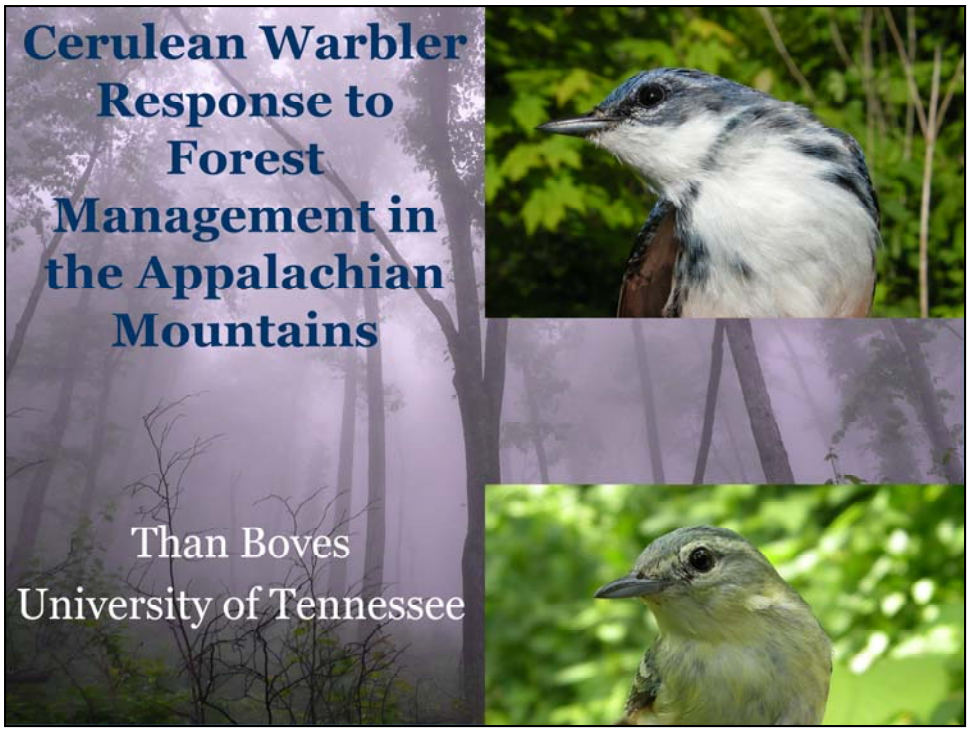
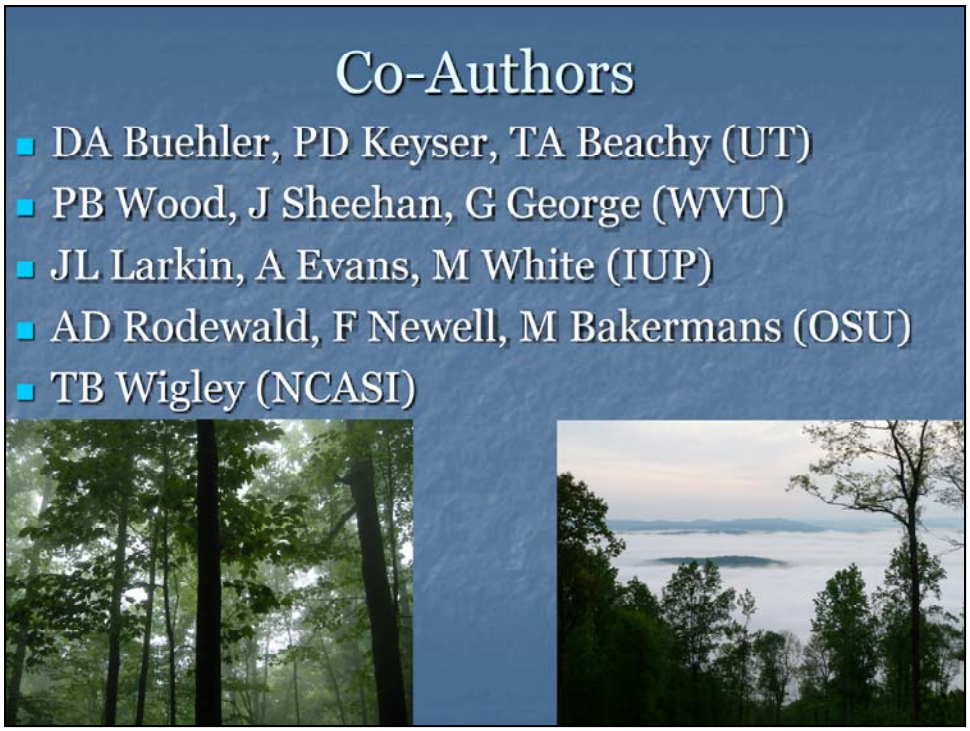
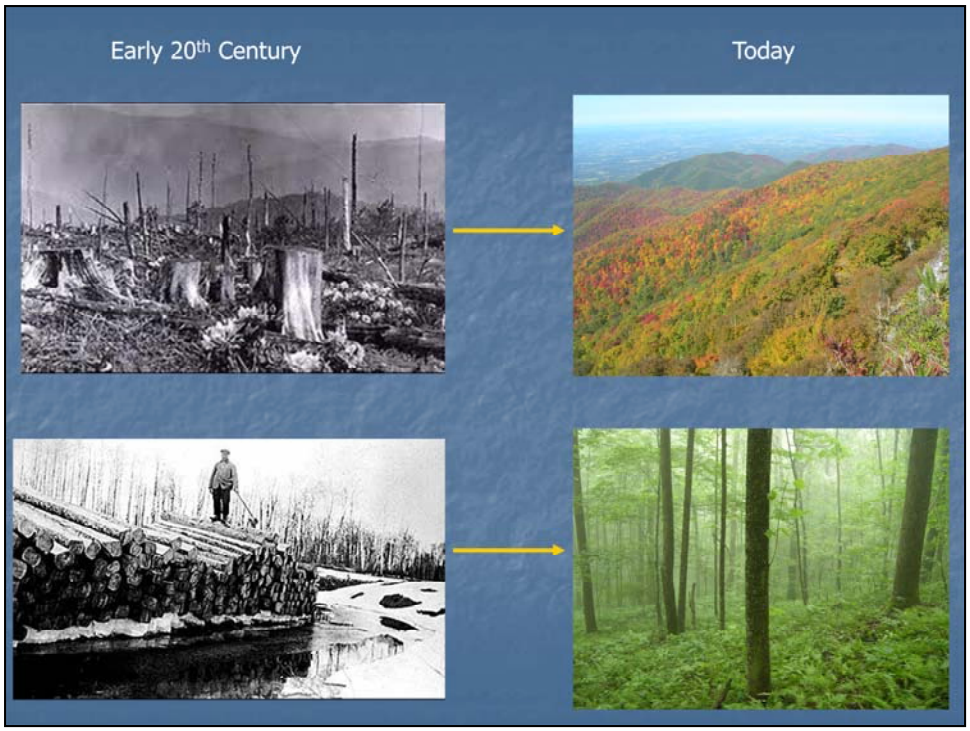


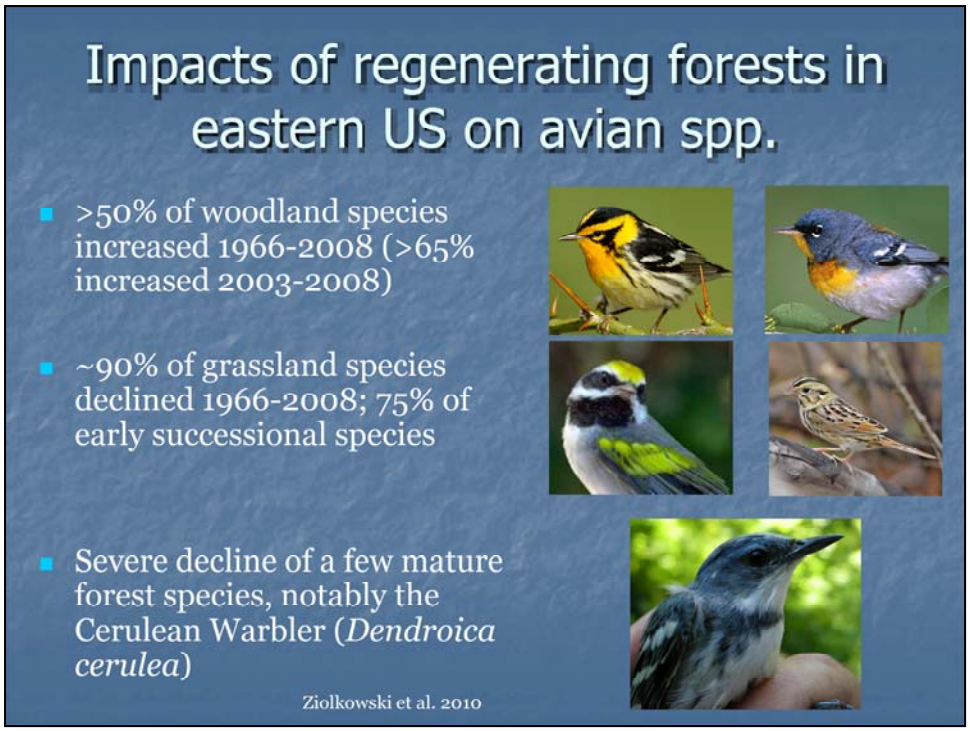
Today, I will be talking about a study that I have been involved with for the past three years and is the basis for my dissertation that I am currently working on at the University of Tennessee.



