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SYMPOSIUM – INVASIVE GRASSES AND SEDGES: DEEP-ROOTED ISSUES
Tuesday, 24 January, 2:15-5:40 PM

Invasive Sedges: Impending Problems (195)

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Tuesday, 24 January, 5:00-5:20 PM

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Intro

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I would like to thank April Fletcher for organizing and inviting me to participate in this symposium.

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Cyperaceae have long been recognized among the World's worst agricultural weeds, and Holm et al. (1977) included five sedges among the 40 worst. Despite such notoriety, until recently virtually all of the literature dealing with cyperaceous weeds has focused on pests of agriculture, turf, lawns, and gardens.

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Sedges exhibit a variety of characteristics that contribute to their weediness. (1) tolerance of a wide range of environments; (2) rapid growth; (3) vegetative reproduction or regeneration from fragments; (4) non-specific pollination, generally anemophily; (5) complex reproductive systems involving sexual and asexual modes; (6) prolonged seed production; (7) copious production of small seeds; (8) brittleness; (9) adaptations for short- and long-range dispersal; (10) allelopathy; and (11) physiological mechanisms, such as C_4 photosynthesis.

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The World's worst weed, *Cyperus rotundus*, reproduces primarily through asexual means from tubers via fragmentation of rhizomes and only rarely produces seeds. Moreover, it exhibits vigorous growth, allelopathy, and C4 photosynthesis, all contributing to its success as a weed.

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Cyperus esculentus is also a major agricultural pest. It reproduces sexually via achenes and asexually, spreading and persisting from rhizomes and tubers shown here.

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Vegetative growth from rhizomes, stolons, runners, tubers and corms is common in many perennial sedges and is undoubtedly important in local expansion. Tips of the arching, aerial stems of *Eleocharis melanocarpa* Torr., shown here, take root when they touch the ground, effecting a kind of "walking" asexual proliferation.

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Sedges are almost exclusively wind-pollinated (anemophilous), and the exposed feathery, stigmas of *Fimbristylis puberula* shown here promote wind pollination.

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Many sedges produce large numbers of very small, single-seeded fruits called achenes, which may be dispersed in a variety of ways. An individual plant of *Cyperus difformis* may produce 50,000 achenes with a germination rate of 60% or more (Holm et al., 1977). Moreover, this annual weed completes its life cycle in only 4 to 6 weeks. Short generation times and high seed production promote rapid dispersal (Vaillant, 1967), large seed reservoirs in the soil, and high population levels (Holm et al., 1977; Bryson, 1984). Its short generation period and large seed production are primary factors in rapid evolution of herbicide resistance in *C. difformis* (Pappas-Fader et al., 1993, 1994; Hill et al., 1994).

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C_4 photosynthesis confers a competitive advantage under conditions of high temperature, high light intensity, and water stress, and C_4 photosynthesis is normally most advantageous in the terrestrial environment under conditions of drought, high light, and high temperatures (Hopkins and Hüner, 2004). Some of the most competitive weeds are characterized by C_4 photosynthesis (Black et al., 1969; Elmore and Paul, 1983), and among them are *Cyperus rotundus*, *C. esculentus* and *C. iria* (Hesla et al., 1982).

However, C_4 photosynthesis is only one of many factors contributing to competitiveness of weeds (Baskin and Baskin, 1978); thus, it is not surprising that other characteristics enable certain C_3 Cyperaceae to be highly competitive. For example, *Cyperus difformis*, almost exclusively a pest of rice, is well adapted to aquatic environments where excessive water ameliorates high temperatures and water stress is normally not a factor. Thus, it is not surprising that *Cyperus difformis* has C_3 photosynthesis. Similarly, the C_3 species *Cyperus haspan* is a major weed of rice agriculture.

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Dispersal is crucial at two points during invasion by plants: first, during the initial introduction of the species and later, after naturalization, as the invasive species spreads, expanding its range (Cronk and Fuller, 1995). Consequently, basic knowledge about attributes of reproduction and natural dispersal can provide insight into which species are likely to become invasive weeds and how they might be dispersed.

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Cyperaceae exhibit diverse adaptations facilitating both long-distance and short-distance dispersal, including fragmentation, dispersal by water (hydrochory), dispersal by wind (anemochory), and various types of dispersal by animals (zoochory).

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Sedges differ markedly with regard to the unit of dispersal. In species such as *Cyperus haspan* L., achenes and floral scales separate sequentially from base to apex of spikelet, resulting in dispersal of the individual achenes.

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In many other sedges, the spikelets are dispersed intact as shown here in *Kyllinga odorata* Vahl.

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In *Cyperus odoratus* L., the spikelets break apart into 1—2-fruited segments, each segment with achene and floral scale still attached. Moreover, in *C. odoratus* the rachilla axis contains spongy, suberized tissue that promotes dispersal by water.

