CASTANEA 76(3): 293–299. SEPTEMBER 2011

Scientific Note

Invasion of a Southeastern Pine Savanna by Japanese Climbing Fern

Ellen R. Leichty,* Becky J. Carmichael, and William J. Platt
Department of Biological Sciences, Louisiana State University, 107 Life Sciences Building, Baton Rouge, Louisiana 70803

1 *Lygodium japonicum* (Thunb. ex Murr.) Sw. is an invasive fern in the southeastern United States. This perennial fern, which produces twining fronds from underground rhizomes (Clarke 1936), is native to open forests and forest edges in temperate, subtropical and tropical regions of eastern and southeastern Asia, East Indies, and northern Australia (Singh and Panigrahi 1984, Munger 2005, Willis et al. 2006). *Lygodium japonicum* was introduced to North America as an ornamental; the first known wild populations were recorded in Georgia in 1903 (Pemberton and Ferriter 1998), but this fern is now widespread in the southeastern United States. Japanese climbing fern occurs in human-modified habitats, as well as forests and woodlands (Langeland and Burks 1998, Rosen et al. 2003), where it often forms dense mats that grow on and cover native species (Gagnon et al. 2005, Zeller and Leslie 2004). Some management plans have emphasized the dearth of scientific data on invasions by climbing ferns (e.g., Ferriter 2001).

Lygodium japonicum has been noted as present in pine savannas. Nonetheless, there is minimal documentation of invasion of pine savannas by this fern in the literature, although it has been designated a threat to southeastern pine savannas (Munger 2005, Stocker and Hupp 2008) and invasion of pine savannas has been hypothesized to be facilitated by fires (e.g., Wade et al. 2000). Pine savannas (sensu Platt 1999) have been reduced to less than 3% of their original extent by fragmentation and fire suppression, and most that remain are degraded (Platt 1999, Varner et al. 2005, Means 2006). Invasion by *L. japonicum* thus could have major consequences for these fire-frequented ecosystems containing species rich and endemic groundcover vegetation (Sorrie and Weakley 2006).

Mesic pine savannas may be particularly vulnerable to invasion by *L. japonicum*. *Lygodium japonicum* tends to be intolerant of extreme drought and/or flooded conditions (Bargeron et al. 2008), suggesting that old-growth mesic pine savannas with mixed sandy-clay soils ideal for fern growth may be susceptible to invasion (e.g., the Wade Tract; Platt et al. 1988). Such pine savannas also tend to have pronounced biodiversity at small scales (Peet 2006, Platt et al. 2006, Carr et al. 2009). Might invasion by a species capable of forming mats on top of existing groundcover plants compromise the high biodiversity of mesic pine savannas?

Lygodium japonicum has been present at Girl Scout Camp Whispering Pines in eastern (Tangipahoa Parish) Louisiana for more than two decades. This upland, mesic site, described in Platt et al. (2006), historically contained pine savannas with a two-layered physiognomy resembling that described in Gilliam et al. (2006). The overstory contained predominantly longleaf pine, *Pinus palustris* Mill. (Noel et al. 1998). Groundcover vegetation was dominated by warm-season grasses, especially bluestems [*Schizachyrium scoparium* (Michx.) Nash, *Schizachyrium tenerum* Nees], but also contained high biodiversity of herbaceous plants mixed with shrubs and lianas (Platt et al. 2006). Pine savannas at Camp Whispering Pines have experienced different land uses during the past century: logging in

*email address: eleich1@tigers.lsu.edu
Received June 8, 2010; Accepted February 18, 2011.

the 1920–30's and 1960–70's, cattle grazing until the 1960's, and fire suppression in the 1980's after becoming a Girl Scout Camp. Nonetheless, pine savanna vegetation persisted in upland areas and along slopes, intermixed with thickets containing native and exotic hardwoods, as well as *Lygodium japonicum* (Platt et al. 2006).

Camp Whispering Pines has been undergoing restoration since the early 1990s. Prescribed fires during the spring-summer transition, when lightning fires would have occurred naturally, have been implemented in alternate years from 1992–2010. Different sections have been burned in prescribed fires each year over this 18 yr period. Cover of hardwood shrubs has been greatly reduced as a result of the biennial fires, but shrub thickets remain scattered in the landscape (Thaxton and Platt 2006, Passmore 2009).