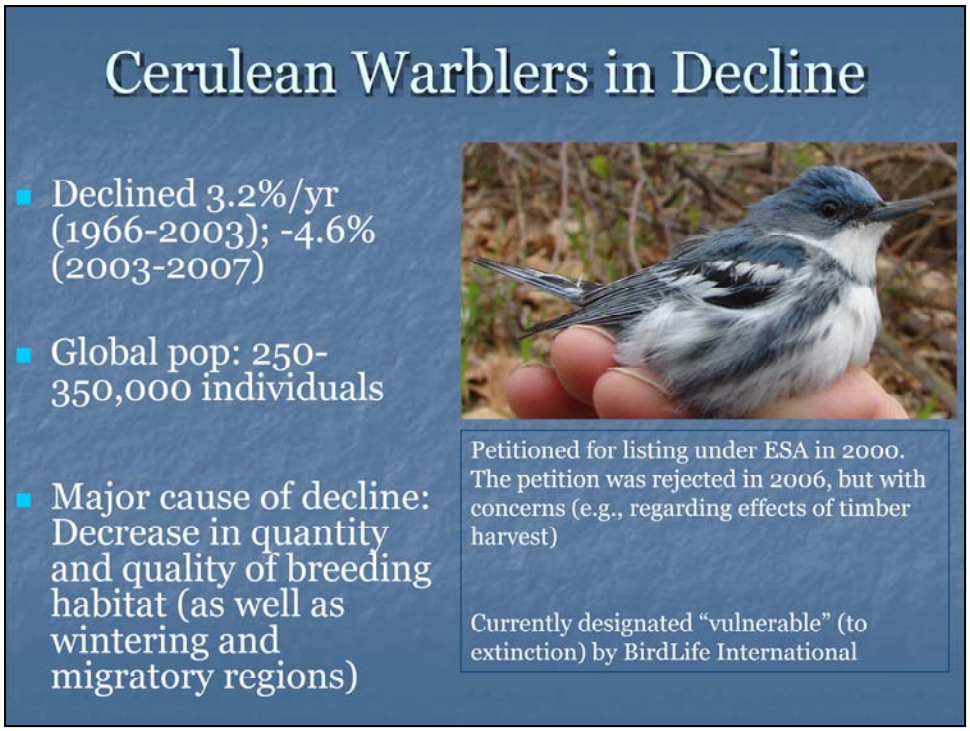
To begin, I'd like to acknowledge the co-authors of this work. Its been a great experience working with all of them and I think we accomplished a lot in our collaboration.



During the late 19th and early 20th century, much of the forested land of the eastern United States was cut for timber and agricultural purposes. However, over the past century, much of that forest has regenerated to now cover a large proportion of its original area, albeit in second growth form.

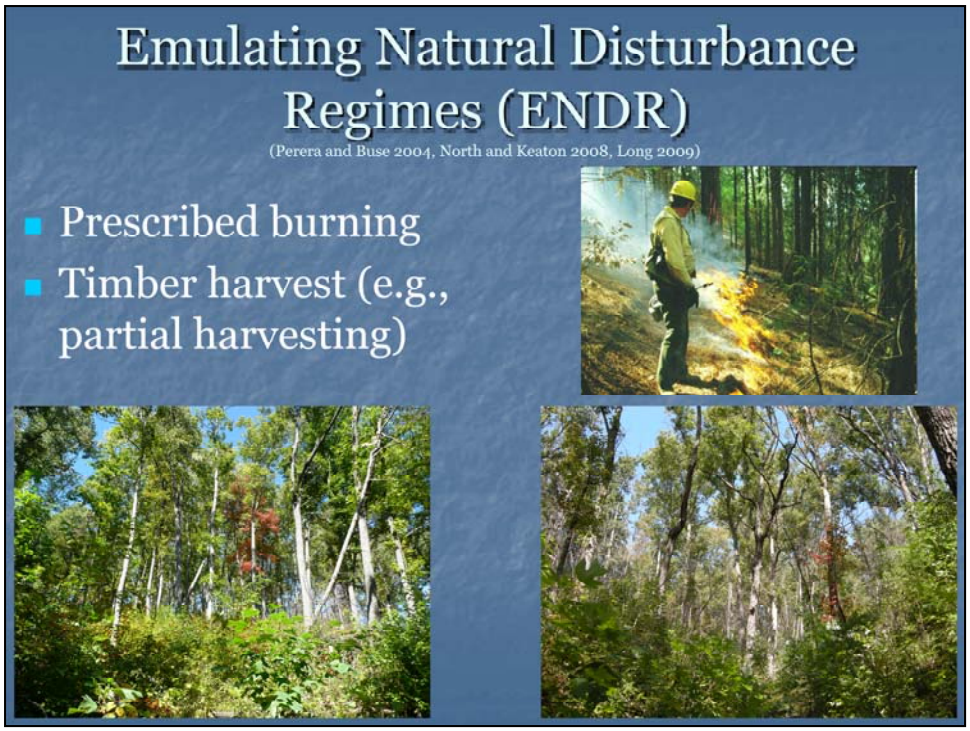


The regeneration of forest in the eastern US is reflected in population trends of many avian species. For example, according to BBS data, >50% of woodland spp. have increased over the past 50 years and that number has even grown further during the past decade. Conversely, as woody plants have encroached into open habitats, ~90% of grassland and 75% of early successional spp. have declined over the past half century. However, somewhat paradoxically, we've seen severe declines of a few mature forest species, most notably the cerulean warbler.

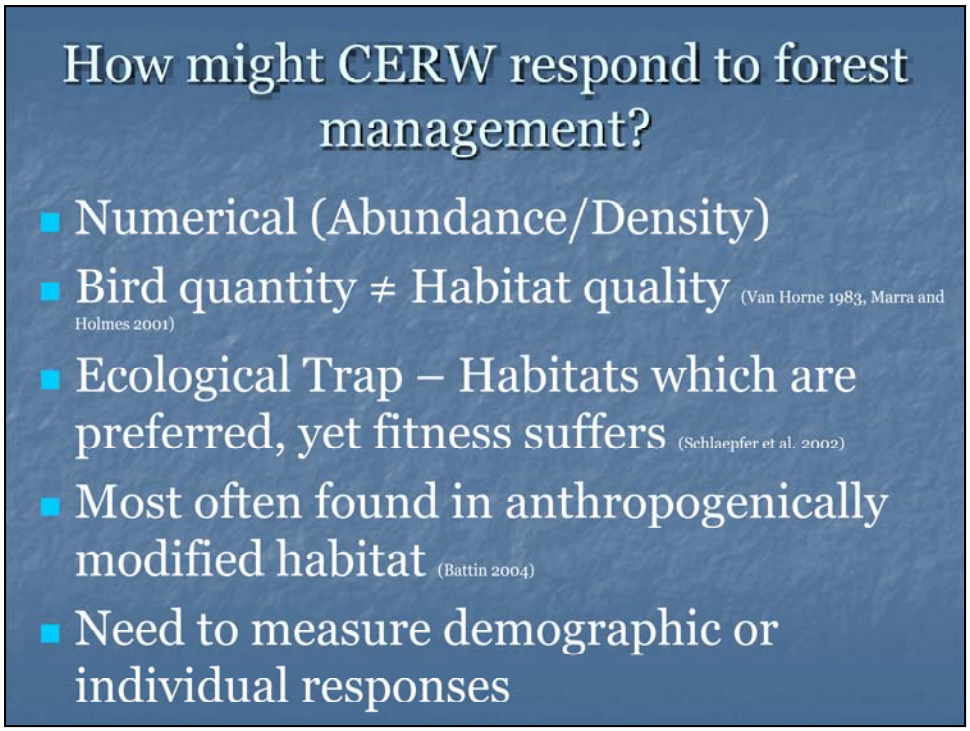


In stark contrast to the majority of woodland species, cerulean warblers have declined by over 3%/yr over the past 50 yrs and this trend appears to be worsening. The current population is estimated to be relatively small, which makes these trends all the more disturbing. **While there are issues with habitat loss and degradation on the winter and migratory range**, most agree that the decrease in quantity and quality of the breeding habitat must play an important role as well. CERW are currently listed as a threatened, endangered, or species of concern at the state level in most of its range and considered vulnerable to extinction by Birdlife Inter.

