eagle Riv Jul 20 1999 *S Hay, L Brouillet, R Charest, C Hanel, N Djan Chekar, S Meades, D Meades, C Wentzell, B Pollock, L Lavers, P Lavers NDC 99 678* (MT)(B0895, GU172646); (3) USA: NC, Hoke Co, Apr 17 2004 *BA Sorrie 11208* (NCU 76547)(B1152, GU172647); *C. heleonastes* L, (1) USA: AK, Kotzebue Quad Jul 02 2003 *CL Parker, AR Batten, R Elven, H Solstad 14224* (ALA 1139107)(B1049, GU172968); (2) Canada: MB, Wapusk National Park Jul 20 2002 *BA Ford, M Piercey Normore, E Punter, D Punter 02 282* (WIN 70327)(B1140, GU172969); (3) Canada: AB, SE of Conklin Jul 11 2005 *GCD Griffiths* (ALTA 114410)(B1347, GU172967); *C. lachenali* Schkuhr, (1) USA: AK, Kotzebue Quad Aug 06 2001 *CL Parker, R Elven, H Solstad 11047* (ALA 1131378)(B1033, GU173060); *C. lapponica* O Lang, (1) USA: AK, Hughes Quad Aug 08 2002 *CL Parker, R Elven, H Solstad 13983A* (ALA 1131696)(B1034, GU173069); (2) Canada: NT, 128 mi SW of Inuvik Jul 13 2004 *PM Peterson, JM Saarela, SF Smith 18579* (CAN)(B1413, GU173070); *C. loliacea* L, (1) USA: AK, Skagway Quad Jul 11 2003 *M Carlson, A Bethe 02 258* (ALA 1138220)(B1043, GU173127); *C. mackenziei* VI Kreczetowicz in VL Komarov *et al.*, (1) Canada: NL, Strait of Belle Isle Dist Aug 08 1992 *A Bouchard, S Hay, L Brouillet, A Brown 92033* (MT)(B0891, GU173165); (2) USA: AK, Yakutat D5 Quad Jul 24 2003 *P Loomis, AR Batten 1722* (ALA 1138580)(B1050, GU173164); *C. marina* Dewey, (1) Canada: MB, Wapusk National Park Jul 23 2003 *E Punter, M Piercey Normore 03 756* (WIN

72283)(B1139, GU173186); *C. praeceptorum* Mack. in NL Britton *et al.*, (1) USA: UT, Duchesne Co, Aug 05 2004 *RFC Naczi WM Knapp 10748* (DOV 056478)(B0549, GU173422); (2) USA: WA, Pend Oreille Co, Jul 23 2003 *F Weinmann, A Weinmann, K Ahlenslager 214* (WTU 353891)(B0988, GU173423); (3) USA: CA, Tuolumne Co, Aug 16 2005 *P moore, D Grossenbacher PM05 45* (UC 1861854)(B1345, GU173421); *C. tenuiflora* Wahl., (1) Canada: MB, 34 km N of Grand Rapids Aug 16 1995 *BA Ford et al. 9574* (DOV 040062)(B0708, GU173675); (2) USA: WA, Okanogan Co, Aug 11 2004 *PF Zika, F Weinmann, B Wilson, B Newhouse 19930* (WTU 361986)(B0982, GU173676); *C. trisperma* Dewey, (1) USA: MI, Cheboygan Co, Jun 28 1989 *RFC Naczi 2248* (DOV 022701)(B0729, GU173728); (2) Canada: MB, 4 km N of town of W Hawk Lk Jun 25 2003 *RFC Naczi, BA Ford 9833* (DOV 037242)(B0730, GU173726); (3) USA: ME, Washington Co, Jun 27 2007 *WM Knapp 2208* (DOV 064036)(B0731, GU173727); (4) USA: NJ, Ocean Co, Jun 19 2004 *RFC Naczi, LC Kelly, RL Mears, WM Knapp 10440* (DOV 050260)(B0850, GU173729); (5) USA: MA, Essex Co, Aug 09 2005 *RFC Naczi 11165* (DOV 053360)(B0851, GU173725); *C. ursina* Dewey, (1) Canada: YT, Ivvavik National Park Aug 07 2005 *BA Bennett, CL Parker, T McIntosh, P Seccombe Hett, M Joe 05 1088* (UBC 223016)(B1368, GU173748); (2) Canada: YT, Bill Storr Channel Jul 31 2006 *BA Bennet, MJ Oldham, CA Kennedy, P Seccombe Hett, DC Gordon 06 394* (CAN 589292)(B1528, GU173749); *C. Wahl. glareosa* subsp *glareosa*, (1) Canada: MB, Cape Merry Jul 14 2004 *BA Ford, M Piercey Normore, D Punter 4121* (WIN 71125)(B1149, GU172918).

Carex L sect *Glaucescens* Reznicek, *C. glaucescens* Elliott, (1) USA: SC, Lexington Co, Jul 19 1993 *CN Horn 7238* (DOV 039311)(B0301, GU172920); (2) USA: MS, Stone Co, Jul 28 2003 *RFC Naczi, PJ Calie 10023* (DOV 038012)(B0308, GU172919); (3) USA: TX, Hardin Co, Aug 22 2003 *RW Sanders 6141* (BRIT)(B1537, GU172921); *C. jorii* LH Bailey, (1) USA: MD, Dorchester Co, Aug 23 2005 *WD Longbottom, WM Knapp 6507* (DOV 051542)(B0300, GU173051); (2) USA: MD, Dorchester Co, Aug 27 2006 *WD Longbottom 7818* (DOV 060850)(B0366, GU173052); (3) USA: FL, Levy Co, Aug 07 2000 *JR Abbott, B Herring 13747* (DOV 020819)(B0367, GU173050); (4) USA: AR, Miller Co, Sep 28 1995 *PE Hyatt 6782* (DOV 039596)(B0368, GU173049); *C. verrucosa* Muhl., (1) USA: FL, Levy Co, Mar 13 2006 *WD Longbottom, DH Williams 7023* (DOV

054842)(B0768, GU173767); (2) USA: GA, Camden Co, Apr 07 2006 *R Carter, W Baker 16445* (DOV 054378)(B0769, GU173768); (3) USA: LA, Allen Parish May 08 2003 *C Reid, P Faulkner, S Kinney, J Jones 4441* (LSU 134481)(B1314, GU173769).

Carex L sect *Granulares* (O Lang) Mack. in NL Britton *et al.*, *C. crawei* Dewey, (1) USA: TN, Maury Co, May 24 2004 *D Estes, K Hefner 6088* (DOV)(B0797, GU172713); (2) Canada: NL, St Barbe South Dist Jul 29 1991 *A Bouchard, S Hay, L Brouillet, M Jean 91004* (MT)(B0868, GU172712); *C. gholsonii* Naczi & Cochrane, (1) USA: AL, Houston Co, May 03 1997 *JR MacDonald 10309* (DOV 026347)(B0335, GU172911); (2) USA: NC, Pender Co, May 20 1992 *AA Reznicek, SA Reznicek, R LeBlond, B Sorrie 8943* (DOV 026606)(B0345, GU172912); *C. granularis* Muhl. ex Willd., (1) USA: MD, Queen Anne's Co, Jun 12 2005 *WD Longbottom 6111* (DOV 051447)(B0313, GU172936); (2) Canada: MB, Souris Riv Wildlife Management Area Jun 26 2003 *RFC Naczi, BA Ford 9886* (DOV)(B0804, GU172935); (3) USA: PA, Bradford Co, Jun 16 2004 *RFC Naczi, RL Mears 10391* (DOV)(B0806, GU172938); (4) USA: MS, Washington Co, May 18 2006 *CT Bryson 21462* (DOV)(B0815, GU172937); *C. microdonta* Torrey & Hooker, (1) USA: MS, Lowndes Co, May 15 1989 *RFC Naczi, CT Bryson 2177* (DOV)(B0817, GU173221); (2) USA: TX, Williamson Co, May 01 2004 *RFC Naczi 10106* (DOV)(B0818, GU173223); (3) USA: NM, Eddy Co, Jun 01 2000 *RD Worthington 29977* (UNM 101722)(B1239, GU173222).

Carex L sect *Griseae* (Bailey) Kük. in Engler, *C. acidicola* Naczi, (1) USA: GA, Clarke Co, May 22 1996 *RFC Naczi, CT Bryson 5437* (DOV 026612)(B0031, FJ597176); (2) USA: AL, Lee Co, Apr 24 2002 *RFC Naczi 9136* (DOV 026602)(B0039, FJ597177); (3) USA: AL, Tuscaloosa Co, May 22 1996 *RFC Naczi, CT Bryson 5437* (DOV 039865)(B0844, FJ597178); *C. amphibola* Steudel, (1) USA: MD, Kent Co, May 10 2002 *WA McAvoy 5467* (DOV 049628)(B0032, FJ597179); (2) USA: SC, Lancaster Co, May 10 2005 *JB Nelson, A Darr, C DeGarady, M Hey, B Pittman, M Robertson et al. 25367* (DOV 049628)(B0034, FJ597180); (3) USA: AL, Lawrence Co, Apr 19 2003 *DD Spaulding 11739* (DOV 034234)(B0035, FJ597181); *C. brysonii* Naczi, (1) USA: AL, Winston Co, May 23 1986 *CT Bryson 4385* (DOV 020207)(B0036, FJ597193); (2) USA: AL, Lawrence Co, May 15 1992

CT Bryson 11619 (MICH)(B1492, GU172629); *C. bulbostylis* Mack., (1) USA: MS, Leflore Co, May 17 1999 *CT Bryson, J MacDonald, R Warren 17147* (DOV 032331)(B0029, FJ597195); *C. calcifugens* Naczi, (1) USA: GA, Burke Co, May 18 1989 *RFC Naczi 2191* (DOV 027114)(B0048, FJ597196); (2) USA: FL, Liberty Co, Apr 01 1990 *SL Orzell, EL Bridges 13061* (DOV 027566)(B0049, FJ597197); *C. conoidea* Willd., (1) USA: MD, Cecil Co, Jun 03 2004 *RFC Naczi 10349* (DOV)(B0823); (2) USA of America: PA, Bradford Co, Jun 16 2004 *RFC Naczi, RL Mears 10396* (DOV)(B0824, FJ597198); (3) USA: DE, New Castle Co, Jun 12 2002 *RFC Naczi, J Ebert, SW Welles 9346* (DOV)(B0825, FJ597199); *C. corrugata* Fernald, (1) USA: MD, Worcester Co, Jun 08 1999 *C Lea 1177* (DOV)(B0033, GU172711); (2) USA: SC, Richland Co, Jun 14 1996 *AB Pittman, A Weakley, R Sharitz 6149602* (DOV 039567)(B0050, FJ597203); (3) USA: AL, Jackson Co, Apr 21 2002 *RFC Naczi 9013* (DOV 026367)(B0051, FJ597204); (4) USA: TX, Lavaca Co, Apr 21 2007 *RFC Naczi 11716* (DOV)(B0821, FJ597205); *C. edwardsiana* EL Bridges & Orzell, (1) USA: TX, Hays Co, *WR Carr 18841* (BRIT)(B1536, GU172823); *C. flaccosperma* Dewey, (1) USA: TX, Jasper Co, Apr 07 2003 *SD Jones 16027* (DOV 041709)(B0026, FJ597206); (2) USA: LA, Natchitoches Co, Apr 16 2001 *PE Hyatt 10056* (DOV 033716)(B0052, FJ597207); (3) USA: SC, Edgefield Co, Apr 25 1996 *JB Nelson 17172* (DOV 037746)(B0053, FJ597208); *C. glaucodea* Tuck. ex Olney, (1) USA: KY, Casey Co, Jun 18 1998 *RFC Naczi, AA Reznicek 7463* (DOV 020980)(B0044, FJ597210); (2) USA: KY, Lincoln Co, May 24 2005 *RFC Naczi 10959* (DOV 020980)(B0822, FJ597211); (3) USA: IN, Porter Co, Jun 17 2001 *AA Reznicek 11258* (WIN 69008)(B0924, FJ597209); *C. godfreyi* Naczi, (1) USA: FL, Wakulla Co, Apr 05 2007 *LC Anderson 22839* (DOV 060622)(B0027, FJ597213); (2) USA: AL, Conecuh Co, Apr 28 2000 *BA Ford, RFC Naczi 75* (WIN 66994)(B0926, FJ597212); (3) USA: AL, Houston Co, Apr 06 1997 *JR MacDonald 10110* (MISS 61376)(B1180, GU172925); *C. grisea* Wahl., (1) USA: KY, Lewis Co, Jun 16 1996 *RA Gelis, ML Gelis M2 1224* (DOV)(B0037, FJ597215); (2) USA: MD, Cecil Co, May 20 1997 *WA McAvoy 2225* (DOV 047455)(B0045, FJ597216); (3) USA: TX, Bastrop Co, May 01 2004 *RFC Naczi 10113* (WIN 71379)(B0932, FJ597214); *C. hitchcockiana* Dewey, (1) USA: KY, Harrison Co, Jun 21 1997 *RFC Naczi 6621* (DOV 020978)(B0038, GU172993); (2) USA: KY, Harrison Co, Jun 21 1997 *RFC Naczi 6621* (DOV 020978)(B0808, FJ597217); (3) USA: TN, Jackson Co, May 15 2005 *D Estes 7203*

(DOV)(B0809, FJ597218); (4) Canada: ON, Simcoe Co, Jul 11 2005 *AA Reznicek 11690* (DOV)(B0810, FJ597219); *C. impressinervia* Bryson Kral & Manhart, (1) USA: AL, Wilcox Co, Apr 06 1993 *R Kral 82016* (NCU 41472)(B1155, GU173027); (2) USA: MS, George Co, Apr 22 1998 *BA Sorrie 9666* (MISS 65686)(B1177, GU173028); *C. oligocarpa* Willd., (1) USA: KY, Kenton Co, May 12 1995 *RFC Naczi 4600* (DOV 020977)(B0054, FJ597236); (2) USA: MO, Christian Co, May 22 1986 *D Castaner 9228* (DOV 024506)(B0055, FJ597237); (3) Canada: QC, MRC Communauté régionale de l'Outaouais Jul 22 1992 *D Gagnon DG92 22* (MT)(B0869, GU173322); (4) USA: AR, Montgomery Co, May 20 1994 *BA Ford, RFC Naczi 9438* (WIN 66629)(B0931, GU173320); (5) USA: OK, Pawnee Co, May 04 2004 *B Hoagland, C Batterson AB 4656* (OKL 233773)(B0948b, GU173321); *C. ouachitana* Kral Manhart & Bryson, (1) USA: KY, Clinton Co, Apr 27 2002 *RFC Naczi 9241* (DOV)(B0819, FJ597238); (2) USA: OK, McCurtain Co, May 26 2003 *RFC Naczi, BA Ford 9654* (DOV)(B0820, FJ597239); (3) USA: WA, Garland Co, May 20 1994 *BA Ford, RFC Naczi 9433* (WIN 66676)(B0937, FJ597240); *C. paeninsulae* Naczi EL Bridges & Orzell, (1) USA: FL, Marion Co, Mar 28 1993 *SL Orzell, EL Bridges 21352* (DOV 026794)(B0030, FJ597241); (2) USA: FL, Clay Co, May 05 1990 *RFC Naczi 2373* (DOV 026577)(B0842, GU173350); (3) USA: FL, Hernando Co, Apr 12 1994 *SL Orzell, EL Bridges 22634* (DOV 026787)(B0848, FJ597242); *C. pigra* Naczi, (1) USA: SC, Greenwood Co, Apr 26 2002 *RFC Naczi, WG Noel, JD Nelson 9206* (DOV 025349)(B0046, GU173403); (2) USA: MS, Chickasaw Co, Apr 27 2002 *CT Bryson, NB Bryson 19161* (WIN 68465)(B0939, FJ597243); (3) USA: MS, Pontotoc Co, May 20 2002 *CT Bryson 19307* (MISS 70114)(B1178, GU173402); (4) USA: AL, Saint Clair Co, Apr 23 2003 *DD Spaulding 11762* (UNA)(B1236, GU173401); *C. planispicata* Naczi, (1) USA: MD, Kent Co, May 10 2002 *WA McAvoy 5468* (DOV 027647)(B0047, FJ597247); (2) USA: MS, Tishomingo Co, May 29 2003 *BA Ford, CT Bryson, JR MacDonald, RFC Naczi, R Warren 394* (WIN)(B0930, FJ597245); (3) USA: TN, Weakly Co, Jun 28 1995 *RFC Naczi, AA Reznicek 4862* (WIN)(B0938, FJ597246); *C. thornei* Naczi, (1) USA: FL, Gadsden Co, Mar 24 1990 *SL Orzell, EL Bridges 12998* (DOV 027112)(B0040, FJ597254); (2) USA: GA, Chattahoochee Co, May 23 1997 *RFC Naczi 6135* (DOV 027110)(B0041, FJ597255); (3) USA: AL, Russell Co, May 03 1996 *RFC Naczi 5201* (DOV 027116)(B0042, GU173685); (4) USA: GA, Walker Co, Apr 08 2000 *SR Hill 32219* (ILLS 203961)(B1133, GU173686).

Carex L sect *Hallerianae* (Ascherson & Graebner) Ruoy in G Ruoy *et al.*, *C. dasycarpa* Muhl., (1) USA: GA, Dekatur Co, Apr 24 2003 *R Kral 93946* (DOV 061986)(B0255, GU172744); (2) USA: FL, Gadsen Co, Apr 14 2003 *LC Anderson 20654* (DOV 029012)(B0256, GU172745); (3) USA: AL, Covington Co, May 16 1997 *JR MacDonald 10515* (DOV 038483)(B0257, GU172743); *C. lativena* SD Jones & GD Jones, (1) USA: NM, Eddy Co, Apr 07 2001 *RD Worthington 30373* (UNM 101885)(B1222, GU173073); (2) USA: TX, Runnels Co, Mar 28 1992 *S Jones, G Jones 8194* (MICH)(B1460, GU173074); *C. planostachys* Kunze, (1) USA: TX, Cooke Co, May 03 2004 *RFC Naci 10156* (DOV 050149)(B0544, GU173407); (2) USA: TX, Hays Co, Apr 27 2003 *CA Morse, EF Smith 9313* (DOV 037572)(B0547, GU173408); *C. tenax* Chapman ex Dewey, (1) USA: AL, Dale Co, May 14 1999 *R Kral 88472A* (DOV 046792)(B0702, GU173665); (2) USA: LA, Natchitoches Parish May 14 1998 *PE Hyatt 8139* (DOV 046875)(B0703, GU173666); (3) USA: SC, Marion Co, May 29 2006 *B Pittman, A Darr, K Boyle, J Nelson 5290608* (DOV 057071)(B0704, GU173667).

Carex L sect *Heleglochin* Dumortier, *C. cusickii* Mack. ex Piper & Beattie, (1) USA: CA, Butte Co, Jul 24 2004 *RFC Naczi, LP Janeway 10526* (DOV 055125)(B0254, GU172740); (2) USA: CA, Nevada Co, Aug 03 2006 *RFC Naczi 11427* (DOV 055125)(B0826, GU172741); (3) USA: WA, Whatcom Co, Jun 13 1989 *E Burnett, M Arnot 103* (WTU 318057)(B0970, GU172742); (4) Canada: BC, Ladysmith Aug 17 1986 *A Ceska, O Ceska, S Hartwell 20784* (UBC 215334)(B1397, GU172739); *C. decomposita* Muhl., (1) USA: DE, New Castle Co, Jun 3 1999 *WA McAvoy 4363* (DOV 036703)(B0218, GU172758); (2) USA: FL, Leon Co, Apr 14 2003 *LC Anderson 20640* (DOV 028826)(B0220, GU172759); *C. diandra* Schrank, (1) USA: CA, Nevada Co, Aug 9 2004 *L Ahart 11355* (DOV 047930)(B0222, GU172776); (2) USA: MI, Montmorency Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9441* (DOV 023853)(B0223, GU172777); (3) Canada: QC, Baie James Aug 11 2006 *M Blondeau WE06 108* (MT)(B0918, GU172778); (4) USA: WA, Ferry Co, Jul 09 1999 *F Weinman, A Weinmann 125* (WTU 351902)(B0973, GU172779); *C. prairea* Dewey in Alph. Wood, (1) Canada: MB, 26 km E of Richer Jun 25 2003 *RFC Naczi, BA Ford 9812* (DOV 037215)(B0563, GU173428); (2) Canada: NB, Kings Co, Aug 30 1998

HR Hinds 11493 (UNB 54604)(B1160, GU173429); (3) Canada: NB, Restigouche Co, Jun 20 1997 *HR Hinds 11229* (UNB 43567)(B1164, GU173430); (4) Canada: BC, Cascade Mountains Jul 22 1978 *CE Jones 3 2A 2* (UBC 167566)(B1344, GU173427).

Carex L sect *Hirtifoliae* Reznicek, *C. hirtifolia* Mack., (1) USA: MO, Pulaski Co, May 25 2003 *RFC Naczi, BA Ford 9632* (DOV 035375)(B0318, GU172988); (2) USA: DE, New Castle Co, Jun 03 2004 *RFC Naczi 10348* (DOV 049935)(B0330, GU172987); (3) Canada: QC, MRC Le Haut Saint Laurent Jun 09 2004 *A Sabourin, J Labrecque, N Lavoie, S Bourdon 2427* (MT)(B0872, GU172989).

Carex L sect *Hispidae* Mack. ex Reznicek, *C. spissa* LH Bailey, (1) USA: AZ, Yavapai Co, Sep 04 2003 *JLC Anderson, B Lambeth 2003 43* (ASU 253704)(B1208, GU173598).

Carex L sect *Holarrhenae* (Döll) Pax in Engler and K Prantl, *C. sartwellii* Dewey, (1) Canada: MB, Jun 25 2003 *RFC Naczi, BA Ford 9794* (DOV 039069)(B0601, GU173504); (2) USA: IL, McDonough Co, Jun 10 1996 *AA Reznicek, PE Rothrock, M Rothrock, SA Reznicek 10222* (DOV 024273)(B0612, GU173503); (3) Canada: BC, Coquitlam May 14 1997 *F Lomer 97 39* (UBC 225081)(B1375, GU173502).

Carex L sect *Hymenochlaenae* (Drejer) Bailey in JM Coulter, *C. aestivalis* MA Curtis ex A Gray, (1) USA: NY, Greene Co, Jul 04 1998 *RFC Naczi 7478* (DOV 021887)(B0061, GU172458); (2) USA: PA, Tioga Co, May 23 2004 *RFC Naczi 10335* (DOV 048308)(B0062, GU172459); (3) USA: NC, Ashe Co, Jun 26 2005 *DB Poindexter 05 845* (DOV 063081)(B0845, GU172457); (4) USA: GA, Lumpkin Co, Jun 19 2004 *PE Hyatt 11729* (MO 1991748)(B1181, GU172456); *C. arctata* Boott in Hooker, (1) Canada: MB, 1.5 km N town of Falcom Lk Jun 25 2003 *RFC Naczi, BA Ford 9851* (DOV 037077)(B0094, GU172522); (2) USA: WI, Forest Co, Jul 19 2003 *TG Lammers 11636* (DOV 039719)(B0113, GU172525); (3) USA: NY, Greene Co, Jul 03 2004 *RFC Naczi 10448* (DOV 054639)(B0114, GU172524); (4) Canada: NS, Kings Co, Jun 08 2002 *RE Newell* (ACAD 17879)(B1243, GU172523); *C. assiniboinensis* Boott, (1) Canada: MB, Winnipeg Jun 19 2002 *BA Ford, SA Ford 247* (DOV 049425)(B0104, GU172535); (2) USA: MN,

Norman Co, Jun 11 1994 *V McNeilus* 94 508 (DOV 024967)(B0105, GU172537); (3) USA: MI, Iron Co, Aug 15 1987 *D Albert* 1987 28 (DOV 052441)(B0121, GU172536); *C. castanea* Wahl., (1) USA: WI, Door Co, Jul 3 2003 *NA Harriman* 21753 (DOV 039753)(B0185, GU172667); (2) Canada: NL, Notre Dame Bay Aug 08 2001 *C Hanel, N Djan Chekar* CH010808 13 (MT)(B0876, GU172666); *C. cherokeensis* Schweinitz, (1) USA: TN, Haywood Co, Jun 26 1995 *AA Reznicek, RFC Naczi* 10044 (DOV 024012)(B0211, GU172678); (2) USA: FL, Wakulla Co, Apr 5 2007 *LC Anderson* 22861 (DOV 060741)(B0212, GU172677); (3) USA: TX, Bastrop Co, May 1 2004 *RFC Naczi* 10118 (DOV 051072)(B0213, GU172679); *C. davisii* Schweinitz & Torrey, (1) USA: DE, New Castle Co, May 30 1999 *RFC Naczi* 8083 (DOV 021950)(B0240, GU172746); (2) USA: KN, Miami Co, May 30 2000 *CA Morse* 4734 (DOV 038034)(B0241, GU172747); (3) USA: TN, Williamson Co, Jun 5 2006 *CT Bryson* 21650 (DOV 056303)(B0242, GU172749); (4) USA: OK, Delaware Co, May 25 1994 *AA Reznicek, SA Reznicek, SD Jones, GD Jones* 9773 (OKL 212318)(B0949b, GU172748); *C. debilis* Michaux var *debilis*, (1) USA: MD, Worcester Co, Jun 12 2007 *WD Longbottom* 9299 (DOV 063881)(B0243, GU172753); (2) USA: FL, Hamilton Co, Mar 18 2001 *JR Abbott, B Carlsward* 14201 (DOV 039559)(B0244, GU172752); (3) USA: OK, Le Flore Co, May 26 2003 *RFC Naczi, BA Ford* 9646 (DOV 037439)(B0245, GU172754); (4) Canada: NL, Bonavista South Dist Jul 18 1996 *R Charest, L Brouillet* 96 1295 (MT)(B0875, GU172751); *C. debilis* Michaux var *rudgei* LH Bailey, (1) USA: TN, Cumberland Co, May 25 2005 *D Estes, J Beack* 7731 (DOV 056790)(B0206, GU172757); (2) USA: PA, Bradford Co, Jun 15 2004 *RFC Naczi, RL Mears* 10375 (DOV 048306)(B0207, GU172756); (3) USA: ME, Penobscot Co, Jun 29 2002 *AA Reznicek, SA Reznicek* 11347 (DOV 040698)(B0217, GU172755); *C. formosa* Dewey, (1) USA: IL, Cook Co, Jul 18 2006 *MJC Murphy* 1512.2 (ILLS 234285)(B1125, GU172885); (2) USA: MN, Olmsted Co, Jun 08 1984 *F Harris* 94046 (MIN 464507)(B1385, GU172886); (3) Canada: ON, Middlesex Co, Jun 15 1983 *VR Brownell, PM Carling* 83 153 (CAN 505067)(B1479, GU172887); *C. gracillima* Schweinitz, (1) USA: AL, Cullman Co, Apr 22 2002 *RFC Naczi* 9089 (DOV 025377)(B0304, GU172931); (2) USA: MD, Talbot Co, Jun 17 1999 *WA McAvoy* 4405 (DOV 046324)(B0311, GU172932); (3) USA: ME, Oxford Co, Jun 30 2001 *AA Reznicek, SA Reznicek* 11277 (DOV 041363)(B0312, GU172934); (4) Canada: MB, Kane Co, Jul 19 2000 *MJC Murphy* 158

(WIN 66988)(B1137, GU172933); *C. gynodynamis* Olney, (1) USA: OR, Curry Co, May 03 1995 *V Stansell 3042* (OSC 184791)(B1061, GU172953); (2) USA: CA, Mendocino Co, Jun 02 2002 *B Maslach 51* (CHSC 83322)(B1081, GU172951); (3) USA: CA, Santa Cruz Co, May 18 1995 *DW Taylor 14915* (JEPS 105324)(B1297, GU172952); *C. hirtissima* Boott in S Watson, (1) USA: CA, Yuba Co, Jul 06 2003 *L Ahart 10359* (CHSC 84464)(B1087, GU172990); (2) USA: CA, Butte Co, Apr 15 2003 *LP Janeway, G Blosser, A Henderson, J Hunt 7758* (CHSC 83936)(B1088, GU172991); (3) USA: CA, Mendocino Co, May 08 1997 *DW Taylor 15995* (JEPS 101100)(B1319, GU172992); *C. mendocinensis* Olney ex Boott in S Watson, (1) USA: OR, Curry Co, Jun 09 1991 *PF Zika, V Stansell 11182* (OSC 185934)(B1066, GU173202); (2) USA: ID, Latah Co, Jul 15 1990 *J Mastrogiuseppe 5756* (ID 126145)(B1256, GU173201); (3) USA: CA, Monterey Co, May 24 1992 *DW Taylor, V Yadon, R Branson 12618* (JEPS 101127)(B1312, GU173200); *C. misera* Buckley, (1) USA: TN, Sevier Co, Jun 23 1990 *S Wiser 90 73* (NCU 32145)(B1157, GU173237); *C. obispoensis* Stacey, (1) USA: CA, San Luis Obispo Co, Mar 20 1993 *MD Proctor, EA Young ROB0293* (RSA 585660)(B1190, GU173307); (2) USA: CA, San Diego Co, May 20 2004 *JP Rebman, J Gregory 10325* (UCR 157561)(B1374, GU173308); *C. oxylepis* Torrey & Hooker, (1) USA: TX, Brazos Co, May 02 2004 *RFC Naczi 10144* (DOV 050498)(B0530, GU173342); (2) USA: KY, Clinton Co, May 20 1999 *RFC Naczi 7982* (DOV 020935)(B0531, GU173341); (3) USA: AL, Tuscaloosa Co, May 02 2005 *CT Bryson, JR MacDonald 20510* (DOV 057046)(B0532, GU173339); (4) USA: AR, Pike Co, Apr 19 1997 *PE Hyatt 7355* (DOV 020800)(B0533, GU173340); (5) USA: FL, Wakulla Co, Apr 05 2007 *LC Anderson 22840* (DOV 060625)(B0535, GU173337); (6) USA: NC, Stanly Co, May 16 2007 *RFC Naczi, BA Sorrie, WA McAvoy 11804* (DOV 063571)(B0538, GU173338); *C. prasina* Wahl., (1) USA: MD, Kent Co, *WA McAvoy 5532* (DOV 041051)(B0559, GU173433); (2) USA: GA, Dawson Co, May 17 2002 *L Kruse 02 169* (DOV 049168)(B0560, GU173431); (3) USA: KY, Boone Co, May 25 1999 *RFC Naczi 8019* (DOV 036710)(B0561, GU173432); *C. roanensis* FJ Hermann, (1) USA: NC, Ashe Co, May 24 2004 *BA Sorrie 11255* (DOV 057314)(B0617, GU173479); (2) USA: TN, Carter Co, Jun 07 1999 *C Nordman* (TENN)(B1170, GU173480); *C. sprengelii* Dewey ex Sprengel, (1) Canada: ON, Simcoe Co, Jul 11 2005 *AA Reznicek 11691* (DOV 053845)(B0670, GU173600); (2) Canada: SK, Cypress Hills Jun 11 1995 *BA Ford, JR Starr*

9527 (DOV 020878)(B0671, GU173602); (3) USA: SD, Lawrence Co, Jun 12 2003 *RL Mears* (DOV 048182)(B0672, GU173601); (4) Canada: NB, Carleton Co, Aug 01 1993 *HR Hinds, J Goltz 11037* (UNB 50791)(B1159, GU173599); *C. sylvatica* Hudson, (1) USA: WA, King Co, May 26 2001 *PF Zika 16086* (WTU 346159)(B0983, GU173663); (2) Canada: ON, Middlesex Co, Jun 4 1987 *MJ Oldham 7263* (CAN 529145)(B1470, GU173661); (3) Spain: Province of Palencia, Castile Leon Aug 31 2004 *JM Marin et al. 14004JMM 2* (UPOS 000162)(B1513, GU173662); (4) USA: NY, Westchester Co, Jun 15 2006 *SD Glenn 10320* (BKL 76190)(B1514, GU173660); *C. venusta* Dewey, (1) USA: NC, Harnett Co, May 18 2007 *RFC Naczi, BA Sorrie, EL Hoffman, WA McAvoy, K Sinclair, G Sinclair 11861* (DOV 063741)(B0766, GU173764); (2) USA: MS, Harrison Co, April 14 2004 *CT Bryson 19958* (DOV 056541)(B0767, GU173763); (3) USA: MD, Wicomico Co, Jun 24 2001 *C Lea 2797* (DOV 045951)(B0770, GU173762).

Carex L sect *Inflatae* Kük. in Engler, *C. breweri* Boott, (1) USA: WA, Chelan / Skagit Co, Aug 10 2002 *A Tribsch, P Schonswetter AP 1 24* (WTU 354230)(B0969, GU172621); (2) USA: CA, Mono Co, Aug 03 1990 *G Helmkamp* (UCR 67407)(B1217, GU172620); *C. engelmannii* LH Bailey, (1) Canada: BC, Cathedral Prov Park Aug 30 1996 *F Lomer 96 144* (UBC 219125)(B1525, GU172837); *C. subnigricans* Stacey, (1) USA: OR, Wallowa Co, Jul 31 1992 *PF Zika 11805* (OSC 178777)(B1067, GU173649).

