CANOPY GAP REPLACEMENT FAILURE IN A PENNSYLVANIA FOREST PRESERVE SUBJECT TO EXTREME DEER HERBIVORY

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While research has demonstrated the adverse effects of deer herbivory on forest regeneration in forests managed for timber production, less study has been devoted to the long term effects of deer on the dynamics of forests set aside as natural areas. At sufficiently high population densities, deer could interrupt the typical cycle of canopy gap formation and replacement by consuming all young trees. But other factors, such as invasive species, may also inhibit tree establishment and gap replacement.

We are comparing the canopy gap replacement process in two forest stands in south-central Pennsylvania (Perry County). At the private Florence Jones Reineman Wildlife Sanctuary (RWS, 1,375 ha), hunting has been prohibited since this preserve's establishment in the 1960s. A sharp browse line and frequent sightings of white-tailed deer (*Odocoileus virginianus*) suggest a high deer density. Asian stilt grass (*Microstegium vimineum* [Trin.] Camus) forms dense stands that exclude other plants. Native vines, principally grape (*Vitis* spp. L.), blanket the canopies of many understory trees. Our comparison stand is 19 km away in State Game Lands 170 (SGL, 3,550 ha), managed by the Pennsylvania Game Commission for wildlife and hunting. Both stands have a northerly aspect and elevations of 230-270 m.

At fixed intervals along line transects, we applied a plotless sampling method to determine the density and basal area of woody stems >1.30 m tall (number of trees sampled: 230 at RWS and 185 at SGL). We searched for woody stems 0.30 to 1.29 m tall in strip transects (strip transect areas: 950 m^2 at RWS and 300 m^2 at SGL). These trees represent the *null gap,* the overall forest composition, for each stand.

To quantify the influence of deer on future canopy trees, we examined null gap trees <30 cm dbh (diameter at breast height, 1.30 m) for buck rubs (cambial damage likely to be from abrasion by deer antlers; number of trees: 133 at RWS and 89 at SGL). We also examined these understory trees for the presence of vines in their canopies (number of trees: 133 at RWS and 90 at SGL).

The extent of canopy gaps was measured as the proportion of line transects intersecting gaps (line transect lengths: 1,820 m at RWS and 600 m at SGL). Asian stilt grass cover was measured as the proportion of line transects intersecting stands of this grass (line transect lengths: 950 m at RWS and 600 m at SGL).

To characterize the past canopy gap replacement process, we identified dead trees >20 cm dbh, large enough that they could have been part of the overstory, in strip transects and noted whether the forest canopy above these dead trees was closed (number of dead trees: 66 at RWS and 65 at SGL; strip transect areas: 7,600 m^2 at RWS and 4,800 m^2 at SGL). To estimate relative gap ages, we rated the state of decomposition of the dead trees on a 0 to 5 scale.

At RWS, we studied the vegetation within 14 gaps in detail. Along line transects we quantified Asian stilt grass cover (as above; line transect length: 580 m). We searched for woody stems 0.30-1.29 m tall in strip transects (strip transect area: 566 m^2). All understory trees >5 cm dbh within these gaps were examined for buck rubs (number of trees: 201) and vines (number of trees: 194).

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Citation for proceedings: Van Sambeek, J.W.; Dawson, J.O.; Ponder, F., Jr.; Loewenstein, E.F.; Fralish, J.S., eds. 2003. Proceedings, 13th Central Hardwood Forest conference; 2002 April 1-3; Urbana, IL. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 565 p. [Research note from poster presentation].

The density of null gap stems <20 cm dbh was nearly 20 times less at RWS (281 stems/ha) than at SGL (5,490 stems/ha), consistent with our hypothesis of extreme deer herbivory at RWS. For stems 0.30 to 1.29 cm tall alone, the difference in null gap stem density was over 50 fold: 84.2 stems/ha at RWS and 4,770 stems/ha at SGL. Further, all of the 0.30 to 1.29 cm tall stems sampled at RWS were witch hazel (*Hamamelis virginiana* L.), a species not capable of joining the forest overstory.