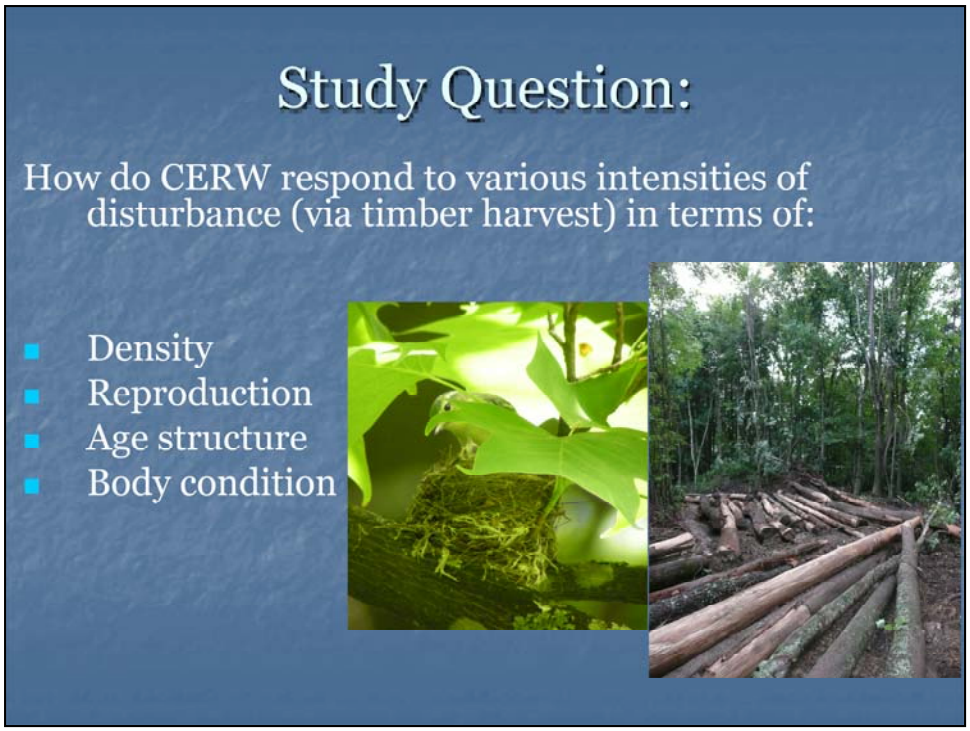
In the Appalachians, **where over 70% of their current population breeds**, we find that cerulean warblers are highly associated with mature deciduous forests with large, tall trees. They are often found on steep slopes with **highly productive** (northerly or easterly) aspects or on ridgetops. A growing body of evidence also indicates that ceruleans associate with canopy gaps or areas of high canopy heterogeneity. For this reason, some have recently suggested that this species may be adapted to disturbance in mature forests. **These disturbances could be caused by natural processes such as fire, windthrow, ice-storms, or natural tree senescence, all of which are much less common in the second-growth forests of the eastern US and as fire has been suppressed over the past century.**



Alternatively, disturbances within the interior of mature forests could be created by anthropogenic activities such as timber harvesting or prescribed burning. As most of you know, many ecologists now suggest that in order to improve the quality of forest ecosystems, we should attempt to emulate the natural disturbance regimes of the past. An example of this can be seen in the two photos here. They both depict forest stands that have been disturbed – one naturally through fire (in the Pisgah NF) and one artificially through a partial timber harvest (from this study). As you can see, they look very similar and the hope would be that they are ecologically similar as well. In this study, we used timber harvest in an attempt to emulate natural disturbances and improve habitat for the declining cerulean warbler.

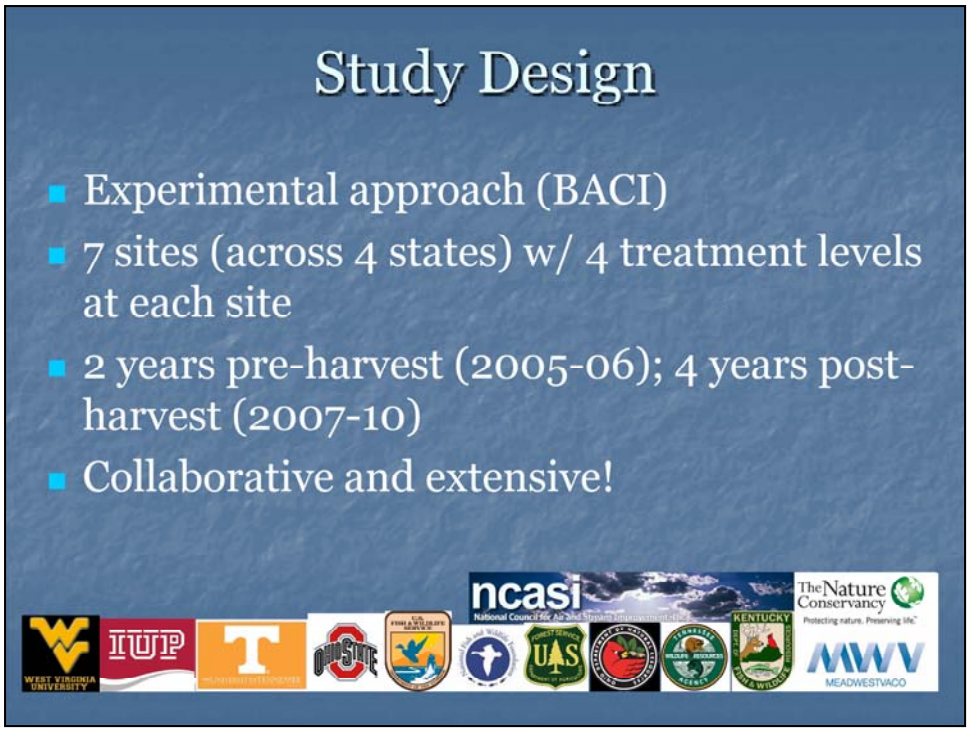


So how can we measure CERW response to forest management? In most studies, avian response is measured numerically in terms of abundance or density. However, this metric can be misleading. As many have documented, bird quantity does not always equal habitat quality, especially in the short-term. The most severe example of this phenomenon occurs in an ecological trap, where habitats are attractive to birds, but their fitness suffers in these same habitats. Ecological traps are most often found in anthropogenically-disturbed habitats and because of this, it is very important to also measure other types of responses to forest management, including individual and demographic responses.