Carex L sect *Lamprochlaenae* (Drejer) Bailey in JM Coulter, *C. glacialis* Mack., (1) Canada: NL, Strait of Belle Isle Dist Aug 05 2000 *L Brouillet, N Djan Chekar, T Ahti, C Wentzell LB 00 508A* (MT)(B0887, GU172917); (2) USA: AK, Lime Hills Quad Jun 30 1999 *CL Parker, AR Batten, MK Reynolds 8864* (ALA 1130506)(B1019, GU172916); *C. supina* Willd. ex Wahl. subsp *spaniocarpa* (Steudel) Hulten, (1) USA: AK, McCarthy C1 Quad Jun 03 2003 *B Bennett, P Loomis 03 147* (ALA 1121279)(B1187, GU173654).

Carex L sect *Laxiflorae* (Kunth) Mack. in NL Britton *et al.*, *C. albursina* E Sheldon, (1) USA: KY, Robertson Co, Jul 05 2002 *TJ Weckman, JE Weckman 7421* (DOV 048677)(B0084, GU172479); (2) USA: KY, Lincoln Co, May 24 2005 *RFC Naczi 10948* (DOV)(B0780, GU172480); (3) USA: OH, Greene Co, Jun 02 2004 *MA Vincent, TG*

Lammers 11664 (DOV)(B0789, GU172481); (4) USA: OK, LeFlore Co, Apr 15 1999 *P Folley 2266* (OKL 212676)(B0950b, GU172482); *C. blanda* Dewey, (1) USA: MD, Kent Co, Jun 13 2006 *WD Longbottom 7534* (DOV 060773)(B0122, GU172604); (2) USA: SC, Lancaster Co, May 10 2005 *JB Nelson, A Darr, C DeGarady, M Hey, B Pittman, M Robertson et al. 25378* (DOV 049571)(B0141, GU172606); (3) USA: MD, Dorchester Co, Apr 29 2005 *WM Knapp 1152* (DOV 054090)(B0404, GU172605); (4) USA: KN, Leavenworth Co, Jun 04 2003 *CA Morse 9453* (UCR 152320)(B1212, GU172603); *C. chapmanii* Steudel, (1) USA: FL, Lake Co, Mar 24 2005 *WD Longbottom, DH Williams 5621* (DOV 048258)(B0214, GU172676); *C. crebriflora* Wiegand, (1) USA: SC, Darlington Co, May 08 2003 *RFC Naczi 9546* (DOV)(B0424, GU172716); *C. gracilescens* Steudel, (1) USA: KY, Laurel Co, May 4 2000 *RL Thompson, EWJ FitzGerald 88* (DOV 023541)(B0309, GU172926); (2) USA: PA, Blair Co, Jun 9 2005 *RFC Naczi, SP Grund, WM Knapp, SV Parker 11085* (DOV)(B0782, GU172927); *C. hendersonii* LH Bailey, (1) USA: CA, Del Norte Co, Jun 05 2005 *CA Morse, EF Smith 11377* (DOV)(B0781, GU172974); (2) USA: WA, King Co, Jun 22 2002 *CJ Antieau, S Bagshaw, N Samargis 02 10 1* (WTU 364651)(B0997, GU172975); (3) Canada: BC, Douglas Island Jul 20 1996 *F Lomer 96 112* (UBC 219221)(B1340, GU172973); *C. kraliana* Naczi & Bryson, (1) USA: MD, Caroline Co, May 18 2005 *W Knapp 1180* (DOV 055357)(B0358, GU173058); (2) USA: AR, Cross Co, May 20 1990 *RFC Naczi 2442* (DOV 028009)(B0363, GU173056); (3) USA: FL, Leon Co, Apr 07 2004 *LC Anderson 20915* (DOV 038860)(B0365, GU173057); *C. laxiflora* Lamarck in Lamarck *et al.*, (1) USA: MI, Cheboygan Co, Jun 22 1986 *RFC Naczi 1329* (DOV 013048)(B0405, GU173084); (2) USA: TN, Blount Co, Apr 29 2001 *MA Feist, LR Philippe, D Busemeyer, C Carroll, G Spyreas 801* (DOV 033712)(B0406, GU173085); *C. leptonervia* (Fernald) Fernald, (1) USA: MD, Garrett Co, May 29 2006 *WD Longbottom, RD Redden 7390* (DOV 059657)(B0415, GU173116); (2) Canada: MB, 1.5 km N of town of Falcon Lk Jun 25 2003 *RFC Naczi, BA Ford 9852* (DOV)(B0790, GU173115); (3) USA: MD, Garrett Co, May 28 2007 *WD Longbottom, DW Hollway, RD Redden, G Van Velsir, P Van Velsir 9038* (DOV 059657)(B0791, GU173117); (4) USA: PA, Bradford Co, May 21 2004 *RFC Naczi 10273* (DOV)(B0792, GU173118); *C. manhartii* Bryson, (1) USA: NC, Macon county May 28 1999 *PE Hyatt 8625* (DOV)(B0866, GU173184); (2) USA: GA, Towns Co, May 03 1991 *RFC Naczi 2862* (NCU 37067)(B1154, GU173183); (3) USA: TN,

Monroe Co, May 13 1993 *JA Churchill 93020* (TENN)(B1169, GU173185); *C. ormostachya* Wiegand, (1) USA: MI, Emmet Co, Jul 02 1986 *RFC Naczi, EG Voss 1364* (DOV 013083)(B0528, GU173331); *C. purpurifera* Mack. in JK Small, (1) USA: KY, Lincoln Co, May 24 2005 *RFC Naczi 10988* (DOV)(B0867, GU173452); (2) USA: TN, Blount Co, Apr 30 2002 *PB Marcum, MA Feist, B Molano Flores PBM 1117* (ILLS 220881)(B1131, GU173454); (3) USA: NC, Haywood Co, May 02 2000 *D Busemeyer, LR Phillippe, RL Larimore 112* (ILLS 220881)(B1132, GU173453); *C. radfordii* Gaddy, (1) USA: SC, Greenville Co, Aug 03 2005 *A Darr, B Pittman 2418* (DOV 057038)(B0835, GU173455); *C. striatula* Michaux, (1) USA: LA, Parish: Winn May 18 1999 *RD Thomas 159901* (DOV 046368)(B0657, GU173634); (2) USA: DE, New Castle Co, Mar 06 2003 *WA McAvoy 5816* (DOV 037592)(B0658, GU173632); (3) USA: GA, Dawson Co, Apr 20 2002 *L Kruse 23408* (DOV 048923)(B0667, GU173633); (4) Canada: QC, MRC Comm Urb de l'Outaouais Jul 24 2001 *G Claude 01 087* (MT)(B0870, GU173635); *C. styloflexa* Buckley, (1) USA: MD, Worcester Co, May 17 2005 *WM Knapp 1167* (DOV 055906)(B0692, GU173639); (2) USA: GA, Dawson Co, May 07 2002 *L Kruse 02 115* (DOV 049043)(B0693, GU173638); (3) USA: SC, Lancaster Co, May 10 2005 *JB Nelson 25394* (DOV 049629)(B0694, GU173640).

Carex L sect *Leptocephalae* Bailey, *C. leptalea* Wahl., (1) USA: ME, Washington Co, Jun 27 2007 *WM Knapp 2207* (DOV 063508)(B0412, GU173112); (2) Canada: BC, Hwy 24 31 km W of Little Fort Jun 30 2000 *BA Ford, JM Saarela 00144* (DOV 022983)(B0413, GU173109); (3) USA: MI, Presque Isle Co, Jul 16 2002 *AA Reznicek, FW Case 11370* (DOV 041345)(B0414, GU173113); (4) USA: DE, New Castle Co, May 21 2002 *W McAvoy 5488* (DOV 042483)(B0427, GU173111); (5) USA: TX, Anderson Co, Apr 25 2007 *RFC Naczi, WB Littrell 11791* (DOV 064039)(B0428, GU173114); (6) USA: FL, Wakulla Co, Apr 05 2007 *LC Anderson 22847* (DOV 060620)(B0429, GU173110).

Carex L sect *Leucoglochin* Dumortier, *C. microglochin* Wahl. subsp *microglochin*, (1) Norway: Stordalen, Butte Co, Jul 19 1962 *T Engelskjon* (COLO 448173)(B1098, GU173224); *C. pauciflora* Lightfoot, (1) USA: MI, Otsego Co, Jul 15 2002 *AA Reznicek, RFC Naczi, FW Case 11366* (DOV 041013)(B0525, GU173367); (2) USA: AK, Kenai

Peninsula Aug 19 2005 *AA Reznicek 11716* (DOV 051968)(B0536, GU173366); (3)
 Canada: NS, Cumberland Co, Jul 06 2000 *CS Blaney 3254* (ACAD 017073)(B1382,
 GU173368).

Carex L sect *Limosae* (Heuffel) Meinshausen, *C. barrattii* Schweinitz & Torrey, (1) USA:
 NJ, Ocean Co, Jun 19 2004 *RFC Naczi, LC Kelly, RL Mears, WM Knapp 10425* (DOV
 050898)(B0129, GU172582); (2) USA: AL, De Kalb Co, May 25 1998 *RFC Naczi, BA Ford*
7270 (DOV 021882)(B0130, GU172580); (3) USA: MD, Dorchester Co, Jun 16 2005 *WM*
Knapp 1309 (DOV 055857)(B0139, GU172581); *C. limosa* L, (1) USA: ME, Hancock Co,
 Jun 28 2007 *WM Knapp 2209* (DOV 063511)(B0416, GU173122); (2) USA: AK, 7 mi SE
 of Wasilla Aug 14 2005 *AA Reznicek, A Leggett, DC McLaughlin 11699* (DOV
 054700)(B0417, GU173120); (3) USA: CA, Plumas Co, Nov 11 2005 *LP Janeway, B*
Castro 8540 (DOV 055903)(B0418, GU173121); (4) USA: MI, Otsego Co, Jul 15 2002
RFC Naczi, FW Case, AA Reznicek 9445 (DOV 023869)(B0419, GU173123); *C.*
macrochaeta CA Meyer, (1) USA: AK, Attu Quad Aug 03 2000 *SS Talbot, SL Talbot, WB*
Schofield 002 5 (ALA 1138766)(B1029, GU173172); (2) USA: OR, Multnomah Co, May
 18 1995 *PF Zika 12326* (OSC 182608)(B1064, GU173175); (3) Canada: BC, Rainy Riv Co,
 Jul 14 1981 *L Donovan, C Siens 419* (UBC 798008)(B1338, GU173173); (4) Canada: BC,
 Wells Gray Provincial Park Jul 04 2004 *C Bjork, T Goward 9226* (UBC 223191)(B1376,
 GU173174); *C. magellanica* Lamarck subsp *irrigua* (Wahl.) Hiitonen, (1) Canada: MB, 1.5
 km N of town of Falcon Lk Jun 25 2003 *RFC Naczi BA Ford 9864* (DOV 035415)(B0558,
 GU173177); (2) USA: ME, Hancock Co, Jun 26 2007 *WM Knapp 2193* (DOV
 063502)(B0574, GU173180); (3) USA: UT, Summit Co, Aug 05 2004 *RFC Naczi, WM*
Knapp 10705 (DOV 055169)(B0575, GU173182); (4) Canada: NL, Bonavista North Dist
 April 7 1996 *R Charest, L Brouillet 96 217* (CAN 584553)(B0948, GU173181); (5) USA:
 AK, Seward Quad Jul 27 2003 *R Lipkin, M Carlson 03 245* (ALA 1139021)(B1030,
 GU173176); (6) USA: CO, Boulder Co, Jun 10 2000 *N Lederer 00 15* (COLO
 475128)(B1112, GU173178); *C. pluriflora* Hulten, (1) USA: AK, Kenai Peninsula Aug 19
 2005 *AA Reznick 11715* (DOV 051966)(B0548, GU173415); (2) USA: AK, Valdez Quad
 Jul 31 1977 *AR Batten, S Murphy 77 440* (UBC 171832)(B1349, GU173414); (3) Canada:
 BC, Douglas Island Jul 17 1997 *F Lomer, N Grove 97364* (UBC 214389)(B1351,

GU173416); *C. rariflora* (Wahl.) Smith in JE Smith and J Sowerby, (1) Canada: YT, Ogilvie Mountains Jun 28 2005 *BA Bennett, H Guest, M Kienzler 05 0076* (UBC 224436)(B1392, GU173462); (2) Canada: NL, White Bay North Dist Aug 6 1991 *A Bouchard, S Hay, L Brouillet, M Jean 91279* (CAN 564347)(B1484, GU173461).

Carex L sect *Longicaules* Mack. ex Reznicek, *C. whitneyi* Olney, (1) USA: CA, Tehama Co, Jul 24 2004 *RFC Naczi, LP Janeway 10533* (DOV 055679)(B0744, GU173795); (2) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11529* (DOV 063483)(B0747, GU173794); (3) USA: OR, Klamath Co, Aug 04 1993 *PF Zika, K Kuykendal, N Otting, BL Wilson 12123* (OSC 180380)(B1070, GU173796).

Carex L sect *Lupulinae* Tuck. ex J Carey, *C. gigantea* Rudge, (1) USA: MD, Caroline Co, Jun 13 2006 *WD Longbottom 7510* (DOV)(B0296, GU172914); (2) USA: TN, Overton Co, Sep 19 1998 *VE McNeilus 98 927* (DOV 020780)(B0298, GU172915); (3) USA: FL, LaFayette Co, May 11 2000 *JR Abbott, H Horne 13555* (DOV 020882)(B0299, GU172913); *C. grayi* J Carey, (1) USA: MD, Kent Co, May 15 2002 *WA McAvoy 5483* (DOV 029727)(B0305, GU172942); (2) USA: KN, Leavenworth Co, Jun 04 2003 *CA Morse 9445* (DOV 037576)(B0306, GU172941); (3) USA: MS, Tunica Co, May 03 2006 *CT Bryson, D Skojac 21405* (DOV 056100)(B0314, GU172943); *C. intumescens* Rudge, (1) Canada: MB, Nopiming Provincial Pk Jun 19 2004 *BA Ford 417* (DOV 047633)(B0355, GU173045); (2) USA: FL, Jackson Co, Mar 19 1976 *R Kral 57403* (DOV 026157)(B0356, GU173044); (3) USA: ME, Oxford Co, Jun 30 2001 *AA Reznicek, SA Reznicek 11279* (DOV 041026)(B0357, GU173046); *C. louisianica* LH Bailey, (1) USA: MD, Caroline Co, Jun 01 2005 *WD Longbottom 5956* (DOV 051045)(B0384, GU173136); (2) USA: LA, Grant Parish May 07 1997 *PE Hyatt 7400* (DOV 026164)(B0389, GU173135); (3) USA: FL, Seminole Co, Mar 23 2005 *WD Longbottom, DH Williams, G Van Velsir, P Van Velsir 5609* (DOV 049188)(B0390, GU173134); *C. lupuliformis* Sartwell ex Dewey, (1) USA: MD, Dorchester Co, Aug 21 2005 *WD Longbottom, R Redden, JD Saffer 6480* (DOV 051630)(B0392, GU173144); (2) USA: FL, Polk Co, Mar 21 2007 *WD Longbottom, DH Williams 8225* (DOV 060475)(B0393, GU173143); (3) USA: TX, Harris Co, Jun 26 2003 *SD Jones, D Severinson, R Phillips 16517* (DOV 041736)(B0403, GU173145); *C. lupulina* Willd., (1)

USA: MI, Washtenaw Co, Aug 02 2002 *AA Reznicek 11377* (DOV 040959)(B0471, GU173147); (2) USA: MD, Caroline Co, Jun 08 2007 *WD Longbottom 9182* (DOV 063450)(B0472, GU173146); (3) USA: MS, Leflore Co, May 29 2003 *CT Bryson, BA Ford, RFC Naczi 19699* (DOV 056392)(B0473, GU173148).

Carex L sect *Macrocephalae* Kük. in Engler, *C. kobomugi* Ohwi, (1) USA: VA, City of Virginia Beach Apr 20 2001 *H Hamilton* (DOV 046143)(B0361, GU173055); (2) USA: DE, Sussex Co, Jul 23 2002 *RFC Naczi, WA McAvoy, CT Bryson, BA Ford, AA Reznicek, JR Starr, BS Walters, VN Williams 9459* (DOV 023467)(B0369, GU173054); *C. macrocephala* Willd. ex Sprengel, (1) USA: AK, Yakutat forelands Jul 29 2003 *MC Stensvold 8154* (DOV 043148)(B0831, GU173169); (2) USA: WA, Jefferson Co, Aug 27 2005 *G Leppig 2316* (DOV 055890)(B0832, GU173171); (3) Canada: BC, Queen Charlotte Islands Jul 23 2007 *JM Saarela, D Percy 1209* (CAN)(B1421, GU173170).

Carex L sect *Mitratae* Kük. in Engler, *C. caryophyllea* Latourrette, (1) Spain: Avila, Arenas de S Pedro, rio Pelayo Jun 14 1987 *M Guzman, M Luceno 86 87 ML* (MICH)(B1457, GU172665).

Carex L sect *Multiflorae* (J Carey) Kük. in Engler, *C. alma* LH Bailey, (1) USA: NV, Clark Co, May 10 1996 *PJ Leary, JS Holland, WE Niles 4546* (DOV 031570)(B0077, GU172484); (2) USA: CA, Tulare Co, May 01 2004 *LP Janeway 8026* (DOV 047910)(B0085, GU172483); (3) USA: UT, Washington Co, Apr 29 1987 *GI Baird 2617* (CAN 554681)(B1465, GU172485); *C. annectens* (EP Bicknell) EP Bicknell, (1) USA: MD, Caroline Co, May 28 2005 *WD Longbottom 5899* (DOV)(B0087, GU172495); (2) USA: ME, Washington Co, Jul 03 2005 *AA Reznicek 11688* (DOV 054692)(B0088, GU172496); (3) USA: AL, Jackson Co, May 19 2005 *RFC Naczi 10866* (B0112, GU172494); *C. chihuahuensis* Mack., (1) USA: AZ, Cochise Co, Apr 24 1992 *Popolizio, Morrison 1307* (ASU 266307)(B1205, GU172680); *C. densa* (LH Bailey) LH Bailey, (1) USA: CA, Colusa Co, Aug 22 2006 *L Ahart 13213* (DOV 060566)(B0221, GU172766); (2) USA: OR, Benton Co, Jun 15 1994 *BL Wilson, K Kuykendall 7026* (OSC 178863)(B1062, GU172767); (3) USA: OR, Benton Co, Jun 22 1998 *BL Wilson, K Kuykendall 9369* (OSC 195821)(B1063,

GU172768); (4) USA: CA, Fresno Co, Apr 29 1992 *TC Fuller 20466* (CDA 20466)(B1281, GU172765); *C. fissa* Mack. var *aristata* FJ Hermann, (1) USA: FL, Volusia Co, Mar 22 2007 *WD Longbottom 8242* (DOV 064066)(B0261, GU172863); (2) USA: GA, Camden Co, Apr 08 2006 *R Carter, W Baker 16477* (DOV 055495)(B0264, GU172864); *C. fissa* Mack. var *fissa*, (1) USA: MD, Talbot Co, Jun 06 2006 *WD Longbottom 7461* (DOV)(B0260, GU172867); (2) USA: TX, Kaufman Co, May 02 1997 *AA Reznicek, SD Jones, SA Reznicek 10341* (DOV 024469)(B0262, GU172865); (3) USA: KN, La Bette Co, May 29 1994 *SG Jones, A Reznicek, S Reznicek 11195* (DOV 023636)(B0263, GU172866); (4) USA: AL, Barbour Co, May 10 1997 *JR MacDonald 10505* (DOV 038485)(B0265, GU172861); (5) USA: AR, Hot Spring Co, May 12 1996 *R Thomas, C Amason 149056* (DOV 027952)(B0266, GU172862); *C. triangularis* Boeckeler, (1) USA: TX, Franklin Co, May 3 1997 *AA Reznicek, SD Jones, SA Reznicek 10390* (DOV 024464)(B0739, GU173710); (2) USA: AR, Chicot Co, May 12 2006 *CT Bryson, NB Bryson 21441* (DOV 056899)(B0741, GU173708); (3) USA: GA, Meriwether Co, Apr 25 2002 *RFC Naczi 9165* (DOV 025813)(B0742, GU173709); *C. vulpinoidea* Michaux, (1) USA: ME, Washington Co, Jul 03 2005 *AA Reznicek 11687* (DOV 054754)(B0743, GU173792); (2) USA: KN, Linn Co, May 23 2002 *CA Morse 7999* (DOV 037602)(B0745, GU173791); (3) USA: CA, Butte Co, Jul 10 2006 *LP Janeway 8810* (DOV 060596)(B0746, GU173790); (4) USA: WA, Lewis Co, Jun 24 2005 *FE Caplow 200503* (WTU 360884)(B0971, GU173793).

Carex L sect *Nardinae* (Tuck.) Mack. in NL Britton *et al.*, *C. nardina* Fries, (1) Canada: QC, Nunavik Aug 08 2002 *J Brunelle* (MT)(B0909, GU173275).

Carex L sect *Obtusatae* (Tuck.) Mack. in NL Britton *et al.*, *C. obtusata* Liljeblad, (1) Canada: MB, Spruce Woods Provincial Pk Jun 26 2003 *RFC Naczi, BA Ford 9925* (DOV 039105)(B0501, GU173311).

Carex L sect *Ovales* Kunth, *C. abrupta* Mack., (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11507A* (DOV 063465)(B0056, GU172443); (2) Canada: BC, Mount Revelstoke Nat'l Pk Aug 30 1997 *BA Ford 9718* (DOV 025911)(B0520, GU172442); (3) USA: CA, Tuolumne Co, Aug 05 2006 *RFC Naczi 11502* (DOV)(B0853, GU172445); (4) USA: CA,

Nevada Co, Aug 04 2006 *RFC Naczi 11466* (DOV)(B0854, GU172446); (5) USA: ID, Lemhi Co, Aug 03 1990 *M Mancuso 448* (ID 107667)(B1232, GU172444); *C. adusta* Boott in Hooker, (1) Canada: MB, 4 km N of town of W Hawk Lk Jun 25 2003 *RFC Naczi, BA Ford 9817* (DOV 037248)(B0060, GU172454); (2) Canada: NL, Green Bay area Aug 08 2001 *C Hanel, N Djan Chekar, L Lavers, D Lavers CH010809* (MT)(B0904, GU172455); (3) Canada: AB, Athabasca Riv Jul 5 1962 *12595* (CAN 275045)(B1466, GU172453); *C. alata* Torrey, (1) USA: MD, Dorchester Co, Jun 01 2005 *WD Longbottom 5949* (DOV 051039)(B0067, GU172465); (2) USA: AL, Covington Co, May 20 1998 *JR MacDonald 11216* (DOV 032653)(B0068, GU172463); (3) USA: FL, Levy Co, Mar 13 2006 *WD Longbottom, DH Williams 7022* (DOV 054677)(B0069, GU172464); (4) USA: OK, LeFlore Co, May 14 2003 *P Folley 2766* (OKL 222063)(B0951, GU172466); *C. albolutescens* Schweinitz, (1) USA: OK, McCurtain Co, May 19 1993 *PE Rothrock, AA Reznicek, CT Bryson, S Jones 2924* (DOV 023429)(B0075, GU172477); (2) USA: MD, Caroline Co, May 28 2005 *WD Longbottom 5901* (DOV 051040)(B0082, GU172476); *C. arapahoensis* Clokey, (1) USA: CO, Mosquito Range Aug 08 2005 *T Kelso 05 102* (COLO 505999)(B1118, GU172516); (2) USA: CO, La Plata Co, Jul 31 2004 *G Rink 3802* (BRY 467238)(B1496, GU172517); (3) USA: CO, Summit Co, Jul 22 1990 *T Hogan 801* (BRY 446250)(B1524, GU172518); *C. argyrantha* Tuck. ex Dewey, (1) USA: MD, Frederick Co, Jun 02 2004 *CT Frye 5291* (DOV 044449)(B0116, GU172529); (2) USA: MI, Wexford Co, Jun 19 2005 *AA Reznicek, A Cleveland 11665* (DOV 053942)(B0117, GU172530); (3) Canada: QC, Parc de la Gatineau, Gatineau Aug 11 1977 *D Gagnon BID 22* (CAN 448650)(B1467, GU172531); *C. athrostachya* Olney, (1) USA: OR, Linn Co, Aug 04 2000 *TG Lammers, MA Vincent 11056* (DOV 039642)(B0108, GU172542); (2) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11521* (DOV 063479)(B0109, GU172541); (3) Canada: SK, Whitewood Sep 14 1998 *JH Hudson 5382* (CAN 582299)(B0946, GU172543); *C. bebbii* (LH Bailey) Olney ex Fernald, (1) Canada: MB, 8.9 km W of Richer Jun 25 2003 *RFC Naczi, BA Ford 9793* (DOV 037422)(B0127, GU172585); (2) Canada: NL, Bonavista South Dist Aug 21 1997 *R Charest, L Brouillet, J Labrecque 97 3218* (MT)(B0912, GU172586); (3) Canada: ON, Essex Co, Jul 11 1988 *J Kamstra, B Larson, M Williamson 188 171* (TRTE 46158)(B1303, GU172587); (4) Canada: ON, Thunday Bay Dist Jul 27 2005 *D Gregory* (TRTE 66965)(B1509, GU172588); *C. bicknellii* Britton in NL Britton &

A Brown, (1) USA: KN, Linn Co, Jun 10 2002 *CA Morse, CC Freeman, D Kettle 8075* (DOV 037724)(B0125, GU172592); (2) USA: IN, Newton Co, Jun 19 1997 *PE Rothrock 3624* (DOV 023973)(B0126, GU172591); (3) Canada: ON, Kenora Co, Jun 16 1999 *WD Bakowsky, MJ Oldham 99 096* (TRTE 64345)(B1288, GU172593); *C. brevior* (Dewey) Mack. ex Lunell, (1) USA: KN, Chautauqua Co, Apr 23 2001 *CA Morse, Walter Michner 5462* (DOV 037647)(B0143, GU172617); (2) USA: WI, Adams Co, Jun 13 1993 *TS Cochran 12923* (DOV 038307)(B0144, GU172619); (3) USA: KY, Campbell Co, May 14 1999 *RFC Naczi 7838* (DOV 021923)(B0145, GU172618); (4) Canada: BC, Cochise Co, Jun 30 1993 *F Lomer* (UBC 15442)(B1216, GU172616); *C. crawfordii* Fernald, (1) USA: WI, Vilas Co, Aug 18 2003 *JW Thieret 61473* (DOV 041942)(B0169, GU172715); (2) USA: NY, Hamilton Co, Jul 7 2003 *RFC Naczi 9984* (DOV 038278)(B0170, GU172714); *C. cristatella* Britton in NL Britton & A Brown, (1) USA: MI, Monroe Co, Jul 5 1999 *RFC Naczi 8277* (DOV 036737)(B0181, GU172725); (2) USA: KY, Casey Co, Jun 18 1998 *AA Reznicek, RFC Naczi 10659* (DOV)(B0182, GU172724); (3) USA: DE, New Castle Co, Jun 3 2004 *RFC Naczi 10343* (DOV 050809)(B0205, GU172723); (4) USA: WI, Brown Co, Aug 01 2002 *NA Harriman, TG Lammers, MA Vincent 21698* (DOV 039726)(B0450, GU172726); *C. cumulata* (LH Bailey) Mack., (1) USA: IL, Iroquois Co, Jun 06 1999 *AA Reznicek, SA Reznicek 10836* (DOV 023135)(B0253, GU172735); (2) Canada: ON, Renfrew Co, Aug 9 1981 *SJ Darbyshire 1517* (CAN 465455)(B1486, GU172736); *C. davyi* Mack., (1) USA: CA, Alpine Co, Aug 06 2006 *RFC Naczi 11531* (DOV)(B0856, GU172750); *C. ebenea* Rydberg, (1) USA: CO, Gilpin Co, Aug 09 2003 *C Lea 3438* (DOV 047119)(B0331, GU172808); (2) USA: AZ, Coconino Co, Jul 24 1986 *R Tallent 419* (ASU 192827)(B1263, GU172807); (3) USA: WY, Albany Co, Aug 10 2002 *B Heidel 2246* (RM 745770)(B1302, GU172810); (4) USA: UT, Servier Co, Jul 21 1993 *S Goodrich 24156* (CAN 567954)(B1478, GU172809); *C. egglestonii* Mack., (1) USA: CA, Butte Co, Apr 16 2007 *L Ahart* (CHSC 96423)(B1095, GU172824); (2) USA: CO, Dolores Co, Aug 07 1994 *LM Moore 3796* (COLO 468510)(B1108, GU172825); (3) USA: UT, Wasatch Co, Jul 20 1992 *S Goodrich 23828* (CAN 565880)(B1201, GU172826); *C. festucacea* Schkuhr ex Willd., (1) USA: IL, Iroquois Co, Jun 06 1999 *AA Reznicek, SA Reznicek 10834* (DOV 024017)(B0272, GU172852); (2) USA: MD, Dorchester Co, May 22 2005 *WD Longbottom 5856* (DOV 051207)(B0273, GU172853); (3) USA: TX, Lamar Co, May 03 1997 *AA Reznicek, SD Jone,*

SA Reznicek 10368 (DOV 024463)(B0274, GU172854); *C. feta* LH Bailey, (1) USA: CA, Butte Co, Jul 23 2004 *RFC Naczi, LP Janeway 10502* (DOV 055132)(B0275, GU172855); *C. foenea* Willd., (1) USA: ME, Hancock Co, Jul 05 1998 *AA Reznicek, SA Reznicek 10696* (DOV 022895)(B0291, GU172880); (2) Canada: ON, Thunder Bay Co, Jul 28 1999 *WD Bakowsky, A Harris, S Bryan, S Mauser, J Line 99 155* (TRTE 064239)(B1330, GU172881); (3) Canada: BC, Wells Gray Provincial Park Jun 11 2004 *C Bjork 9122* (UBC 223185)(B1393, GU172879); *C. fracta* Mack., (1) USA: OR, Lane Co, Jun 22 1989 *D Castaner 10275* (DOV 039526)(B0277, GU172892); (2) USA: CA, Fresno Co, Jul 26 2004 *RFC Naczi 10554* (DOV 055122)(B0278, GU172888); (3) USA: CA, Butte Co, Jul 25 2006 *L Ahart 13068* (DOV 060597)(B0279, GU172889); (4) USA: DE, Dorchester Co, Jul 01 2002 *W McAvoy 5520* (DOV 046443)(B0283, GU172891); (5) USA: CA, Fresno Co, Jul 26 2004 *RFC Naczi 10564* (DOV 056481)(B0457, GU172890); *C. gracilior* Mack., (1) USA: CA, Yuba Co, May 24 2006 *LP Janeway 8631* (DOV 060570)(B0303, GU172930); (2) USA: CA, Butte Co, Apr 16 2007 *L Ahart 13675* (CHSC 96423)(B1085, GU172928); (3) USA: CA, Butte Co, May 29 1994 *L Ahart 7291* (JEPS 87706)(B1310, GU172929); *C. harfordii* Mack., (1) USA: CA, Santa Cruz Co, Jun 04 2002 *DW Taylor 18095* (DOV 023999)(B0347, GU172959); *C. haydeniana* Olney in S Watson, (1) Canada: AB, Waterton Lakes National Park Jul 29 1970 *G Armstrong, J Nagy 4652* (CAN 378976)(B1480, GU172963); *C. hormathodes* Fernald, (1) Canada: NL, St George's Dist Jul 10 2000 *N Djan Chekar, C Hanel NDC00 1651* (MT)(B0906, GU173001); (2) Canada: NS, Colchester Co, Jul 7 1992 *WJ Crins et al. 8848* (TRTE 054615)(B1508, GU173002); *C. hyalina* Boott, (1) USA: TX, Henderson Co, Apr 24 2007 *RFC Naczi 11782* (DOV 063397)(B0284, GU173011); (2) USA: MS, Coahoma Co, May 03 2006 *CT Bryson, D Skojac 21430* (DOV 056896)(B0294, GU173009); (3) USA: TN, Dyer Co, Jun 27 1995 *AA Reznicek, RFC Naczi 10056* (DOV 024800)(B0295, GU173010); *C. illota* LH Bailey, (1) USA: CO, Gilpin Co, Aug 09 2003 *C Lea 3442* (DOV 046910)(B0342, GU173024); (2) USA: CA, Alpine Co, Aug 06 2006 *RFC Naczi 11537* (DOV 063486)(B0343, GU173022); (3) USA: UT, Duchesne Co, Aug 05 2004 *RFC Naczi, WM Knapp 10732* (DOV 053224)(B0351, GU173025); (4) USA: WA, Okanogan / Chelan Co, Jul 25 2003 *AC Yen, R Robohm, S Bagshaw, L Van Volkenburgh, T Ohlson 03 055* (WTU 356940)(B0999, GU173026); (5) USA: CO, San Juan Co, Aug 24 1996 *T Hogan 3110* (COLO 465916)(B1110, GU173023);