This note compiles data from two different experimental field studies that documented invasion of mesic pine savanna by *L. japonicum*. One study examined effects of granivores and herbivores on species composition and abundance in pine savanna groundcover. The other study explored the combined influence of hurricane, fire, and animal disturbances on species composition and abundance in pine savanna groundcover. During the course of both field experiments, changes in the presence and abundance of *L. japonicum* offered an opportunity to examine invasion in this pine savanna.

We first asked ''Is *Lygodium japonicum* more likely to occur in disturbed than undisturbed areas of pine savannas?'' We documented the occurrence of *L. japonicum* at 20 randomly selected sites at Camp Whispering Pines. In 2006, ten sites were located along margins of shrub thickets (presumed local sites of past disturbance) and a similar number were located in nearby herbaceous groundcover. Three one-meter square plots were installed at each site. *Lygodium japonicum* occurred in all sites with shrub thickets (10/10), but in only 2 of 10 of the sites with herbaceous groundcover. On average, the fern occurred in 2.3 of the 3 plots in each shrub thicket, but in 0.3 of 3 plots in the herbaceous groundcover sites where it was present. Japanese climbing fern thus occurred at higher frequency and at greater local abundance in shrub thickets than in open pine savanna.

We further asked ''Is this species invading the herbaceous groundcover of pine savannas at Camp Whispering Pines?'' In 2006, 128 one square meter circular plots were randomly located in herbaceous groundcover without *Lygodium japonicum* within three different regions of Camp Whispering Pines. Plots were censused annually in the summer from 2006 through 2009. Stem counts were recorded for all plants within each plot. Plants were identified to species and placed in the following categories: fern, forb, graminoid, vine, or woody. Complete census of all plots did not occur each year; some plots were destroyed by salvage operations after Hurricane Gustav, and time constraints reduced sampling in some years. *Lygodium japonicum* occurrence increased over time in these plots. The percentage of plots that contained *L. japonicum* increased, especially after fires in 2006 and 2008 (Figure 1). More than twice as many plots contained the fern after four years as when the plots were installed. These results indicate that the herbaceous groundcover in pine savannas at Camp Whispering Pines is being invaded by *L. japonicum*. In addition, data suggest that frequent fire may facilitate local spread of Japanese climbing fern.

Understanding responses of *L. japonicum* to fire is important because fire is an integral part of restoring and managing pine savannas. We used 23 one square meter plots in shrub thickets at Camp Whispering Pines to assess responses to prescribed fires. These plots were burned in 2006 and 2008. We clipped and removed all fronds of *L. japonicum* eight times beginning in 2006. We clipped *L. japonicum* at the time that the plots were burned in the spring, and again 3 months and 15 months after spring fires, during the late summer when annual growth of fronds had slowed. Fronds were clipped the year of fire (2006, 2008), as well as the year without fire (2007, 2009); as a result, biomass collected during the 3 and 15 month post-fire sampling periods represented only the current season's growth. All underground rhizomes were left intact. The fern fronds were oven dried at 75°C and weighed to the nearest 1/100th gram.