At least 90 percent of the 0.30-1.29 cm tall stems sampled at SGL were species capable of joining the forest overstory, including blackgum (*Nyssa sylvatica* Marsh.), 65 percent; oak (*Quercus* spp. L.), 10 percent; and sassafras (*Sassafras albidum* [Nutt.] Nees), 10 percent. In typical forests, the density of stems is substantially greater in canopy gaps than for the forest as a whole. However, at RWS the density of trees 0.30 to 1.29 m tall in the gaps (17.7 stems/ha) was less than for the null gap (84.2 stems/ha).

The two forest stands have comparable overstories; the density of trees >20 cm dbh was 154 stems/ha at RWS and 130 stems/ha at SGL. Total basal area was 17.6 m^2/ha at RWS and 19.3 m^2/ha at SGL. At RWS, five genera accounted for 83 percent of the basal area: tulip magnolia (*Liriodendron tulipifera* L.), 23 percent; maple (predominantly *Acer rubrum* L.), 20 percent; birch (*Betula lenta* L.), 15 percent; oak (including *Quercus alba* L., *Q. prinus* L., *Q. rubra* L., and *Q. velutina* Lam.), 13 percent; and hickory (including *Carya glabra* [Mill.] Sweet var. *glabra*, *Carya glabra* var. *odorata* [Marsh.] Little, and *Carya ovata* [Mill.] K. Koch, 13 percent). At SGL, three genera accounted for 83 percent of the basal area: oak, 54 percent; maple, 17 percent; and birch, 12 percent. The largest tree at RWS was 65.9 cm dbh and largest tree at SGL was 69.4 cm dbh.

We found evidence that past gap replacement has been less successful at RWS than at SGL. Despite the greater age of the gaps at RWS (average state of decomposition ratings of the dead trees: 3.6 at RWS and 2.7 at SGL), dead trees were more likely to still be in gaps at RWS (42 percent) than at SGL (31 percent). The RWS stand also had more gap area (12 percent) than the SGL stand (8 percent) even though the RWS stand had a lower density of dead trees (86.8 stems/ha) than SGL (135 stems/ha).

Our expectation of a higher deer density at RWS is supported by the greater frequency of buck rubs at RWS (15 percent) compared to SGL (8 percent). The trees within gaps at RWS were even more likely to be affected (23 percent) suggesting deer were preferentially using the gap habitat. To quantify relative deer density in our two stands, we will be measuring fecal pellet production during winter 2002 (and reporting the results at the conference). Other recent studies suggest the significance of deer herbivory at RWS. A previous deer fecal pellet production study found 1.6 deer/ha, over 20 times that recommended by the Pennsylvania Game Commission to insure forest regeneration. An 8 year exclosure study shows that trees capable of reaching the forest canopy can regenerate at RWS when protected from deer.

Asian stilt grass cover was greater at RWS (55 percent) than at SGL (0.0 percent; but Asian stilt grass was observed within exclosures at SGL). Within the 14 gaps at RWS, Asian stilt grass cover was slightly higher (62 percent). Similarly, vines influenced more null gap trees at RWS (35 percent) than at SGL (24 percent). Within the gaps at RWS, vines influenced 51 percent of the trees.

In conclusion, the canopy gap replacement process at RWS has been inhibited. While Asian stilt grass and vines are a major presence at RWS, these species are not solely responsible. Large areas of the forest floor are free of Asian stilt grass, even in gaps, and half of the understory trees within gaps are unaffected by vines. Rather, our findings, along with those of others, indicate that deer herbivory is responsible for the gap replacement failure. Without reductions in deer herbivory the future forest at RWS will become increasingly open as overstory trees die and are not replaced. However, reductions in deer herbivory at RWS may not lead to successful canopy gap replacement if Asian stilt grass spreads and prevents tree establishment even in the absence of deer browsing.