C. integra Mack., (1) USA: CA, Tulare Co, Aug 29 2004 *LP Janeway 8205* (DOV 047918)(B0359, GU173037); (2) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11507C* (DOV 063467)(B0360, GU173038); (3) USA: CA, Siskiyou Co, Jul 04 2006 *LP Janeway 8790* (DOV 060747)(B0370, GU173039); *C. leporinella* Mack., (1) USA: WY, Bighorn Co, Aug 10 1983 *D Castaner 7870* (DOV 038911)(B0426, GU173108); (2) USA: WA, Yakima Co, Aug 16 2003 *PF Zika 18599* (WTU 359365)(B1006, GU173107); *C. longii* Mack., (1) USA: FL, Lake Co, Mar 24 2005 *WD Longbottom, DH Williams 5625* (DOV 049224)(B0382, GU173133); (2) USA: AR, Dallas Co, May 25 2002 *PE Hyatt 10956* (DOV 033714)(B0383, GU173131); (3) USA: DE, Sussex Co, Jun 11 2006 *WD Longbottom 7485* (DOV 062223)(B0388, GU173132); *C. macloviana* D'Urville, (1) USA: AK, Anchorage Quad Jun 30 1994 *M Duffy, J Tande 420* (ALA 1138662)(B1028, GU173166); (2) USA: AZ, Yavapai Co, Jun 13 1992 *MA Baker 9403* (ASU 198014)(B1266, GU173167); (3) Canada: BC, N of Chase Jul 29 2005 *SA Harris* (TRTE 066557)(B1320, GU173168); *C. mariposana* LH Bailey ex Mack., (1) USA: AZ, Yavapai Co, May 17 1994 *T Wright, M Baker 1089* (ASU 203666)(B1277, GU173187); *C. merritt-feraldii* Mack., (1) Canada: MB, 4 km N of West Hawk Lake Jun 25 2003 *RFC Naczi, BA Ford 9819* (DOV 035417)(B0443, GU173203); (2) USA: ME, Cumberland Co, Jul 03 1999 *AA Reznicek, SA Reznicek 10916* (DOV 023129)(B0444, GU173204); (3) USA: WI, Waushara Co, Jul 30 2002 *MA Vincent, TG Lammers, N Harriman 10759* (DOV 030503)(B0445, GU173206); (4) Canada: ON, Rainy Riv Co, Jun 12 1999 *WD Bakowsky, MJ Oldham 99 034* (TRTE 064427)(B1327, GU173205); *C. microptera* Mack., (1) USA: NV, Elko Co, Jul 31 2004 *RFC Naczi, WM Knapp 10656* (DOV 055139)(B0316, GU173234); (2) USA: CA, Alpine Co, Aug 06 2006 *RFC Naczi 11543* (DOV 063490)(B0492, GU173231); (3) USA: CO, Jefferson Co, Jun 23 2003 *C Lea 3418* (DOV 047157)(B0493, GU173233); (4) USA: WA, Okanogan Co, Jul 22 2001 *PE Hyatt 10448* (DOV 049933)(B0494, GU173235); (5) USA: CO, San Juan Co, Aug 01 2003 *J Flaig, K Flaig 2138* (RM 795921)(B1273, GU173232); (6) Canada: YT, 86 mi NE of Ross Riv July 17 2004 *PM Peterson, JM Saarela, SF Smith 18627* (CAN)(B1417, GU173236); *C. missouriensis* PE Rothrock & Reznicek, (1) USA: KN, Douglas Co, Jun 12 2002 *CA Morse, W Busby 8161* (DOV 037737)(B0458, GU173239); (2) USA: IL, McDonough Co, Jun 10 1996 *AA Reznicek, PM McKenzie, SA Reznicek 10224* (DOV 026800)(B0460, GU173238); (3) USA: MO, Audrain Co, Jun 08

1996 *AA Reznicek, PM McKenzie, SA Reznicek 10194* (DOV 044159)(B0461, GU173240); *C. molesta* Mack. ex Bright, (1) USA: MS, Washington Co, May 06 2006 *CT Bryson, NB Bryson 21434* (DOV 058329)(B0462, GU173246); (2) USA: DE, New Castle Co, May 21 2002 *J Ebert 267* (DOV 040944)(B0463, GU173244); (3) USA: KN, Miami Co, May 28 1994 *AA Reznicek, SA Reznicek, SD Jones, GD Jones 9816* (DOV 023982)(B0464, GU173245); *C. molestiformis* Reznicek & PE Rothrock, (1) USA: OK, Delaware Co, May 25 1994 *AA Reznicek, SA Reznicek, SD Jones, GD Jones 9770* (DOV 024054)(B0465, GU173249); (2) USA: AR, Marion Co, May 26 2002 *PE Hyatt 10967* (DOV 033722)(B0466, GU173247); (3) USA: KY, Rockcastle Co, Jun 15 1998 *AA Reznicek, RFC Naczi 10617* (DOV 021740)(B0468, GU173248); *C. multicosata* Mack., (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11508* (DOV 063468)(B0487, GU173262); (2) USA: NV, Elko Co, Jul 31 2004 *RFC Naczi, WM Knapp 10647* (DOV 055339)(B0488, GU173263); (3) USA: OR, Lake Co, Jul 10 2008 *BL Wilson, N Otting 14964* (B Wilson)(B1279, GU173264); (4) USA: OR, Lake Co, Jul 25 2008 *BL Wilson 15015* (B Wilson)(B1298, GU173265); *C. muskingumensis* Schweinitz, (1) USA: WI, LaCrosse Co, Jun 29 1994 *V McNeil 94 362* (DOV 024841)(B0489, GU173272); (2) USA: MO, Mississippi Co, Jun 06 1996 *AA Reznicek, G Yatskievych, B Summers, SA Reznicek 10175* (DOV 024818)(B0508, GU173270); (3) USA: MI, Washtenaw Co, Aug 02 2002 *AA Reznicek 11375* (DOV 040990)(B0509, GU173269); (4) Canada: ON, Kent Co, Jun 25 1987 *MJ Oldham, GM Allen 7461* (TRTE 47626)(B1337, GU173271); *C. normalis* Mack., (1) USA: ME, Penobscot Co, Jun 29 2002 *AA Reznicek, SA Reznicek 11344* (DOV)(B0420, GU173295); (2) USA: AL, Jackson Co, May 19 2005 *RFC Naczi 10880* (DOV 049853)(B0451, GU173293); (3) USA: IA, Dubuque Co, Jun 09 1994 *WR Norris 94 6 9 3* (ISC 425753)(B1186, GU173294); *C. opaca* (FJ Hermann) PE Rothrock & Reznicek, (1) USA: AR, Lawrence Co, May 27 2002 *PE Hyatt 10999* (DOV 049934)(B0507, GU173325); (2) USA: IL, Washington Co, Jun 09 1999 *AA Reznicek, SA Reznicek 10856* (DOV 023207)(B0526, GU173326); (3) USA: OK, Pushmataha Co, May 19 1993 *PE Rothrock, AA Reznicek, CT Bryson, S Jones 2922* (DOV 023468)(B0527, GU173327); *C. oronensis* Fernald, (1) USA: ME, Penobscot Co, Jun 29 2002 *AA Reznicek, SA Reznicek 11343* (DOV 040706)(B0529, GU173333); (2) USA: ME, Waldo Co, May 31 1999 *Gilman 99024* (MAINE 82351)(B1291, GU173332); *C. ovalis* Goodenough, (1) USA: WA, Snohomish

Co, Jun 10 1991 *M Arnot* 321 (WTU 335238)(B1010, GU173335); (2) USA: NC, Mitchell Co, May 24 2004 *BA Sorrie* 11254 (NCU 580432)(B1153, GU173334); (3) USA: WI, Ashland Co, Jun 22 1991 *EJ Judziewicz* 6689 (WIS 41373)(B1173, GU173336); *C. ozarkana* PE Rothrock & Reznicek, (1) USA: AR, Conway Co, May 18 1993 *AA Reznicek, SA Reznicek, PE Rothrock, PE Hyatt* 9325 (DOV 023983)(B0517, GU173343); (2) USA: TX, Upshur Co, May 04 1997 *AA Reznicek, SD Jone, SA Reznicek* 10391 (DOV 024853)(B0518, GU173345); (3) USA: OK, Pushmataha Co, May 19 1993 *AA Reznicek, SA Reznicek, PE Rothrock, SD Jones, G Jones* 9348 (DOV 024355)(B0534, GU173344); *C. pachystachya* Chamisso ex Steudel, (1) USA: CA, Plumas Co, Jul 24 2004 *RFC Naczi, LP Janeway* 10541 (DOV 055337)(B0519, GU173347); (2) USA: WA, Klickitat Co, Jun 15 2001 *S Rodman, PF Zika, S Bagshaw, D Blum* 01 533 (WTU 351996)(B0994, GU173349); (3) USA: CO, Dolores Co, Jul 27 1995 *LM Moore, S Smith* 7585 (COLO 472241)(B1119, GU173348); (4) USA: AK, Lena Cove Jul 13 1997 *AC Sanders* 20870 (UCR 158092)(B1257, GU173346); *C. petasata* Dewey, (1) USA: UT, Summit Co, Aug 06 2004 *RFC Naczi, WM Knapp* 10737 (DOV 055167)(B0586, GU173392); (2) USA: CA, Sierra Co, Aug 04 2006 *RFC Naczi* 11433 (DOV)(B0855, GU173391); *C. phaeocephala* Piper, (1) USA: NV, Eko Co, Jul 31 2004 *RFC Naczi, WM Knapp* 10655 (DOV 055085)(B0587, GU173397); (2) Canada: BC, Cascade Mountains Aug 04 1997 *F Lomer* 97 574 (UBC 225180)(B1333, GU173396); *C. praticola* Rydberg, (1) Canada: MB, 3.0 km E of Treherne Jun 26 2003 *RFC Naczi, BA Ford* 9868 (DOV 037218)(B0556, GU173435); (2) USA: CO, Jefferson Co, Jul 21 2003 *C Lea* 3429 (DOV 047058)(B0557, GU173434); (3) USA: UT, Summit Co, Aug 12 2004 *S Goodrich, A Huber, R Zobell, G Brown* 26834 (UCR 169125)(B1262, GU173437); (4) Canada: ON, Rainy Riv Dist Jul 18 1997 *MJ Oldham* 20218 (TRTE)(B1512, GU173436); *C. preslii* Steudel, (1) Canada: BC, Mount Revelstoke Nat'l Pk Aug 30 1997 *BA Ford* 9719 (DOV 025915)(B0567, GU173438); (2) USA: OR, Klamath Co, Jun 20 1989 *D Castaner* 10263 (DOV 039484)(B0568, GU173439); *C. projecta* Mack., (1) Canada: QC, Brome Co, Jul 12 1998 *AA Reznicek, SA Reznicek* 10708 (DOV 022672)(B0569, GU173443); (2) Canada: MB, 4 km N of town of W Hawk Lk Jun 25 2003 *RFC Naczi, BA Ford* 9821 (DOV 037211)(B0570, GU173440); (3) USA: ME, Oxford Co, Jun 30 2001 *AA Reznicek, SA Reznicek* 11280 (DOV 041025)(B0571, GU173441); (4) Canada: NB, York Co, Jul 28 1995 *HR Hinds* 11534 (UNB 51953)(B1162,

GU173442); *C. proposita* Mack. in NL Britton *et al.*, (1) USA: WA, Chelan Co, Aug 03 1991 *E Burnett, M Arnot 406* (WTU 339782)(B0990, GU173446); (2) USA: ID, Blaine Co, Aug 24 1993 *B Moseley 2818* (ID 118386)(B1230, GU173445); (3) USA: CA, Fresno Co, Jul 01 1990 *B Ertter, J Shevock et al. 9192* (UC 1563881)(B1334, GU173444); *C. reniformis* (LH Bailey) Small, (1) USA: TX, Brazoria Co, Apr 16 2004 *DJ Rosen 2811* (DOV 047462)(B0580, GU173468); (2) USA: GA, Meriwether Co, Apr 25 2002 *RFC Naczi 9154A* (DOV 026514)(B0581, GU173466); (3) USA: MS, Lawrence Co, Apr 15 2004 *CT Bryson 20006* (DOV 047011)(B0582, GU173467); *C. scoparia* Schkuhr ex var *tessellata* Fernald & Wiegand, (1) USA: ME, Washington Co, Jul 02 2000 *AA Reznicek 11177* (DOV 040438)(B0629, GU173542); (2) USA: ME, Washington Co, Jul 11 1998 *AA Reznicek, SA Reznicek 10698* (QFA 452630)(B1276, GU173540); (3) USA: ME, Washington Co, Jul 07 1999 *B Newcomer* (MAINE 81559)(B1289, GU173541); *C. scoparia* Schkuhr ex Willd. var *scoparia*, (1) USA: KN, Linn Co, May 24 2000 *CA Morse, W Michener 4582* (DOV 047406)(B0627, GU173536); (2) USA: NC, Haywood Co, Jun 16 2006 *CT Bryson, NB Bryson 21850* (DOV 056903)(B0628, GU173537); (3) USA: ME, Washington Co, Jul 02 2000 *AA Reznicek 11176* (DOV 041338)(B0648, GU173539); (4) Canada: QC, Papineau Jul 22 1995 *G Claude 95 125* (MT)(B0916, GU173538); *C. shimmersii* PE Rothrock & Reznicek, (1) USA: KN, Douglas Co, Jun 18 2000 *CA Morse 4812* (DOV 037728)(B0618, GU173562); (2) USA: OK, Pawnee Co, May 04 2004 *B Hoagland, C Batterson AB 4663* (OKL 233777)(B0945, GU173564); (3) USA: KN, Anderson Co, Jul 01 2002 *CA Morse 8408* (OKL 233777)(B1254, GU173563); *C. silicea* Olney, (1) USA: DE, Sussex Co, May 26 1993 *WA McAvoy 278* (DOV 037301)(B0625, GU173575); (2) USA: ME, Cumberland Co, Jul 03 1999 *AA Reznicek, SA Reznicek 10915* (DOV 023980)(B0626, GU173576); (3) Canada: NB, Albert Co, Aug 24 1991 *HR Hinds, G Flanders 10358* (UNB 49513)(B1161, GU173577); *C. specifica* LH Bailey, (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11509* (DOV 063473)(B0686, GU173589); (2) USA: CA, Alpine Co, Aug 06 2006 *RFC Naczi 11542* (DOV 063472)(B0687, GU173590); (3) USA: CA, Nevada Co, Jul 22 2004 *RFC Naczi 10485* (DOV 055686)(B0688, GU173591); *C. stenoptila* FJ Hermann, (1) USA: UT, Duchesne Co, Aug 05 2004 *RFC Naczi, WM Knapp 10727* (DOV 055688)(B0676, GU173608); (2) USA: MT, Park Co, Aug 14 1998 *P Lesica 7736* (MT 131050)(B0954, GU173607); (3) USA: CO, Grand Co, Aug 21 1993 *RJ Rondeau 93 787* (COLO

507232)(B1102, GU173606); *C. straminea* Willd. in Schkuhr, (1) USA: IN, Pulaski Co, Jun 23 1993 *PE Rothrock 3051* (DOV 023254)(B0643, GU173624); (2) USA: MO, Shannon Co, May 21 1993 *PE Rothrock, AA Reznicek, G Yatskievych 2927 2928* (DOV 023981)(B0644, GU173625); (3) USA: DE, New Castle Co, May 30 1999 *RFC Naczi 8067* (DOV 021961)(B0645, GU173623); *C. straminiformis* LH Bailey, (1) USA: UT, Salt Lake Co, Aug 04 2004 *RFC Naczi, WM Knapp 10673* (DOV 055695)(B0660, GU173628); (2) USA: CA, Nevada Co, Aug 09 2004 *LP Janeway 11346* (DOV 047914)(B0661, GU173626); (3) USA: ID, Adams Co, Jul 01 1999 *CR Bjork 4788* (ID 125613)(B1255, GU173627); *C. subbracteata* Mack., (1) USA: CA, Marin Co, Apr 02 1993 *GF Hrusa 10850* (CDA 10850)(B1348, GU173642); *C. suberecta* (Olney) Britton, (1) USA: OH, Miami Co, Jun 16 1999 *RFC Naczi, SM Yelton 8259* (DOV 039973)(B0695, GU173645); (2) USA: AR, Baxter Co, Jun 19 1993 *PE Hyatt 5683* (OKL 210588)(B0953, GU173643); (3) USA: IA, Story Co, Jun 24 1999 *JD Thompson, SC Zager* (ISC 426870)(B1182, GU173644); *C. subfusca* Boott in S Watson, (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11507* (DOV 063464)(B0696, GU173647); (2) USA: CA, Nevada Co, Jul 22 2004 *RFC Naczi 10480* (DOV 055796)(B0697, GU173648); (3) USA: CA, Mono Co, Aug 02 1990 *GK Helmkamp* (UCR 67031)(B1261, GU173646); *C. tahoensis* Smiley, (1) USA: OR, Wallowa Co, Aug 09 1994 *BL Wilson, K Kuykendall, B Newhouse, PF Zika 7401* (OSC 185041)(B1068, GU173664); *C. tenera* Dewey var *echinodes* (Fernald) Wiegand, (1) USA: MI, Monroe Co, Jul 05 1999 *RFC Naczi 8282* (DOV 036815)(B0705, GU173669); (2) Canada: MB, Souris Riv Wildlife Management Area Jun 26 2003 *RFC Naczi, BA Ford 9887* (DOV 036815)(B0707, GU173668); *C. tenera* Dewey var *tenera*, (1) USA: MI, Monroe Co, Jul 05 1999 *RFC Naczi 8278* (DOV 036814)(B0128, GU173670); (2) USA: ME, Waldo Co, Jun 29 2002 *AA Reznicek, SA Reznicek 11341* (DOV 041057)(B0706, GU173673); (3) Canada: QC, Vaudreuil Soulanges Jun 01 2002 *S Hay, C Morisse SH02 04* (MT)(B0914, GU173671); (4) Canada: MB, Souris Wildlife Management Area Jun 26 2003 *BA Ford, RFC Naczi 379* (WIN 69115)(B1143, GU173672); (5) USA: WI, Ashland Co, Jun 16 1992 *EJ Judziewicz 9770* (WIS 45391)(B1174, GU173674); *C. tetrastachya* Scheele, (1) USA: OK, Jefferson Co, May 10 1997 *LK Magrath 19838* (DOV 020791)(B0662, GU173679); (2) USA: TX, Karnes Co, Apr 23 2007 *RFC Naczi 11773* (DOV 063394)(B0663, GU173681); (3) USA: TX, Brazoria Co, Apr 10 2003 *DJ Rosen, C Yeargan 2451* (DOV 031513)(B0664,

GU173680); *C. tincta* (Fernald) Fernald, (1) USA: ME, Hancock Co, Jul 11 1998 *AA Reznicek, SA Reznicek 101701* (DOV 022688)(B0737, GU173690); (2) Canada: NB, Madawaska Co, Aug 03 1997 *AA Reznicek, SA Reznicek 10566* (MT)(B0913, GU173691); (3) USA: CA, Fresno Co, Jul 06 2003 *LP Janeway 7874* (CHSC 86115)(B1076, GU173692); *C. tribuloides* Wahl. var *sangamonensis* Clokey, (1) USA: KN, Leavenworth Co, Jul 24 2003 *CA Morse 9769* (DOV 037725)(B0720, GU173715); (2) USA: LA, Iberville Parish May 26 2004 *DM Ferguson, V Karaman Castro 1499* (LSU 116870)(B1342, GU173716); *C. tribuloides* Wahl. var *tribuloides*, (1) USA: MD, Wicomico Co, Jun 18 2006 *WD Longbottom, G Van Velsir, A MacDonough Plant, RD Redden, JD Saffer 7545* (DOV 060776)(B0716, GU173712); (2) USA: FL, Gilchrist Co, Oct 30 2000 *JR Abbott, RL Mears 14073* (DOV 029347)(B0717, GU173711); (3) USA: SC, Marion Co, May 17 2006 *B Pittman, A Darr, K Boyle, J Nelson 5170609* (DOV 059245)(B0718, GU173717); (4) USA: MI, Otsego Co, Jul 15 2002 *AA Reznicek, RFC Naczi, FW Case 11368* (DOV 040314)(B0719, GU173713); (5) USA: KN, Douglas Co, Jun 18 2000 *CA Morse 4813* (DOV 037720)(B0721, GU173718); (6) Canada: QC, Monteregie, Le Bas Richelieu Jul 10 2006 *M Blondeau, M Peloquin SQ 2006 05* (MT)(B0908, GU173714); *C. unilateralis* Mack., (1) USA: WA, Clark Co, Jun 07 2001 *PF Zika 16199* (WTU 347733)(B0985, GU173747); (2) USA: OR, Jackson Co, Jul 15 1999 *BL Wilson 10097* (OSC 205090)(B1069, GU173746); (3) Canada: BC, Somenos Lake Jul 11 1993 *GW Douglas, C Norris 12734* (UBC 211782)(B1241, GU173744); (4) Canada: BC, Empress Mountain Apr 14 1993 *A Ceska, O Ceska, RT Ogilvie, R Hebda, NJ Korelus, L Husted 11499* (UBC 215828)(B1358, GU173745); *C. vexans* FJ Hermann, (1) USA: FL, Hillsborough Co, Mar 25 1992 *PE Rothrock 2378* (DOV 023460)(B0760, GU173775); (2) USA: FL, Hendry Co, Mar 24 1992 *PE Rothrock 2376* (DOV 023258)(B0761, GU173774); (3) USA: FL, Volusia Co, Mar 22 2007 *WD Longbottom 8243* (DOV 063871)(B0762, GU173776); *C. wootonii* Mack., (1) USA: NM, Sandoval Co, Jul 28 2001 *RL Hartman 73040* (DOV 047801)(B0765, GU173806); (2) USA: AZ, Coconino Co, Jun 24 1986 *R Tallent 401* (ASU 227729)(B1206, GU173805); *C. xerantica* LH Bailey, (1) Canada: ON, Thunder Bay Co, Jun 30 1996 *WD Bakowsky, MJ Oldham* (TRTE 062037)(B1306, GU173808); (2) Canada: BC, Uintah Co, Jul 04 1994 *T Goward, C Clement 94 390* (UBC 215425)(B1371, GU173807).

Carex L sect *Paludosae* G Don in JC Loudon, *C. acutiformis* Ehrhart, (1) South Africa: North West Province, Transvaal *C Reid 1367* (UPOS 003084)(B1516, GU172450); *C. congdonii* LH Bailey, (1) USA: CA, Mono Co, Jul 21 2002 *LP Janeway 7678* (CHSC 82748)(B1079, GU172706); (2) USA: CA, Yosemite National Park Aug 22 2005 *A Colwell, D Grossenbacher AC05 363* (UC 1861912)(B1290, GU172707); *C. halliana* LH Bailey, (1) USA: WA, Skamania Co, Jun 16 2001 *S Rodman 558* (WTU 352115)(B0996, GU172956); (2) USA: OR, Klamath Co, Sep 09 1995 *W Rolle 958* (OSC 184794)(B1060, GU172955); (3) USA: CA, Siskiyou Co, Jul 13 2002 *LP Janeway 7638* (CHSC 82811)(B1082, GU172954); *C. heterostachya* Bunge, (1) USA: IL, Winnebago Co, Jun 27 2008 (MOR)(B1415, GU172980); *C. houghtoniana* Torrey ex Dewey, (1) Canada: MB, 4 km N of town of W Hawk Lk Jun 25 2003 *RFC Naczi, BA Ford 9816* (DOV 037097)(B0843, GU173006); (2) Canada: NB, York Co, Aug 2 1997 *AA Reznicek, SA Reznicek 10564* (MT)(B0921, GU173007); (3) USA: WI, Ashland Co, Jun 03 1991 *EJ Judziewicz 6194* (WIS 189026)(B1175, GU173008); *C. hyalinolepis* Steudel, (1) USA: MD, Somerset Co, Jun 05 2001 *C Lea 2638* (DOV 045865)(B0297, GU173013); (2) USA: TX, Jackson Co, Apr 22 2007 *RFC Naczi 11745* (DOV 063370)(B0338, GU173014); (3) USA: FL, Jefferson Co, Apr 12 2007 *LC Anderson 22885* (DOV 062955)(B0349, GU173012); *C. lacustris* Willd., (1) USA: DE, Kent Co, Nov 01 2003 *WA McAvoy 5963* (DOV 043208)(B0372, GU173061); (2) Canada: MB, 26 km of Richer Jun 25 2003 *RFC Naczi, BA Ford 9809* (DOV 035519)(B0373, GU173062); *C. lasiocarpa* Ehrhart, (1) USA: MD, Garrett Co, Jun 28 2005 *WM Knapp, C Frye, J Harrison 1400* (DOV 054116)(B0377, GU173072); (2) USA: AK, Anchorage Aug 19 2005 *AA Reznicek 11712* (DOV 052444)(B0379, GU173071); *C. melanostachya* M Bieberstein ex Willd., (1) Austria: Niederosterreich, Wiener Becken Jun 23 2005 *T Barta 2005 468* (DOV 063873)(B0441, GU173195); (2) USA: OK, Grady Co, May 07 1991 *LK Magrath 18345* (OKL 197362)(B0947b, GU173198); (3) USA: KN, Douglas Co, Jun 10 1997 *RL McGregor 41316* (KANU 312971)(B1284, GU173196); (4) USA: NE, Cedar Co, Jun 01 1989 *S Rolfsmeier 5056* (NEB 27736)(B1336, GU173197); *C. pellita* Willd., (1) USA: MI, Monroe Co, Jul 05 1999 *RFC Naczi 8284* (DOV 036823)(B0522, GU173377); (2) USA: CA, Tehama Co, Jun 11 2004 *L Ahart 10527* (DOV 055173)(B0542, GU173374); (3) USA: DE, Kent Co, Jul 26

2002 *RFC Naczi 9461* (DOV 023454)(B0543, GU173376); (4) USA: CA, Butte Co, Jul 24
 2004 *RFC Naczi, LP Janeway 10527* (DOV 055173)(B0545, GU173375); (5) Canada: YT,
 Whitehorse Jul 27 2003 *H Solstad, R Elven 03/0890* (ALA 1136195)(B1197, GU173378);
C. pumila Thunberg in A Murray, (1) USA: NC, Dare Co, May 19 1992 *AA Reznicek, SA
 Reznicek 8935* (MICH)(B1461, GU173451); *C. sartwelliana* Olney, (1) USA: CA, Tulare
 Co, Aug 29 2004 *LP Janeway 8190* (DOV 044218)(B0834, GU173501); (2) USA: CA,
 Riverside Co, Jun 25 2003 *V Soza, N Fraga, S Swarzenruber 1700* (RSA 627574)(B1191,
 GU173500); *C. striata* Michaux, (1) USA: MD, Wicomico Co, Jul 13 2005 *WD
 Longbottom, WM Knapp 6284* (DOV 051339)(B0659, GU173630); (2) USA: FL, Franklin
 Co, Apr 26 2000 *RFC Naczi, BA Ford 8436* (DOV 021931)(B0668, GU173629); (3) USA:
 SC, Horry Co, Apr 10 1997 *JB Nelson 18 070* (DOV 039592)(B0669, GU173631); *C.
 vestita* Willd., (1) USA: DE, New Castle Co, Jun 17 1994 *WA McAvoy 559* (DOV)(B0758,
 GU173772); (2) USA: PA, Chester Co, Jun 11 2002 *RFC Naczi, J Ebert, J Holt, BA Ford,
 AA Reznicek, VN Williams 9340* (DOV 028616)(B0759, GU173773).

Carex L sect *Paniceae* G Don in JC Loudon, *C. biltmoreana* Mack., (1) USA: SC, Pickens
 Co, Jun 11 2003 *B Pittman, A Darr 6110311* (DOV 057059)(B0123, GU172602); (2) USA:
 NC, Transylvania Co, May 26 2000 *D Pittillo, M Ivey* (MICH)(B1462, GU172601); *C.
 californica* LH Bailey, (1) USA: WA, Gray's Harbor Co, Jun 17 1998 *E Habegger, P
 Dunwiddie* (WTU 338884)(B0967, GU172641); (2) USA: CA, Mendocino Co, Jul 12 2000
R Weiss (CHSC 79114)(B1078, GU172639); (3) USA: ID, Idaho Co, Aug 22 1995 *S Walker
 77* (ID 132582)(B1228, GU172640); *C. klamathensis* B.L Wilson & Janeway, (1) USA: OR,
 Josephine Co, May 14 1994 *BL Wilson, F Camacho, C Savonen, PF Zika 6782* (B
 Wilson)(B1463, GU173053); *C. laxa* Wahl., (1) USA: AK, Nabesna A4 Quad Jun 18 1996
C Roland 95 134 (ALA 1131786)(B1036, GU173075); (2) Canada: YT, Vicinity of Halfway
 Lake Jul 18 1967 *RT Porsild 887* (CAN 312391)(B1487, GU173076); *C. livida* (Wahl.)
 Willd., (1) USA: NJ, Burlington Co, Jun 21 1994 *RFC Naczi, JW Thieret 4413*
 (DOV)(B0807, GU173126); (2) USA: AK, Mt Fairweather Quad Jul 21 2001 *B Koltun, S
 Klein BK01 44* (ALA 1138143)(B1041, GU173124); (3) USA: CA, Lassen Co, Aug 03
 1993 *VH Oswald, L Ahart 5742* (UC 1609199)(B1316, GU173125); *C. meadii* Dewey, (1)
 USA: AR, Prairie Co, Apr 17 1999 *R Kral 88237* (DOV 051626)(B0440, GU173188); (2)

USA: DE, New Castle Co, Jun 11 2000 *J Ebert, J Holt 187* (DOV 037391)(B0449, GU173189); (3) Canada: MB, Pender Co, Jul 05 1994 *BA Ford, D Punter, N Kenkel, JR Starr 94179* (WIN 67362)(B1135, GU173190); *C. panicea* L, (1) Canada: NS, Antigonish Co, Jun 14 1992 *MJ Oldham 13799* (QFA 522715)(B1272, GU173358); (2) USA: ME, Owls Head KNO Jul 13 2001 *G Hall* (MAINE 82953)(B1299, GU173357); (3) Spain: Huesca, Parque Nacional de Ordesa Jul 30 2004 *M Buide, JM Marin 50MBR04* (UPOS 000183)(B1503, GU173359); *C. polymorpha* Muhl., (1) USA: PA, Luzerne Co, Jun 15 2001 *AF Rhoads, TA Block* (DOV 027313)(B0550, GU173420); (2) USA: ME, Cumberland Co, Jul 05 2001 *DS Cameron, TM Bingel* (MAINE 8300)(B1300, GU173419); *C. tetanica* Schkuhr, (1) Canada: MB, 12 km N of Fisher Branch Jun 20 2002 *BA Ford, M Piercey Normore, E Punter, D Punter 266* (DOV 049385)(B0709, GU173678); (2) USA: IA, Benton Co, May 28 1990 *MJ Leoschke, R Glime, E Howes Vonstein 1083* (ISC 440950)(B1184, GU173677); *C. vaginata* Tausch, (1) Canada: NL, St George's Dist Jul 29 2000 *S Hay, N Djan Chekar CH 000729 27* (MT)(B0898); (2) Canada: YT, Peel/Blow Riv Delta Jul 31 2006 *BA Bennett, MJ Oldham, CA Kennedy, P Seccombe Hett, DC Gordon 06 368* (UBC 224457)(B1367, GU173757); *C. woodii* Dewey, (1) USA: NC, Macon Co, May 04 2000 *PE Hyatt 9217* (DOV 047199)(B0763, GU173804); (2) USA: MD, Allegany Co, Jun 4 2005 *WD Longbottom, RFC Naczi, G Van Velsir 5989* (DOV 051443)(B0764, GU173803); (3) USA: IA, Dubuque Co, Jun 14 1994 *WR Norris 94 6 14 1* (ISC 419069)(B1183, GU173802).