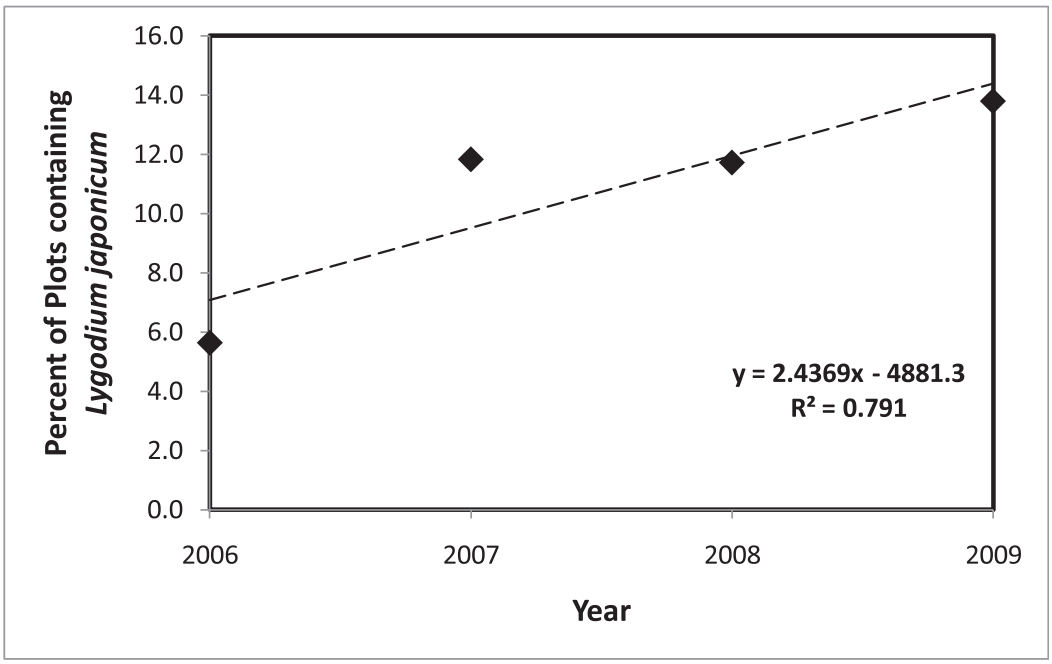

Figure 1. The occurrence of *Lygodium japonicum* in pine savanna groundcover at Camp Whispering Pines, Independence, Louisiana over a four year period.

Aboveground growth of *L. japonicum* fronds was greater in the year of fire than in the year without fire. More aboveground biomass of the fern was produced the year of fire than the year without fire (Figure 2). These differences occurred in both pairs of years (2006/2007: $t = 2.98$, $df = 22$, $p = 0.007$; 2008/2009: $t = 2.07$, $df = 22$, $p = 0.051$). Furthermore, mechanical removal had no long term effect on the mass of *L. japonicum* fronds in plots; total dry weight mass of *L. japonicum* did not differ between the two successive sampling periods. These data thus show little effect of long-term removal of aboveground biomass, but increases in above-ground biomass immediately after fire. We thus propose that frequent fires should not deter invasion of pine savannas by *L. japonicum* in mesic pine savannas like Camp Whispering Pines.

The invasion by *L. japonicum* of pine savannas at Camp Whispering Pines may have been facilitated by past land uses and recent management practices. *Lygodium japonicum* may have invaded and established large populations in shrub thickets during the past periods of logging and fire suppression, before frequent prescribed fires were restored to Camp Whispering Pines. Past open-range grazing also may have altered the groundcover in some unknown way (e.g., reduction of cover of bunchgrasses) that now is facilitating invasion by *L. japonicum* in frequently burned areas without high densities of shrubs. Although almost twenty years of prescribed fires have reduced shrub thickets to remnant patches, *L. japonicum* rhizomes already established in these areas survived prescribed fires that opened the habitat. Frequent prescribed fires during the transition from spring to summer, essential for restoration and management of diverse groundcover in mesic pine savannas like Camp Whispering Pines, do not appear to deter invasion by *L. japonicum*. If post-fire responses include increased spore production, propagules widely dispersed into surrounding herbaceous groundcover could constitute a ''spore rain of terror,'' to paraphrase Horvitz et al. (1998).

Based on the results of the two studies, we conclude that *L. japonicum* is invading the longleaf pine savanna at Camp Whispering Pines. We propose that shrub thickets, as localized disturbances in pine savannas (in the sense proposed by Rejmánek et al. 1989),