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Dispersal of achenes by animals (zoochory), especially birds, is important in Cyperaceae. Zoochory may involve the internal (endozoic) transport of achenes within the digestive system or external (epizoic) transport. Achenes of *Carex, Cladium, Cyperus, Fimbristylis, Rhynchospora* and *Scirpus* have been identified in the alimentary systems of waterfowl (Ridley, 1930). Waterfowl and other birds consume large quantities of achenes, especially of *Cyperus* spp. and *Eleocharis* spp., and their endozoic transport plays an important role in dispersal of sedges over long and short distances (Ridley, 1930; Kern, 1974; Haines and Lye, 1983).

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The epizoic transport of achenes in mud adhering to the feet of migratory waterfowl is implicated in long-distance dispersal in *Cyperus, Eleocharis, Rhynchospora,* and *Scirpus* (Ridley, 1930; Kern, 1974).

The achenes of many species of *Eleocharis*, *Fuirena*, *Rhynchospora*, *Schoenoplectus* and *Websteria* are subtended by persistent bristles beset with barbs that readily attach to feathers or hair of animals (Kern, 1974; Haines and Lye, 1983).

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Cyperus plukenetii Fern. exhibits modifications that facilitate dispersal of intact spikelets by attachment to animal hair (Carter, 1993).

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A number of mechanisms involving dispersal of achenes by wind (anemochory) are known in Cyperaceae. For example, in *Scirpus cyperinus* a persistent perianth attached to the achene is modified into long, silky hairs promoting transport by wind.

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Also, the flattened, winged spikelets of certain *Kyllinga* spp. (Haines and Lye, 1983) promote wind-dispersal of the achenes retained within, and such dispersal of spikelets has been observed over short distances during the collection of specimens of the introduced weed *K. squamulata*, shown here.

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In a survey of 65 floras, weed lists, and journal articles for references to sedge weeds, we have found explicit citations of 449 spp. as weeds.

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We found references to 22 genera containing weeds in Cyperaceae. The top eight genera were *Cyperus* with 148 weedy spp. or 33% of the total; *Carex* with 83 spp. or 18%; *Eleocharis* with 52 spp. or 12%; *Fimbristylis* with 46 spp. or 10%; and *Scleria* with 24 spp. or 5%. Interestingly, 11 genera, one-half of the total, had five or fewer species cited as weeds.

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Here we identify genera that are exclusively C_3 with dark blue and exclusively C_4 with red. Mixed genera that are primarily C_3 are shown in light blue and those that are primarily C_4 in pink. *Cyperus*, by far the largest genus of weeds in Cyperaceae, is predominantly C_4, and it would appear that the majority of weedy sedges exhibit C_4 photosynthesis.

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In a general survey of literature for references to anthropogenic dispersal of sedges, we found citations of >250 spp.

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Among ways that sedges are *unintentionally* dispersed are ballast, rice agriculture, wool aliens, construction and maintenance of roads, movement of traffic along roads and railroads, and by airplane.

Intentional dispersal of sedges occurs through their use as ornamentals and for re-vegetation, erosion control, and water purification and in a variety of minor uses.

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Here we show the number of weedy species by genus that are known or suspected to be dispersed through human activity.

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The role of rice agriculture in dispersal of Asian sedges into the Americas has long been known. Among genera whose species have been dispersed through rice cultivation are *Bolboschoenus*, *Cyperus*, *Fimbristylis*, *Kyllinga* and *Schenoplectus*. *Fimbristylis miliacea* is widely distributed in the southeastern United States and was introduced into North America in colonial times through rice agriculture.

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Extensive highways throughout the United States support dispersal of many weeds including sedges such as *Carex oklahomensis*, which is spreading eastward along roadsides from the mid-western states.

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The tiny, wind-borne achenes of *Scirpus cyperinus* are well adapted to dispersal along highways, and this species is often locally abundant in ditches along roads in the southeastern United States.

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Sedges are also dispersed in contaminated hay & grass seed used for erosion control along highways.

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Cyperus hyalinus has been known from eastern Africa, Madagascar, Mauritius, India, Sri Lanka, tropical Australia (Queensland) and Malaysia, and it has recently been found in southern Florida adjacent to the Miami International Airport where it was apparently introduced by air-traffic.

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We found that 13% of the species subject to anthropogenic dispersal were transported as wool aliens; 7% each were transported with ship ballast, rice agriculture, and through use in re-vegetation and erosion control; and 3% were dispersed along roads and railroads. The great number of references to ornamental and cultivated sedges, 153 spp. or 53%, was not anticipated.

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A survey of horticultural literature shows a drastic increase in references to ornamental sedges in the past century! This indicates a need for increased research into the reproductive biology, physiology, and growth characteristics of ornamental sedges to determine which species may be safely used, and where, and which will likely become invasive. There is also a need for greater awareness about problems inherent in the unwise and irresponsible use of ornamental sedges and for additional measures to be taken toward intervention to prevent importation and transportation of ornamental Cyperaceae.

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Curiously, the paleotropical species, *Cyperus cyperoides,* was recently observed for sale in hanging baskets in Georgia.

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It is difficult, admittedly even for a cyperologist, to see the ornamental value of this species, but "there is no disputing taste" [*De gustibus non est disputandum*].

