Journal of the Torrey Botanical Society 134(1), 2007, pp. 126–134

First report of *Carex macrocephala* in eastern North America with notes on its co-occurrence with *Carex kobomugi* in New Jersey[1]

Louise Wootton[2,3]

Department of Biology, Georgian Court University, 900 Lakewood Avenue, Lakewood, NJ 08701

Louise Wootton (Department of Biology, Georgian Court University, 900 Lakewood Avenue, Lakewood, NJ 08701). First report of *Carex macrocephala* in eastern North America with notes on its co-occurrence with *Carex kobomugi* in New Jersey. Torrey Bot. Soc. 134: 126–134. 2007.—The discovery of three populations of the large-headed sedge, *Carex macrocephala*, in New Jersey described in this paper, represents the first report of this species from Eastern North America. *Carex macrocephala* grows at much lower densities in New Jersey than does the closely related Asiatic sand sedge, *Carex kobomugi*. We thus expected invasion by *C. macrocephala* to have less impact of on the abundance and diversity of native dune plants than have been seen in previous studies of the closely related invasive sedge, *C. kobomugi*. This expectation was largely supported: the presence of *C. macrocephala* in New Jersey's coastal dunes had no significant impact on the abundance of co-occurring plant species. Indeed, species richness and diversity were actually significantly higher in areas occupied by *C. macrocephala* than in surrounding areas. New Jersey appears to be one of the few places in the world where *C. macrocephala* grows in close proximity to *C. kobomugi*, suggesting the possibility of hybridization between these species in the future. Since hybrids have the potential to be more invasive than their parent species, this has serious management repercussions.

Key words: *Carex kobomugi*, *Carex macrocephala*, coastal sand dunes, exotic species, impact on species diversity, New Jersey, species richness.

The large-headed sedge *Carex macrocephala* Willd. ex Spreng has an amphipacific distribution. It is found on sandy coastal dunes in Japan where it is occasionally planted as a dune stabilizer (Ohmasa 1956). It is also found in the Russian Far East and Northern China, as well as on the West Coast of North America, from Alaska to Oregon (Flora of North America Editorial Committee 2003). Its status has not been ranked in Alaska or Washington, but the species is considered to be "vulnerable" in Oregon and "vulnerable to secure" in British Columbia (Douglas et al. 2001, Kartesz 1994). However, until now, the species had not been observed on the East Coast of North America.

Until being recognized as a separate species by Ohwi in 1930, *Carex kobomugi* was considered to be a variety of *C. macrocephala* (Flora of North America Editorial Committee 2003). Native to Asia, *C. kobomugi* grows in sandy coastal dunes from Russia, China, Japan, Korea and Taiwan. It was reported to have been introduced into Portland, Oregon in the early 1900s, but is believed to subsequently have been extirpated from this region, perhaps as a result of habitat loss (Kartesz 1994). *Carex kobomugi* was first observed in North America on the New Jersey shore in 1929 (Small 1954). Because the first stand was observed near the site of one of the original "Life Saving Stations" on the Jersey Shore, it was initially suggested that the species might have been used to package oriental porcelain, crates of which might have washed up and been salvaged by locals after one of the many shipwrecks taking place on the Jersey Shore at the turn of the century, releasing the plant or its seeds to the surrounding dunes (Small 1954). However, there is actually no evidence that *C. kobomugi* was ever used as packing

[1] This study was supported by funding from the Ademas Foundation, the Anderson Rogers Foundation, Wal-Mart and the National Sea Grant College Program of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration under NOAA grant #NA16RG107. e views expressed herein do not necessarily reflect the views of any of those organizations. This is Sea Grant publication NJSG-06-622.

[2] This project could not have been conducted without the cooperation and support received from staff and managers at both Sandy Hook Unit and Seven President's Oceanfront Parks. Jim Burkitt, Katy Bevaart, Kathleen Brown, Audrey McGough, Emily Parker and Courtney Rella helped with the counting and mapping effort. Jim Burkitt also created the map used in Figure 1. Grateful thanks are extended to Linda Kelly, Robert Naczi and Michael Gross and two anonymous reviewers for reading drafts of this manuscript and for their many insights and helpful suggestions for its improvement.