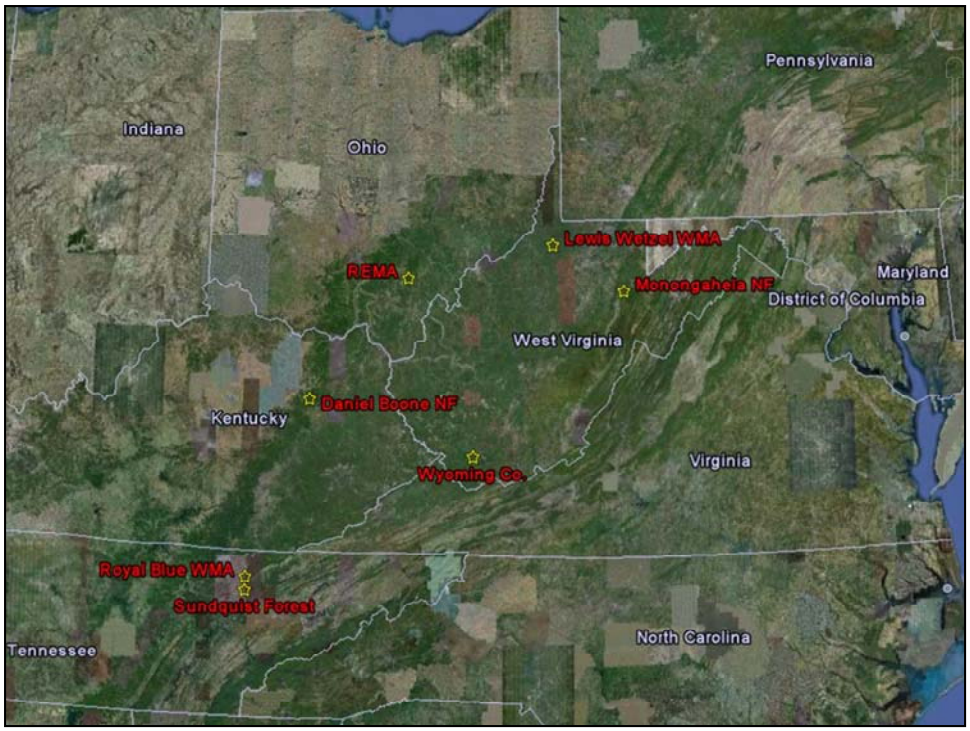


So the questions we asked in this study were:

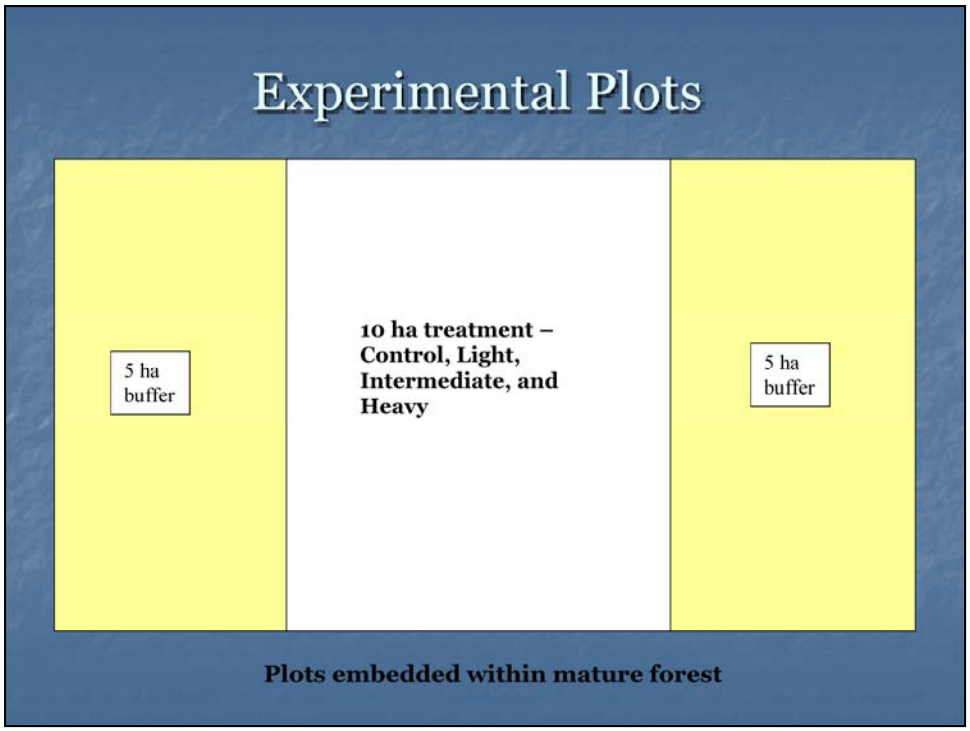
And then we hope to use this information to evaluate the potential to use timber harvesting as a strategy to improve habitat for cerulean warblers in the Appalachian Mts.



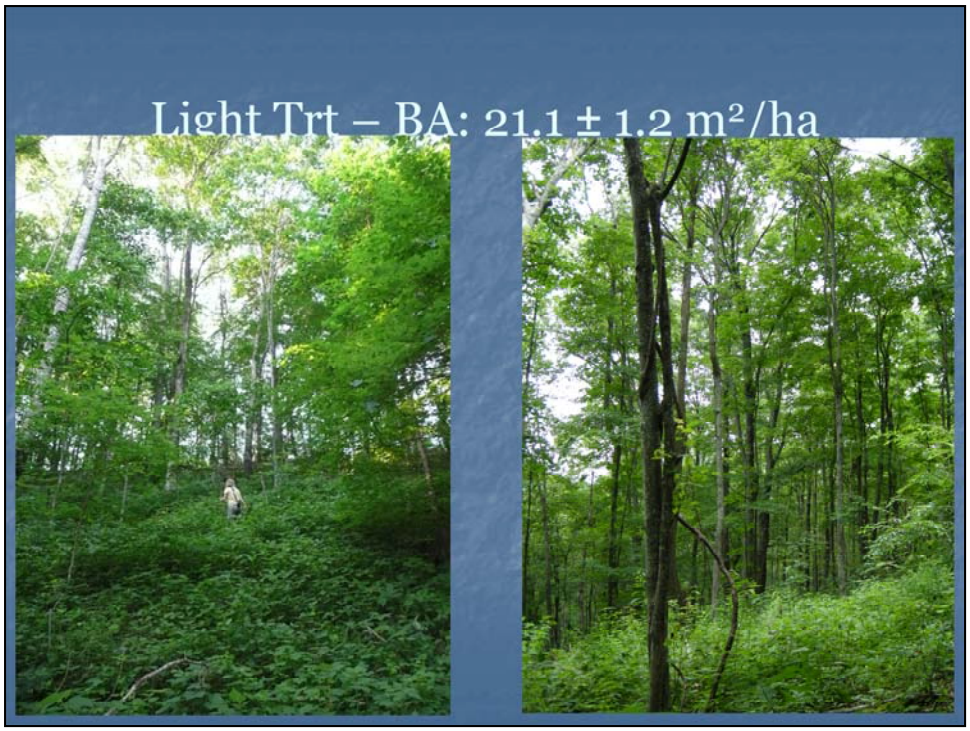
To answer these questions, we took an experimental approach using 7 sites across four states, partially with a BACI design. Each site was replicated with four treatment levels which allowed us to examine response across a disturbance continuum. We collected two years of pre-treatment data collection and four years post-harvest. This project was a collaboration among a bunch of groups and is among the most extensive forest management experiments ever undertaken.



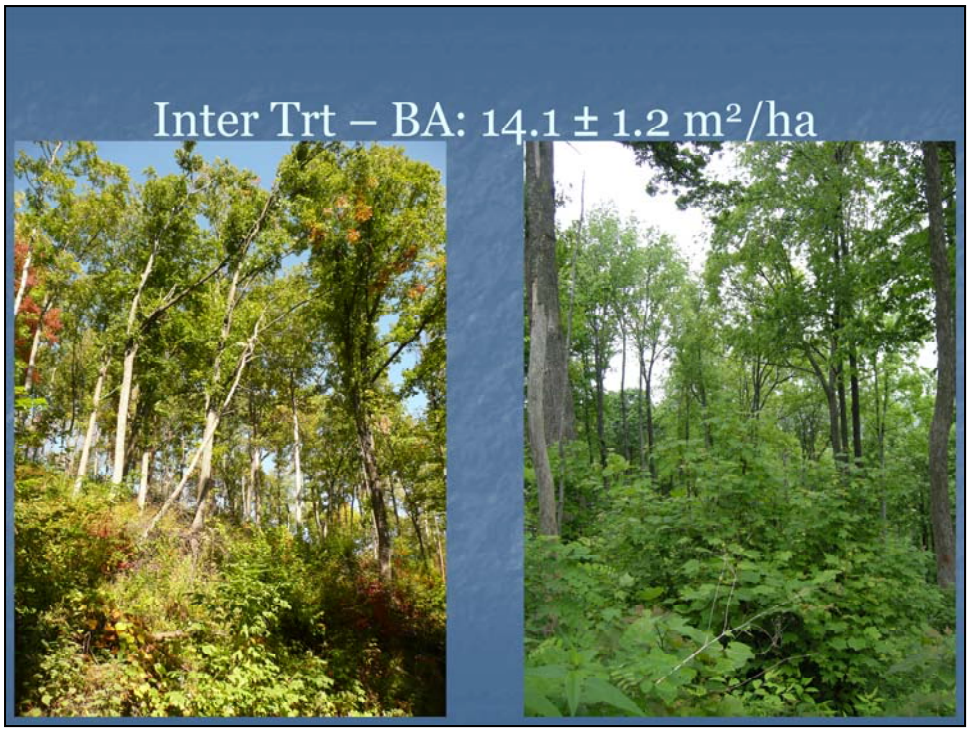
Here we have our study sites, which were spread out across the core of the CERW's range in the central and southern Apps. We had 3 sites in WV, 2 in TN, 1 in OH, and 1 in KY. At each site, we had four study plots with varying intensities of timber harvest. These plots were all located in regions of known cerulean warbler occupancy, most were on northerly or easterly slopes, and were located in areas where timber harvest was logistically feasible.