Carex L sect *Phacocystis* Dumortier, *C. angustata* Boott in Hooker, (1) USA: CA, Butte Co, Jul 16 2006 *L Ahart 12974* (DOV 060603)(B0095, GU172491); (2) USA: CA, Placer Co, Aug 03 2006 *RFC Naczi 11411* (DOV)(B0828, GU172492); (3) USA: OR, Lane Co, Jul 14 1994 *BL Wilson, F Camacho, K Kuykendall 7334B* (OSC 184782)(B1051, GU172493); *C. aperta* Boott in Hooker, (1) USA: OR, Linn Co, Aug 08 2000 *TG Lammers, MA Vincent 11054* (DOV 039721)(B0101, GU172502); (2) USA: WA, King Co, May 15 2000 *PF Zika, A Weinmann, F Weinmann 14979* (WTU 347727)(B0962, GU172501); (3) Canada: BC, Kilby Rd Apr 30 1994 *F Lomer* (UBC 208471)(B1235, GU172500); *C. aquatilis* Wahl. var *aquatilis*, (1) Canada: MB, 26 km E of Richer Jun 25 2003 *RFC Naczi, BA Ford 9814* (DOV 037098)(B0091, GU172511); (2) Canada: NL, Eagle Riv Aug 21 1999 *R Charest, C Hanel,*

N Djan Chekar, C Wentzell, B Pollock, L Brouillet, S Hay NDC 99 799 (MT)(B0884, GU172506); (3) Canada: NB, Mount Carleton Provincial Park Jun 22 1998 *G Bishop, B Bagnell* 2151 (UNB 53962)(B1167, GU172512); (4) Canada: NL, Strait of Belle Isle Dist Aug 14 1992 *A Bouchard, S Hay, L Brouillet* 92251 (CAN 566788)(B1343, GU172513); *C. aquatilis* Wahl. var *dives* (Holm) Kük in Engler, (1) USA: WA, Pierce Co, Aug 07 2006 *S Rodman* 640B (WTU 366544)(B1005, GU172510); (2) USA: AK, Yakutat D 8 Quad Jul 27 2003 *P Loomis, A Batten* 1909 (ALA 1120849)(B1021, GU172507); (3) USA: CA, Del Norte Co, Jul 29 2003 *LP Janeway* 7935 (CHSC 84870)(B1077, GU172509); (4) Canada: BC, Wells Gray Provincial Park Jun 02 2002 *CR Bjork* 9178 (UBC 223250)(B1234, GU172508); *C. aquatilis* Wahl. var *substricta* Kük in Engler, (1) Canada: NB, Archipel de la Ristigouche Jul 03 2001 *B Gauthier, A Jobin* 50 2001 (QFA 505656)(B1275, GU172514); (2) USA: NE, Grant Co, Jun 18 1996 *SB Rolfsmeier* 12416 (NEB 292409)(B1304, GU172515); *C. barbarae* Dewey in Emory, (1) USA: CA, Madera Co, Jul 27 2004 *RFC Naczi* 10577 (DOV 053255)(B0132, GU172577); (2) USA: CA, Butte Co, Jul 13 2004 *LP Janeway, B Castro* 8136 (DOV 047940)(B0846, GU172578); (3) USA: CA, Shasta Co, May 17 2006 *LP Janeway* 8603 (DOV 060571)(B0849, GU172579); *C. bigelowii* Torrey ex Schweinitz subsp *bigelowii*, (1) Canada: NL, St Barbe South Dist Aug 20 1993 *A Bouchard, L Brouillet, S Hay, P Turcotte* 93075 (MT)(B0885, GU172599); (2) Canada: SK, Hasbala Lake Jul 16 1963 *GW Argus* 286 63 (CAN 282684)(B1468, GU172600); *C. bigelowii* Torrey ex Schweinitz subsp *lugens* (Holm) Ergorova, (1) USA: AK, Vicinity of Goldstream Crk Aug 04 2003 *AA Reznicek, DF Murray* 11536 (DOV 041016)(B0124, GU172598); (2) USA: AK, Chandler Lake Co, Jul 20 2002 *CL Parker, R Elven, H Solstad* 12191 (ALA 1115793)(B1211, GU172597); *C. crinita* Lamarck var *brevicrinis* Fernald, (1) USA: MD, Worcester Co, Jun 18 2006 *WD Longbottom, RD Redden, JD Saffer, A MacDonough Plant, G Van Velsir* 7558 (DOV 060857)(B0171, GU172718); (2) USA: MS, Marshall Co, May 28 2006 *CT Bryson, NB Bryson* 21573 (DOV 056666)(B0187, GU172719); (3) USA: AR, Miller Co, Apr 14 2001 *PE Hyatt* 10068 (DOV 033710)(B0188, GU172717); *C. crinita* Lamarck var *crinita*, (1) USA: ME, Washington Co, Jul 24 1996 *AA Reznicek* 10318 (DOV 025311)(B0183, GU172722); (2) USA: KY, Laurel Co, Jun 15 1998 *AA Reznicek, RFC Naczi* 10624 (DOV 021737)(B0184, GU172720); (3) USA: MD, Kent Co, Jun 13 2006 *WD Longbottom* 7531 (DOV 057573)(B0189, GU172721); *C. eleusinoides* Turczaninow ex

Kunth, (1) USA: AK, Norton Bay Quad Jul 02 1998 *CL Parker, AR Batten, C Roland 8003* (ALA 1125982)(B1016, GU172827); (2) Canada: YT, Driftwood Riv Jun 30 1973 *SL Walsh, JK Rigby 12297* (CAN 381443)(B1485, GU172828); *C. emoryi* Dewey in Emory, (1) USA: TX, Williamson Co, May 01 2004 *RFC Naczi 10112* (DOV 050491)(B0248, GU172835); (2) USA: IN, Harrison Co, Apr 22 2005 *M Homoya* (DOV 052440)(B0258, GU172833); (3) USA: DE, New Castle Co, May 30 1999 *RFC Naczi 8077* (DOV 021948)(B0267, GU172832); (4) Canada: NB, Charlotte Co, Jul 17 1985 *HR Hinds, M Lulham 7521* (CAN 516260)(B1522, GU172834); *C. endlichii* Kük., (1) USA: AZ, Cochise Co, May 24 1994 *MC Fritts, HC Fritts 94 6* (MICH)(B1489, GU172836); *C. gynandra* Schweinitz, (1) USA: KY, Laurel Co, May 19 1999 *RFC Naczi, JR Abbott 7904* (DOV 021924)(B0336, GU172945); (2) USA: DE, New Castle Co, Jun 07 1993 *WA McAvoy 894* (DOV 020830)(B0346, GU172944); (3) USA: NC, Jackson Co, May 29 2005 *D Estes, S Estes 7770* (DOV 064238)(B0362, GU172946); *C. haydenii* Dewey, (1) Canada: ON, Algoma Co, Jun 07 1999 *M Oldham 21684* (MT)(B0878, GU172966); (2) USA: IA, Story Co, Jul 04 1997 *WR Norris, K Lyles 97 7 4 11* (ISC 420718)(B1185, GU172964); (3) USA: MA, Hampshire Co, Jun 16 1980 *HE Ahles 88117* (CAN 458122)(B1482, GU172965); *C. interrupta* Boeckeler, (1) USA: WA, Lewis Co, May 29 2002 *PF Zika 16944* (WTU 350333)(B1002, GU173043); (2) USA: OR, Linn Co, Aug 13 1996 *R Brainerd, K Kuykendall, D Lytjen, B Newhouse, N Otting, BL Wilson, PF Zika, BL Wilson 8224* (OSC 178862)(B1059, GU173042); *C. lenticularis* Michaux var *dolia* (ME Jones) LA Standley, (1) USA: AK, Hatcher Pass Aug 03 2003 *AA Reznicek, JA Dragon, R Lipkin 11531* (DOV 052443)(B0397, GU173095); (2) Canada: AB, Jasper Nat'l Pk Jul 24 2004 *BA Ford, AJ Gould 4211* (DOV 049492)(B0400, GU173094); (3) Canada: AB, Jasper National Park Jul 27 2004 *BA Ford, AJ Gould 4420* (WIN 70900)(B1138, GU173093); (4) Canada: BC, Moresby Island Aug 21 1997 *F Lomer, N Grove 97510* (UBC 214368)(B1398, GU173096); *C. lenticularis* Michaux var *impressa* (LH Bailey) LA Standley, (1) USA: CA, Nevada Co, Aug 09 2004 *L Ahart 11354* (DOV 048078)(B0395, GU173097); (2) USA: CA, Plumas Co, Jul 09 2006 *L Ahart 12922* (DOV 060573)(B0398, GU173098); *C. lenticularis* Michaux var *lenticularis*, (1) USA: UT, Salt Lake Co, Aug 04 2004 *RFC Naczi, WM Knapp 10677* (DOV 056087)(B0396, GU173106); (2) USA: MI, Chippewa Co, Jun 29 1989 *RFC Naczi, EG Voss et al. 2255* (DOV 022679)(B0401, GU173105); (3) Canada: NL, St Barbe Dist Jul 26

2000 *L Brouillet, N Djan Chekar, T Ahti, C Wentzell LB 00 86* (MT)(B0877, GU173099); *C. lenticularis* Michaux var *limnophila* (Holm) Cronquist in CL Hitchcock *et al.*, (1) USA: WA, Kittitas Co, Sep 26 1991 *J Mastrogiuseppe, D Pock 6662* (WTU 358383)(B1004, GU173102); (2) Canada: BC, Vancouver Island Jun 25 1969 *JH Soper, TC Brayshaw, MJ Shchepanek 12 158* (CAN 341483)(B1474, GU173101); (3) USA: AK, Kupreanof Island May 31 1997 *PF Zika 13111* (MICH)(B1490, GU173100); *C. lenticularis* Michaux var *lipocarpa* (Holm) LA Standley, (1) USA: CA, El Dorado Co, Aug 24 2006 *LP Janeway 8871* (DOV 060575)(B0394, GU173103); (2) USA: CA, Siskiyou Co, Jul 01 2006 *LP Janeway 8716* (DOV 060748)(B0399, GU173104); (3) USA: AK, Talkeetna Quad Jul 18 2002 *M Duffy MD02 72* (ALA 1131847)(B1042, GU173092); *C. lyngbyei* Hornemann in GC Oeder, (1) USA: OR, Clatsop Co, Aug 20 1993 *BL Wilson 6445* (DOV 020784)(B0479, GU173163); *C. mitchelliana* MA Curtis ex A Gray, (1) USA: MD, Dorchester Co, Jun 01 2005 *WD Longbottom 5950* (DOV 051131)(B0459, GU173242); (2) USA: AL, Franklin Co, May 09 2004 *DD Spaulding 12105* (DOV 059241)(B0495, GU173241); (3) USA: OH, Ashtabula Co, Jul 14 2001 *JK Bissell, B Danielson 76* (DOV 053907)(B0496, GU173243); *C. nebrascensis* Dewey, (1) USA: CA, Plumas Co, Jul 24 2004 *RFC Naczi, LP Janeway 10543* (DOV 055338)(B0510, GU173276); (2) USA: CO, Jefferson Co, Jul 21 2003 *C Lea 3427* (DOV 046879)(B0511, GU173277); *C. nigra* (L) Reichard, (1) Austria: Steiermark, 3.8 km NW of Rettenegg Jul 20 2005 *RFC Naczi, J Starr, B Ford, J Thibault 11134* (DOV 052960)(B0512, GU173284); (2) Canada: NL, Bay of islands Jul 19 2000 *N Djan Chekar, C Hanel, L Brouillet, J Maunder, C Wentzell, S Powell NDC 00 369* (MT)(B0894, GU173285); (3) Finland: Lapland, Laponia Aug 5 2005 *M Luceno, M Guzman 3305ML* (UPOS 000332)(B1502, GU173286); *C. nudata* Boott in S Watson, (1) USA: CA, Tehama Co, Jun 11 2004 *L Ahart 11022* (DOV 042317)(B0455, GU173305); (2) USA: CA, Siskiyou county Jul 19 1989 *D Castaner 10239* (DOV 038923)(B0837, GU173304); (3) USA: OR, Douglas Co, Jun 17 1992 *P Zika, B Newhouse, R Brainerd 11646* (OSC 177922)(B1052, GU173306); *C. obnupta* LH Bailey, (1) USA: CA, Humboldt Co, Jun 11 2004 *LP Janeway, B Castro 8321* (DOV 047932)(B0499, GU173309); (2) USA: OR, Benton Co, Aug 17 1993 *B Wilson, D Zobel 6435* (DOV 020759)(B0500, GU173310); *C. paleacea* Schreber ex Wahl., (1) USA: ME, Washington Co, Jul 23 1995 *AA Reznicek, SA Reznicek 10085* (DOV 034112)(B0521, GU173351); *C. ramenskii* Komlarov, (1) USA: AK, Anchorage area Jul 27

2003 *AA Reznicek, J DeLapp 11510* (DOV 041020)(B0836, GU173460); (2) USA: AK, Kotzebue Quad Jul 08 2003 *CL Parker, R Elven, H Solstad 14491* (ALA 1137070)(B1038, GU173459); *C. salina* Wahl., (1) Canada: NL, Bonavista South Dist Jul 06 1996 *R Charest, L Brouillet, A Bouchard, S Hay 96 2510* (MT)(B0899, GU173498); (2) Canada: QC, Vuntut National Park Jun 28 1995 *M Blondeau IAB95077* (WAT)(B1346, GU173499); *C. schottii* Dewey in WH Emory, (1) USA: CA, LA Co, Mar 10 1990 *J Dittes, D Stolp 46* (CHSC 82145)(B1074, GU173515); (2) USA: CA, San Diego Co, Apr 05 2004 *S Boyd, H Bigelow 10783* (RSA 726827)(B1192, GU173516); (3) USA: CA, San Bernardino Co, Jun 23 1995 *SD White 3369* (RSA 726827)(B1250, GU173517); (4) USA: CA, Orange Co, Jul 20 2006 *AC Sanders, FM Roberts, M Balk 33049* (UCR 174019)(B1363, GU173518); *C. scopulorum* Holm var *bracteosa* (LH Bailey FJ Hermann, (1) USA: CA, Mono Co, Aug 20 2004 *LP Janeway 8269* (DOV 048035)(B0631, GU173544); (2) USA: AK, Taylor hwy Aug 1 1968 *JK Monton NA 2080* (CAN 340886)(B1471, GU173543); *C. scopulorum* Holm var *prionophylla* (Holm) LA Standley, (1) USA: WA, Chelan Co, Aug 12 1991 *M Arnot, E Burnett 418* (WTU 324339)(B0980, GU173546); *C. scopulorum* Holm var *scopulorum*, (1) USA: CA, Fresno Co, Jul 26 2004 *RFC Naczi 10566* (DOV 055352)(B0630, GU173545); (2) USA: CO, Gilpin Co, Aug 09 2003 *C Lea 3439* (DOV 047120)(B0632, GU173548); (3) USA: CO, Garfield Co, Aug 08 1991 *JP Vanderhorst 3919A* (COLO 471083)(B1100, GU173547); *C. senta* Boott, (1) USA: CA, Mariposa Co, Apr 30 2004 *LP Janeway 8014* (DOV 044215)(B0633, GU173550); (2) USA: CA, Tulare Co, May 01 2004 *LP Janeway 8019* (DOV 044217)(B0634, GU173551); (3) USA: AZ, Gila Co, Jun 28 2004 *K McBride, D Castle* (ASU 262812)(B1278, GU173549); *C. stricta* Lamarck in J Lamarck *et al.*, (1) USA: TX, Anderson Co, Apr 25 2007 *RFC Naczi 11790* (DOV 063730)(B0690, GU173637); (2) USA: MD, Garrett Co, Jun 04 2005 *WD Longbottom, RFC Naczi, G Van Velsir 6058* (DOV 051418)(B0691, GU173636); *C. subspathacea* Wormskjold in GC Oeder *et al.*, (1) USA: AK, St Matthew Quad Jul 20 1997 *DF Murray 12552* (ALA 1121179)(B1040, GU173650); (2) Canada: MB, Churchill Area Jul 07 1983 *M Zbigniewicz 83 39* (WIN 57797)(B1150, GU173651); (3) Canada: QC, MRC Basques Jun 08 1994 *M Garneau, R Gauthier, S Fiset 94 028M* (QFA 233777)(B1265, GU173652); *C. torta* Boott in Tuck., (1) USA: GA, Dawson Co, Apr 21 2002 *L Kruse 02 90* (DOV 049258)(B0714, GU173706); (2) USA: PA, Bradford Co, May 21 2004 *RFC Naczi 10292* (DOV

050281)(B0715, GU173707); (3) USA: AR, Polk Co, May 17 1997 *PE Hyatt 7447* (DOV 020853)(B0723, GU173705); *C. vacillans* Drejer in CJ Hartman, (1) Canada: NB, Charlotte Co, Jul 14 1992 *HR Hinds 10666* (UNB 50147)(B1168, GU173755); (2) USA: ME, Washington Co, Aug 26 2004 *S Rooney, J Weber F04SCR382* (MAINE 83939)(B1282, GU173754); (3) Canada: QC, Riv du Loup Co, Aug 31 1966 *E Lepage 15644* (CAN 304493)(B1481, GU173756).

Carex L sect *Phaestoglochin* Dumortier, *C. aggregata* Mack., (1) USA: MD, Cecil Co, May 29 1999 *RFC Naczi 8052* (DOV 035835)(B0064, GU172461); (2) USA: OK, Delaware Co, May 25 1994 *SG Jones, AA Reznicek, S Reznicek 11121* (DOV 044155)(B0065, GU172462); (3) USA: KY, Scott Co, May 25 2005 *RFC Naczi 11016* (DOV 052452)(B0066, GU172460); *C. appalachia* Webber & Ball, (1) USA: MD, Garrett Co, May 29 2006 *WD Longbottom, RD Redden 7391* (DOV 063124)(B0086, GU172504); (2) USA: TN, Json Co, Jun 22 1994 *TF Wieboldt 8933* (DOV 022935)(B0102, GU172505); (3) USA: MA, Franklin Co, Jun 03 1999 *TM Zebryk 6189* (DOV 046252)(B0103, GU172503); *C. arkansana* (LH Bailey) LH Bailey, (1) USA: TX, Freestone Co, May 02 2004 *RFC Naczi 10147* (DOV 050927)(B0118, GU172534); (2) USA: IL, Saline Co, Jun 06 1995 *SR Hill, LR Philippe 26649* (DOV 037089)(B0119, GU172532); (3) USA: KN, Anderson Co, Jun 13 2003 *CA Morse 9525* (DOV 037604)(B0120, GU172533); *C. austrina* Mack., (1) USA: MD, Caroline Co, May 14 1998 *WA McAvoy 3591* (DOV 039433)(B0172, GU172564); (2) USA: MS, Holmes Co, May 6 2002 *CT Bryson, JP Goodlett 19220* (DOV 024631)(B0173, GU172565); (3) USA: TX, Lavaca Co, Apr 22 2007 *RFC Naczi 11737* (DOV 064041)(B0174, GU172566); *C. cephaloidea* (Dewey) Dewey, (1) USA: MA, Hampden Co, May 14 1999 *TM Zebryk 6151* (DOV 046273)(B0186, GU172668); (2) USA: PA, Bradford Co, May 23 2004 *RFC Naczi 10337* (DOV 052000)(B0198, GU172669); *C. cephalophora* Muhl. Ex Willd., (1) USA: KN, Linn Co, May 23 2002 *CA Morse 7970* (DOV 037633)(B0190, GU172671); (2) USA: MS, Marshall Co, May 28 2006 *CT Bryson, NB Bryson 21587* (DOV 056669)(B0191, GU172672); (3) USA: MD, Cecil Co, May 9 2000 *WA McAvoy 4654* (DOV 037192)(B0210, GU172670); *C. divulsa* Stokes subsp *divulsa*, (1) Bulgaria:, Northern coastal area of Black Sea Jun 7 1999 *T Raus, F Pina Gata 46 1 8* (DOV 064054)(B0228, GU172801); (2) USA: WA, King Co, Nov 16 2000 *PF Zika 15681* (WTU

350436)(B0974, GU172802); *C. gravida* LH Bailey, (1) USA: KN, Saline Co, May 30 2003 *CC Freeman, J Elliott 19808* (DOV 037571)(B0352, GU172939); (2) USA: OK, Roger Mills Co, May 31 2001 *CA Morse, CC Freeman 6375* (DOV 054768)(B0364, GU172940); *C. hoodii* Boott in Hooker, (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11519* (DOV 063477)(B0280, GU172996); (2) USA: WA, Okanogan Co, 10440 (DOV 049747)(B0281, GU172997); (3) USA: WY, Converse Co, Jul 01 1989 *D Castaner 10344* (DOV 039490)(B0282, GU172998); (4) USA: CA, Trinity Co, Jul 26 1987 *B Ertter 7330* (UC 1561800)(B1323, GU172995); *C. hookerana* Dewey, (1) USA: MN, Becker Co, Jun 16 2005 *MD Lee MDL3973* (MIN 897939)(B1386, GU173000); (2) Canada: AB, Elk Island National Park Jul 12 2001 *GCD Griffiths* (ALTA 105726)(B1507, GU172999); *C. leavenworthii* Dewey, (1) USA: AL, Jackson Co, May 19 2005 *RFC Naczi 10881* (DOV 049854)(B0407, GU173086); (2) USA: MI, Washtenaw Co, May 24 1991 *SG Jones, A Reznicek 6931* (DOV 043019)(B0408, GU173087); (3) USA: TX, Karnes Co, Apr 23 2007 *RFC Naczi 11774* (DOV 063393)(B0409, GU173088); *C. mesochorea* Mack., (1) USA: DE, New Castle Co, May 09 2002 *RFC Naczi, BA Ford 9279* (DOV 028723)(B0480, GU173211); (2) USA: KN, Douglas Co, May 03 2000 *CA Morse, ME Terry 4354* (DOV 037695)(B0490, GU173212); (3) USA: AL, Jackson Co, May 21 2005 *RFC Naczi 10910* (DOV 049845)(B0491, GU173210); *C. muehlenbergii* Schkuhr ex Willd. var *enervis* Boott, (1) USA: MD, Frederick Co, May 25 2002 *C Lea 2948* (DOV 046513)(B0481, GU173252); (2) USA: KN, Linn Co, May 23 2002 *CA Morse 7973* (DOV 037634)(B0482, GU173251); (3) USA: AR, Polk Co, May 18 1993 *S Jones, G Jones 10148* (UTC 217734)(B1359, GU173250); *C. muehlenbergii* Schkuhr ex Willd. var *muehlenbergii*, (1) USA: MD, Wicomico Co, Jun 12 2007 *WD Longbottom 9255* (DOV 063780)(B0467, GU173254); (2) USA: KN, Miami Co, May 20 2000 *CA Morse 4739* (DOV 037605)(B0483, GU173255); (3) USA: MS, Marshall Co, May 28 2006 *CT Bryson, NB Bryson 21572* (DOV 056661)(B0484, GU173257); (4) USA: TX, Cooke Co, May 03 2004 *RFC Naczi 10168* (DOV 050489)(B0485, GU173258); (5) USA: FL, Gadsden Co, Apr 14 2003 *LC Anderson 20679* (DOV 029013)(B0497, GU173253); (6) USA: MI, Washtenaw Co, May 24 1991 *SG Jones, A Reznicek, S Reznicek 6981* (DOV 042954)(B0498, GU173256); *C. muricata* L. subsp *lamprocarpa* Celakovsky, (1) Morocco:, Marrakech Tensift Al Haouz May 12 2005 *P Jiménez Mejias, E Narbona, AJ Chaparro, M Parra 220PJM05* (UPOS 001613)(B1504,

GU173266); *C. occidentalis* LH Bailey, (1) USA: CO, Jefferson Co, Jun 27 2004 *C Lea 3451* (DOV 046887)(B0502, GU173313); (2) USA: NM, Lincoln Co, May 16 2005 *RD Worthington 33128* (UNM 109339)(B1219, GU173314); (3) USA: NM, Bandelier National Monument Jul 31 2003 *Y Chauvin* (UNM 111091)(B1221, GU173315); (4) USA: NV, Clark Co, Jun 05 1994 *J Leary 4643* (UCR 94096)(B1252, GU173316); (5) USA: CA, San Bernardino Co, Jul 25 1986 *AC Sanders, KR Cooper 6788* (UCR 48605)(B1526, GU173312); *C. perdentata* SD Jones, (1) USA: TX, Williamson Co, May 01 2004 *RFC Naczi 10111* (DOV 050472)(B0576, GU173388); (2) USA: TX, Gonzales Co, Apr 23 2007 *RFC Naczi 11770* (DOV 063373)(B0585, GU173389); (3) USA: OK, Pawnee Co, May 04 2004 *B Hoagland, C Batterson AB 4660* (OKL 233776)(B0946b, GU173387); *C. radiata* (Wahl.) Small, (1) USA: GA, Upson Co, Apr 25 2002 *RFC Naczi 9171* (DOV 028810)(B0577, GU173456); (2) USA: MI, Wayne Co, May 19 2005 *AA Reznicek, S Campbell 11632* (DOV 053844)(B0592, GU173458); (3) USA: MA, Franklin Co, Jun 11 1999 *TM Zebryk 6279* (DOV 046388)(B0593, GU173457); *C. retroflexa* Muhl. ex Willd., (1) USA: MO, Warren Co, May 25 2003 *RFC Naczi, BA Ford 9621* (DOV 035204)(B0583, GU173470); (2) USA: DE, Sussex Co, Jun 5 2003 *WA McAvoy 5754* (DOV 040935)(B0584, GU173469); (3) USA: TX, Henderson Co, Apr 24 2007 *RFC Naczi 11780* (DOV 063396)(B0602, GU173471); *C. rosea* Schkuhr ex Willd., (1) USA: ME, Hancock Co, Jun 30 2003 *AA Reznicek 11486* (DOV 040969)(B0607, GU173482); (2) USA: AL, Chilton Co, Apr 23 2002 *RFC Naczi 9097* (DOV 025405)(B0608, GU173481); (3) USA: WI, Waupaca Co, Jun 30 2003 *NA Harriman, TL Eddy 21738* (DOV 039750)(B0609, GU173483); *C. socialis* Mohlenbrock & Schwegman, (1) USA: SC, Marion Co, May 17 2006 *B Pittman, A Darr, K Boyle, J Nelson 5170614* (DOV 059246)(B0680, GU173585); (2) USA: AR, Chicot Co, May 12 2006 *CT Bryson, NB Bryson 21451* (DOV 056189)(B0681, GU173584); (3) USA: AL, Jackson Co, Apr 21 2002 *RFC Naczi 9014* (DOV 025330)(B0682, GU173583); *C. sparganioides* Muhl. ex Willd., (1) USA: DE, New Castle Co, Jun 01 1999 *RFC Naczi 8128* (DOV 037013)(B0683, GU173586); (2) USA: WI, Fond du Lac Co, Jun 17 2000 *TG Lammers, M Batterman 10971* (DOV 039722)(B0684, GU173587); (3) USA: TN, Franklin Co, May 24 1998 *RFC Naczi, BA Ford 7253* (DOV 024318)(B0685, GU173588); *C. spicata* Hudson, (1) USA: DE, New Castle Co, May 09 2002 *RFC Naczi, BA Ford 9280* (DOV 028784)(B0665, GU173597); (2) Bulgaria: Northern

costal area of Black Sea Jun 6 1999 *T Raus, FP Gata 44 1 14* (DOV 064072)(B0666, GU173596); *C. texensis* (Torrey ex LH Bailey) LH Bailey, (1) USA: TX, Brazoria Co, Mar 12 2003 *DJ Rosen, SD Jones 2431* (DOV 031526)(B0734, GU173684); (2) USA: SC, Orangeburg Co, Apr 12 2001 *AB Pittman, AR Darr 4120121* (DOV 040356)(B0735, GU173683); (3) USA: CA, Butte Co, May 08 1988 *LP Janeway, M Halterman 2660* (CHSC 47139)(B1073, GU173682); *C. tumulicola* Mack., (1) USA: CA, Madera Co, Jul 27 2004 *RFC Naczi 10578* (DOV 053348)(B0733, GU173732); (2) USA: WA, Island Co, May 07 2004 *B Legler 1581* (WTU 357725)(B0984, GU173733); *C. vallicola* Dewey, (1) USA: CA, Mono Co, Aug 05 2006 *RFC Naczi 11495* (DOV)(B0860, GU173760); (2) USA: CO, Gunnison Co, Jun 17 1997 *KJ Taylor 1640* (COLO 498956)(B1105, GU173761); (3) USA: AZ, Gila Co, May 01 1992 *GJ Imdorf 658* (ASU 196793)(B1204, GU173758); (4) Canada: BC, Ashnola Riv Valley Jun 06 1993 *F Lomer 93 048* (UBC 210709)(B1379, GU173759).

Carex L sect *Phyllostachyae* Tuck. ex Kük. in Engler, *C. backii* Boott in Hooker, (1) USA: MI, Cheboygan Co, Jun 22 1986 *RFC Naczi 1326* (DOV 013077)(B0007, FJ597184); (2) Canada: MB, 1 km ESE of Treesbank Jun 26 2003 *RFC Naczi, BA Ford 9913* (DOV)(B0783, FJ597182); (3) Canada: MB, NE of town of Falcon Lk Jun 25 2003 *RFC Naczi, BA Ford 9846* (DOV)(B0784, FJ597183); (4) Canada: MB, 4 km N of town of W Hawk Lk Jun 25 2003 *RFC Naczi, BA Ford 9829* (DOV)(B0785b, GU172572); (5) Canada: BC, Bulkley Nechako Regional District Jul 12 1974 *VJ Krajina, J Pojar, C Parons 1309* (UBC 150083)(B1400, GU172571); *C. basiantha* Steudel, (1) USA: AR, Phillips Co, May 20 2006 *CT Bryson, NB Bryson 21475* (DOV 057426)(B0006, FJ597186); (2) USA: SC, Hampton Jun 15 2000 *AB Pittman, AR Darr 6150007* (DOV 040375)(B0017, GU172584); (3) USA: GA, Upson Co, Apr 25 2002 *RFC Naczi 9174* (WIN 68079)(B0922, GU172583); (4) USA: AL, Coosa Co, Apr 29 2000 *BA Ford, RFC Naczi 95* (WIN)(B0934, FJ597261); *C. cordillerana* Saarela & BA Ford, (1) USA: UT, Cache Nat'l Forest Jun 15 2003 *JM Saarela, A Roe 196* (WIN 70354)(B0925, FJ597202); (2) USA: UT, Salt Lake Co, Aug 13 1993 *RFC Naczi, JW Thieret* (WIN 71025)(B0942, FJ597200); (3) Canada: BC, Cawston Jun 28 2000 *BA Ford, JM Saarela 135* (WIN 67266)(B0943, FJ597201); *C. jamesii* Schweinitz, (1) USA: MD, Kent Co, Jun 09 2002 *RFC Naczi, WA McAvoy, CT Bryson, BA Ford, AA Reznicek, JR Starr, BS Walters, VN Williams 9320* (DOV 028815)(B0008,

FJ597223); (2) USA: OK, McCurtain Co, May 26 2003 *RFC Naczi*, *BA Ford 9656* (DOV 037437)(B0009, FJ597224); (3) USA: AL, Madison Co, May 08 1986 *RFC Naczi 1020* (DOV 028031)(B0010, FJ597225); *C. juniperorum* Catling, Reznicek & Crins, (1) USA: KY, Lewis Co, May 30 1996 *RFC Naczi*, *AE Trauth 5538* (DOV 026418)(B0011, FJ597226); (2) USA: OH, Adams Co, May 30 1996 *RFC Naczi*, *AE Trauth*, *BR Dalto*, *MH McAllister 5508* (DOV 026383)(B0013, FJ597227); *C. latebracteata* Waterfall, (1) USA: OK, McCurtain Co, May 26 2003 *RFC Naczi*, *BA Ford 19958* (DOV)(B0778, FJ597231); (2) USA: AR, Howard Co, May 27 2003 *RFC Naczi*, *BA Ford 7023* (DOV)(B0779, FJ597232); (3) USA: AR, Sevier Co, May 27 2003 *RFC Naczi*, *BA Ford 9664* (DOV)(B0786, FJ597233); *C. saximontana* Mack., (1) Canada: MB, 3.0 km E of Treherne Jun 26 2003 *RFC Naczi*, *BA Ford 9871* (DOV)(B0787b, GU173509); (2) Canada: MB, Spruce Woods Provincial Pk Jun 26 2003 *RFC Naczi*, *BA Ford 9929* (DOV)(B0788, FJ597250); (3) Canada: MB, Souris Riv *RFC Naczi*, *BA Ford 9883* (WIN 197362)(B0940, FJ597248); (4) Canada: MB, Treesbank *RFC Naczi*, *BA Ford 9912* (WIN 233773)(B0941, FJ597249); (5) USA: CO, Boulder Co, Jun 08 2000 *T Hogan 3675* (COLO 474788)(B1120, GU173508); *C. superata* Naczi, Reznicek & BA Ford, (1) USA: KY, Monroe Co, Jun 16 1998 *RFC Naczi*, *A Reznicek 7406* (DOV 020809)(B0012, GU173653); (2) USA: GA, Upson Co, Apr 25 2002 *RFC Naczi 9170* (DOV 028600)(B0014, FJ597251); (3) USA: FL, Gadsden Co, May 27 1997 *RFC Naczi 6226* (DOV 044394)(B0015, FJ597252); (4) USA: GA, Decatur Co, Mar 25 2005 *RL Myers* (DOV 048490)(B0018, FJ597253); *C. timida* RFC Naczi & BA Ford, (1) USA: AR, Howard Co, May 23 2003 *RFC Naczi*, *BA Ford 9681* (DOV 035200)(B0004, FJ597257); (2) USA: AL, Jackson Co, May 20 2005 *RFC Naczi 10883* (DOV 049843)(B0005, FJ597258); (3) USA: KY, Campbell Co, Jun 05 1996 *RFC Naczi*, *AE Trauth*, *LA Heeg 5650* (DOV 026385)(B0016, GU173689); *C. willdenowii* Schkuhr ex Willd., (1) USA: MD, Cecil Co, Jun 13 1990 *RFC Naczi 2575* (DOV 019505)(B0001, GU173799); (2) USA: PA, Somerset Co, May 19 2003 *RFC Naczi 9601* (DOV 035196)(B0002, FJ597259); (3) USA: KY, Lincoln Co, May 24 2005 *RFC Naczi 10927* (DOV 052598)(B0003, FJ597260).