[3] E-mail: wootonl@georgian.edu

Received for publication February 23, 2006, and in revised form September 10, 2006.

material and, since this species is relatively rare in its native range (Shin-Ichi Ishikawa, Gunma University, Japan, pers. comm.), extensive use of this species for this purpose seems unlikely. It seems more probable that shoots or seeds were included in solid or liquid ballast collected from portside locations within the Orient and released in New Jersey when ships de-ballasted before entering the ports of Newark or New York.

However it got here, *C. kobomugi* is currently found on a number of coastal sand dunes on the East Coast of North America; from North Carolina to Rhode Island. A small stand reported from a gravel quarry in Massachusetts (Svenson and Pyle 1979) appears to have been extirpated (Massachusetts Invasive Plant Advisory Group 2005). However, the species is particularly abundant in New Jersey, where it has expanded into many of the State's remaining coastal dune systems. While some of this expansion has presumably resulted from natural propagation, the plant also received a great deal of help in its expansion from human hands since, in the 1960s, the Cape May Plant Materials Center (CMPMC) developed the 'Sea Isle' (PI-433953) clone of *C. kobomugi* for use as an alternative to American Beachgrass (*Ammophila breviligulata* Fern) for dune stabilization. By the mid-1970s, tens of thousands of these plants had been distributed and planted throughout New Jersey, Delaware, Maryland and Virginia (Shisler et al. 1987). The species is no longer propagated by CMPMC and is currently considered to be invasive in the coastal dune systems of Mid Atlantic North America (Plant Conservation Alliance, Alien Plant Working Group 2005). Recent studies (Wootton et al. 2005) have shown that native plant diversity is strongly depressed wherever *C. kobomugi* occurs, suggesting that the expansion of this species has serious consequences for the abundance and diversity of native species. The species also threatens many rare or endangered species, including piping plovers (*Charadrius melodus* Ord), beach tiger beetles (*Cicindela hirticollis* Say) and seabeach amaranth (*Amaranthus pumilus* Raf.) through direct competition or reduction of appropriate habitat or food availability.

Materials and Methods. STUDY SITE DESCRIPTION. Seven Presidents Oceanfront Park (hereafter referred to as "Seven Presidents") is a 38 acre (15.5 ha) coastal Park located in Monmouth Beach, New Jersey (Fig. 1). It is part of the Monmouth County Park System. While much of the park is heavily used for recreation, and the entire park is bordered by roads and heavily developed suburban areas, there are several larger dunes areas within the park that are home to populations of *Amaranthus pumilus* and *Charadrius melodus*, among other native species. However, throughout most of the park, the dune systems are strongly foreshortened by the presence of boardwalks, playgrounds and other human-associated land uses.

SURVEY METHODS. Since 2001, my students and I have been walking the coastal dunes within New Jersey and mapping the position, size and shape of any stands of *Carex kobomugi* encountered, using differential GPS units (Leica GS5+). In the summer of 2004 we surveyed a stand of putative *C. kobomugi* at Seven Presidents. We were struck by the different growth patterns exhibited by the plants at this location relative to those seen in *C. kobomugi* elsewhere in the state (much lower shoot density, but with more sturdy and lush individual shoots, notably larger and darker-colored seed-heads, and perigynia with sharp distal beaks and proximate lacerate wings). Based on these observations, we suspected that this population was not *C. kobomugi*, but rather was *C. macrocephala*. In August, 2005 we collected and archived several specimens which were sent to local botanist Linda Kelly, New Jersey's State Botanist, David Snyder, and to Robert Naczi, Curator of the Claude E. Phillips Herbarium in Dover, Delaware for formal identification. Linda Kelly, David Snyder and Robert Naczi all confirmed that the plants observed and collected from primary and secondary coastal dunes at Seven Presidents were indeed *Carex macrocephala*. Specimens of *Carex macrocephala* have been deposited at the Claude E. Phillips Herbarium, at the New York Botanical Garden (L. Wootton [sic] and L. Kelly s.n.) and at the Georgian Court University Herbarium (GCU) (M. Gross, L. Kelly and L. Wootton s.n., GCU accession numbers 349 and 350). For comparison, *C. kobmugi* specimens are available at GCU (M. Gross, L. Kelly and L. Wootton s.n., GCU numbers 347 and 348).