As each site, we created four plots designed that more or less looked like this. Each plot consisted of a 10 ha “treatment” area. The 10 ha treatments include a control treatment, a light harvest, an intermediate (or shelterwood) harvest, and a heavy (or modified clearcut) harvest. These harvests are bordered by 5 ha buffers, which were included to look for any sort of edge effect.



Our light treatments were managed in a single-tree selection manner and we reduced basal area (and correspondingly canopy cover) by 20-25% and the post-harvest treatments had an average basal area of 21.1 meters squared/ha with a SE of 1.2 m^2/ha. These harvests resembled natural tree fall gaps caused by senescence or minimal blow-downs.

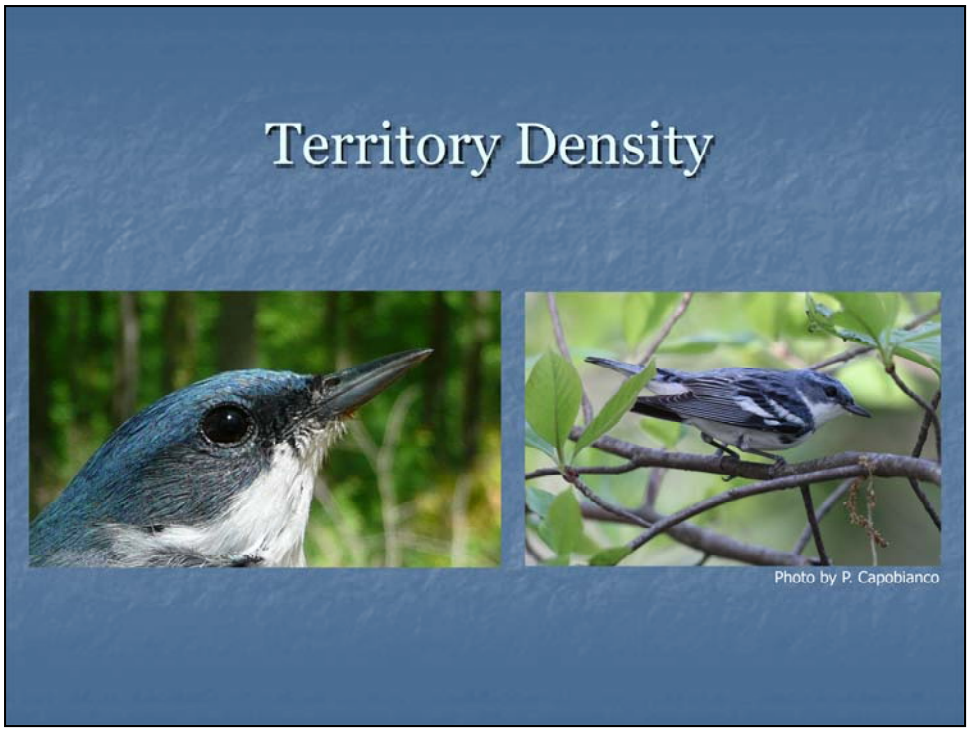


On our intermediate, or shelterwood, treatments, pictured here, we reduced basal area and canopy cover by about 40-50% and had an average BA of 14.1 meters squared/ha with a SE of 1.2. These treatments resemble forest stands impacted by fire, more severe windthrow, or severe ice-storms.

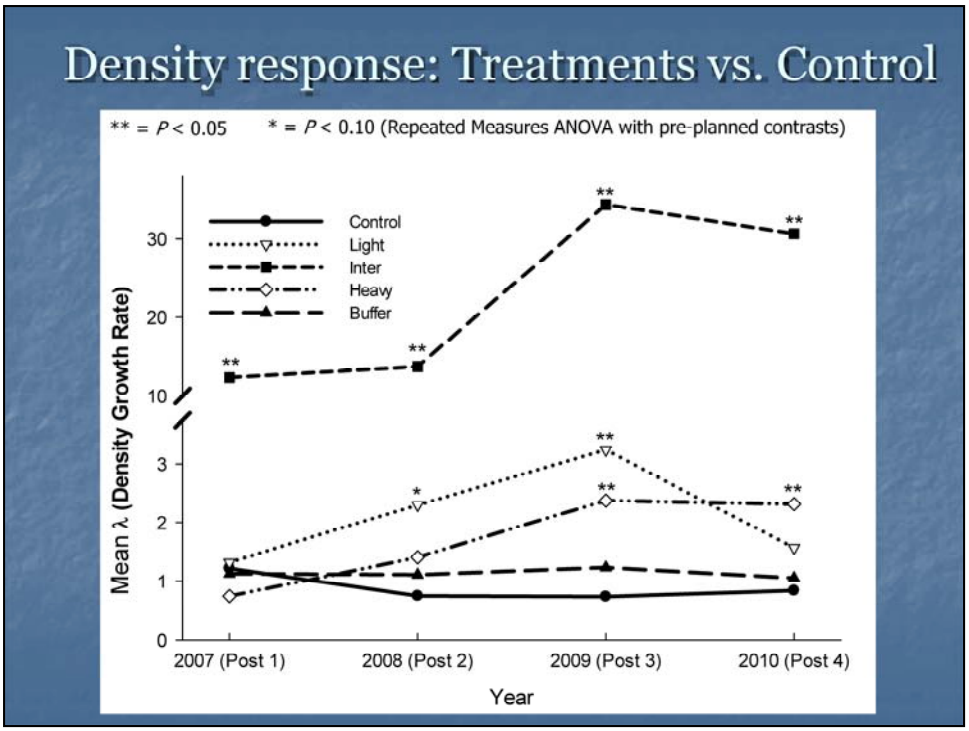
On our heavy treatments, or modified clearcut, we reduced basal area and canopy cover by ~75% and ended up with an average BA of 6.5 m^2/ha with a SE of 1.1. These treatments mimicked more forests disturbed by more intense fires, severe windthrow, or other intense natural disturbance.

And finally, our control plots are left harvested throughout the study and they had an average basal area of 27 meters squared per ha.

Our field methods included spot-mapping to determine density of CERW territories, intensive nest-searching and monitoring to evaluate reproductive success, and target banding and morphometrics to examine age structure and body condition.