Carex L sect *Physoglochin* Dumortier, *C. gynocrates* Wormskjöld ex Drejer, (1) USA: MI, Oscoda Co, Jul 15 2002 *AA Reznicek*, *RFC Naczi*, *FW Case 11362* (DOV 041014)(B0337,

GU172949); (2) Canada: QC, Cte Portneuf, Neuville, Lomert Aug 28 1973 *R Gauthier* (MT)(B0896, GU172950); (3) USA: AK, Nabesna B1 Quad Jul 10 2003 *P Loomis, K Beattie 1072* (ALA 1130905)(B1023, GU172947); (4) USA: CO, Gunnison Co, Aug 07 1996 *N Lederer, W Jennings, W Marotti, P Murphy 96 CP 13* (COLO 465879)(B1094, GU172948).

Carex L sect *Pictae* Kük. in Engler, *C. baltzellii* Chapman ex Dewey, (1) USA: FL, Liberty Co, Mar 14 1994 *RFC Naczi 3621* (DOV)(B0138, GU172576); (2) USA: FL, Okaloosa Co, Jun 02 1994 *LC Anderson 14914* (FSU 186613)(B1307, GU172575); *C. picta* Steudel, (1) USA: GA, Cobb Co, May 28 2004 *M Manthey 204* (DOV 047423)(B0553, GU173398); (2) USA: KY, McCreary Co, Apr 27 2002 *RFC Naczi 9237* (DOV 028393)(B0554, GU173399); (3) USA: MS, Simpson Co, Mar 23 2004 *CT Bryson 19893* (DOV 047026)(B0555, GU173400).

Carex L sect *Porocystis* Dumortier, *C. bushii* Mack., (1) USA: DE, New Castle Co, Jun 12 2002 *RFC Naczi, J Ebert, SW Welles 9343* (DOV 028790)(B0159, GU172633); (2) USA: MS, Scott Co, Apr 28 2006 *CT Bryson 21371* (DOV 056335)(B0160, GU172634); (3) USA: TX, Brazos Co, Apr 6 2003 *SD Jones 15099* (DOV 041727)(B0161, GU172635); *C. caroliniana* Schweinitz, (1) USA: MD, Caroline Co, Jun 13 2006 *WD Longbottom 7508* (DOV 060447)(B0195, GU172663); (2) USA: TX, Brazoria Co, Apr 10 2003 *DJ Rosen, C Yeargan 2458* (DOV 031521)(B0196, GU172664); (3) USA: AL, Jackson Co, Apr 21 2002 *RFC Naczi 9018* (DOV 025779)(B0197, GU172662); *C. complanata* Torrey & Hooker, (1) USA: MD, Dorchester Co, May 22 2005 *WD Longbottom 5857* (DOV 051126)(B0163, GU172700); (2) USA: TX, Colorado Co, Apr 21 2007 *RFC Naczi 11705* (DOV 063461)(B0164, GU172701); (3) USA: FL, Leon Co, Apr 14 2003 *LC Anderson 20644* (DOV 029015)(B0165, GU172699); *C. hirsutella* Mack., (1) USA: DE, New Castle Co, Jun 12 2002 *RFC Naczi, J Ebert, SW Welles 9348* (DOV 028823)(B0317, GU172981); (2) USA: MS, Marshall Co, May 28 2006 *CT Bryson, NB Bryson 21577* (DOV 056651)(B0326, GU172983); (3) USA: KN, Linn Co, May 23 2002 *CA Morse 8018* (DOV 037582)(B0327, GU172982); *C. pallescens* L, (1) USA: NY, Clinton Co, Jul 01 2000 *AA Reznicek, SA Reznicek 11161* (DOV 041340)(B0523, GU173356); (2) Austria: Steiermark, 3.0 km NW of

Rettenegg Jul 20 2005 *RFC Naczi, JR Starr, BA Ford, J Thibault 11142* (DOV 053545)(B0524, GU173352); (3) Canada: NL, Bay of Islands Jul 20 2000 *S Hay, N Djan Chekar CH 000720 31* (MT)(B0892, GU173355); (4) Canada: BC, Greater Vancouver Regional District May 20 1993 *F Lomer* (UBC 15481)(B1401, GU173353); (5) Canada: BC, New Westminster May 22 1997 *F Lomer 97 62* (ubc 225105)(B1402, GU173354); *C. swanii* (Fernald) Mack., (1) USA: MD, Queen Anne's Co, Jun 12 2005 *WD Longbottom 6103* (DOV 051419)(B0698, GU173656); (2) USA: AR, Monroe Co, May 20 2006 *CT Bryson, NB Bryson 21490* (DOV 057427)(B0699, GU173655); *C. torreyi* Tuck., (1) Canada: MB, Souris Riv Wildlife Management Area Jun 26 2003 *RFC Naczi, BA Ford 9897* (DOV 037034)(B0713, GU173703); (2) USA: CO, Boulder Co, Jun 24 1997 *T Hogan, J Korb, D D'Amico 3110* (COLO 467251)(B1101, GU173702); (3) USA: TN, Norman Co, May 25 1993 *VE McNeilus 93 823* (WIS 186691)(B1172, GU173704); *C. virescens* Muhl. ex Willd., (1) USA: AL, Lawrence Co, Jun 17 2006 *CT Bryson, NB Bryson 21899* (DOV 056487)(B0751, GU173777); (2) USA: CA, Greenville Co, Jun 7 2005 *B Pittman, A Darr 6070515* (DOV 057891)(B0752, GU173779); (3) USA: MI, Essex Co, Jun 28 2002 *AA Reznicek, SA Reznicek 11329* (DOV 040953)(B0753, GU173778).

Carex L sect *Racemosae* G Don in JC Loudon, *C. aboriginum* ME Jones, (1) USA: ID, Adams Co, May 28 1999 *CR Bjork 4263* (ID 135678)(B1231, GU172441); *C. adelostoma* VI Kreczetowicz in VL Komarov *et al.*, (1) USA: AK, Valdez D 2 Quad Aug 07 2003 *P Loomis, S Backensto 2031* (ALA 1114450)(B1012, GU172451); (2) USA: AK, Gulkana B 2 Quad Aug 09 2003 *P Loomis, S Backensto 2174* (ALA 1114451)(B1013, GU172452); *C. albonigra* Mack. in Rydberg, (1) USA: AK, Talkeetna D 5 Quad Jul 01 2000 *C Roland, A Batten, S Goeking 4510* (ALA 1114487)(B1014, GU172478); *C. atratiformis* Britton, (1) Canada: AB, Jasper National Park Jul 24 2004 *BA Ford, AJ Gould 4208* (WIN 70887)(B1144, GU172551); (2) Canada: MB, Parker Bog Jul 24 1983 *JL Parker 83 488* (WIN 39656)(B1238, GU172554); (3) Canada: BC, Cassia Co, Jul 17 1973 *J Pojar* (UBC 146377)(B1240, GU172553); (4) Canada: NL, Humber West Dist Jul 29 1995 *A Bouchard, S Hay, L Brouillet 95026* (CAN 582237)(B1469, GU172552); *C. atosquama* Mack., (1) USA: WA, Okanogan Co, Jul 18 2003 *T Ohlson 71803 04* (WTU 362475)(B0964, GU172558); (2) USA: MT, Lincoln Co, Aug 17 1999 *A Stachurska 480* (COLO

520263)(B1113, GU172557); (3) Canada: YT, 39 mi NW of Stewart Crossing Jul 15 2004 *PM Peterson, JM Saarela, SF Smith 18600* (CAN)(B1414, GU172559); *C. bella* LH Bailey, (1) USA: CO, Buffalo Canyon Jun 27 2005 *T Kelso, G Maentz 26054* (COLO 520318)(B1114, GU172589); (2) USA: UT, Grand Co, Aug 21 1985 *B Franklin 2242* (CAN 515686)(B1475, GU172590); *C. buxbaumii* Wahl., (1) USA: AK, Kenai peninsula Aug 19 2005 *AA Reznicek 11718* (DOV 051969)(B0147, GU172636); (2) USA: UT, Summit Co, Aug 5 2004 *RFC Naczi, WM Knapp 10697* (DOV 055126)(B0148, GU172638); (3) USA: DE, New Castle Co, May 17 2000 *WA McAvoy 4678* (DOV 037272)(B0162, GU172637); *C. chalciolepis* Holm, (1) China: Taiwan, Taichung Hsieh Jul 14 2002 *WC Leong et al. 3197* (DOV 040881)(B0175, GU172675); (2) USA: CO, La Plata Co, Jul 18 1993 *T Cramer 75* (COLO 453139)(B1115, GU172673); (3) USA: CO, Huerfano Co, Aug 14 1998 *CC Freeman, RL Hartman 11765* (MT 125331)(B1523, GU172674); *C. epapillosa* Mack. in Rydberg, (1) USA: UT, Duchesne Co, Aug 05 2004 *RFC Naczi, WM Knapp 10721* (DOV 055004)(B0268, GU172838); (2) USA: WA, Okanogan Co, Aug 22 2005 *M Foster 264* (WTU 361606)(B0977, GU172839); (3) USA: WY, Albany Co, Jul 11 1994 *DL Hazlett, J Rice 6635* (COLO 527749)(B1092, GU172840); (4) USA: WY, Fremont Co, Aug 15 1996 *L Kinter, W Conley 2372* (RM 728143)(B1292, GU172841); *C. gmelinii* Hooker & Arnott, (1) USA: AK, Seldovia Quad Jul 09 2003 *R Lipkin, B Rice 03 37* (ALA 1130792)(B1022, GU172923); (2) USA: AK, Unalakleet Quaad Jul 09 1997 *CL Parker, AR Batten, D Blank, M Duffy, J Cole 6981* (MICH)(B1459, GU172924); *C. hallii* Olney in FV Hayden, (1) Canada: MB, Otterburne Jun 22 1958 *J Bernard 58/244* (WIN 22244)(B1147, GU172957); (2) USA: MN, Kittson Co, Jul 07 1990 *R Dana 91070* (MIN 827904)(B1384, GU172958); *C. helleri* Mack., (1) USA: CA, Nevada Co, Aug 04 2006 *RFC Naczi 11454* (DOV)(B0861, GU172972); (2) USA: CA, Mono Co, Jul 20 2002 *LP Janeway 7665* (CHSC 83262)(B1083, GU172970); (3) USA: CA, Inyo Co, Aug 01 2000 *JP Janeway, B Castro 6923* (JEPS 98948)(B1321, GU172971); *C. heteroneura* Boott in S Watson, (1) USA: NV, Elko Co, Jul 31 2004 *RFC Naczi, WM Knapp 10651* (DOV 055133)(B0307, GU172979); (2) USA: CA, Alpine Co, Aug 06 2006 *RFC Naczi 11541* (DOV 063487)(B0315, GU172976); (3) USA: CA, Nevada Co, Aug 04 2006 *RFC Naczi 11467* (DOV)(B0857, GU172977); (4) USA: NV, White Pine Co, Jul 04 1990 *JC Lyman, BL Phillips 939* (UCR 66139)(B1210, GU172978); *C. holostoma* Drejer, (1) USA: AK, Kotzebue Quad Jul 04 2003 *CL Parker, R Elven, H*

Solstad 14396 (ALA 1131086)(B1024, GU172994); *C. idahoa* LH Bailey, (1) USA: MT, Beaverhead Co, Jun 25 2003 *P Lesica 8668* (MT 129453)(B0956, GU173021); (2) USA: CA, Mono Co, Jul 09 1992 *DW Taylor 13025* (UC 1736037)(B1328, GU173020); *C. media* R Brown ex Richardson in J Franklin *et al.*, (1) Canada: QC, Lac Bienville Aug 15 1990 *J Deshaye 90 947a* (MT)(B0880, GU173193); (2) Canada: NB, Madawaska Co, Aug 04 1990 *HR Hinds, G Flanders 9813* (UNB 48891)(B1165, GU173191); (3) USA: NB, Madawaska Co, Jul 25 1980 *HR Hinds 3647* (UNB 34865)(B1188, GU173192); (4) Canada: YT, 39 mi NW of Stewart Crossing Jul 15 2004 *PM Peterson, JM Saarela, SF Smith 18602* (CAN)(B1416, GU173194); *C. mertensii* JD Precott ex Bongard, (1) USA: CA, Siskiyou Co, Jul 01 2006 *LP Janeway 8718* (DOV 060742)(B0446, GU173208); (2) USA: OR, Lane Co, Jul 14 1994 *B Wilson, F Camacho, K Kuykendall 7338* (DOV 020767)(B0447, GU173209); (3) USA: AK, Anchorage vicinity Aug 20 2005 *AA Reznicek 11729* (DOV 051972)(B0448, GU173207); *C. nelsonii* Mack., (1) USA: MT, Carbon Co, Aug 15 1991 *P Lesica 5584* (MT 115024)(B1225, GU173278); *C. norvegica* Retzius, (1) USA: OR, Wallowa Co, Jul 21 2002 *RG Olmstead, PF Zika 02 87* (WTU 361165)(B1009, GU173296); *C. nova* LH Bailey, (1) USA: CO, Park Co, Jul 08 2004 *C Lea 3452* (DOV 046659)(B0081, GU173297); (2) USA: UT, Summit Co, Aug 05 2004 *RFC Naczi, WM Knapp 10718* (DOV 055335)(B0452, GU173300); (3) USA: CO, Saguache Co, Jul 12 1991 *T Hogan 1311* (RM 589142)(B1226, GU173298); (4) USA: ID, Blaine Co, Aug 19 1993 *B Moseley 2789* (ID 109324)(B1527, GU173299); *C. parryana* Dewey, (1) Canada: MB, Lake Francis Wildlife Management Area Jun 30 1995 *BA Ford 9561* (DOV 021839)(B0830, GU173365); (2) USA: AK, McCarthy C1 Quad Jun 05 2003 *B Bennett, P Loomis 03 228* (ALA 1119889)(B1027, GU173362); (3) USA: CO, Moffat Co, Jun 02 1989 *T Naumann 323* (COLO 23167)(B1093, GU173363); (4) Canada: MB, Manitoba Lake Francis Wildlife Management Area Jun 30 1995 *BA Ford 9561* (WIN 62266)(B1148, GU173364); *C. pelocarpa* FJ Hermann, (1) USA: NV, Elko Co, Jul 31 2004 *RFC Naczi, WM Knapp 10660* (DOV 055172)(B0589, GU173379); (2) USA: OR, Wallowa Co, Aug 29 1990 *PF Zika 10978* (OSC 172958)(B1189, GU173380); *C. raynoldsii* Dewey, (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11504* (DOV 063340)(B0578, GU173463); (2) USA: WY, Teton Co, Jun 30 1989 *D Castaner 10333* (DOV 039014)(B0579, GU173465); (3) USA: ID, Cassia Co, Jul 25 2000 *M Mancuso 2110* (ID 120616)(B1229, GU173464); *C. sabulosa*

Turczninow ex Kunth, (1) Canada: YT, Kusawa Dunes Aug 16 2003 *BA Bennett, R Mulder 03 074* (ALA 1137953)(B1039, GU173496); (2) Canada: YT, Kluane National Park Jul 13 2006 *BA Bennett, P Catling, S Cannings, B Kostiuk 06 078* (UBC 224433)(B1390, GU173497); *C. serratodens* Boott in S Watson, (1) USA: CA, Colusa Co, Jun 11 2006 *L Ahart 12669* (DOV 000065)(B0619, GU173557); (2) USA: OR, Josephine Co, Jun 19 1992 *PF Zika, F Lang, R Brainerd, B Newhouse 11661* (OSC 178776)(B1058, GU173558); *C. specuicola* JT Howell, (1) USA: AZ, Apache Co, Jul 24 2002 *D Roth 1397* (ASU 174705)(B1207, GU173595); *C. stevenii* (Holm) Kalela, (1) USA: CO, Eagle Co, Jul 19 1986 *D Castaner 9483* (DOV 039865)(B0833, GU173613); (2) USA: CO, Albany Co, Jun 20 2006 *B Bouwer, T Kelso, G Maentz 6.207* (COLO 520197)(B1103, GU173611); (3) USA: CO, Gunnison Co, Jul 25 1994 *RJ Rondeau 94 213* (COLO 459288)(B1104, GU173612); (4) USA: NM, Taos Co, Jul 21 2004 *RD Worthington 32659* (UNM 106508)(B1220, GU173614); *C. stylosa* CA Meyer, (1) Canada: NL, Great Northern Peninsula Jul 27 2000 *L Brouillet, N Djan Chekar, T Ahit, C Wentzell LB 00 178* (MT)(B0889, GU173641).

Carex L sect *Rhynchocystis* Dumortier, *C. pendula* Hudson, (1) USA: WA, Washington Co, May 11 1998 *CT Bryson 16368* (DOV 025200)(B0590, GU173382); (2) Austria:, Bezirk, Wienerwald Jun 24 2006 *B Wallnofer 14001* (DOV 063353)(B0591, GU173381); (3) USA: WA, King Co, Jun 15 2001 *PF Zika 16284* (WTU 346654)(B0986, GU173383).

Carex L sect *Rostrales* Meinshausen, *C. folliculata* L, (1) USA: ME, Hancock Co, Jun 26 2007 *WM Knapp 2200* (DOV 063504)(B0276, GU172883); (2) USA: NC, Transylvania Co, Jun 02 2003 *RFC Naczi 9744* (DOV 035246)(B0285, GU172884); (3) USA: DE, Kent Co, Jun 06 2003 *WA McAvoy 5839* (DOV 040991)(B0293, GU172882); *C. lonchocarpa* Willd. ex Sprengel, (1) USA: MD, Wicomico Co, Jun 12 2007 *WD Longbottom 9282* (DOV 063801)(B0380, GU173130); (2) USA: FL, Columbia Co, May 02 2000 *JR Abbott, B Herring 13518* (DOV 020881)(B0381, GU173128); (3) USA: LA, Vernon Co, Apr 24 2002 *PE Hyatt 10844* (LSU 104581)(B1355, GU173129); *C. michauxiana* Boeckeler, (1) Canada: NL, S of JT Cheeseman Provincial Pk Aug 07 2000 *N Djan Chekar, C Hanel, H Mann NDC 00 1532* (MT)(B0920, GU173214); (2) Canada: MB, Stall Lake Jul 20 1994 *E Punter 94*

153 (WIN 56803)(B1141, GU173213); (3) Canada: NS, Richmond Co, Aug 20 1991 *RE Newell, RB Newell* (ACAD 14124)(B1381, GU173215); *C. turgescens* Torrey, (1) USA: MS, Forrest Co, Apr 14 2004 *CT Bryson 19963* (DOV 056626)(B0839, GU173736); (2) USA: NC, Harnett Co, May 18 2007 *RFC Naczi, BA Sorrie, EL Hoffman, WA McAvoy, K Sinclair, G Sinclair 11848* (DOV 063738)(B0840, GU173737).

Carex L sect *Rupestres* (Tuck) Meinshausen, *C. rupestris* Allioni, (1) Canada: NL, Humber West Aug 15 1999 *L Brouillet, S Hay, D Ballam LB 99 272* (MT)(B0901); (2) Spain: Huesca, Panticosa Jul 1 1992 *M Luceno et al. 1002ML 2/2* (UPOS 000171)(B1515, GU173492).

Carex L sect *Schiedeanae* Kük. in Engler *C. muriculata* FJ Hermann, (1) USA: NM, Eddy Co, Apr 05 2004 *A Kennedy 00AK032 G5* (UNM)(B1203, GU173268); (2) USA: NM, Eddy Co, Sep 07 1998 *RD Worthington 27998* (UCR 105716)(B1361, GU173267).

Carex L sect *Scirpinae* (Tuck.) Kük. in Engler, *C. curatorum* Stacey, (1) USA: UT, Uintah Co, Jul 18 2003 *J Simonsen 6293* (UTC 243634)(B1360, GU172738); (2) USA: UT, Coyote Gulch(B1409, GU172737); *C. scabriuscula* Mack., (1) USA: CA, Plumas Co, Jul 29 2004 *RFC Naczi 10640* (DOV 055350)(B0639, GU173513); (2) USA: CA, Siskiyou Co, Jul 04 2006 *LP Janeway 8788* (DOV 060745)(B0640, GU173514); *C. scirpoidea* Michaux subsp *convoluta* (Kük.) DA Dunlop, (1) Canada: ON, Bruce Co, Jul 12 1975 *DG Cuddy, D Emslie 525119* (CAN 391989)(B1313, GU173521); (2) Canada: ON, Kotaneelee Ridge Jun 27 1992 *L Lamb* (WAT)(B1350, GU173522); *C. scirpoidea* Michaux subsp *pseudoscirpoidea* (Rydberg) DA Dunlop, (1) USA: CO, Park Co, Aug 07 1998 *R Orthner, T Hogan, L Yeatts, D Yeatts 734* (COLO 473220)(B1099, GU173528); (2) Canada: BC, Murray Ridge Jul 19 1996 *JL Penny 156* (UBC 214619)(B1396, GU173527); (3) USA: UT, Summit Co, Aug 5 1988 *B Franklin 6359* (CAN 554539)(B1483, GU173529); *C. scirpoidea* Michaux subsp *scirpoidea*, (1) USA: AK, Eklutna Lake Aug 20 2005 *AA Reznicek 11727* (DOV 051973)(B0641, GU173530); (2) USA: UT, Duchesne Co, Aug 05 2004 *RFC Naczi, WM Knapp 10724* (DOV 055348)(B0642, GU173535); (3) USA: NV, Elko Co, Jul 31 2004 *RFC Naczi, WM Knapp 10658* (DOV 055345)(B0650, GU173525); (4) Canada: MB, 12 km N of

Fisher Branch Jun 20 2002 *BA Ford, M Piercey Normore, E Punter, D Punter* 264 (DOV 049418)(B0651, GU173523); (5) Canada: NL, Bonavista South Dist Jul 27 1997 *R Charest, L Brouillet, J Labrecque, R Irwin* 97 3516 (MT)(B0905, GU173524); (6) USA: OR, Grant Co, Aug 16 1995 *BL Wilson, D Lytjen, B Newhouse, J Oliphant, N Otting, D Williams, PF Zika* 8010 (OSC 184218)(B1056, GU173531); (7) Canada: ON, Barrier Island May 01 1979 *T Hogg* *EH34, 67* (CAN 469136)(B1308, GU173526); *C. scirpoidea* Michaux subsp *stenochlaena* (Holm) A Löve & D Löve, (1) USA: WA, Pierce Co, Aug 08 2006 *L Massey* 06 17 (WTU 350405)(B0979, GU173534); (2) USA: AK, Tongass National Forest Jun 19 1980 *MC Muller* 3586 (WTU 289168)(B1194, GU173532); (3) USA: WA, Chelan Co, Aug 08 2004 *S Hahn, PF Zika* 1302 (WTU 361975)(B1195, GU173533).

Carex L sect *Scitae* Kük. in Engler, *C. microchaeta* Holm subsp *microchaeta*, (1) Canada: YT, Buckland Hills Jul 13 1988 *SG Aiken* 88 250 (CAN 534136)(B1200, GU173220); (2) Canada: YT, Shingle Point area Jul 28 2005 *BA Bennett, T McIntosh, J Line, J Staniforth, DC Gordon* 05 0795 (CAN 589269)(B1287); (3) Canada: YT, Kotaneelee Ridge Jul 13 2004 *BA Bennett, P Seccombe Hett* 04 0601 (CAN 589267)(B1339, GU173216); (4) USA: WY, Park Co, Aug 18 1973 *WA Weber* 15013 (CAN 374064)(B1477, GU173219); *C. microchaeta* Holm subsp *nesophila* (Holm) DF Murray, (1) USA: AK, Dillingham Quad Jul 19 2003 *AR Batten, M McWhorter* 03 124 (ALA 1115832)(B1317, GU173217); (2) USA: AK, Seward Peninsula Jun 04 1979 *T Kelso, J Flock, M Colson* 280 (CAN 473000)(B1326, GU173218); *C. podocarpa* R Brown ex Richardson in J Franklin *et al.*, (1) Canada: BC, NWern BC Jul 22 1989 *GB Straley, KW Nicholls* 5719 (UBC 200897)(B1325, GU173417); (2) Canada: YT, Vuntut National Park Aug 04 2000 *BA Bennett, R Markel* 00 1057 (CAN 589275)(B1335, GU173418); *C. spectabilis* Dewey, (1) USA: CA, Nevada Co, Aug 09 2004 *L Ahart* 11341 (DOV 048080)(B0689, GU173594); (2) Canada: BC, Eddy Co, Sep 02 1974 *J Pinder Moss* 997 (UBC 156444)(B1372, GU173592); (3) Canada: BC, Mountain Marmots Jul 16 1978 *A Ceska* 10085 (UBC 214091)(B1395, GU173593).

Carex L sect *Shortianae* (Bailey) Mack. in NL Britton *et al.*, *C. shortiana* Dewey, (1) USA: MD, Allegany Co, Jun 04 2005 *WD Longbottom, RFC Naczi, G Van Velsir* 5995 (DOV 051067)(B0620, GU173567); (2) USA: KY, Scott Co, May 25 2005 *RFC Naczi* 11014

(DOV 052793)(B0621, GU173566); (3) USA: KY, Douglas Co, 17 May 2000 *CA Morse 4515* (DOV 037699)(B0622, GU173565).

Carex L sect *Spirostachyae* (Drejer) Bailey in JM Coulter, *C. diluta* Bieberstein, (1) USA: MT, Jefferson Co, Jul 16 2006 *D Hanna, P Husby 190* (MT 132617)(B0957, GU172789); (2) USA: MT, Madison Co, Aug 08 1996 *P Lesica 7353* (MT 122405)(B0958, GU172790); (3) USA: MT, Madison Co, Sep 05 1995 *P Lesica 7173* (MT 122398)(B0959, GU172791); *C. distans* L, (1) Greece: Agais E, Chios *J Walter 5711* (DOV 063871)(B0226, GU172796); (2) Greece:, Epiro Jul 12 2004 *P Vargas 268PV04* (UPOS 000821)(B1500, GU172797); *C. extensa* Goodenough, (1) USA: VA, York Co, Aug 24 2004 *JF Townsend, N Van Alstine, P Coulling 3321* (VPI 100901)(B1246, GU172851); (2) Turkey: Çanakkale Province, Çanakkale Jun 1 2006 *M Escudero, M Luceno, SM Bravo, P Vargas 75ME06* (UPOS 002190)(B1501, GU172850).

Carex L sect *Squarrosae* J Carey, *C. aureolensis* Steudel, (1) USA: SC, Georgetown Co, Sep 28 2001 *J Nelson 22355* (DOV 040151)(B0151, GU172562); (2) USA: MS, Washington Co, May 18 2006 *CT Bryson 21467* (DOV 057887)(B0152, GU172561); (3) USA: TX, Burleson Co, May 2 2004 *RFC Naczi 10133* (DOV 050889)(B0153, GU172563); *C. frankii* Kunth, (1) USA: MD, Dorchester Co, Jun 11 2006 *WD Longbottom 7497* (DOV 063211)(B0319, GU172895); (2) USA: KN, Woodson Co, Jun 18 2002 *CA Morse 8256* (DOV 037579)(B0320, GU172894); (3) USA: AL, Madison Co, Jun 03 2006 *CT Bryson 21611* (DOV 058358)(B0321, GU172893); *C. squarrosa* L, (1) USA: DE, New Castle Co, Jun 3 2003 *WA McAvoy 5814* (DOV 043211)(B0673, GU173604); (2) USA: GA, Meriwether Co, Apr 25 2002 *RFC Naczi 9159* (DOV 025887)(B0674, GU173605); (3) USA: AR, Phillips Co, Jul 02 2001 *RD Thomas, E Sundell, C Amason 170 971* (DOV 020959)(B0675, GU173603); *C. typhina* Michaux, (1) USA: DE, Kent Co, May 27 2004 *WA McAvoy 6019* (DOV 049184)(B0722, GU173739); (2) USA: GA, Meriwether Co, Apr 25 2002 *RFC Naczi 9157* (DOV 025888)(B0724, GU173740); (3) USA: LA, Monroe Co, Jul 02 2001 *RD Thomas, E Sundell, C Amason 170740* (DOV 020964)(B0725, GU173738).

Carex L sect *Stellulatae* Kunth, *C. atlantica* LH Bailey subsp *atlantica*, (1) USA: DE, New Castle Co, May 16 2002 *RFC Naczi 9299* (DOV 029905)(B0110, GU172548); (2) USA: KY, Laurel Co, May 19 1999 *RFC Naczi, JR Abbott 7934* (DOV 024859)(B0111, GU172549); (3) USA: MS, Montgomery Co, May 03 2003 *CT Bryson, NB Bryson 19696* (DOV 056428)(B0131, GU172550); (4) USA: NC, Hoke Co, May 01 1991 *JR Estes, DW George B0566* (OKL 187954)(B0952, GU172544); *C. atlantica* LH Bailey subsp *atlantica* (LH Bailey) Reznicek, (1) USA: MD, Wicomico Co, May 14 2006 *WD Longbottom, DW Rowan 7307* (DOV 060461)(B0098, GU172546); (2) USA: MI, Barry Co, May 25 2004 *AA Reznicek, S Kogge 11565* (DOV 051974)(B0099, GU172547); (3) USA: FL, Wakulla Co, Apr 05 2007 *LC Anderson 22848* (DOV 060621)(B0100, GU172545); *C. echinata* Murray subsp *echinata*, (1) USA: MD, Cecil Co, May 1 2006 *CT Frye, JW Harrison* (DOV 059637)(B0250, GU172818); (2) USA: ME, Hancock Co, Jun 26 2007 *W Knapp 2194* (DOV 063523)(B0251, GU172819); (3) USA: UT, Summit Co, Aug 05 2004 *RFC Naczi, W Knapp 10695* (DOV 55061)(B0252, GU172822); (4) Canada: NL, 8 km au SO de Labrador City Aug 04 2001 *M Blondeau 01FER577* (MT)(B0910, GU172817); (5) USA: AK, Unalaska Quad Aug 31 1996 *CL Paker 6941* (ALA 1125901)(B1026, GU172816); *C. echinata* Murray subsp *phyllomanica* (Boott) Reznicek, (1) USA: WA, King Co, Aug 03 2002 *J Walker, N Job, B Cohen Walker 10* (WTU 364241)(B0976, GU172821); (2) USA: AK, Talkeetna Quad Jul 07 2002 *M Duffy MD02 16* (ALA 1125909)(B1048, GU172820); (3) Canada: BC, Malahat Land District Jul 12 2007 *P Henderson* (UBC 224763)(B1377, GU172815); *C. exilis* Dewey, (1) USA: DE, Sussex Co, Jun 14 2001 *WA McAvoy 5125* (DOV 036927)(B0269, GU172842); (2) USA: MI, Luce Co, Jun 29 1989 *RFC Naczi, E Voss, his Boreal Flora Class 2257* (DOV 022669)(B0270, GU172844); (3) USA: ME, Hancock Co, Jun 26 2007 *WM Knapp 2192* (DOV 063501)(B0271, GU172843); (4) USA: MS, Harrison Co, May 22 1997 *BA Sorrie 9250* (MISS 64130)(B1176, GU172845); *C. interior* LH Bailey, (1) USA: MD, Cecil Co, May 17 2006 *CT Frye, JM Harrison* (DOV 059638)(B0353, GU173040); (2) USA: MI, Oscoda Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9427* (DOV 023494)(B0354, GU173041); *C. ruthii* Mack. in NL Britton *et al.*, (1) USA: VA, Grayson Co, Jun 13 2006 *CT Bryson, NB Bryson 21781* (DOV 057096)(B0599, GU173495); (2) USA: NC, Clay Co, May 23 1979 *R Kral 61854* (DOV 038057)(B0600a, GU173493); (3) USA: TN, Sevier Co, Jun 20 1992 *RD Thomas, SD*

Thomas 130034 (DOV 028075)(B0600b, GU173494); *C. seorsa* Howe in HC Gordinier and EC Howe, (1) USA: MI, Washtenaw Co, Jun 12 2005 *AA Reznicek, B Walters 11662* (DOV 053843)(B0611, GU173554); (2) USA: FL, Hamilton Co, Apr 01 2001 *JR Abbott, B Carlsward 14233* (DOV 059810)(B0615, GU173553); (3) USA: DE, Kent Co, May 15 2004 *RFC Naczi 10247* (DOV 050186)(B0635, GU173552); *C. sterilis* Willd., (1) USA: OH, Miami Co, Jun 16 1999 *RFC Naczi, SM Yelton 82601* (DOV 036160)(B0677, GU173610); (2) Canada: MB, Cook Co, Jul 20 1988 *GM Keleher 1199* (WIN 46470)(B1136, GU173609); *C. wiegandii* Mack. in NL Britton *et al.*, (1) USA: ME, Washington Co, Jul 4 1999 *AA Reznicek 10920* (DOV 040025)(B0748, GU173797); (2) Canada: ON, Iroquois Falls Jul 9 1959 *E Lepage, WKW Baldwin 8090* (CAN 275414)(B0947, GU173798).

Carex L sect *Thuringiaca* G Don in J Loudon, *C. flacca* Schreber, (1) Austria: Steiermark Jul 20 2005 *RFC Naczi, JR Starr, B Ford, J Thibault 11124* (DOV 052773)(B0286, GU172870); (2) USA: CA, Riverside Co, Jun 25 2003 *V Soza, N Fraga, S Swarzenruber 1700* (RSA 627574)(B1202, GU172871).