To compare the relative impact of the two exotic sedges (*Carex macrocephala* and *Carex*

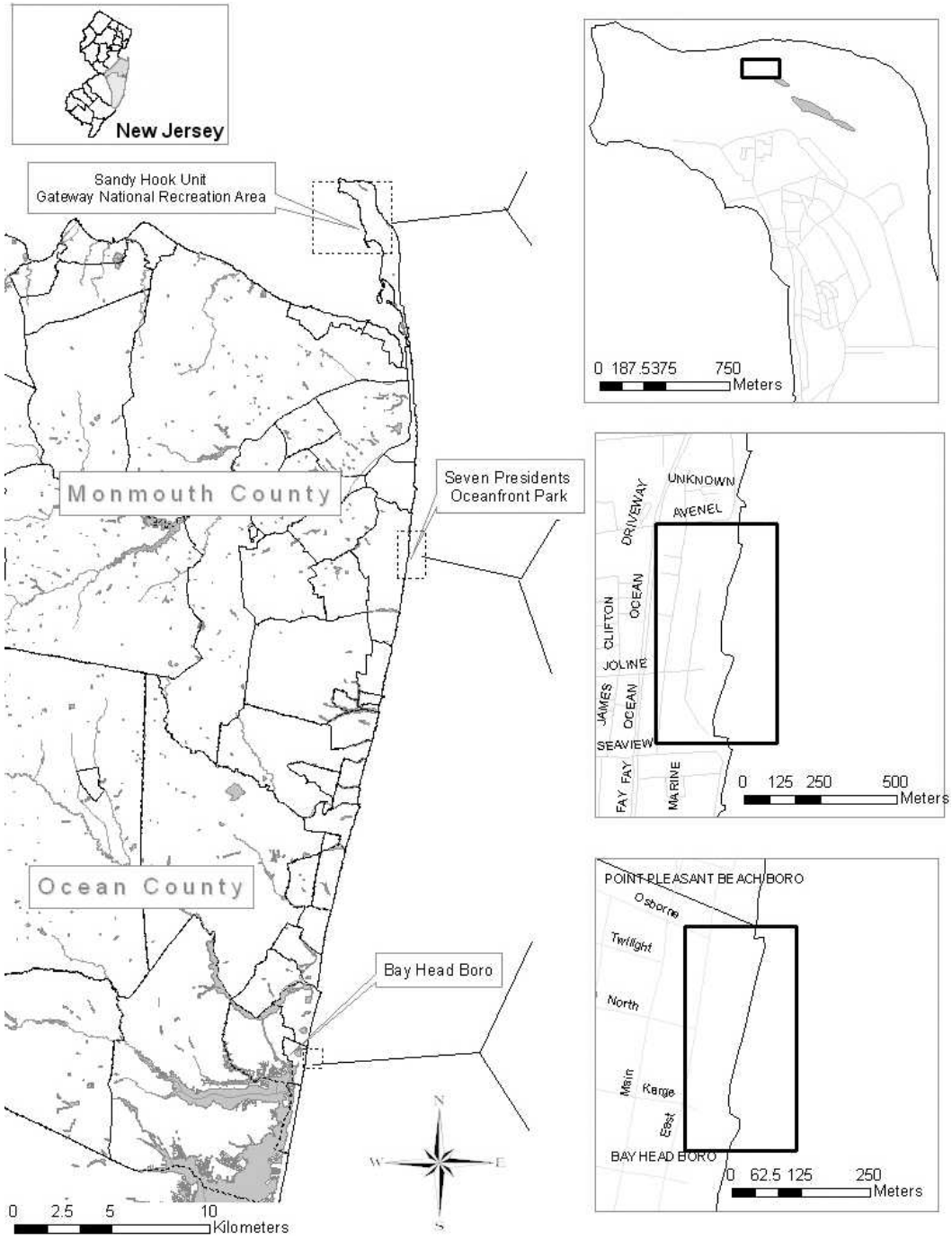

FIG. 1. Locations of known stands of *Carex macrocephala* and *C. kobomugi* in New Jersey.

kobomugi) on native dune plant species composition, *C. macrocephala* stem densities and overall species composition were determined using the methods of Shisler et al. (1987). Specifically, a systematic sampling design was used to locate sample sites within each major *C. macrocephala* stand at Seven Presidents. We then identified and counted all plants within a $1m^2$ circular area (radius between fixed and moveable stake =