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Cyperus papyrus is cultivated in water gardens in tropical and subtropical areas around the World and has become naturalized in Florida. Based upon descriptions of its dominance of aquatic ecosystems in its native Africa, one may assume it will be invasive elsewhere.

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Similarly, *Cyperus involucratus* has been cultivated for more than 200 years and is widely introduced and naturalized in Florida and California.

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Within the last decade, a number of sedges have been reported to be invasive in natural areas in the southeastern United States.

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Among these is *Cyperus entrerianus*, about which Charles Bryson and David Rosen have given excellent presentations this afternoon. Although collections of this species from the United States have been found dating from 1941, *Cyperus entrerianus* was not correctly identified and reported in the United States until 1990.

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The aquatic sedge *Cyperus prolifer,* indigenous to eastern Africa, is widely sold as an ornamental for use in water gardens. In 1996, it was reported naturalized in central peninsular Florida, where it has invaded the edges of natural karst ponds, forming floating mats. In 1997, naturalized populations of *Cyperus prolifer* were reported in Hawaii (Strong & Wagner, 1997).

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Cyperus alopecuroides is native to and widely distributed in the paleotropics. It has long been naturalized in the West Indies and in 1996 was reported as naturalized in Florida. This robust, aggressive perennial, produces numerous, small achenes and forms extensive floating mats in reclamation wetlands. Although it has only been found in heavily disturbed wetlands in central Florida, it appears to have the potential to invade natural wetlands and karst ponds.

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In 2001, the robust, emergent sedge *Scleria lacustris,* long known from tropical Africa and South America, was reported from open marshes in peninsular Florida by Colette Jacono. This species appears to be rapidly dispersing in Florida.

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In 2004, *Eleocharis mutata* was reported in a coastal fresh marsh community in southeastern Texas by David Rosen and Stanley Jones.

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Eleocharis acutangula has recently been found as an invasive in natural areas of southern Florida. At one site in Lee County, a severe infestation covers an estimated 11 acres.

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Oxycaryum cubense is widely distributed in the tropics and subtropics of Africa and the Americas. In the southeastern United States, it occurs sporadically in Florida, southern Georgia, southern Alabama, Louisiana, and coastal Texas. This aquatic sedge invades ponds, lakes, ditches or impounded swamps where it forms extensive floating mats covering large areas to the exclusion of other aquatic vegetation. *Oxycaryum cubense* has been in the United States for more than a century and was probably dispersed into North America from the West Indies or South America by migratory birds or with ships' ballast.

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Two forms differing only in gross inflorescence features occur throughout the range of the species. Plants with umbellate inflorescences are called forma *cubense*, while those with monocephalous inflorescences are called forma *paraguayense*. Its corky, buoyant achenes are adapted to dispersal by water, and its mat-forming, floating habit facilitates asexual reproduction and transport of vegetative fragments by moving water.

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Because sedges are adapted to a wide variety of habitats and are readily dispersed by humans, most any natural community could be subject to invasion. The increased horticultural use of sedges, especially of aquatic species, poses a particular threat to hydric ecosystems and wetlands.

Also, the Asian species, *Carex kobomugi*, has invaded coastal dunes along the mid-Atlantic coast of eastern North America, and there are a number of *Cyperus* species well adapted to open sands that could become invasive along coasts or on inland dunes, e.g.,

- *Cyperus arenarius* Retz. currently ranging from southern Iran through Pakistan, India and Ceylon into Indochina;
- *C. crassipes* Vahl, an inhabitant of sandy seashores and riverbanks in coastal southeastern Africa;
- *C. stoloniferus* Retz., a vegetative colonizer of coastal sands, currently ranging from Pakistan and India to China and northern Australia;
- and our indigenous North American species *C. dentatus*, *C. lecontei* and *C. onerosus* are similarly adapted and could pose threats elsewhere.

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In conclusion

- Sedges are highly competitive and well adapted for dispersal and to diverse environmental conditions and human disturbance.
- The continued disturbance of ecosystems by humans will promote invasion by additional sedge species.
- The unprecedented frequency of distant travel by humans and transportation of cargo will continue, increasing the probability of long-distance dispersal of sedges.
- Heightened interest in the use of sedges as ornamentals will increase the intentional dispersal of a greater diversity of sedge species.
- As a greater diversity of non-indigenous sedges is introduced, the potential for occupation of a much greater array of ecological niches will increase.
- If the importation and movement of sedges is not regulated and curtailed, natural communities that were previously little threatened by non-indigenous sedges will be placed at risk; e.g., aquatic systems, wetlands, forests, grasslands, beaches & dunes.

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Possible solutions include

- Increased emphasis in university curricula on systematic botany, field botany & plant ecology;
- Increased support for thorough floristic inventories of natural areas;
    - Short-term support to obtain reliable base-line data on the current state of ecosystems;
    - Long-term support to monitor ecosystems for changes;
- Increased interdisciplinary collaboration among botanists, weed scientists, horticulturists, restoration ecologists, natural resource managers, and representatives of governmental agencies; and
- Increased international collaboration to exchange data and ideas about actually and potentially invasive species at home and abroad

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Without vigilance and action, this could become….

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….this!

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Thank you.