On to the results: first we'll look at the density response



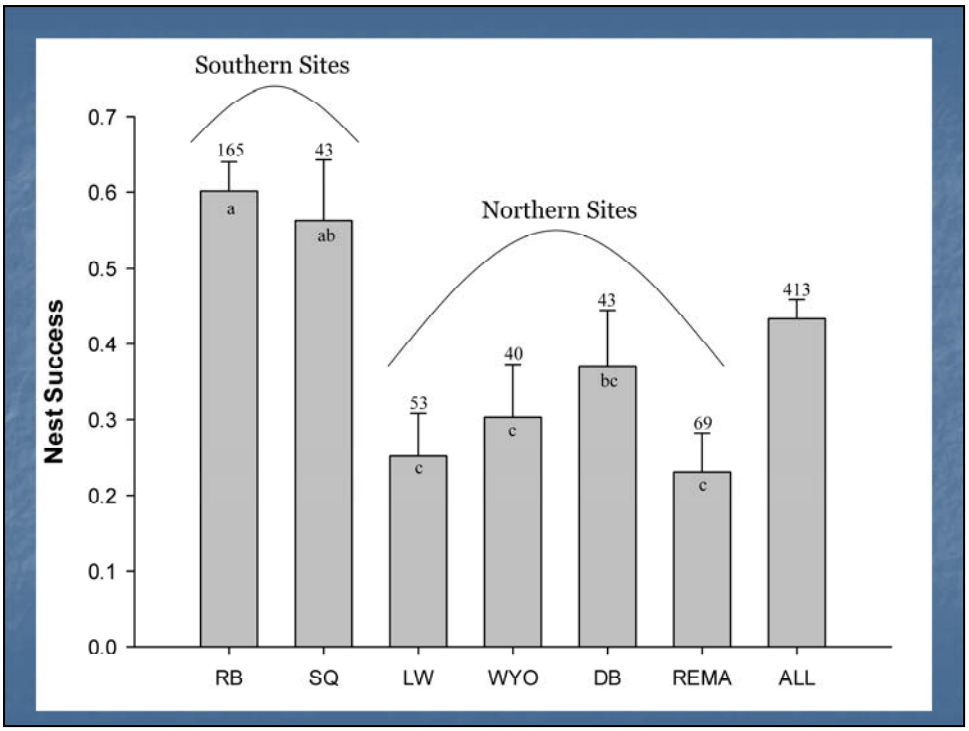
This figure depicts mean lambda, or growth rate, from pre- to post-harvest conditions on the y-axis and post-harvest year on the x-axis. **A Lambda of one indicates a stable population, anything above grew, below declined. I'll point out the controls first; they remained pretty stable throughout the study (as did the buffers). We found a main treatment effect and a year x treatment interaction so we analyzed the response separately for each year**. In the first post-harvest year, only on the intermediate treatment did density increase significantly more than the control. In 2008, the light treatment increased marginally vs. control and the intermediate remained much greater. By 2009, the light, intermediate, and the heavy treatments had increased significantly vs. the control, and in 2010, the intermediate and heavy treatments remained increased significantly, while the light treatment was no longer different. **I think this clearly shows that CERW are very attracted and likely uniquely adapted to moderate to severe disturbances within the interior of highly forested Appalachian Mts.**

For many studies of the effect of disturbance on avian species, this is where the data collection often ends. However again, as many have acknowledged – simply because birds are present does not mean that the habitat is of the highest quality. That is why including other measures of avian response is very important (esp. in short term studies). Another way birds can be effected by timber harvest is that their reproductive output can be altered.

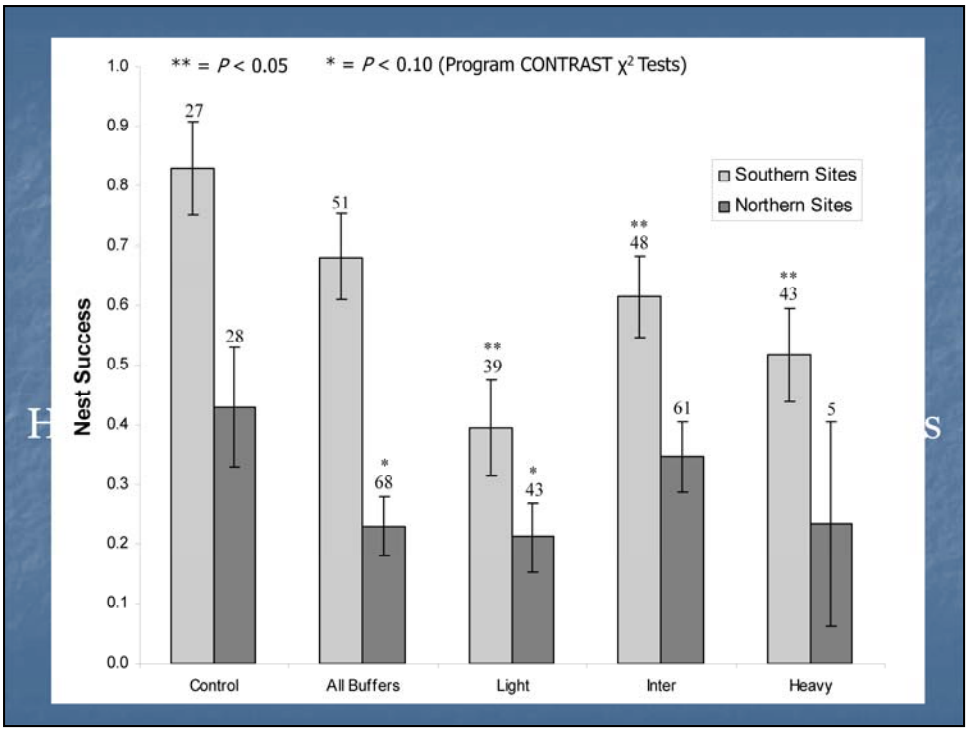
Daily Nest Survival: Logistic exposure models (n=413 nests; 6879 exposure days)

MODEL	AIC_c	ΔAIC_c	AIC_c Weight	Parameters
S(site+year+trt)	1523.8670	0.0000	0.96	12
S(site+trt)	1530.6697	6.8027	0.03	10
S(site+year)	1532.5201	8.6531	0.01	8
S(site)	1539.1739	15.3069	0.00	6
S(year+trt)	1543.3859	19.5189	0.00	7
S(year)	1551.4878	27.6208	0.00	3
S(trt)	1559.9158	36.0488	0.00	5
S(.)	1567.2450	43.3780	0.00	1

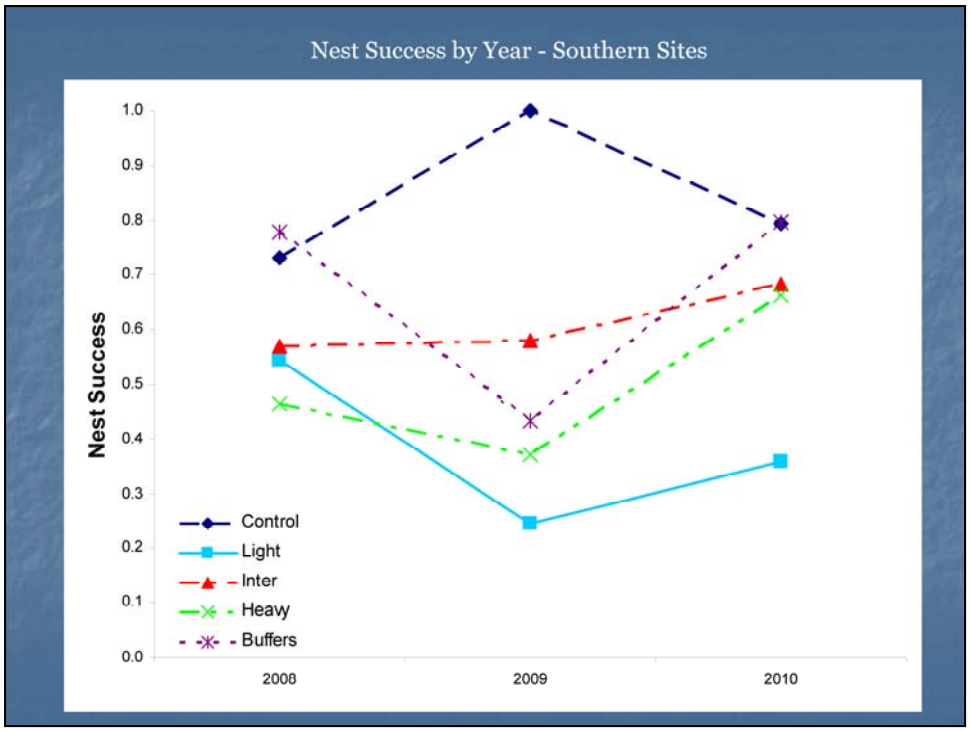
We first analyzed daily nest survival by comparing logistic exposure models in Program MARK. We found that, by far, the best model was one that incorporated site, year, and treatment. What this means is that all three of those factors were important in influencing whether a nest survived.