56.5 cm) at each sampling location until the sampled area represented a minimum of 1% of the overall area of each stand. To assess the species composition in areas unaffected by *C. macrocephala*, similar plots were also established at multiple points 5 m outside both the seaward and landward edges of the stand, and at both ends. Two control plots were also established to answer concerns that comparison of species in affected areas to those in a 5 m ring around that area may result in artifacts, since areas seaward of the stands include unvegetated upper beach areas rather than dunes, and areas landward of the same stands potentially include areas in the higher diversity uplands. The control plots were of similar size (ca. 50–60 m N → S and 25–30 m E → W), and in similar locations on the dune, as a typical population of *C. macrocephala* or a small *C. kobomugi* population, but were located within healthy stands of *Ammophila breviligulata*. One of these plots was located at Island Beach State Park (near parking lot A-14), while the other was located just north of the bathing pavilion at Seven Presidents. Species composition and number of plants in these plots were assessed as for those within the stand. All plant identifications were made using Gleason and Cronquist (1991).

Species richness was calculated by simply totaling the number of species observed in each 1-m^2 plot sampled. Species diversity for each 1-m^2 plot sampled was calculated using a Shannon-Weiner diversity index. Species diversities and richness, as well as mean stem densities for each species encountered within plots inside and outside the stands at each location and within control plots, were compared using an ANOVA followed by post-hoc analysis using Least Squared Difference (LSD) tests for those data sets meeting the requirements for homogeneity of variance and Dunnett's T3 tests for those that did not. All analyses were run using the Statistical Program for Social Sciences (SPSS) 13.0. These data were then compared with previously published data collected using the same methods (Wootton et al. 2005) for areas invaded by *Carex kobomugi* at Island Beach State Park (a barrier peninsula park located in Ocean County, New Jersey), and Sandy Hook (another barrier peninsula park at the northern tip of the New Jersey coast).

Results. At least 8 separate patches of *Carex macrocephala* were found at Seven Presidents. Some of these were separated only by beach access pathways, but others were separated by areas of dune dominated by *Ammophila breviligulata*. Patch sizes ranged from about 400 to 900 m^2 with a total impacted area of approximately 4800 m^2. Since that time, two additional populations of this species have been identified from New Jersey's coastal dunes. The first of these is a population of a similar size to that at Seven Presidents Park that is growing in front of a number of waterfront homes on a primary dune in Bay Head, New Jersey. The second is a much smaller population (< 1000 ramets) that is growing in a dune swale behind a dune system stabilized by *C. kobomugi* at the North End of Sandy Hook. The stand of *C. macrocephala* at Bay Head is disjunct from other stands of both *C. kobomugi* and *C. macrocephala*, with the nearest substantial stands of the former being more than ten kilometers south at Island Beach State Park, and the stands of the latter at Seven Presidents being tens of kilometers to the north (Fig. 1). However, there are several populations of *C. kobomugi* less than half a kilometer north of the *C. macrocephala* population at Seven Presidents and populations of the two species are separated by less than 20 meters on the dunes at Sandy Hook (Fig. 1).

Stem densities of *Carex macrocephala* were an order of magnitude lower than those typically observed for *C. kobomugi* in New Jersey (Table 1). Mean species richness and species diversity of plots in areas invaded by *C. macrocephala* at Seven Presidents were actually significantly higher than those outside the stand, but were similar to those in the *Ammophila breviligulata*-dominated "control bed" at that location. These results contrast with those reported for *C. kobomugi* at Sandy Hook (Wootton et al. 2005), where species richness and diversity were lower within invaded areas than in the surrounding dunes (Table 1), but were similar to the results for *C. kobomugi* at Island Beach State Park. Abundances of other common plant species within the *C. macrocephala* beds were not significantly different than those in the areas immediately surrounding the affected areas, or from those in the *A. breviligulata*-dominated "control beds", and, indeed, sometimes appeared to be somewhat higher in areas where the species co-occurred with *C. macrocephala* (Table 1). By contrast, abundances of *A. breviligulata* were significantly lower in areas occupied by

Table 1. Comparison of species richness, species diversity and shoot densities / m^2 of native species within and outside *Carex kobomugi* stands (Sandy Hook and Island Beach State Park) in 2001 (data from Wootton et al. 2005 reanalyzed to show SEs rather than SDs) and those within and outside *Carex macrocephala* stands (Seven Presidents) in 2004 (this study). For each comparison within site and species, means denoted with the same letter are statistically similar. Means denoted with different letters within the same row are statistically different at the $P < 0.05$ level.