Carex L sect *Triquetrae* (Bailey) Mack. in NL Britton *et al.*, *C. triquetra* Boott, (1) USA: CA, Los Angeles Co, May 15 2003 *L Gross, V Soza 903* (RSA 710498)(B1193, GU173722); (2) USA: CA, San Diego Co, Jun 02 2005 *AC Sanders 30358* (RSA 710498)(B1251, GU173723); (3) USA: CA, Riverside Co, Mar 29 1997 *DL Banks 1563* (UCR 108996)(B1520, GU173724).

Carex L sect *Vesicariae* (Heuffel) J Carey, *C. baileyi* Britton, (1) USA: KY, McCreary Co, Aug 26 1989 *Allen C Risk 3805* (DOV 039784)(B0133, GU172573); (2) USA: NY, Greene Co, Jul 03 2004 *RFC Naczi 10452* (DOV 054638)(B0135, GU172574); *C. bullata* Schkuhr ex Willd., (1) USA: MD, Dorchester Co, Jun 16 2005 *WM Knapp 1335* (DOV 055909)(B0156, GU172631); (2) USA: MA, Essex Co, Aug 7 2005 *RFC Naczi 11151* (DOV 053417)(B0157, GU172630); (3) USA: NJ, Burlington Co, Jun 19 2004 *RFC Naczi, LC Kelly, RL Mears, WM Knapp 10432* (DOV 051057)(B0158, GU172632); *C. comosa* Boott, (1) USA: FL, Wakulla Co, May 22 2007 *LC Anderson 23067* (DOV 062928)(B0176, GU172697); (2) USA: MD, Talbot Co, Jun 13 2007 *WD Longbottom 9366* (DOV

063448)(B0180, GU172698); (3) USA: CA, Shasta Co, Aug 13 1999 *DW Taylor 17335* (DOV 023310)(B0208, GU172696); *C. elliotti* Schweinitz & Torrey, (1) USA: FL, Nassau Co, Jun 02 2000 *LC Anderson 19297* (DOV 037188)(B0246, GU172830); *C. elliottii* Schweinitz & Torrey, (1) USA: NC, Pender Co, Apr 17 1999 *SR Hill 31273* (ILLS 204205)(B1124, GU172831); (2) USA: FL, Bay Co, May 09 2002 *LC Anderson 20185* (FSU 17498)(B1309, GU172829); *C. exsiccata* LH Bailey, (1) USA: CA, Amador Co, Aug 06 2006 *RFC Naczi 11530* (DOV 063482)(B0756, GU172848); (2) USA: WA, Snohomish Co, Jun 24 1991 *M Arnot, E Burnett 344* (WTU 321910)(B0978, GU172849); (3) USA: CA, Humboldt Co, Jul 30 2003 *LP Janeway 7941* (CHSC 85994)(B1080, GU172847); (4) Canada: BC, Saturna Island May 25 1996 *J Penny, C Norris, H Janszen 65* (UBC 223796)(B1369, GU172846); *C. hystericina* Muhl. ex Willd., (1) USA: MD, Baltimore Co, Jun 20 1995 *WA McAvoy 1097* (DOV 036888)(B0339, GU173017); (2) USA: AR, Sharp Co, Jun 15 2002 *PE Hyatt 11091* (DOV 043145)(B0340, GU173015); (3) USA: MI, Oscoda Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9430* (DOV 023846)(B0341, GU173018); (4) USA: AR, Stoner Co, Jun 15 2002 *PE Hyatt 11091* (DOV 043145)(B0475, GU173016); (5) USA: WA, Yakima Co, May 02 1990 *C Bagley, J Mastrogiuseppe, D Wilcox 5521* (WTU 358992)(B0998, GU173019); *C. lurida* Wahl., (1) USA: MD, Talbot Co, Jun 13 2007 *WD Longbottom 9363* (DOV 063456)(B0474, GU173151); (2) USA: FL, Escambia Co, Jun 21 2002 *JR Abbott, B Carlsward 14961* (DOV 031816)(B0476, GU173149); (3) USA: LA, Vernon Co, Apr 24 2002 *PE Hyatt 10845* (LSU 104590)(B1352, GU173150); *C. membranacea* Hooker in GF Lyon, (1) USA: AK, Jul 19 1981 *J Hughes 18* (DOV 054920)(B0442, GU173199); *C. oligosperma* Michaux, (1) USA: New Hampshire, Carroll Co, Jul 11 1999 *AA Reznicek, SA Reznicek 10940* (DOV 024335)(B0506, GU173324); (2) Canada: MB, Gemmell Lake Aug 28 1974 *PJ Cotterill 22* (WIN 28642)(B1146, GU173323); *C. pseudocyperus* L, (1) Austria: Niederosterreich, Wiener Becken Aug 13 2005 *T Barta 2005 582* (DOV 063774)(B0572, GU173447); (2) USA: MI, Cheboygan Co, Jul 18 1986 *RFC Naczi 1411* (DOV 013071)(B0573, GU173448); (3) Canada: QC, Iles de la Madeleine Sep 16 2006 *M Blondeau IM06 151* (MT)(B0917, GU173450); (4) Canada: MB, Kane Co, Aug 16 1993 *E Punter, GM Keleher 93/794* (WIN 55272)(B1134, GU173449); *C. retrorsa* Schweinitz, (1) USA: MI, Otsego Co, Jul 15 2002 *RFC Naczi, FW Case, AA Reznicek 9451* (DOV 023858)(B0603, GU173472); (2) USA:

WA, Ferry Co, Jul 11 1999 *S Bagshaw* 208 (WTU 349553)(B0992, GU173473); *C. rostrata* Stokes in W Withering, (1) USA: AK, 7 mi NE of Wasilla Aug 14 2005 *AA Reznicek, A Leggett, DC McLaughlin* 11701 (DOV 054693)(B0596, GU173487); (2) Canada: MB, Jun 13 1994 *BA Ford, JR Starr, D Punter, E Punter* 94142 (DOV 022943)(B0597, GU173488); (3) USA: WA, Snohomish Co, Jun 11 2004 *B Legler* 1739 (WTU 363412)(B0993, GU173489); *C. rotundata* Wahl., (1) USA: AK, Anchorage Aug 16 2005 *AA Reznicek* 11707 (DOV 054765)(B0598, GU173490); (2) Canada: MB, Wapusk National Park Jul 12 2004 *BA Ford, M Piercey Normore, D Punter* 484 (WIN 70950)(B1142, GU173491); *C. saxatilis* L, (1) USA: CO, Summit Co, Aug 10 2001 *MA Vincent, TG Lammers* 9862 (DOV 029407)(B0614, GU173505); (2) USA: UT, Duchesne Co, Aug 05 2004 *RFC Naczi, WM Knapp* 10731 (DOV 055349)(B0616, GU173507); (3) Canada: NB, Northumberland Co, Jul 16 1994 *G Bishop* 87 (UNB 51478)(B1163, GU173506); *C. schweinitzii* Dewey ex Schweinitz, (1) USA: MI, Manistee Co, Jul 15 2000 *CA Morse, JF Morse* 5026 (DOV 037573)(B0649, GU173519); (2) USA: VA, Montgomery Co, May 14 2003 *TF Wieboldt, JF Townsend* 11152 (VPI 103064)(B1247, GU173520); *C. thurberi* Dewey in WH Emory, (1) USA: AZ, Cochise Co, Jun 04 1992 *S Pilversack, G Onder* 31 (ASU 233554)(B1209, GU173687); (2) USA: AZ, Cochise Co, May 24 1994 *MC Fritts, HC Fritts* 94 3 (MICH)(B1491, GU173688); *C. tuckermanii* Dewey, (1) USA: WI, Brown Co, Aug 01 2002 *TG Lammers, MA Vincent, NA Harriman* 11565 (DOV 039715)(B0732, GU173731); (2) USA: MI, Washtenaw Co, Aug 2 2002 *AA Reznicek* 11376 (DOV 040966)(B0740, GU173730); *C. utriculata* Boott in WJ Hooker, (1) USA: AK, 7 mi NE of Wasilla Aug 14 2005 *AA Reznicek, A Leggett, DC McLaughlin* 11703 (DOV 054704)(B0774, GU173750); (2) USA: CA, Fresno Co, Jul 26 2004 *RFC Naczi* 10567 (DOV 055800)(B0775, GU173751); (3) Canada: MB, Nopiming Provincial Park Jul 05 2004 *BA Ford* 424 (DOV 049721)(B0776, GU173752); (4) USA: PA, Wayne Co, Aug 23 2003 *RFC Naczi* 10056 (DOV 038003)(B0777, GU173753); *C. vesicaria* L, (1) USA: DE, New Castle Co, May 21 2002 *WA McAvoy* 5490 (DOV 037742)(B0755, GU173770); (2) USA: MO, Shannon Co, Jun 19 1996 *B Summers, G Yatskievych, M Skinner* 7885 (DOV 044982)(B0757, GU173771).

Carex L sect *Vulpinae* (Heuffel) Christ, *C. alopecoidea* Tuck., (1) USA: NY, Essex Co, Jun 28 2002 *AA Reznicek, SA Reznicek 11336* (DOV 040707)(B0096, GU172487); (2) Canada: QC, Lac Saint Pierre Jul 05 1997 *S Hay, C Morisset 97 11* (MT)(B0919, GU172488); (3) USA: IL, Lake Co, Aug 04 2005 *MJC Murphy 484* (ILLS 232141)(B1121, GU172486); *C. conjuncta* Boott, (1) USA: DE, New Castle Co, Jun 12 2002 *RFC Naczi 9367* (DOV 028827)(B0166, GU172708); (2) USA: MO, Warren Co, May 25 2003 *RFC Naczi, BA Ford 9623* (DOV 037673)(B0167, GU172710); (3) USA: KN, Miami Co, May 30 2000 *CA Morse 4752* (DOV 037721)(B0168, GU172709); *C. crus-corvi* Shuttleworth in G Kunze, (1) USA: VA, Greensville Co, Jun 18 2003 *RFC Naczi, AE Schuyler, CT Frye 9758* (DOV 037221)(B0202, GU172729); (2) USA: TX, Burleson Co, May 2 2004 *RFC Naczi 10134* (DOV 050811)(B0203, GU172728); (3) USA: FL, Taylor Co, Apr 3 2001 *JR Abbott, B Carlsward, C Benson 14239* (DOV 029028)(B0204, GU172727); *C. jonesii* LH Bailey, (1) USA: WA, Chelan Co, Jul 30 2006 *C Baughman 06 2* (WTU 366982)(B1003, GU173048); (2) USA: CO, Jackson Co, Aug 02 1989 *B Neely, A Carpenter 5362* (COLO 443090)(B1109, GU173047); *C. laevivaginata* (Kük.) Mack. in NL Britton & A Brown, (1) USA: MD, Wicomico Co, Jun 12 2007 *WD Longbottom 9283* (DOV 063804)(B0374, GU173068); (2) USA: AL, Saint Clair Co, Apr 23 2003 *DD Spaulding 11751* (DOV 034221)(B0375, GU173067); *C. nervina* LH Bailey, (1) USA: CA, Tehama Co, Jun 24 2001 *LP Janeway 7226* (JEPS 105666)(B1233, GU173279); (2) USA: CA, Tehama Co, Jun 24 2001 *LP Janeway 7226* (JEPS 105666)(B1283, GU173280); (3) USA: NV, Washoe Co, 1956 *ME Lewis 588* (CAN 515397)(B1476, GU173281); *C. neurophora* Mack. in L Abrams and RS Ferris, (1) USA: WA, King Co, Aug 03 2002 *CJ Antieau, T Deady, T Solitto 02 22 3* (WTU 362680)(B1008, GU173282); (2) USA: WY, Carbon Co, Jul 11 1995 *S Goodrich 25119* (COLO 458326)(B1218, GU173283); *C. oklahomensis* Mack., (1) USA: MD, Caroline Co, Jul 02 2005 *WD Longbottom 6224* (DOV 051116)(B0503, GU173318); (2) USA: MS, Grenada Co, May 14 1996 *J MacDonald 9400* (DOV 024470)(B0504, GU173319); (3) USA: AR, Pike Co, May 27 2003 *RFC Naczi, BA Ford 9689* (DOV 035242)(B0505, GU173317); *C. stipata* Muhl. ex Willd. var *maxima* Chapman ex Boott, (1) USA: KY, Campbell Co, May 17 1999 *RFC Naczi 7869* (DOV 020937)(B0653, GU173618); (2) USA: FL, Leon Co, Apr 26 2003 *LC Anderson 20692* (DOV 029569)(B0654, GU173617); *C. stipata* Muhl. ex Willd. var *stipata*, (1) USA: KY, Boone

Co, May 25 2009 *RFC Naczi 8020* (DOV 036702)(B0376, GU173615); (2) Canada: MB, 4 km N of town of W Hawk Lk Jun 25 2003 *RFC Naczi, BA Ford 9825* (DOV 037084)(B0646, GU173622); (3) USA: ME, Oxford Co, Jun 30 2001 *AA Reznicek, SA Reznicek 11274* (DOV 040440)(B0647, GU173620); (4) USA: CO, Jefferson Co, Jul 21 2003 *C Lea 3428* (DOV 046880)(B0652, GU173621); (5) USA: MD, Caroline Co, Jun 01 2005 *WD Longbottom 5959* (DOV 051202)(B0656, GU173619); (6) Canada: NL, Eagle Riv Aug 21 1999 *R Charest, C Hanel, N Djan Chekar, C Wentzell, B Pollock, L Brouillet, S Hay NDC 99 737* (MT)(B0902, GU173616).

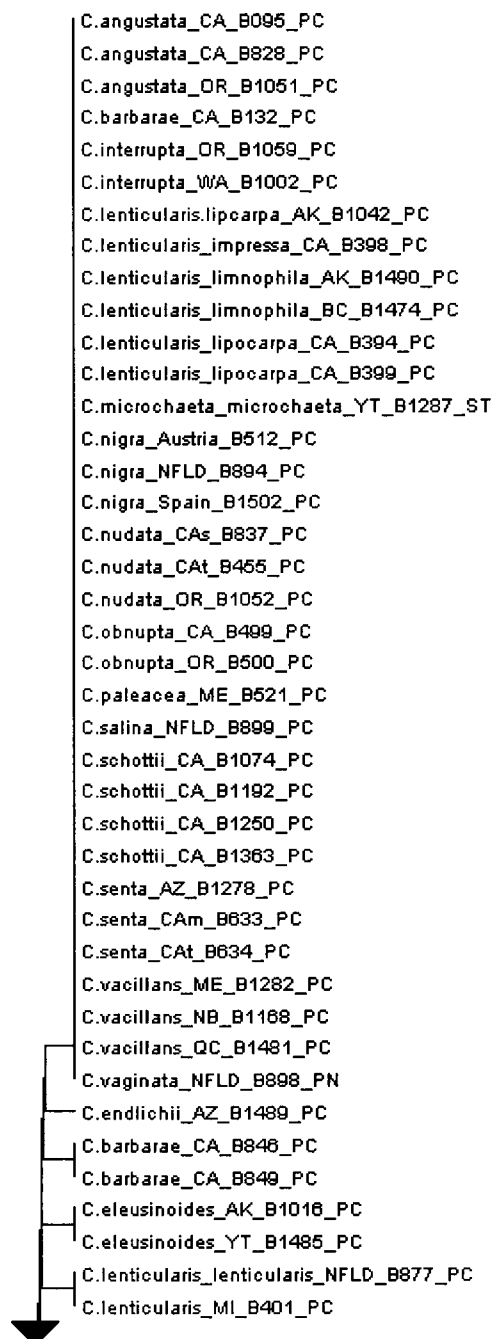
Carex L fraserianus Ker Gawl., (1) USA: VA, Grayson Co, Jun 13 2006 *CT Bryson, NB Bryson 21764* (DOV 057055)(B0332, GU172898); (2) USA: PA, Somerset Co, May 19 2003 *RFC Naczi 9611* (DOV 041664)(B0333, GU172897); (3) USA: MD, Garrett Co, Jun 04 2005 *WD Longbottom, RFC Naczi, G Van Velsir 6000* (DOV 051066)(B0334, GU172896).

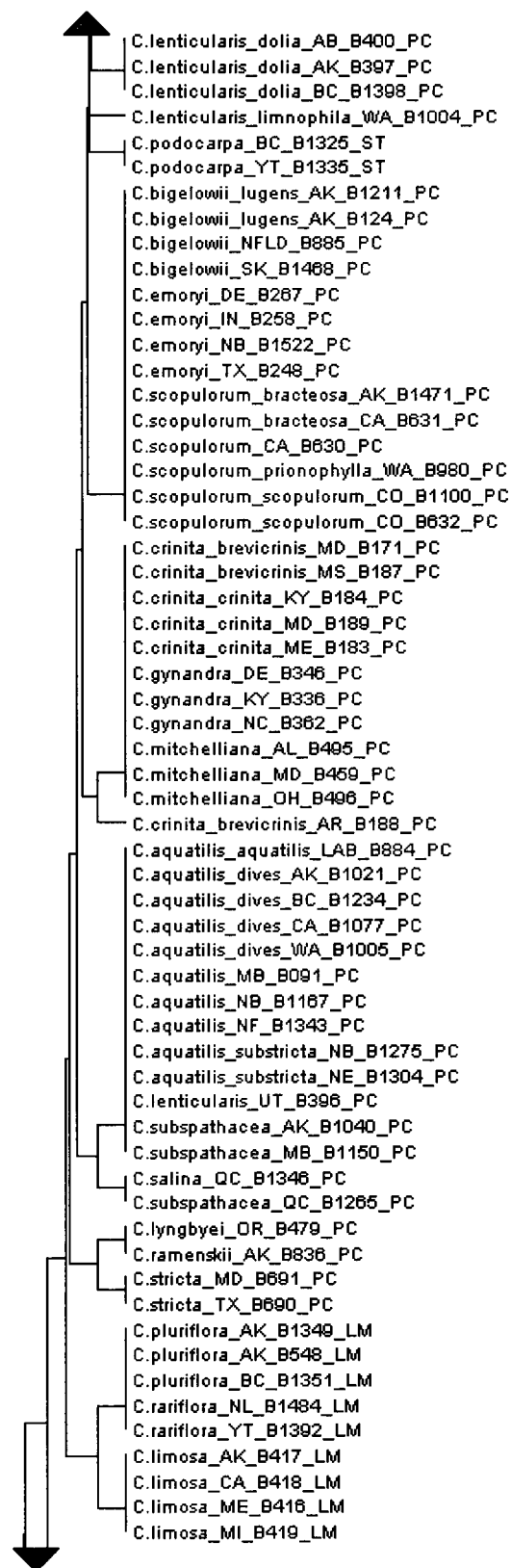
Kobresia Willd. *mysurooides* (Villars) Fiori in A Fiori *et al.*, (1) USA: OR, Wallowa Co, Jul 05 1992 *N Otting 9* (OSC 215849)(B1054, GU173274); (2) Canada: BC, 2 mi W of Teepee Heart Ranch Jul 2 1978 *CE Jones 146* (UBC 167581)(B1518, GU173273).

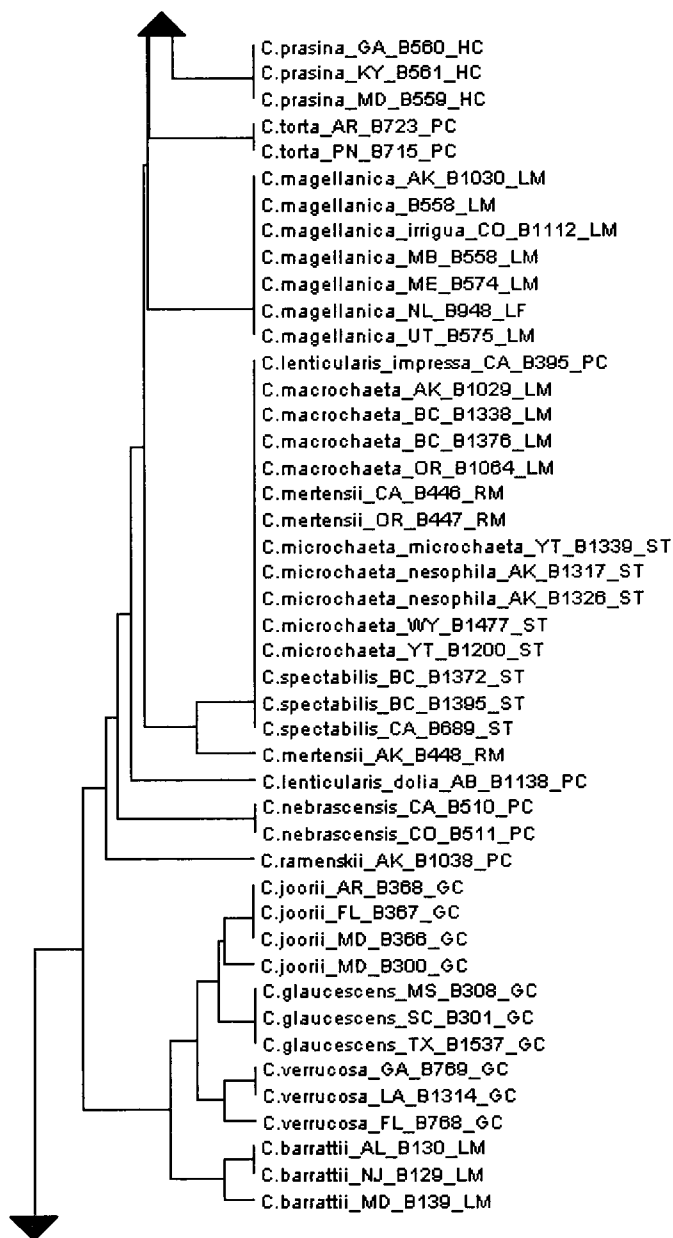
Kobresia Willd. *sibirica* (Turczaninow ex Ledebour) Boeckeler, (1) USA: AK, Beechy Point Quad Jul 20 1984 *MD Walker 84 101* (COLO 419670)(B1096, GU173568); (2) USA: MT, Carbon Co, Aug 16 1991 *P Lesica 5588* (MT 115252)(B1224, GU173569).

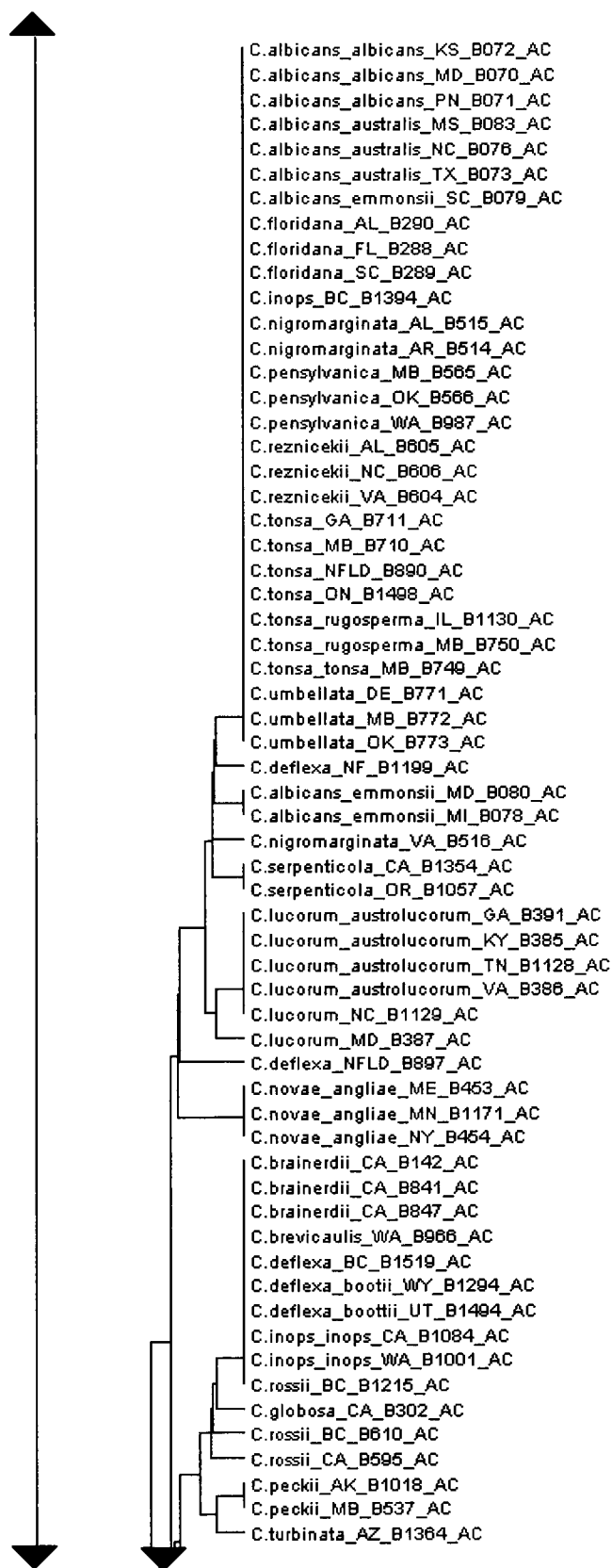
Kobresia Willd. *simpliciuscula* (Wahl.) Mack., (1) USA: OR, Wallowa Co, Jul 05 1992 *N Otting 6319* (OSC 179984)(B1055, GU173578); (2) Canada: YT, Ivvavik National Park Aug 07 2005 *BA Bennett, CL Parker, T McIntosh, P Seccombe Hett, M Joe 05 1083* (UBC 224454)(B1380, GU173579).

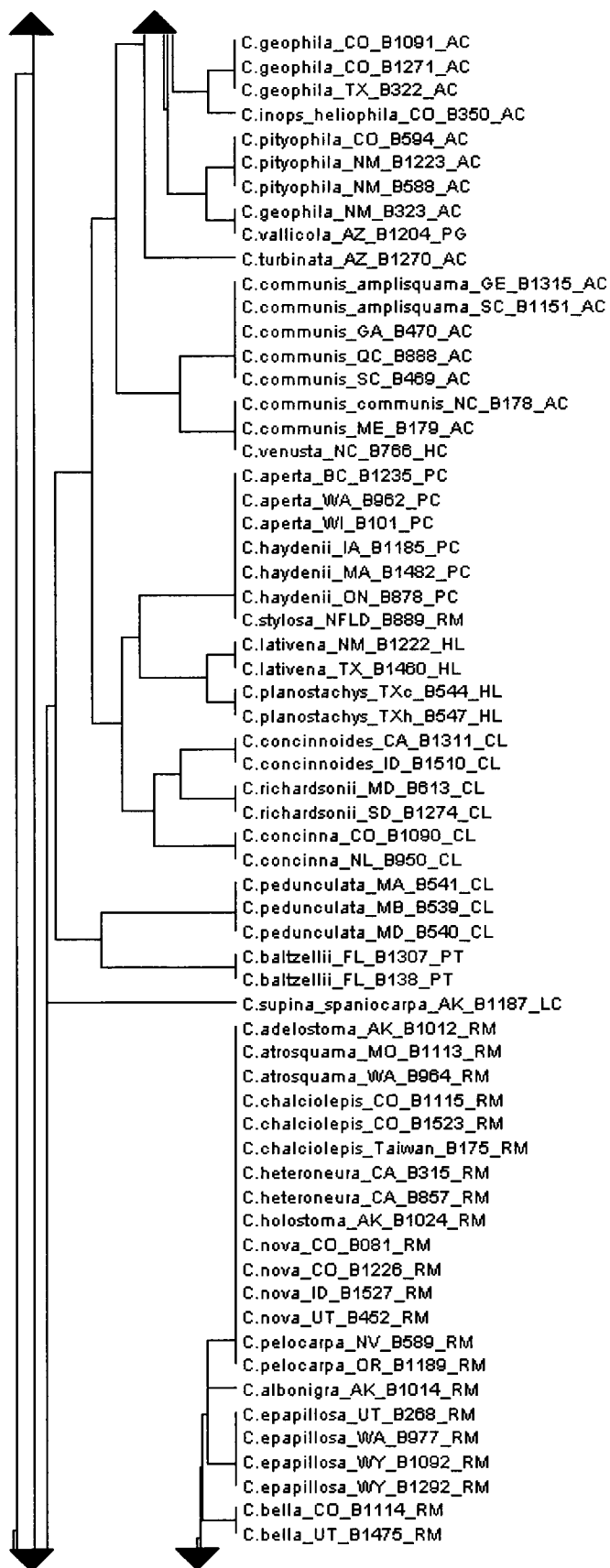
Appendix C. UPGMA analysis of an 815 base pair region of the chloroplast gene *matK*, sequenced from *Carex* and *Kobresia* taxa from across North America, north of Mexico. Node labels are presented in the following format: taxon, State/Province abbreviation, sample number, and section abbreviation.