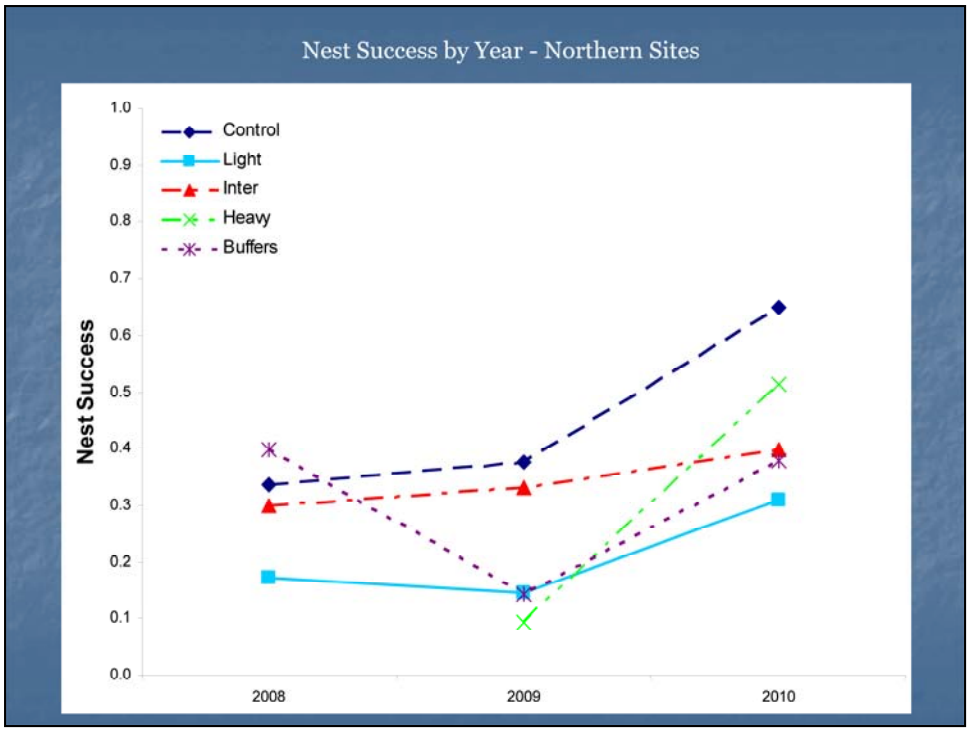
First, we'll look the effect of site on nest success. This figure depicts nest success at each of our sites and overall. On the y-axis is overall nest success (more or less equivalent to Mayfield, DSR^25). Numbers above bars indicate sample size and differing letters indicate statistical difference at alpha=0.05 using chi-square analysis. **What jumps out is the fact that the southern sites (both located in the Cumberland Mountains) had much higher nest success than the northern sites. So to look at treatment effect on nest success, I pooled nests from each region.**



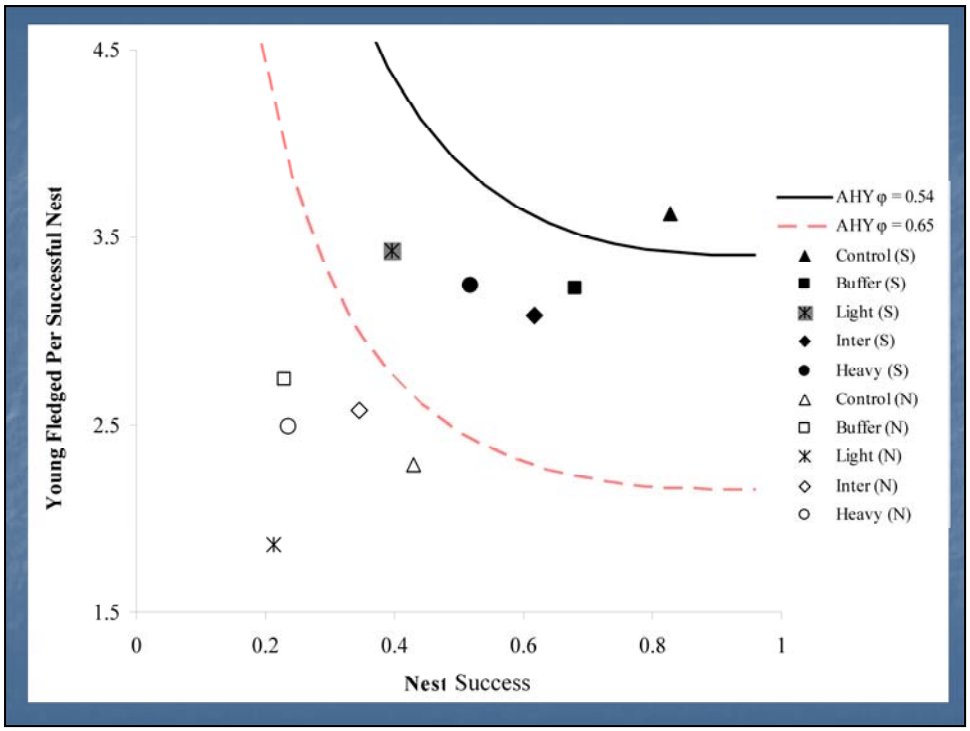
At southern sites, nest success was significantly higher on the controls than on any treatment type. At the northern sites, where overall nest success was much lower, nest success was still highest on the controls, but only marginally higher than on the light trt and buffers. Only five nests were found in heavy treatments, so a lack of significance there could be simply because of a small sample size. So combining the two sets of data**, I think this clearly shows that while anthropogenically-disturbed habitats are very attractive to CERW, the birds inhabiting these harvests suffer reproductively, producing what is coined a "severe" ecological trap.**



From an annual, treatment, and regional perspective, we see the nests on the controls at southern sites surviving at a higher rate than nests in any of the seemingly more-attractive treatments in all years at the southern sites. Light and heavy treatments had the poorest nest success in all three years.

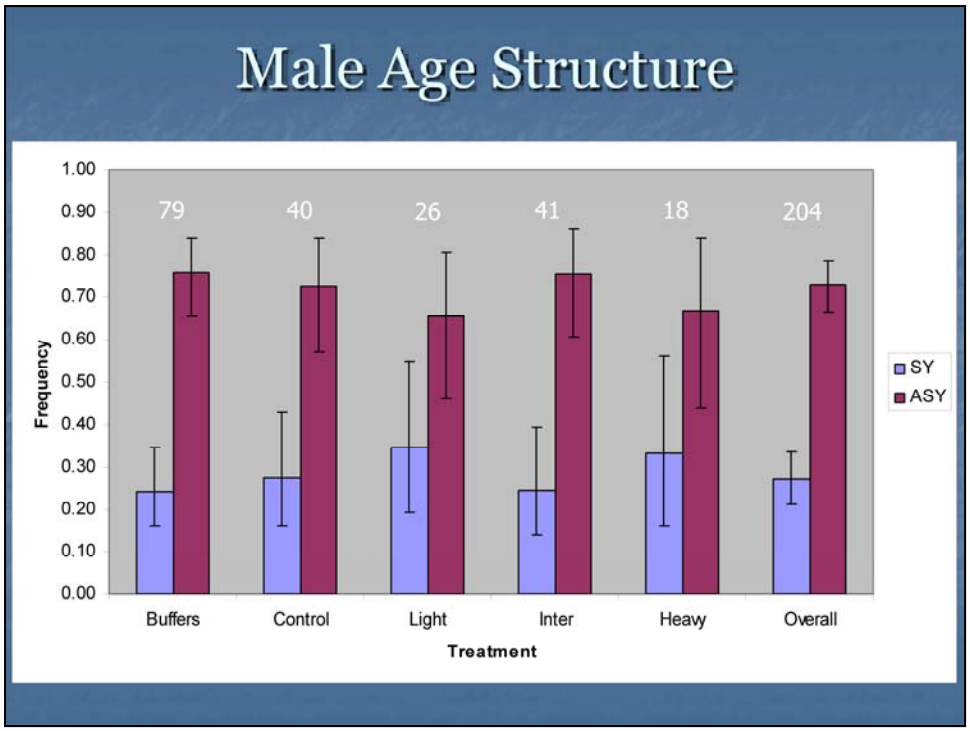


Now looking at all the northern sites, you can see that a similar pattern exists, but just at much less productive levels. Once again, control nests (and buffers in 2008) were more successful than the treatment nests year after year. Again, this is contrary to the pattern of attraction that we saw in the density data.