	Sandy Hook *C. kobomugi* (± SE)		IBSP *C. kobomugi* (± SE)		Seven Presidents Park *C. macrocephala* (± SE)		IBSP Control Bed (± SE)	Seven Presidents Control Bed (± SE)
	Inside Stands $n = 397$	Outside Stands $n = 227$	Inside Stands $n = 712$	Outside Stands $n = 490$	Inside Stands $n = 139$	Outside Stands $n = 129$	$n = 48$	$n = 83$
Species richness (species m^{-2})	2.51 ± 0.05 [d]	2.25 ± 0.10 [c, d]	2.31 ± 0.04 [c, d]	1.63 ± 0.06 [a]	2.58 ± 0.10 [d]	1.87 ± 0.12 [a, b]	2.02 ± 0.11 [b, c]	2.33 ± 0.13 [c, d]
Species diversity (H')	0.30 ± 0.01 [b]	0.46 ± 0.03 [c]	0.32 ± 0.01 [b]	0.32 ± 0.02 [b]	0.52 ± 0.03 [c]	0.30 ± 0.04 [b]	0.20 ± 0.03 [a]	0.47 ± 0.04 [c]

	Mean number of shoots (± SE)		Mean number of shoots (± SE)		Mean number of shoots (± SE)		Mean number of shoots (± SE)	Mean number of shoots (± SE)
Carex macrocephala					10.2 ± 1.0			
Carex kobomugi	174.8 ± 4.4		123.0 ± 2.8					
Ammophila breviligulata	7.66 ± 0.76 [a]	14.49 ± 1.54 [b]	7.61 ± 0.42 [a]	17.23 ± 1.06 [b]	30.19 ± 2.99 [cd]	35.14 ± 4.52 [d]	44.08 ± 2.35 [e]	28.00 ± 2.12 [c]
Solidago sempervirens	0.97 ± 0.12 [a]	3.25 ± 0.69 [b]	2.23 ± 0.17 [b]	2.6 ± 0.2 [b]	0.64 ± 0.29 [a]	0.25 ± 0.08 [a]	0.56 ± 0.29 [a]	0.13 ± 0.07 [a]
Euphorbia polygonifolia	0.00 ± 0.00 [a]	0.02 ± 0.01 [a]	0.42 ± 0.06 [a]	2.04 ± 0.31 [b]	1.03 ± 0.54 [a, b]	0.33 ± 0.14 [a]	0.27 ± 0.08 [a]	1.72 ± 0.87 [b]

C. kobomugi than in the areas immediately surrounding the bed at both Sandy Hook and Island Beach. Similarly, abundances of *Solidago sempervirens* L. were significantly negatively impacted by the presence of *C. kobomugi* at Sandy Hook, while those of *Euphorbia polygonifolia* L. were significantly decreased in the presence of *C. kobomugi* at Island Beach (Table 1).

Discussion. The pathway of the introduction of *Carex macrocephala* into New Jersey is unclear. After its accidental introduction into the US, *Carex kobomugi* was deliberately propagated by the Cape May Plant Materials Laboratory (CMPML) and was widely distributed through local nurseries for planting as a dune stabilizer (Shisler et al. 1987). However, the ''Sea Isle'' clone of *C. kobomugi* distributed by CMPML was certified for purity, so it seems unlikely that *C. macrocephala* was accidentally distributed as part of this stock. There is also no evidence that *C. macrocephala* plant stock was deliberately sold within the state. Another possible vector is the accidental introduction of propagules contained in ballast water offloaded from a ship before entering the port systems of New York or New Jersey. However, perhaps the most likely pathway of introduction for the Seven Presidents and Bay Head populations is propagation from *C. macrocephala* seed obtained from seed distributors on the West Coast or overseas, where the plant is native. Dispersal of seeds or clones from the Seven Presidents population during a storm that over-washed the dunes at Sandy Hook would then be the most likely source for the population in the dune swale at that location. *Carex macrocephala* seeds are readily available for purchase from several commercial vendors today (e.g., Sandeman Seeds, Berkutenko Seeds, etc.), so I assume that the same would have been true in the past. Park managers and homeowners may even have found outdated references suggesting that *C. macrocephala* was a synonym for *C. kobomugi* and thought that they were planting the same species as the *C. kobomugi* that was being marketed as plant stock by local nurseries.