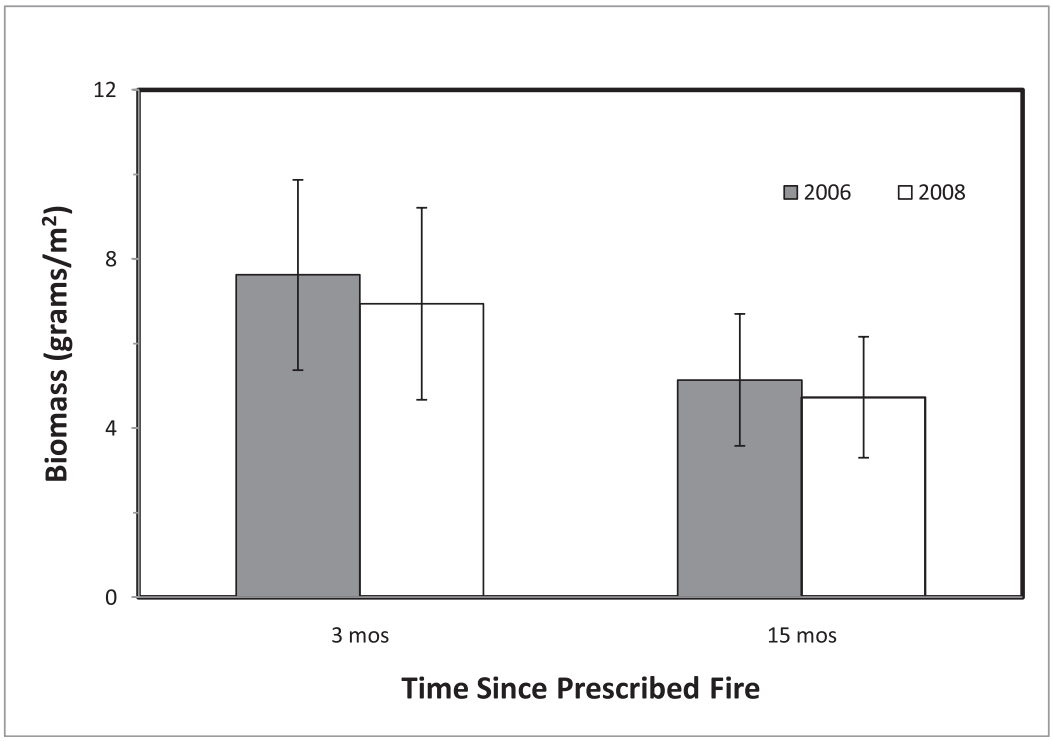

Figure 2. The mean biomass (above ground dry weight) of *Lygodium japonicum* fronds in one square meter plots in shrub thickets at Camp Whispering Pines. Data are from 3 and 15 month post-fire sampling in 2006 and 2008. Vertical bars denote standard errors.

facilitate establishment and survival of ferns. Shrub thickets are microsites of increased soil moisture, provide ample structure for twining fronds, and tend to suppress fire within the localized area. By twining up shrubs as opposed to forming mats at ground level, most tissue consumable by fire is located away from the soil surface, which should reduce heating of subterranean rhizomes of *L. japonicum* and further facilitate spread of established clones. Research is planned that includes examining how fire moving from open pine savanna into a shrub thicket influences characteristics of fires, as well as survival of fern rhizomes and responses of fronds (re-emergence, spore production). We anticipate that *L. japonicum* should have increased survival and re-emergence within shrub thickets compared to more open herbaceous-dominated ground cover. We propose that management targeted at shrub thickets in mesic pine savannas should slow and reduce invasion of more open herbaceous groundcover by *L. japonicum*.

Current prescribed fire techniques alone appear insufficient to limit or even slow *L. japonicum* invasion of pine savannas. Additional methods need consideration. Herbicide application, coupled with fire, is being tested in the rhizosphere (Pieterson 2010, pers. comm.); such localized application should directly target the portion of the fern protected from fire with minimal effects on surrounding plants. Further study of herbicide treatment is necessary to determine potential negative consequences for native species within application areas.

Fire intensity and severity may also play an important role in *L. japonicum* invasion. The fuel type, amount, and how it is distributed influences fire intensity in longleaf pine savannas (Thaxton and Platt 2006). Differences between fine-fuels (i.e., pine needles) and woody fuels (i.e., shrubs) may influence persistence of fern rhizomes (Passmore 2009). Presently, an examination of how differences in fine-fuels influence frond recovery is being conducted that includes fire temperature

measurements at and below the soil surface to determine whether soil heating potentially damages rhizomes of *L. japonicum*.

Lygodium japonicum is likely to compete with species indigenous to mesic pine savannas. Such species might include other rhizomatous ferns [e.g., *Pteridium aquilinum* (L.) Kuhn; *Botrychium biternatum* (Sav.) Underw.], as well as lianas [e.g., *Galactia volubilis* (L.) Britton, *Gelsemium sempervirens* (L.) St. Hil., *Smilax glauca* Walter]. *Pteridium aquilinum*, for example, exhibits similar growth characteristics to *L. japonicum* (Smith and Taylor 1986). Like *L. japonicum*, persistent subterranean rhizomes with nutrient reserves enable *P. aquilinum* to survive, re-grow and expand quickly after frequent fires (Schneider 2006). These similarities suggest post-fire competition between *L. japonicum* and native species with similar underground structures that readily survive and re-grow following frequent fires. As *L. japonicum* invades, occupation of space underground and use of available nutrients should increase, potentially depressing native species, especially because the fern can also overtop them with its climbing growth form. Thus, studies are needed to examine if invasion by *L. japonicum* might compromise high plant species biodiversity in the ground cover of mesic pine savannas.