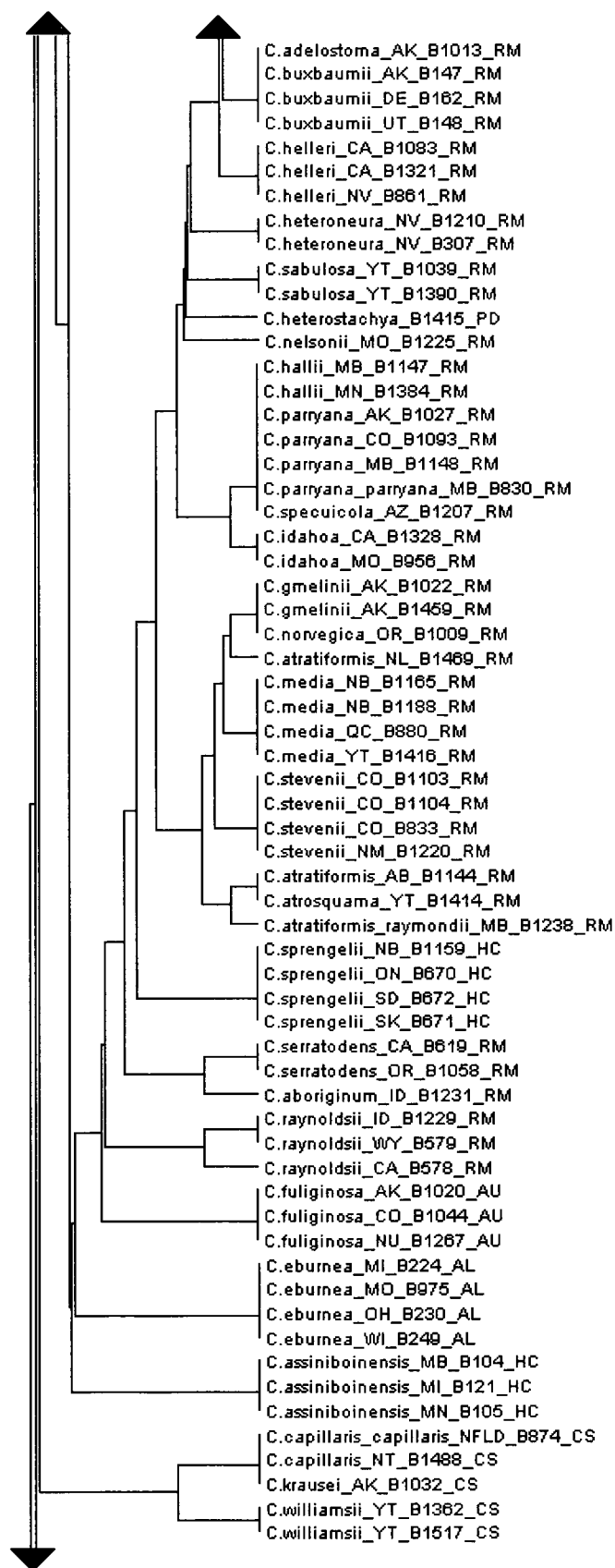


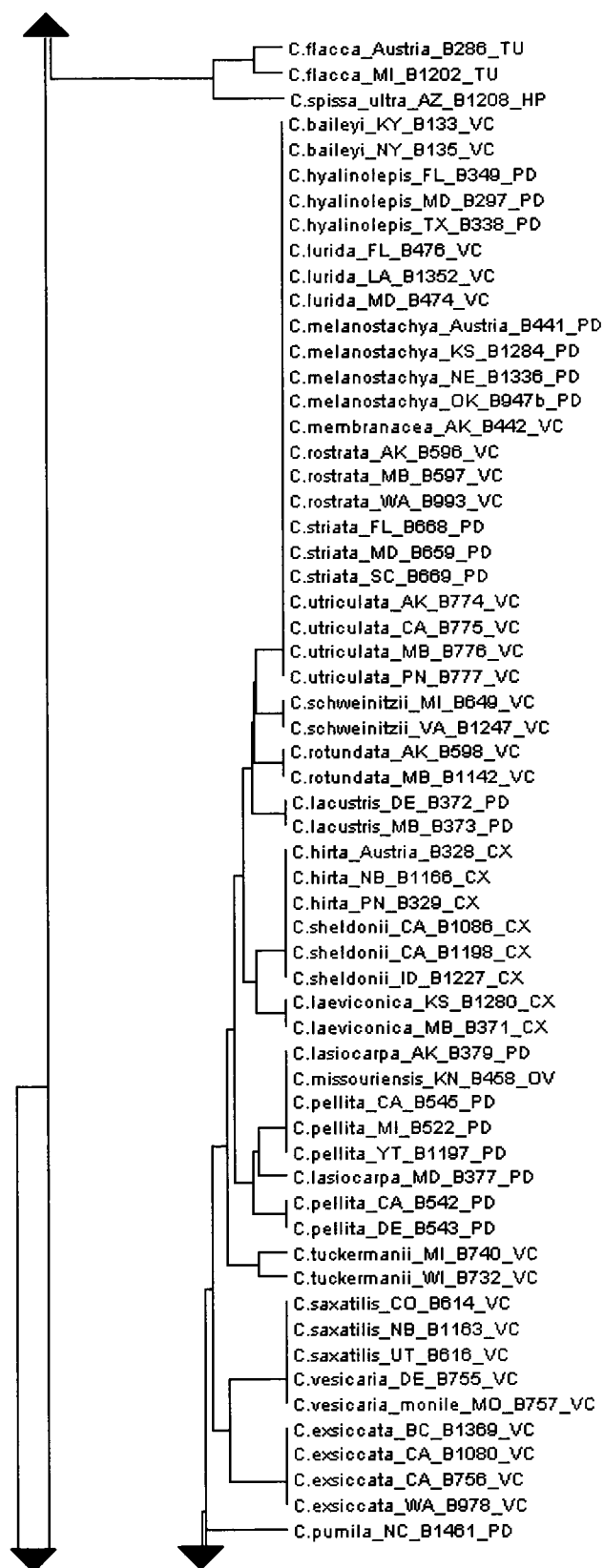


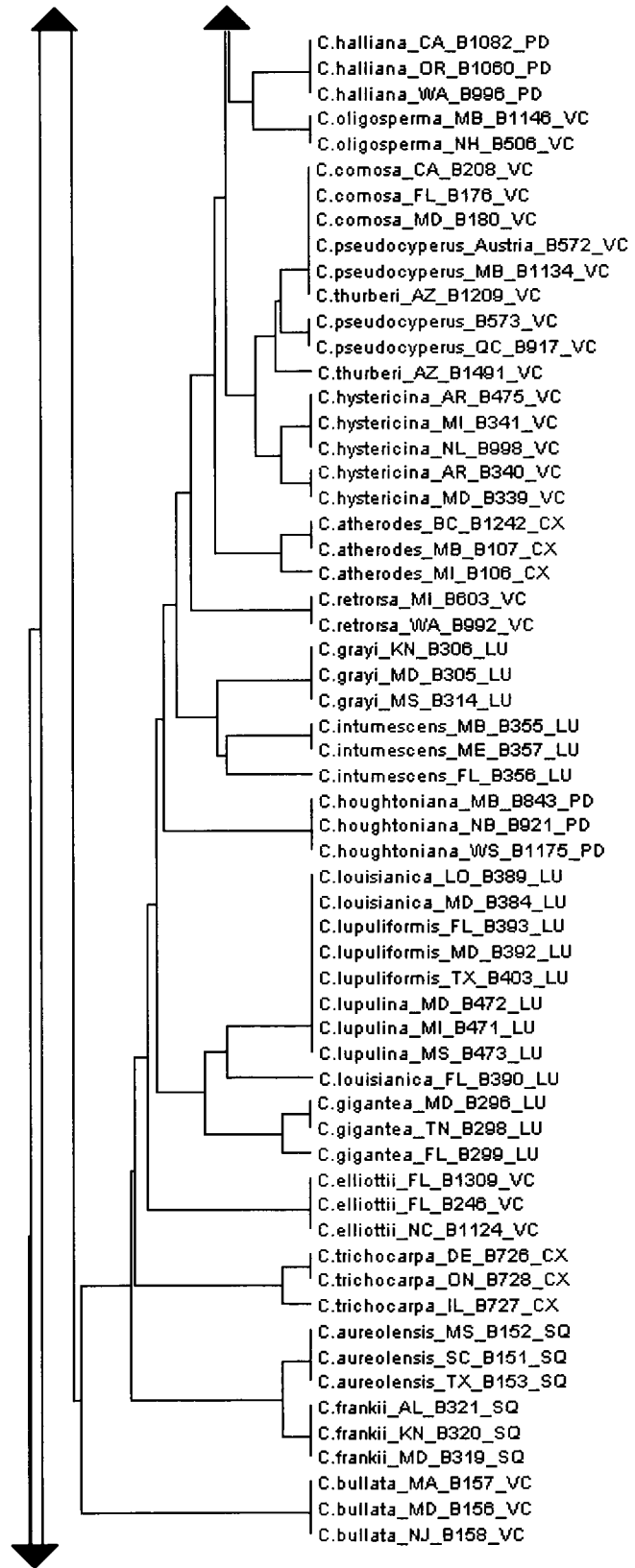


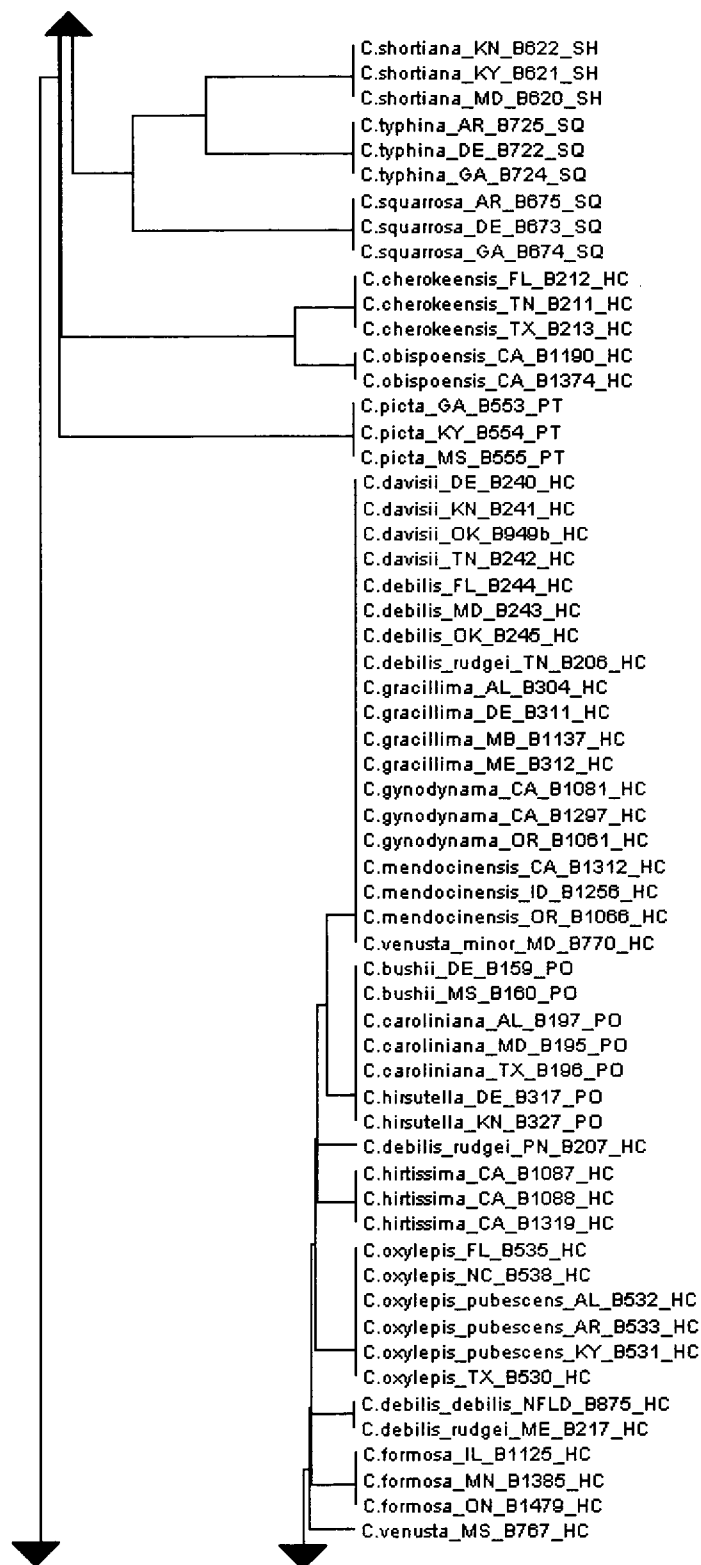


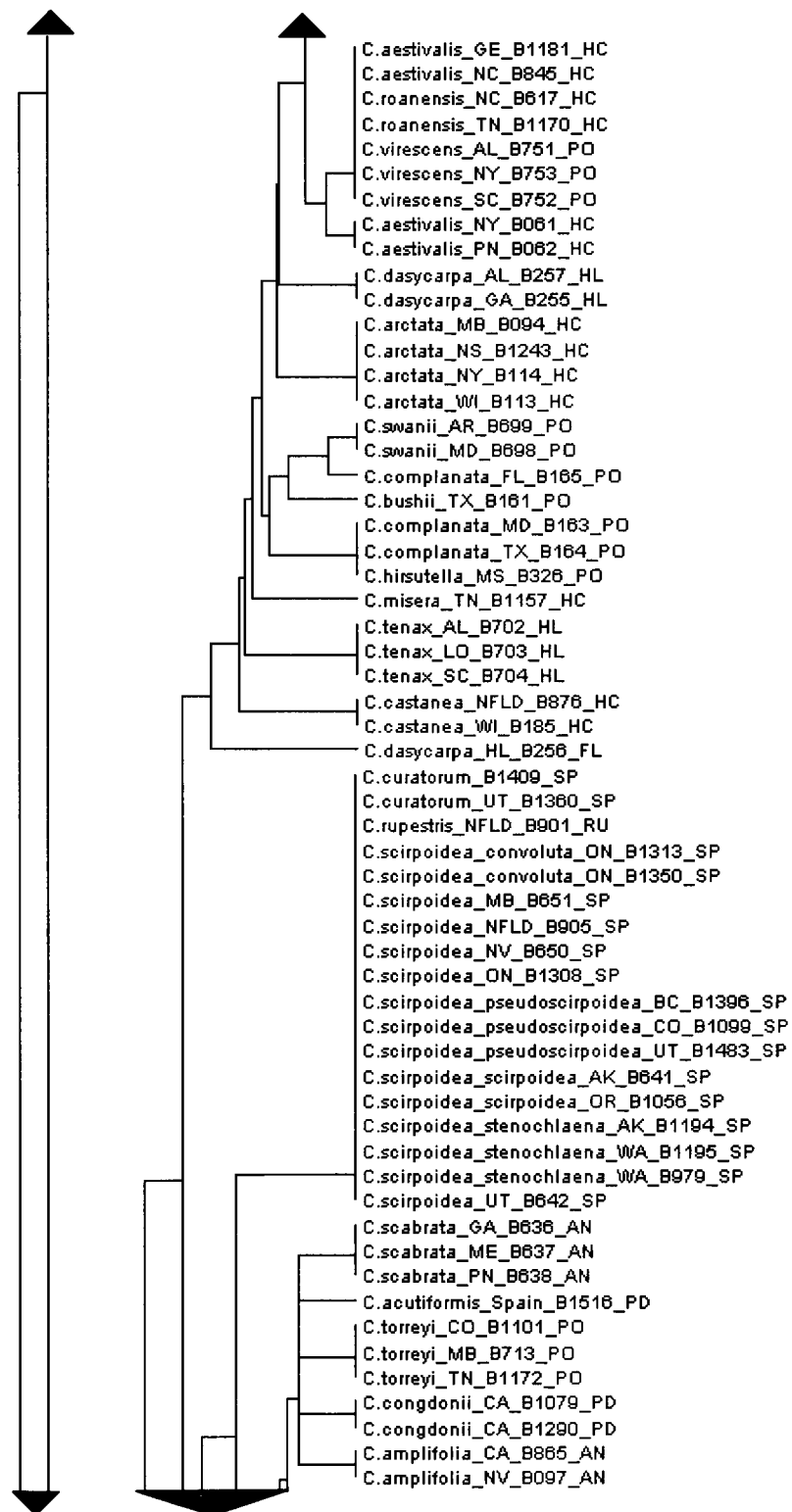


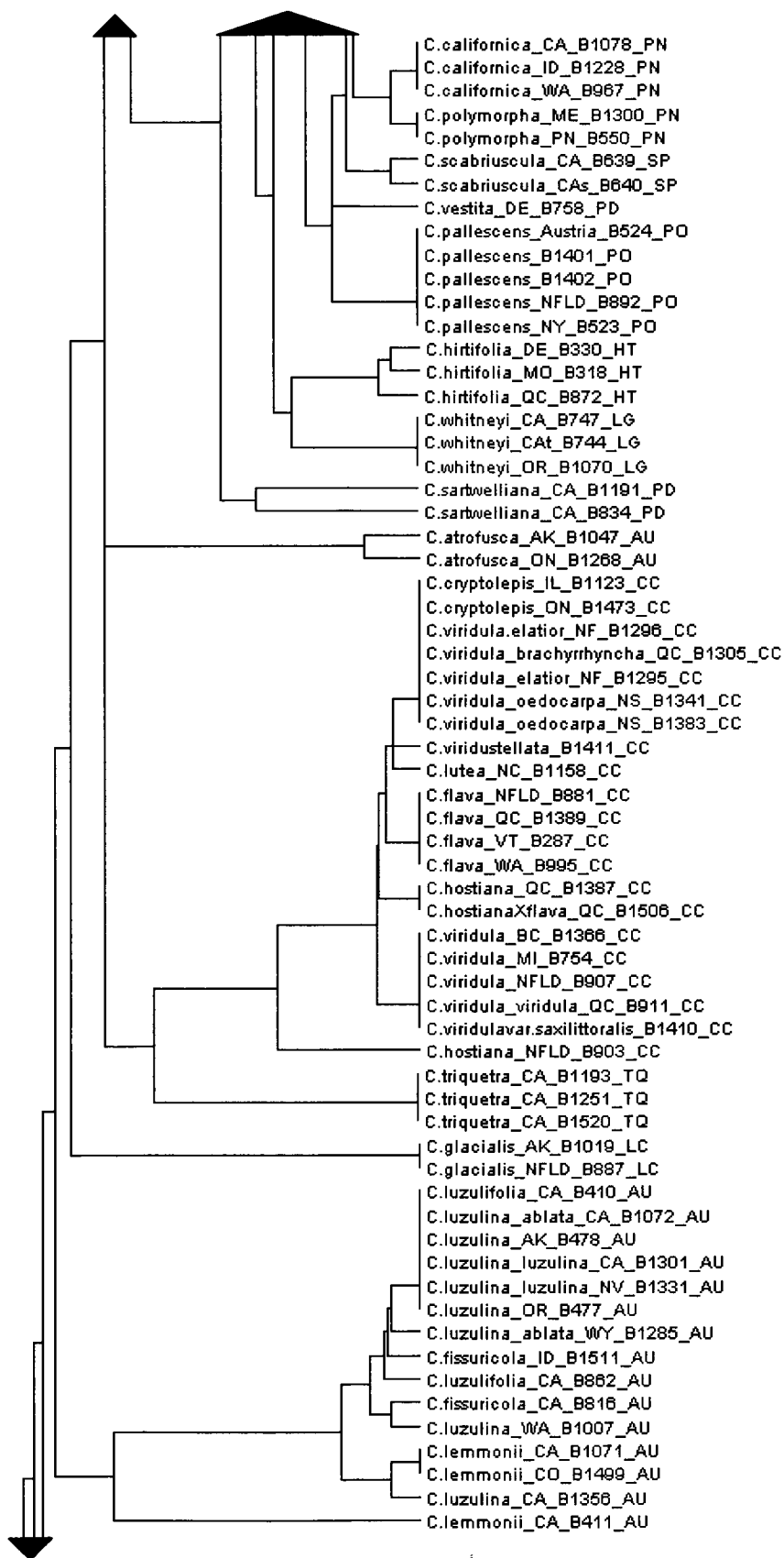


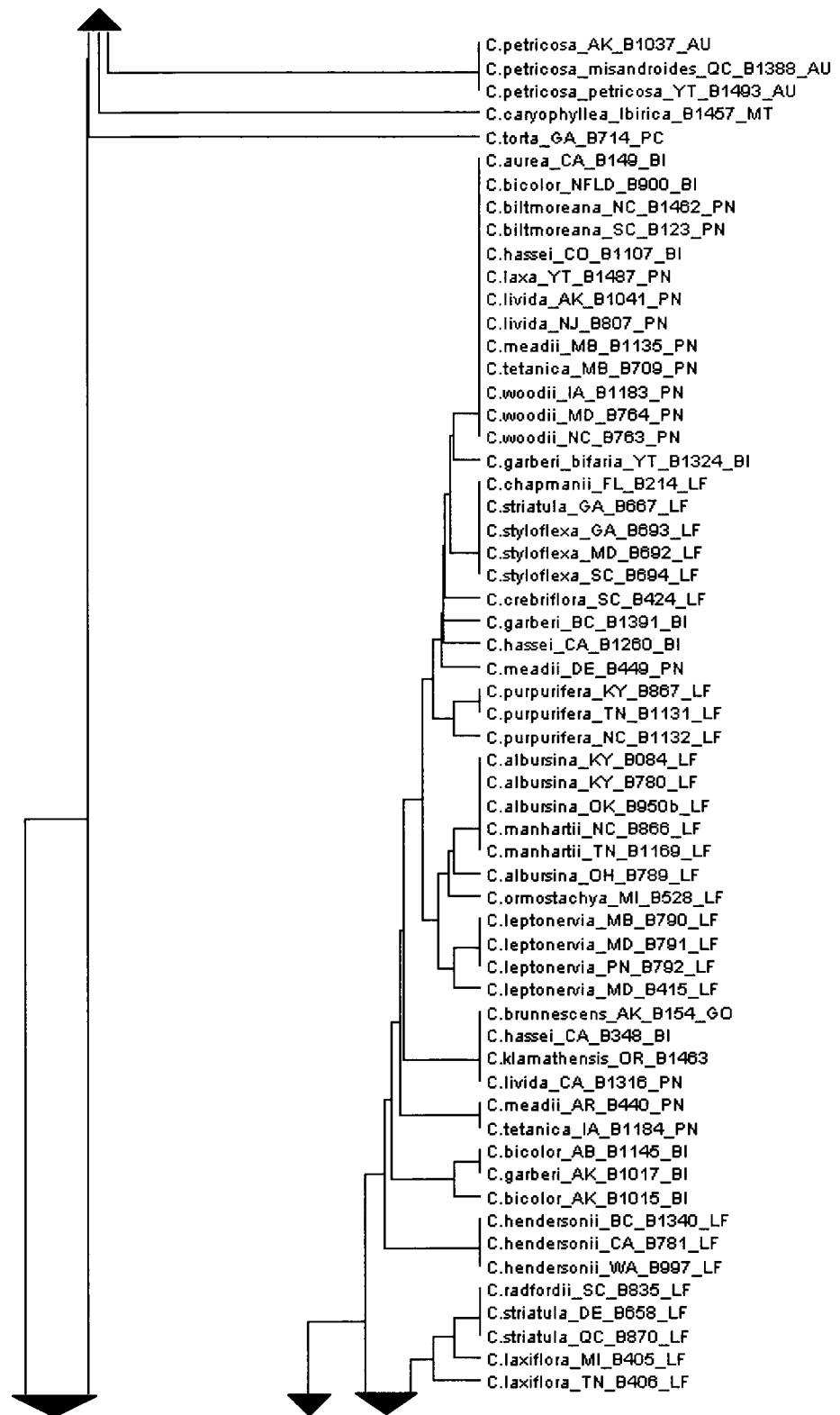


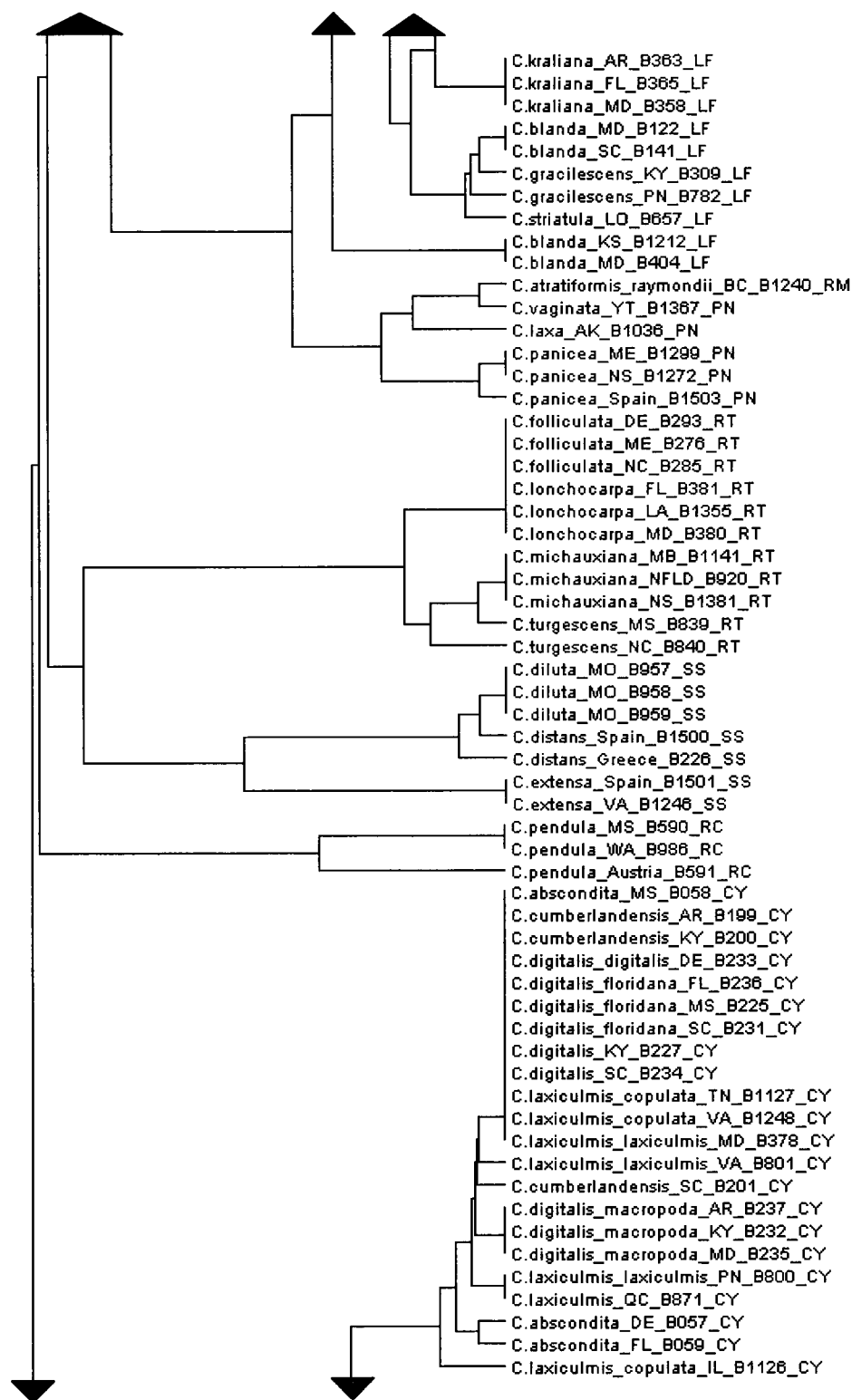


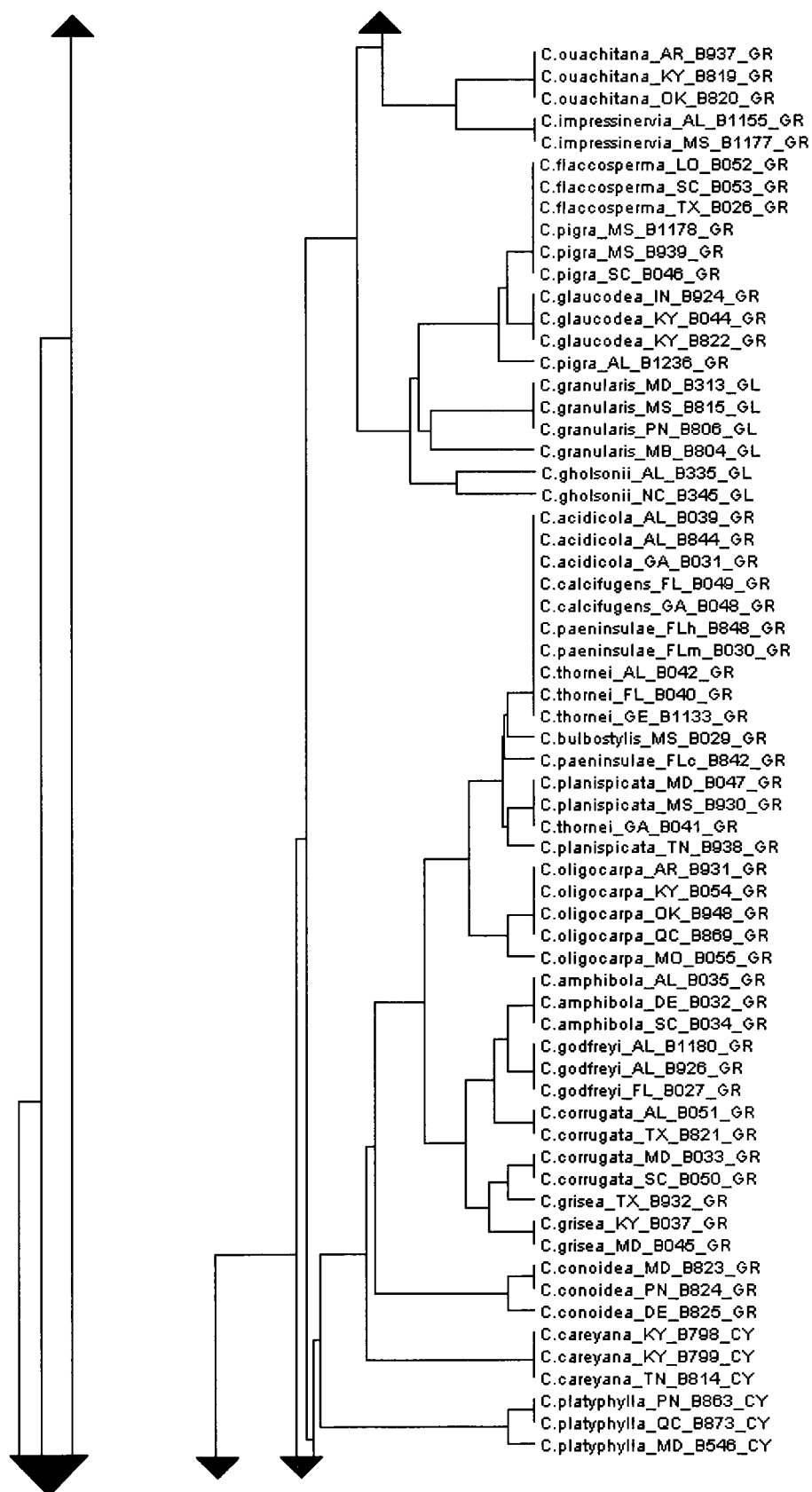


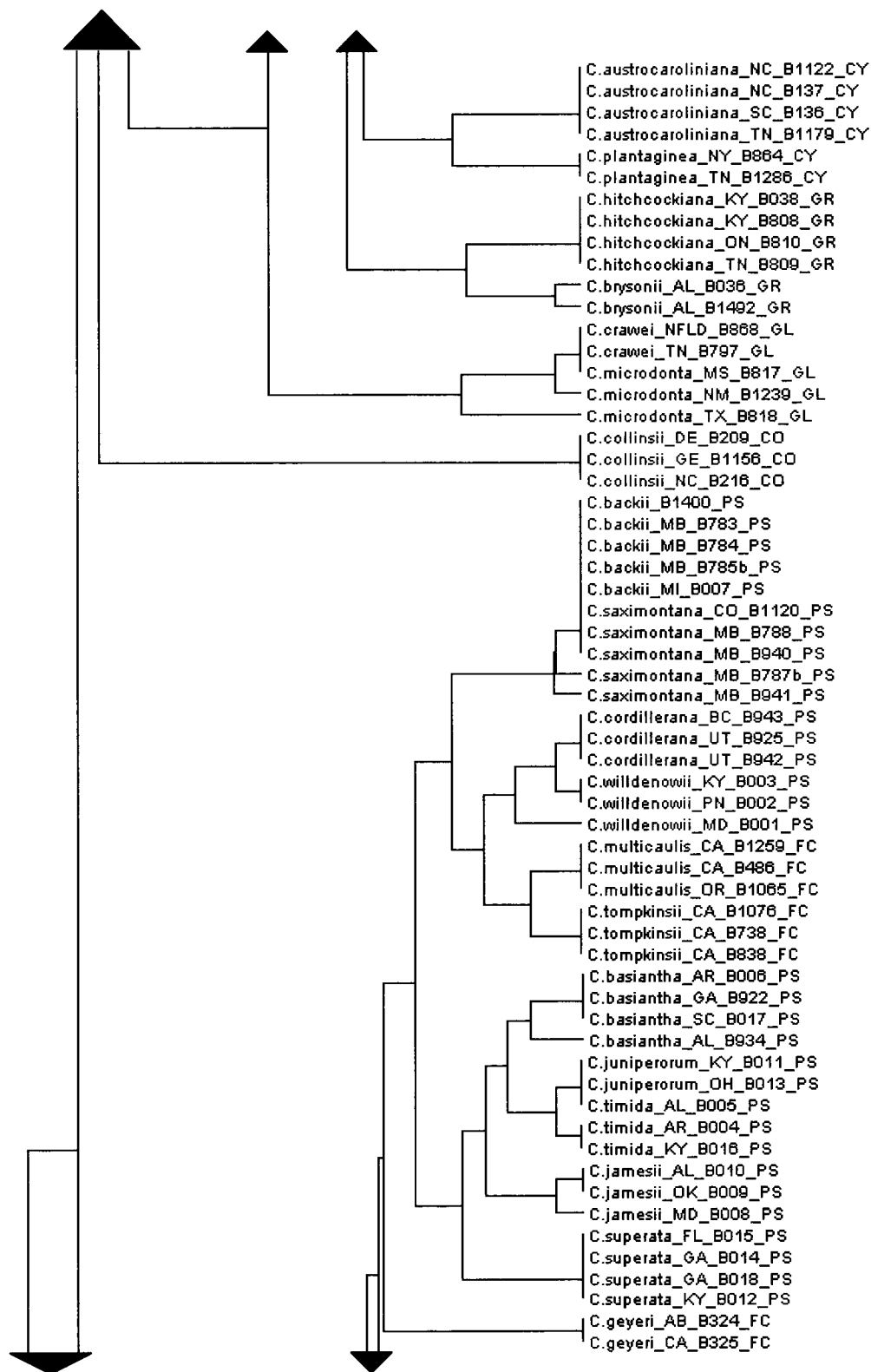


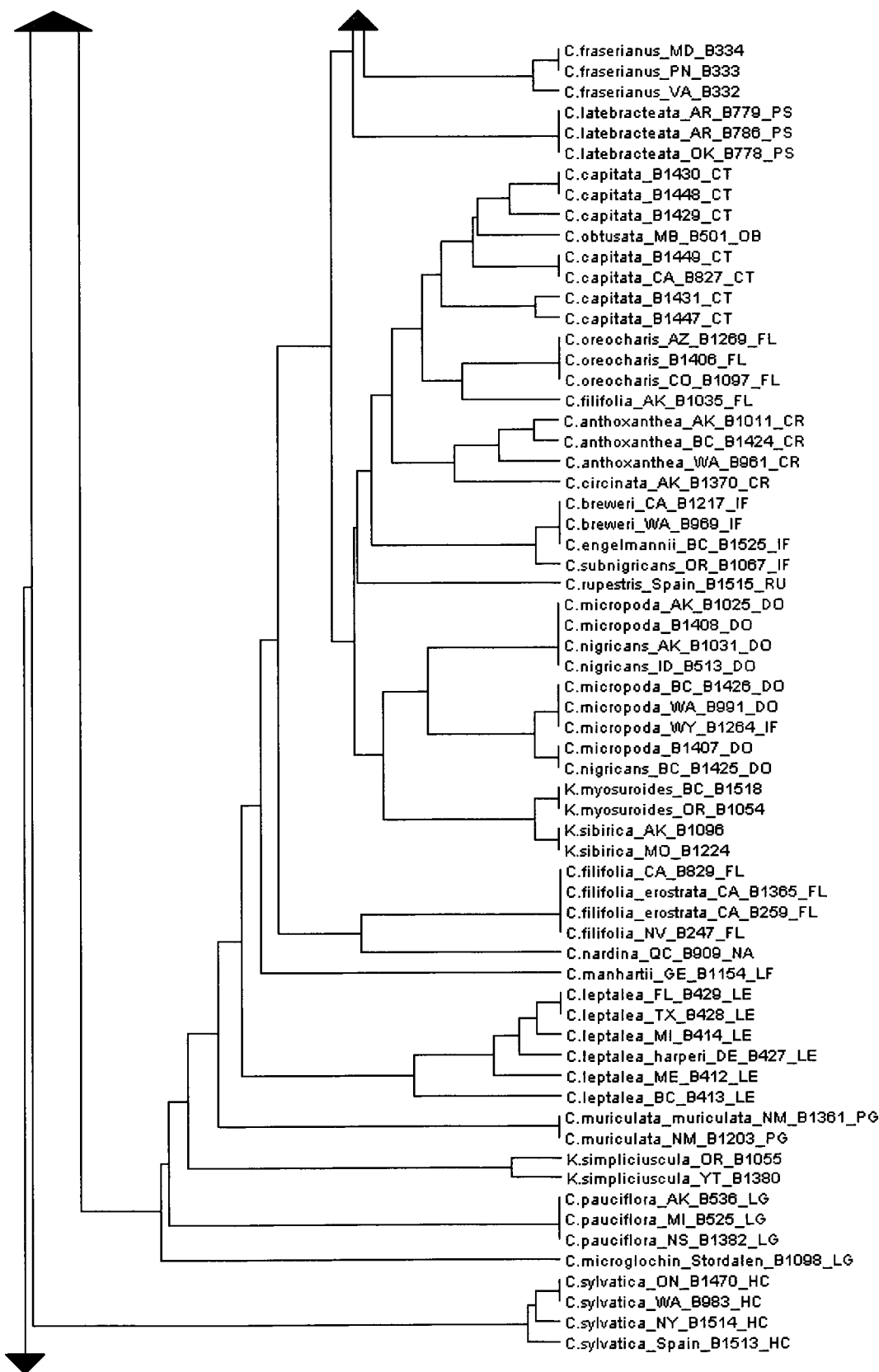






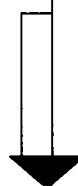


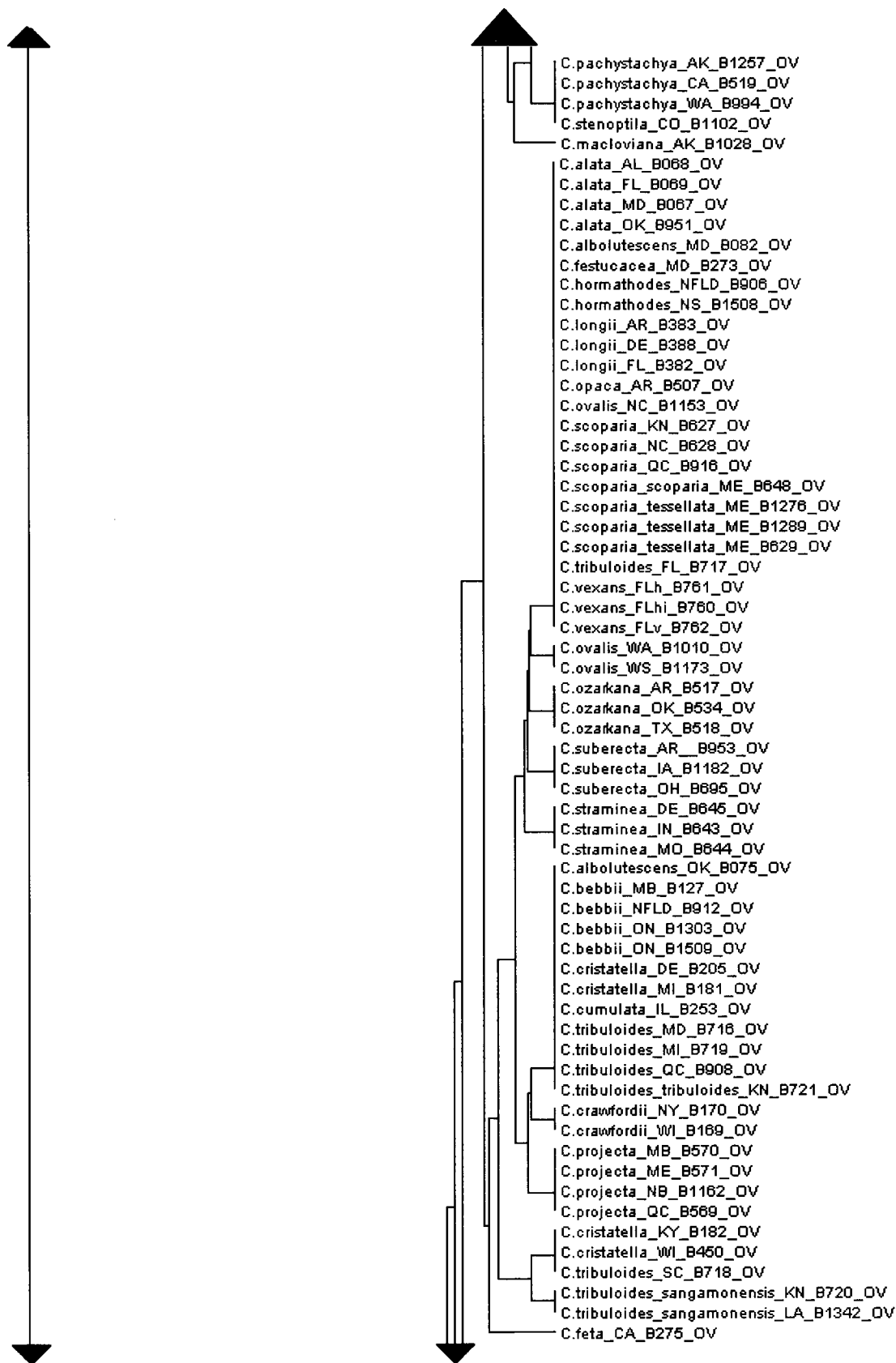


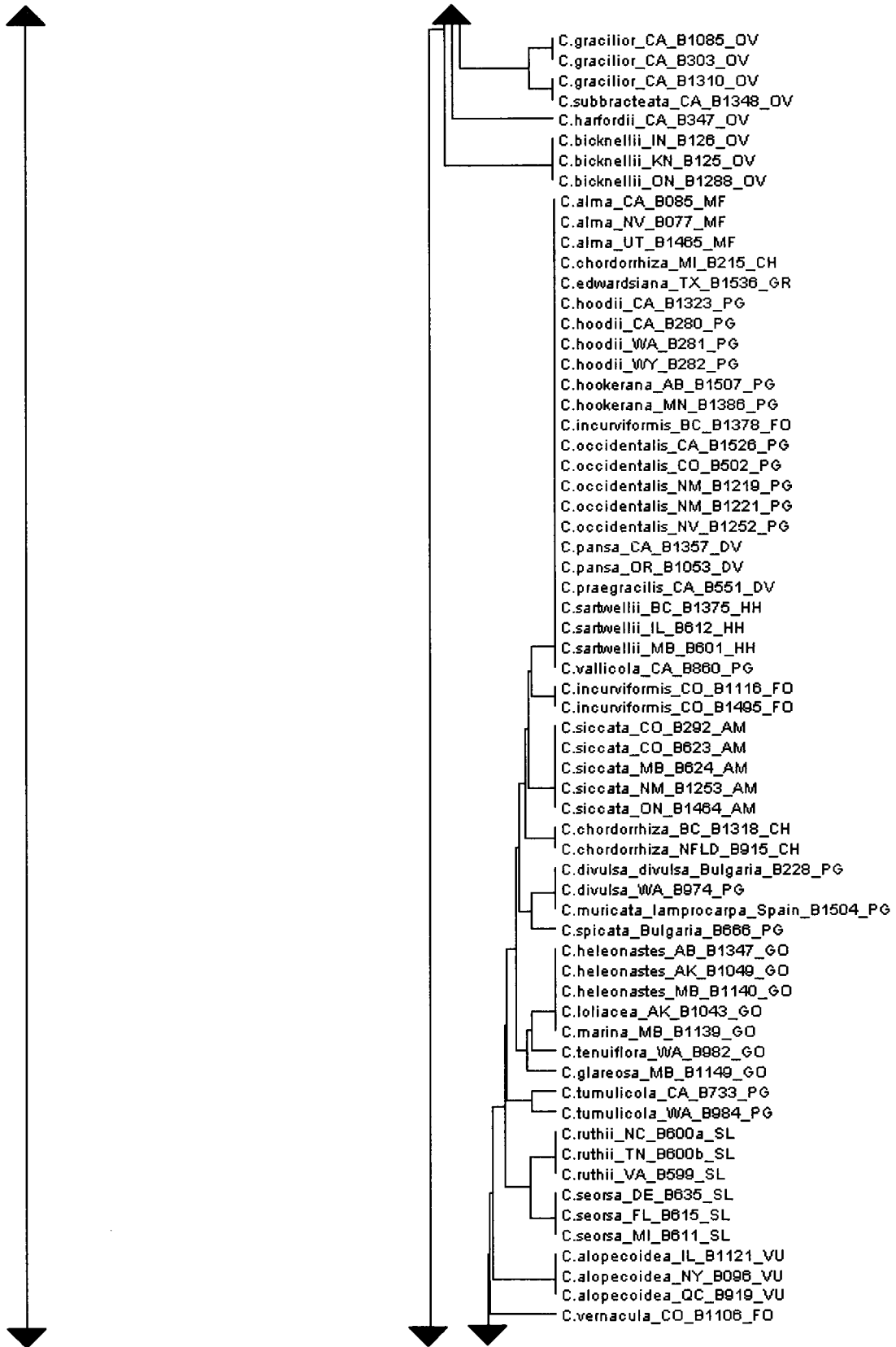


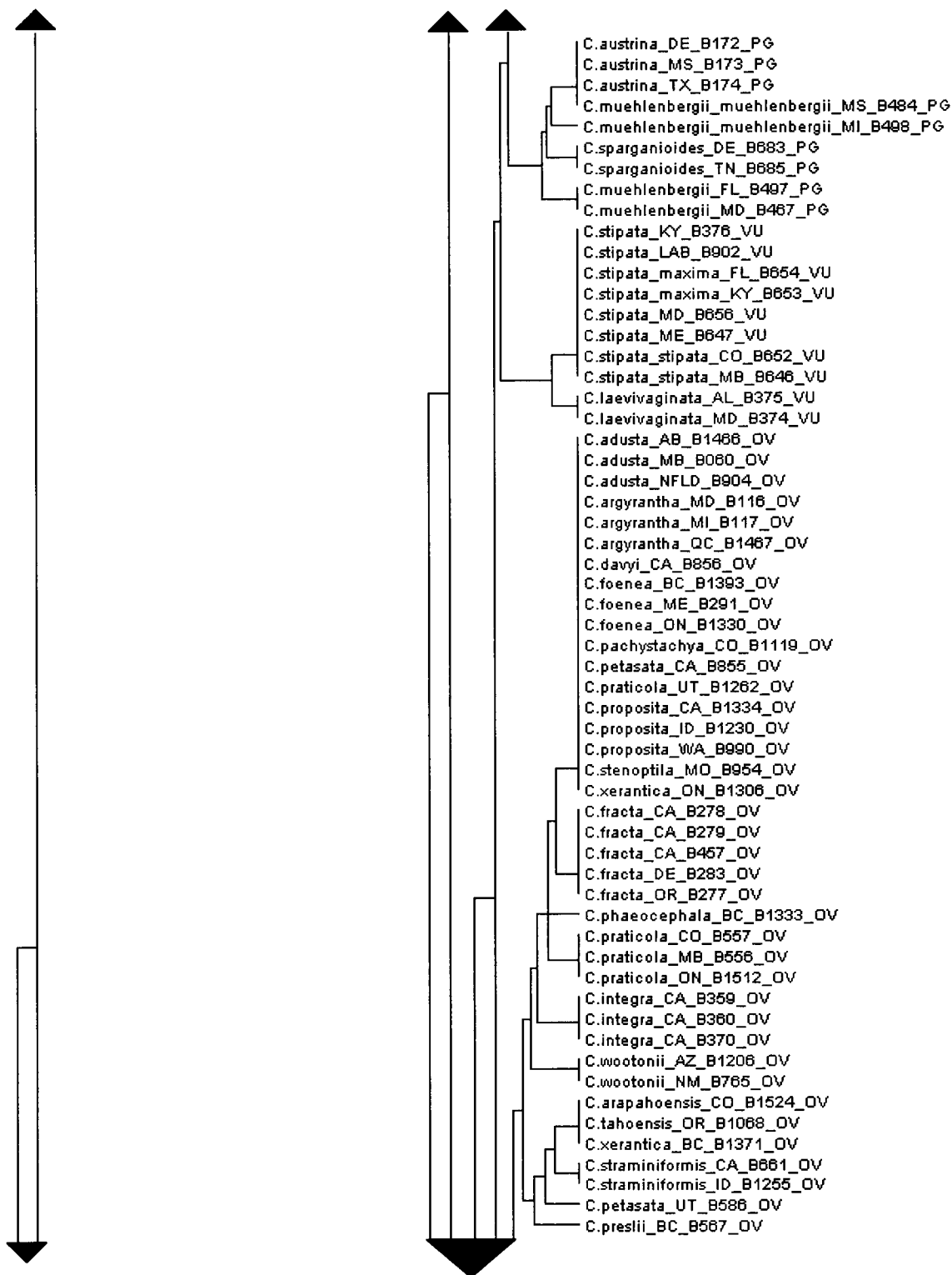


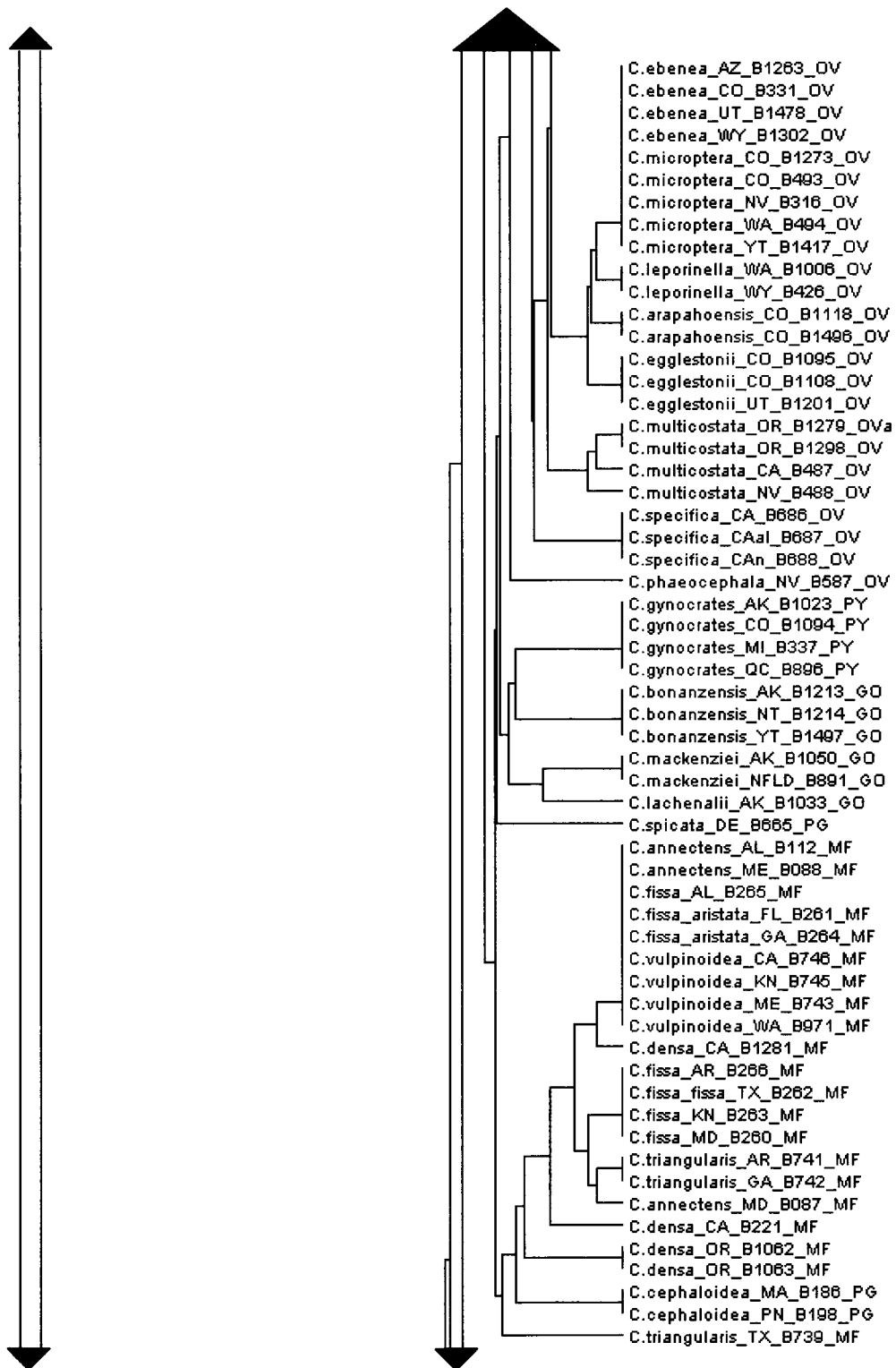
C.athrostachya_SK_B946_OV
C.brevior_BC_B1216_OV
C.brevior_KN_B143_OV
C.brevior_KY_B146_OV
C.brevior_WI_B144_OV
C.festucacea_IL_B272_OV
C.festucacea_TX_B274_OV
C.hyalina_MS_B294_OV
C.hyalina_TN_B295_OV
C.merritt_fernaldii_MB_B443_OV
C.merritt_fernaldii_ME_B444_OV
C.merritt_fernaldii_ON_B1327_OV
C.merritt_fernaldii_WI_B446_OV
C.missouriensis_IL_B460_OV
C.missouriensis_MO_B461_OV
C.molesta_DE_B463_OV
C.molesta_KN_B464_OV
C.molesta_MS_B462_OV
C.molestiformis_KY_B468_OV
C.muskingumensis_MI_B509_OV
C.muskingumensis_MO_B508_OV
C.muskingumensis_ON_B1337_OV