Carex kobomugi and *C. macrocephala* are rather similar in appearance, perhaps explaining why the latter species was able to thrive right next to highly trafficked boardwalks in Seven Presidents as well on the highly developed oceanfront of Bay Head, NJ, without the existence of this species in New Jersey having previously been recognized. Both have similar shaped leaves, with notable serration or serulation being present on the leaf edges. Both show paradioecy (male and female inflorescences on separate shoots, but both male and female shoots produced by an individual clone) (Standley 1983 and pers. obs.). The general appearance of the seed heads is similar, although the seed heads of *C. macrocephala* are usually larger and contain darker colored perigynia that have much sharper, bidentate beaks. Features used to diagnose between the species include the angle of culm branching, the size of the proximal pistillate scales and the length of the anthers (Flora of North America 2003).

A major difference noted between these two species of *Carex* on New Jersey's coastal dunes was that the clone of *C. kobomugi* found in New Jersey tends to form extremely dense mats (Table 1) with maximum shoot densities of over 500 m^{-2} (Wootton et al. 2005). By contrast, *C. macrocephala* in New Jersey showed much less dense growth patterns (Table 1) with maximum stem densities rarely exceeding 40 m^{-2}. Thus, when seen side by side in New Jersey, *C. macrocephala* is easily distinguished from the more mat-forming *C. kobomugi* by its more robust and deeper green shoots and sparse growth pattern. It is possible that the differences in growth pattern have to do with the age of the two populations: if the *C. macrocephala* populations are younger than the *C. kobomugi* stands, they might not yet have had the chance to fill in fully. It is unclear when *C. macrocephala* was introduced in Seven Presidents, since historical records of the park's flora are unavailable. However, an environmental impact study carried out in 1977, when the park was added to the Monmouth County park system, documents the presence of an ''unidentified ornamental grass'' which may, or may not have been this species (Environmental Assessment for Green Acres Local Assistance Program 1977). In addition, each of the patches of *C. macrocephala* at Seven Presidents is tens of meters long and wide, suggesting a stand-age of at least several decades, based on growth rates from *C. kobomugi* (growth rates of *C. macrocephala* are, as yet, unavailable). In my experience, stem densities of *C. komomugi* in similar sized patches in New Jersey are usually

at least an order of magnitude higher than those seen for *C. macrocephala* at Seven Presidents. Moreover, in their native range, stem densities of both *C. macrocephala* and *C. kobomugi* are much lower than those seen for *C. kobomugi* in New Jersey (Shin-Ichi Ishikawa, Gunma University, Japan; Andrey Kozhevnikov, Institute of Biology and Soil Science, Vladivostok, Russia, pers. comm.). It appears that the dense growth pattern for the *C. kobomugi* clone in New Jersey is atypical of this species elsewhere in the world, whereas growth patterns of *C. macrocephala* are similar to those of this species elsewhere in its range. It seems more likely, then, that the differences in stem densities between the two species represent real differences in the growth patterns of the clones present in New Jersey, rather than being due to the immaturity of the *C. macrocephala* population at Seven Presidents.