We gratefully acknowledge the support of the Girl Scouts of America for their permission to use Camp Whispering Pines for our research and their involvement with our research and restoration program. We especially thank Jean Fahr and Allison Pastor for their support, and Larry Ehrlich for implementing and conducting the fire management program. We acknowledge support for the field studies that form the basis of this note: T. Vinton Holmes Award (E. Leichty), Louisiana Wildlife and Fisheries Environmental Education Commission Environmental Education Grant (B. J. Carmichael and E. Leichty), Louisiana State University BioGrads (B. J. Carmichael and E. Leichty), Environmental Defense (W. J. Platt, PI) and the National Science Foundation (Award 0950302, W. J. Platt, PI). We thank David J. Moorhead, an anonymous reviewer, and the subject editor at Castanea for help in improving the manuscript.

LITERATURE CITED

Bargeron, C.T., C.R. Minteer, C.W. Evans, D.J. Moorhead, G.K. Douce, and R.C. Reardon (techn. coordinators). 2008. Invasive plants of the United States DVD-ROM: Identification, biology and control. United States Department of Agriculture, Forest Service. Forest Health Technology Enterprise Team. Morgantown, West Virginia. FHTET-08-11. Available: http://www.invasive.org/weedcd/species/3045.htm (accessed 6/3/2010).

Carr, S.C., K.M. Robertson, R.K. Peet, and W.J. Platt. 2009. A model of geographic environmental and regional variation in vegetation composition of pyrogenic grasslands of Florida. J. Biogeogr. 36:1600–1612.

Clarke, H.M. 1936. The morphology and anatomy of *Lygodium japonicum*. Amer. J. Bot. 23:405–413.

Ferriter, A. (ed.). 2001. *Lygodium* management plan for Florida: a report from the Florida Exotic Pest Plant Council's *Lygodium* Task Force. Florida Exotic Pest Plant Council, Orlando, Florida. Available: http://www.fleppc.org/Manage_Plans/lymo_mgt.pdf (Accessed 6/7/2010).

Gagnon, J.L., S.B. Jack, B.D. Yahn, and J.M. Stober. 2005. Chemical control of the invasive exotic *Lygodium japonicum*. *In:* Proceedings of the fifth longleaf alliance regional conference. Longleaf Alliance Report No. 8. Hattiesburg Lake Terrace Convention Center, Hattiesburg, Mississippi.

Gilliam, F.S., W.J. Platt, and R.K. Peet. 2006. Natural disturbances and the physiognomy of pine savannas: a phenomenological model. Appl. Veg. Sci. 9:83–96.

Horvitz, C.C., J.B. Pascarella, S. McMann, A. Freedman, and R.H. Hofstetter. 1998. Functional roles of invasive non-indigenous plants in hurricane-affected subtropical hardwood forests. Ecol. Appl. 8: 947–974.

Langeland, K.A. and K.C. Burks (eds.). 1998. Identification and biology of non-native plants in Florida's natural areas. University Press of Florida, Gainesville, Florida.

Means, D.B. 2006. Vertebrate faunal diversity in longleaf pine ecosystems. p. 157–213. *In:* Jose, S., E. Jokela, and D. Miller (eds.).

Longleaf pine ecosystems: ecology, management, and restoration. Springer, New York, New York.

Munger, Gregory T. 2005. *Lygodium* spp. *In:* Fire Effects Information System, [Online]. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer), Missoula, Montana. Available: http://www.fs.fed.us/database/feis/ (Accessed 6/7/2010).

Noel, J.M., W.J. Platt, and E.B. Moser. 1998. Structural characteristics of old- and second-growth stands of longleaf pine (*Pinus palustris*) in the Gulf coastal region of the USA. Conserv. Biol. 12:533–548.

Passmore, H.A. 2009. Hurricane and fire effects in savanna-forest landscapes. VDM Verlag Dr. Müller, Berlin, Germany.

Peet, R.K. 2006. Ecological classification of longleaf pine woodlands. p. 51–93. *In:* Jose, S., E. Jokela, and D. Miller (eds.). Longleaf pine ecosystems: ecology, management, and restoration. Springer, New York, New York.

Pemberton, R.W. and A.P. Ferriter. 1998. Old World climbing fern (*Lygodium microphyllum*), a dangerous invasive weed in Florida. Amer. Fern J. 88:165–175.