C.muskingumensis_WI_B489_OV
C.normalis_IA_B1186_OV
C.normalis_ME_B420_OV
C.opaca_IL_B526_OV
C.opaca_OK_B527_OV
C.oronensis_ME_B1291_OV
C.oronensis_ME_B529_OV
C.reniformis_GA_B581_OV
C.reniformis_TX_B580_OV
C.shinnersii_KN_B618_OV
C.shinnersii_KS_B1254_OV
C.shinnersii_OK_B946_OV
C.silicea_DE_B625_OV
C.silicea_ME_B626_OV
C.silicea_NB_B1161_OV
C.tenera_echinodes_MB_B707_OV
C.tetrastachya_OK_B662_OV
C.tetrastachya_TXb_B664_OV
C.tetrastachya_TXk_B663_OV
C.tincta_ME_B737_OV
C.tincta_NB_B913_OV
C.cumulata_ON_B1486_OV
C.normalis_AL_B451_OV
C.preslii_OR_B568_OV
C.reniformis_MS_B582_OV
C.hyalina_TX_B284_OV
C.molestiformis_AR_B466_OV
C.molestiformis_OK_B465_OV
C.tenera_echinodes_MI_B705_OV
C.tenera_MI_B128_OV
C.tenera_QC_B914_OV
C.tenera_tenera_MB_B1143_OV
C.tenera_tenera_ME_B706_OV
C.tenera_WS_B1174_OV
C.abrupta_BC_B520_OV
C.abrupta_CA_B058_OV
C.abrupta_CA_B1232_OV
C.abrupta_CA_B853_OV
C.abrupta_CA_B854_OV
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C.subfusca_CA_B696_OV
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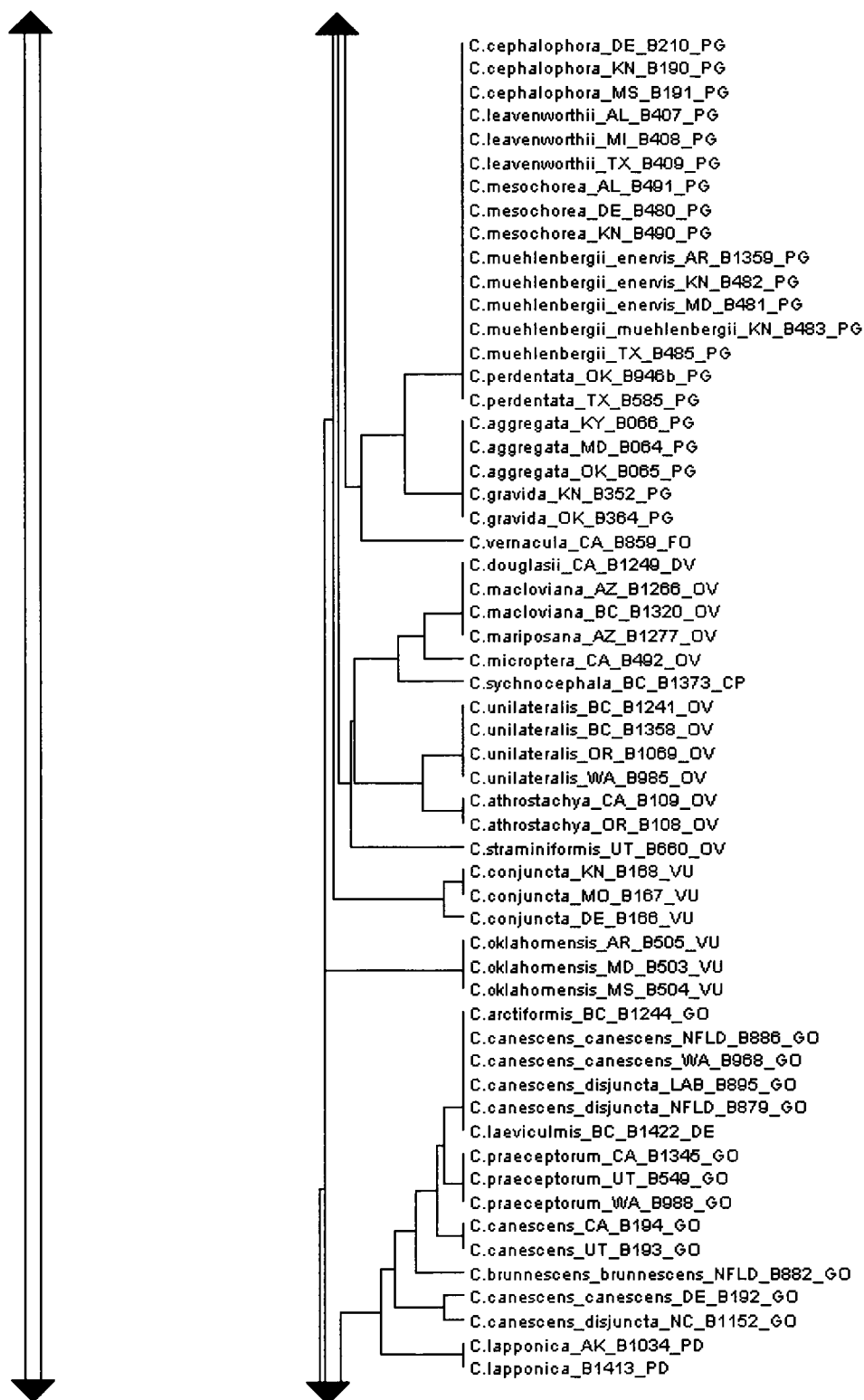


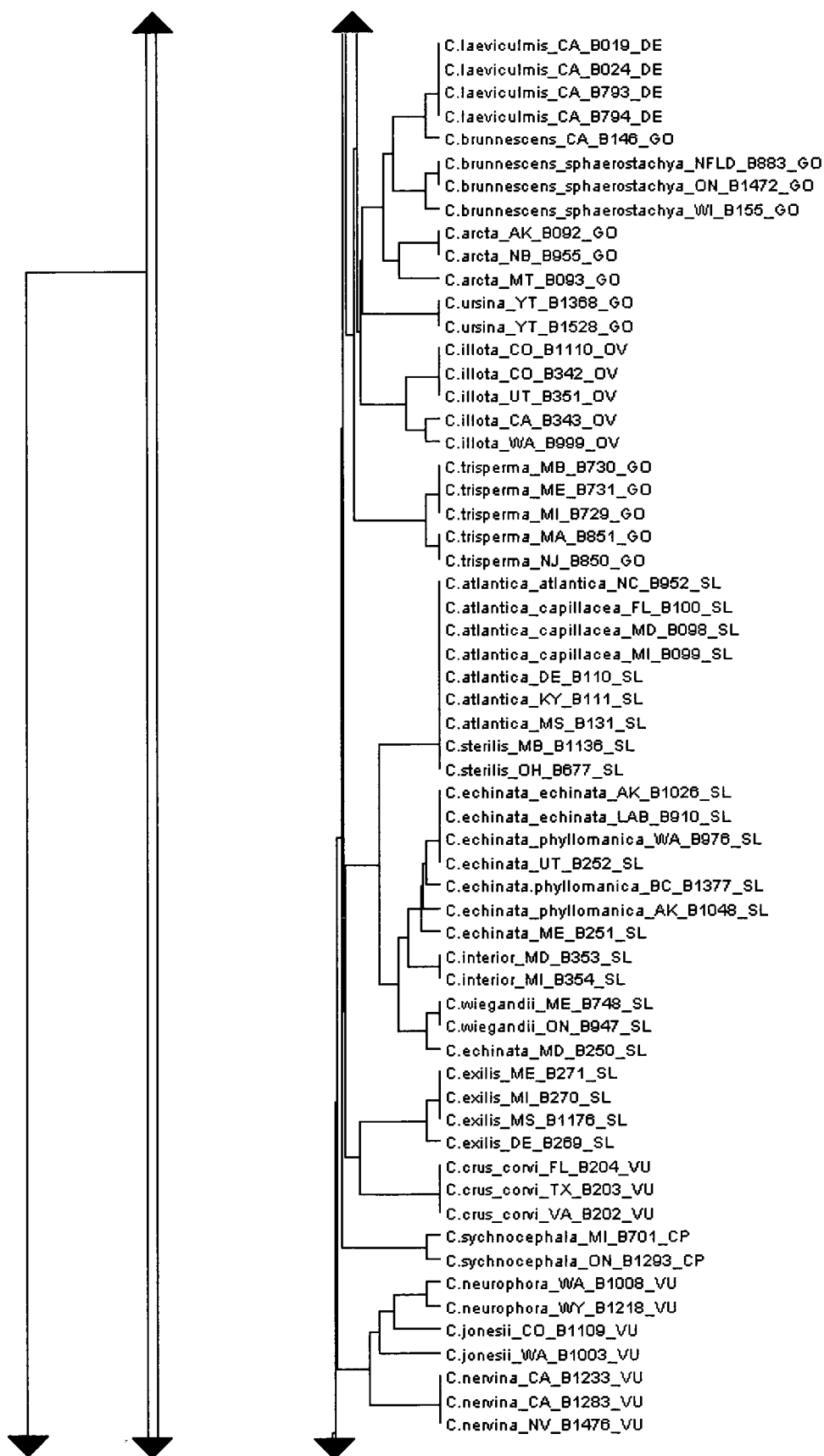


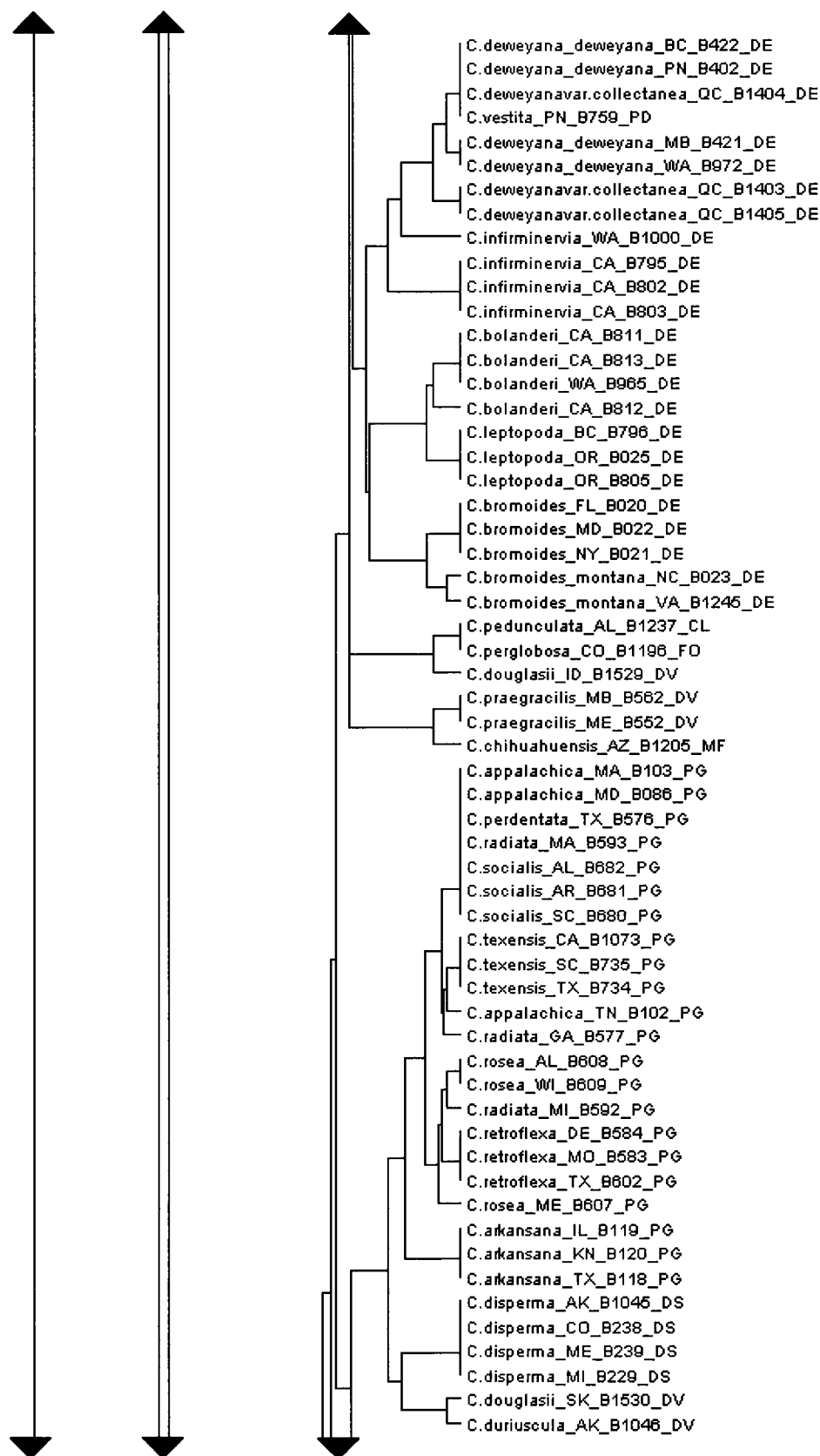


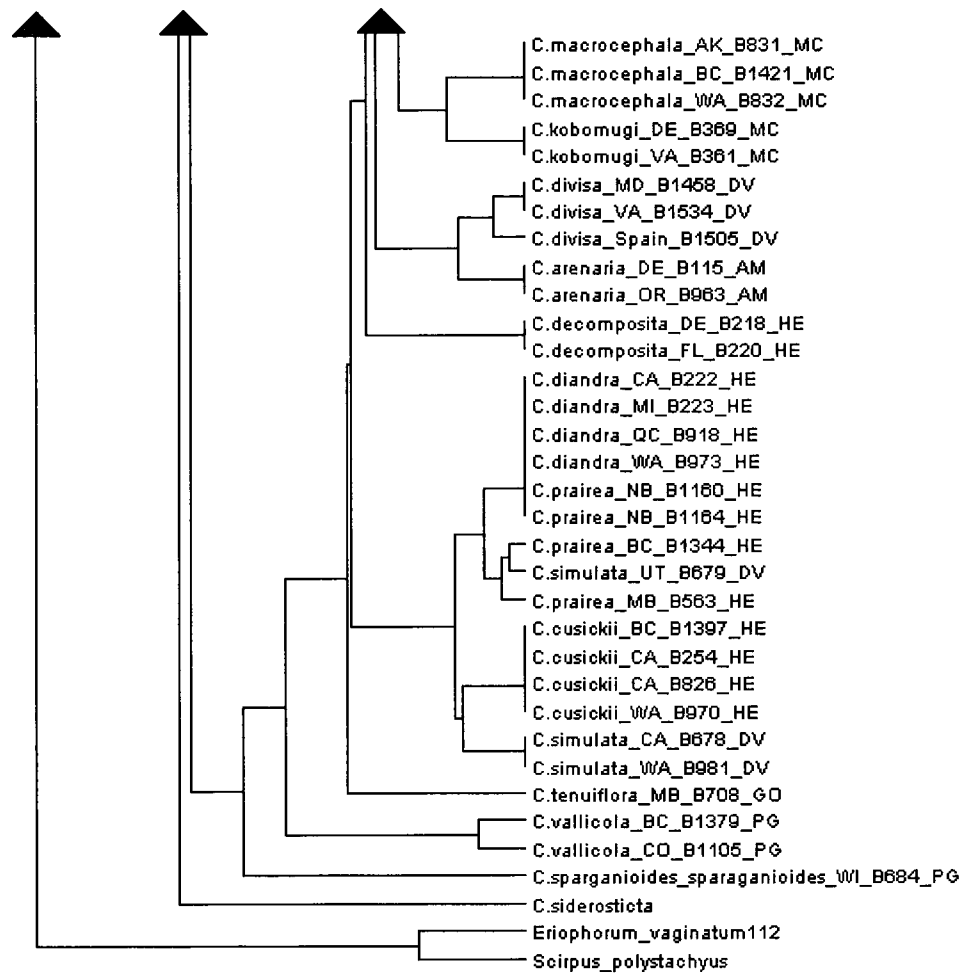












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