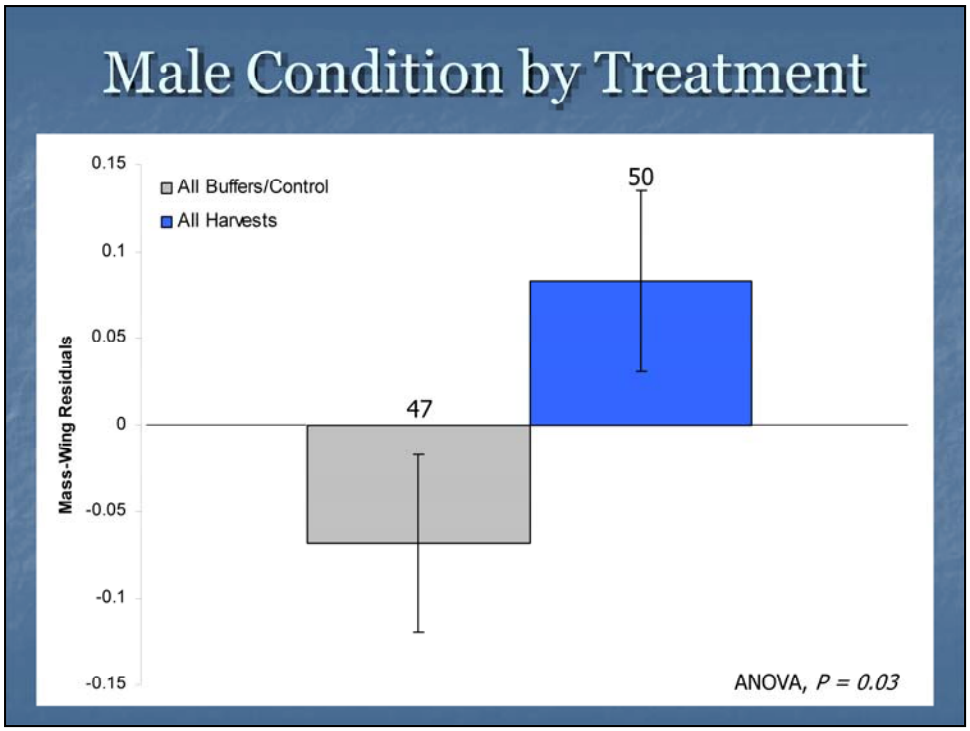


We can further view the effects of treatment/region combinations from a source-sink perspective using a simple graphical model. This figure depicts the # of young fledged/succ nest on the y-axis and nest success on x. Filled markers represent point estimates from data from the treatments on the southern sites. Open markers represent point estimates of data from treatments on the northern sites. The two curved lines in this figure represent survival curves, and indicate the rate of adult survival that must occur in order to maintain a stable population. Anything above and to the right of a line represents a source population; anything below or to the left represents a sink (at that putative survival rate). I have depicted two survival curves, one from birds breeding in Ontario and one from birds wintering in Venezuela. At 54% adult survival, only unharvested habitat on the southern sites (Cumberland Mts) could be expected to act as a source for the global population. However, if adult survival is increased to 65%, ALL habitat in the Cumberlands, disturbed or not, would act as sources for the global population. These harvested treatments would still function as local ecological traps, but as global sources. No matter which survival curve we use, all habitats at the northern sites function as sinks.

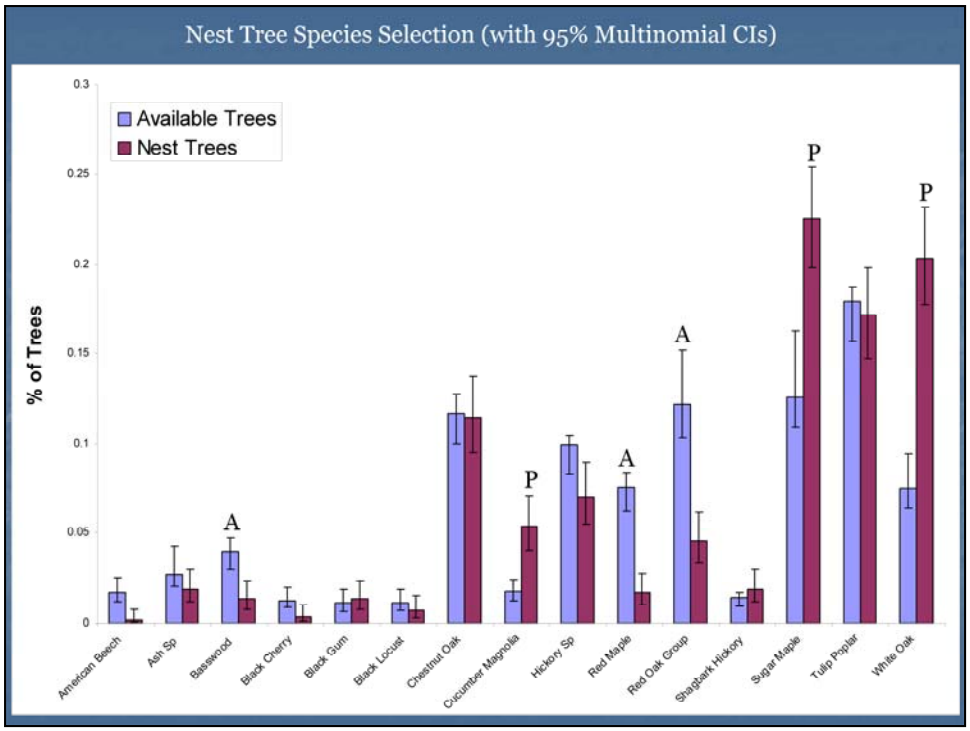
Age Structure and Condition



This figure depicts male age structure on the various treatments, all sites and years pooled. There was little difference in age structure of the males inhabiting the various treatments, but the light and heavy treatments did have the highest proportion of young, inexperienced males, while the buffers and intermediate treatments had the highest proportion of experienced, older males.



However, when we examine body condition, we do see a pattern. On the y-axis we have a body condition index in the form of the body mass-wing residual. **Measurements above zero indicate greater than avg. condition; measurements below zero indicate lower than avg. condition**. Male CERW occupying harvests were in significantly better condition than males inhabiting buffers and controls. **This difference exists despite the fact that density was higher and the amount of canopy foliage is much lower on the harvests. This suggests that CERW are adapted to foraging on the arthropods that inhabit disturbed canopy conditions.**



The final results I'd like to present are not directly related to our forest management experiment, however could be important in terms of future management. We found that cerulean warblers selectively chose some tree species while actively avoiding others. This figure depicts the % of trees that were available (from random points on plots) and the proportion of trees that were selected as nest trees over the four years post-harvest. 95% multinomial confidence intervals are indicated on each column. By comparing 95% intervals of available trees to 95% intervals of nest trees, we found that three species of trees were avoided as nest trees: basswood, red maple, and red oaks. We found that CERW preferred three species as nest trees as well: cucumber magnolia, sugar maple, and white oak. This pattern of selection may be related to physical structure, tree-specific insect composition, or other differences among the tree species. I think the most interesting pattern is the extreme preference for white oaks as nest trees and the extreme avoidance of the red oaks. The reason for the difference is not known, but would definitely be something of interest for further research to examine.

Summary

- Male CERW were attracted to interior disturbances in mature forest (esp. Intermediate)
- Reproductive success declined in artificially disturbed habitat - harvests acted as severe ecological traps (esp. light and heavy; sensu Robertson and Hutto 2006)
- No evidence of age-related despotism existed among treatments
- CERW appear to be adapted to foraging in open canopies as body condition improved in harvested stands
- Cumberland Mountains of TN are the most productive region for CERW in their breeding range (only source?)
- White Oak, Cucumber Magnolia, Sugar Maple preferred as nest trees; Red Oaks, Red Maple, Basswood avoided

Future Questions

- How dynamic are these patterns? Do they vary through time or do they persist after 5, 10, 15, etc. yrs?
- How is adult and juvenile survivorship and dispersal affected by treatments?
- How does female response differ from male (in terms of age structure, condition, etc.)?
- What are the main causes of nest failure (and does it differ by treatment)?

Acknowledgements

- Funding and collaborators:
- Over 80 field assistants!

Thanks! and Questions?