The difference in stem densities between *Carex kobomugi* and *C. macrocephala* populations in New Jersey was expected to correspond to a strong difference in the impact of these two closely related exotic sedges on the native species diversity within coastal dunes. The lack of detectable decreases in the abundance of other plant species within *C. macrocephala* beds relative to the plots five meters outside those beds, or to the *Ammophila breviligulata*-dominated ''control bed'' at that site, while significant differences were noted for several species in *C. kobomugi* beds at both Island Beach State Park and Sandy Hook, supports this expectation (Table 1). Indeed, the species richness and diversity were actually higher within *C. macrocephala* beds than in the areas immediately surrounding them. This may reflect, in part, the fact that about a third of the plots outside the *C. macrocephala* beds were in the seaward direction, where there were few, if any plants. The inclusion of multiple zeros within the data set for plots outside the *C. macrocephala* populations strongly depressed the calculated mean species richness and diversity in this data set. However, the same is true of the data collected for inside versus outside *C. kobomugi* beds at Sandy Hook, where the opposite result was found (Table 1). Wootton et al. (2005) speculated that the reason for the higher species richness observed in *C. kobomugi* beds relative to the surrounding areas at Island Beach State Park might be high levels of human impact at that location. They suggest that these human impacts lower species richness within dunes not invaded by *C. kobomugi* sufficiently that, when the sedge invades, it actually adds to, rather than detracting from, the number of species found in these areas. The fact that the *A. breviligulata*-dominated ''control bed'' at Island Beach also had significantly lower species diversity than the areas impacted by *C. kobomugi,* supports the hypothesis that *C. kobomugi* is actually filling a previously species depauperate community at that location. Since the dunes at Seven Presidents are also highly impacted by human activities, the same effect may be in play there. However, unlike Island Beach, the *A. breviligulata* control bed at Seven Presidents had similar species richnesses and diversities to the areas affected by *C. macrocephala.* This again suggests that *C. macrocephala* has little impact the communities where it grows, neither reducing native species abundance or diversity, nor significantly adding to species richness or diversity (Table 1).

One tantalizing question raised by the presence of both of these closely related species within New Jersey is the possibility of hybridization. While a number of instances of hybridization between closely related *Carex* species are known (e.g., Hoshino and Waterway 1994, Standley 1990, Waterway 1990, Whitkus 1988), I was unable to find any references to hybridization between *C. kobomugi* and *C. macrocephala* within the literature. However, it is unclear whether this absence reflects the presence of biological isolation between the species, or whether this is more a reflection of geographical isolation between them within their native ranges. In general, the range of *C. macrocephala* is more northerly than is that of *C. kobomugi.* Even where, on paper, the two species' ranges do overlap, the two species rarely grow together. For example, in Japan, *C. kobomugi* is distributed mainly in southern Hokkaido whereas *C. macrocephala* grows mainly in northern areas of that island. Similarly, on the main island, *C. macrocephala* grows only in Aomori, which is at the northward edge of the Japanese Main Island, close to Hokkaido, whereas *C. kobomugi* tends to be found in coastal areas from Okinawa to the Main Island, but not in Aomori (Shin-Ichi Ishikawa, Gunma University, Japan, pers. comm.). In the Western US, a small population of *C. kobomugi* has recently been identified on the Washington coast, only a few meters from a native population of *C. macrocephala.*

However, so far this stand of *C. kobomugi* has produced only female flowering heads, and these do not develop to maturity, thereby precluding effective hybridization in this location to date (Matthew King, Washington State University, pers. comm.). However, in New Jersey, populations of the two species are now growing within tens of meters of one another, and both species are producing large numbers of both male and female flowers. Moreover, the female flowering heads of both species commonly develop to maturity in this area. Since these species flower at the same times in New Jersey and are both wind pollinated, cross-fertilization between the two species at both Seven Presidents and Sandy Hook seems possible.

The potential for hybridization between these two sedges is of special concern, since a number of studies have shown that hybrid species may demonstrate increased invasiveness relative to either parent species, reflecting increased vigor within the hybrid species (Ellstrand and Schierenbeck 2000, Facon et al. 2005). While no examples of increased invasiveness of hybrids in genus *Carex* are known (insight offered by anonymous reviewer), further studies to see if fertile hybrids are forming between these species would still seem prudent. For example, if hybridization is occurring, we would expect to find cells with chromosome numbers intermediate between those of the two parent species (2n = 88 for *C. kobomugi* (Anonymous N. D.), 2n = 74 or 78 for *C. macrocephala* depending on which strain has been introduced to New Jersey (Flora of North America Editorial Committee 2003)). Similarly, we would expect to see intermediate macromorphological (plant size, shape, growth patterns, flower size and shape etc.) and micromorphological (pollen shape and size, seed surfaces (observed via SEM), etc.) characteristics in plants within the contact zone. In addition, to reduce the chances of possible hybridization, managers may want to consider rapid removal of *C. macrocephala*, particularly from the Seven Presidents and Sandy Hook locations where *C. kobomugi* populations are present in close proximity to this species.