Pieterson, E.C., S. Jose, S.B. Jack, K. Kitajima, and P.J. Minogue. 2010. Choice of vegetation response measure may alter perceived efficacy of an invasive species control strategy. *In:* Ecological Society of America Annual Meeting 95th Annual Meeting, Pittsburgh, Pennsylvania 1–6 August 2010. (Pers. comm. August 3, 2010)

Platt, W.J. 1999. Southeastern pine savannas. p. 23–51. *In:* Anderson, R.C., J.S. Fralish, and J. Baskin (eds.). The savanna, barren, and rock outcrop communities of North America. Cambridge University Press, Cambridge, England.

Platt, W.J., G.W. Evans, and S.L. Rathbun. 1988. The population dynamics of a long-lived conifer (*Pinus palustris*). Amer. Naturalist 131:491–525.

Platt, W.J., S.M. Carr, M. Reilly, and J. Fahr. 2006. Pine savanna overstory influences on ground-cover biodiversity. Appl. Veg. Sci. 9:37–50.

Rejmánek, M., D.M. Richards, and P. Pyšek. 1989. Plant invasions and invisibility of plant communities. p. 332–355. *In:* Drake, J.A., F. Di Castri, R.H. Groves, F.J. Kruger, H.A. Mooney, M. Rejmánek, and M.H. Williamson (eds.). Ecology of biological invasion: a Global Perspective. Wiley and Sons, New York, New York.

Rosen, D.J., S.D. Jones, and V.E. Rettig. 2003. A floristic survey of Big Branch Marsh National Wildlife Refuge, St. Tammany Parish, Louisiana. SIDA 20:1189–1216.

Schneider, L.C. 2006. Invasive species and land-use: the effect of land management practices on bracken fern invasion in the region of Calakmul, Mexico. J. Latin Amer. Geogr. 5:91–107.

Singh, S. and G. Panigrahi. 1984. Systematics of genus *Lygodium* Sw. (Lygodiaceae) in India. Proc. Indian Acad. Sci. (Plant Sci.) 93:119–133.

Smith, R.T. and J.A. Taylor (eds.). 1986. Bracken: ecology, land use and control technology. Lancs: The Parthenon Publishing Group Limited, Carnforth, England.

Sorrie, B.A. and A.S. Weakley. 2006. Conservation of the endangered *Pinus palustris* ecosystem based on Coastal Plain centers of plant endemism. Appl. Veg. Sci. 9:59–66.

Stocker, R. and K.V.S. Hupp. 2008. Fire and nonnative invasive plants in the southeast bioregion. p. 91–111. *In:* Zouhar, K., J.K. Smith, S. Sutherland, and M.L. Brooks (eds.). Gen. Tech. Rep. RMRS-GTR-42-Volume 6. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah, Available: http://www.fs.fed.us/rm/pubs/rmrs_gtr042_6.pdf (Accessed 6/7/2010).

Thaxton, J.M. and W.J. Platt. 2006. Small-scale fuel variation alters fire intensity and shrub abundance in a pine savanna. Ecology 87:1331–1337.

Varner, J.M., D.R. Gordon, F.E. Putz, and J.K. Hiers. 2005. Restoring fire to long-unburned *Pinus palustris* ecosystems: Novel fire effects and consequences for long-unburned ecosystems. Restor. Ecol. 13:536–544.

Wade, D.D., B.L. Brock, P.H. Brose, J.B. Grace, G.A. Hoch, and W.A. Patterson III. 2000.

Fire in eastern ecosystems. *In:* Brown, J.K. and J.K. Smith (eds.). Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-Volume 2. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, Utah. Available: http://www.fs.fed.us/rm/pubs/rmrs_gtr042_2.pdf (Accessed 6/7/2010).

Willis, M., S. Zerbe, and W. Breitung. 2006. Habitat survey, mapping, and assessment in the Mai Po Nature Reserve, Hong Kong (China). Archive for Nature Conservation and Landscape Research 45:53–70.

Zeller, M. and D. Leslie. 2004. Japanese climbing fern control trials in planted pine. Wildland Weeds 7:6–9.

Authors Queries

Journal: **Castanea**
Paper: **cast-76-03-10**
Title: **Invasion of a Southeastern Pine Savanna by Japanese Climbing Fern**

Dear Author
During the preparation of your manuscript for publication, the questions listed below have arisen. Please attend to these matters and return this form with your proof. Many thanks for your assistance

Query Reference	Query	Remarks
1	Author/Editor: Please provide short title for running head.	