Literature Cited

Anonymous, N. D. 2005. *Carex kobomugi*. Retrieved February 12, 2005. <http://flowers.la.coocan.jp/Cyperaceae/Carex%20kobomugi.htm>

Douglas, G. W., D. Meidinger, and J. Pojar, eds. 2001. Illustrated Flora of British Columbia, Vol. 6, Monocotyledons (Acoraceae through Najadaceae). B.C. Minist. Environ., Lands and Parks, and B.C. Minist. For.. Victoria, BC. 361 p.

Ellstrand, N. C. and K. A. Schierenbeck. 2000. Hybridization as a stimulus for the evolution of invasiveness in plants? Proc. Natl. Acad. Sci. USA 97(13): 7043–7050.

Environmental Assessment for Green Acres Local Assistance. 1977. Seven Presidents Oceanfront Park, Long Branch, Monmouth County, New Jersey, Prepared by Monmouth County Park System, P.O. Box 326, Newman Springs Road (now just 805 Newman Springs Road), Lincroft, NJ. Page 10, section f. Terrestrial Ecology.

Facon, B., P. Jarne, J. P. Pointier, and P. David. 2005. Hybridization and invasiveness in the freshwater snail *Melanoides tuberculata*: hybrid vigour is more important than increase in genetic variance. J. Evol. Bio. 18: 524–535.

Flora of North America Editorial Committee. 2003. Flora of North America Volume 23: Magnoliophyta: Commelinidae (in part): Cyperaceae. Retrieved December 27, 2005. <http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=302714>

Gleason, H. A. and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. Second Edition, New York Botanical Garden, Bronx, NY. 910 p.

Hoshino, T. and M. J. Waterway. 1994. Cytogeography and meiotic chromosome configurations of six intraspecific aneuploids of *Carex conica* Boott (Cyperaceae) in Japan. J. Plant Res. 107: 131–138.

Kartesz, J. T. 1994. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. 2nd edition. 2 vols. Timber Press, Portland, OR.

Massachusetts Invasive Plant Advisory Group. 2005. *Final Report*: "The Evaluation of Non-Native Plant Species for Invasiveness in Massachusetts". Retrieved December 27, 2005. <http://www.mass.gov/dfwele/dfw/nhesp/findingslistapr05.pdf>

Ohmasa, M. 1956. Tree planting practices in Temperate Asia: Japan. (Forestry Dept. Paper 10), - FAO, Rome. 156 p.

Plant Conservation Alliance, Alien Plant Working Group. 2005. Fact sheet: Asiatic sand sedge. Retrieved July 18, 2006. <http://www.nps.gov/plants/alien/fact/cako1.htm>

Shisler, J. K., R. N. Wargo, and R. A. Jordan. 1987. Evaluation of Japanese sedge, *Carex kobomugi*, for use in coastal dune planting and stabilization. New Jersey Agricultural Experiment Station Publication # P-40502-03-87. New Brunswick, NJ.

Small, J. A. 1954. *Carex kobomugi* at Island Beach, New Jersey. Ecology 35: 289–291.

Standley, L. A. 1983. *Carex kobomugi* Owhi, an adventive sedge new to New England. Rhodora 85: 265–267.

Standley, L. A. 1990. Allozyme evidence for the hybrid origin of the maritime species *Carex*

salina and *Carex recta* (Cyperaceae) in Eastern North America. Syst. Bot. 15: 182–191.

SVENSON, H. K. AND R. W. PYLE. 1979. The flora of Cape Cod: An annotated list of the ferns and flowering plants of Barnstable County, Massachusetts. The Cape Cod Museum of Natural History, Brewster, MA. 139 p.

WATERWAY, M. J. 1990. Genetic differentiation and hybridization between *Carex gynodynama* and *C. mendocinoensis* (Cyperaceae) in California. Am. J. Bot. 77: 826–838.

WHITKUS, R. 1988. Experimental hybridizations among chromosome races of *Carex pachystachya* and the related species *C. macloviana* and *C. preslii* (Cyperaceae). Syst. Bot. 13: 146–153.

WOOTTON, L., S. HALSEY, K. BEVAART, A. MCGOUGH, J. ONDREIKA, AND P. PATEL. 2005. When invasive species have benefits as well as costs: Managing *Carex kobomugi* (Asiatic sand sedge) in New Jersey's coastal dunes. Biol. Invasions 7: 1017–1027.