FINAL PROJECT REPORT 3:

Protecting live oak seedlings from herbivores on Jekyll Island, Georgia

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About this report: We explain two experiments that used protective exclosures and wildlife camera surveillance to determine that squirrels were destroying newly planted live oak seedlings on Jekyll Island. Regardelss of whether deer are limiting live oak regeneration overall on Jekyll, this study shows that squirrels are a short-term concern when planting live oak seedlings for restoration. We present our study in four sections:

Background: Herbivore impacts on live oak seedlings → Objectives, Experimental Design, and Methods → Main Results and Secondary Findings → Implications for Jekyll Island Management

Herbivores, live oak regeneration, and restoration

On Jekyll Island, research is underway to understand the role of environmental stressors, including deer herbivory, as limitations to live oak regeneration in maritime live oak (MLO) forests.

White-tailed deer have a well-known capacity to limit the regeneration of trees. They may do so by consuming acorns, browsing on seedlings, or by eating bark or rubbing trunks to kill saplings. Since managers have noticed virtually no natural live oak recruitment on Jekyll Island, the potential role of deer, and the implications for the future of MLO forests, are key concerns.

Deer impact studies typically compare vegetation inside and outside of fenced exclosures over time. However, on Jekyll, there were very few naturally occurring live oak seedlings or saplings. Therefore, live oak seedlings had to be planted first in order to study this problem. As described in Final Report 2, about 1000 live oak seedlings were planted inside and outside of 10x10m fenced deer exclosures to determine the influence of deer on seedling mortality.

Planting tree seedlings is also a common technique in forest restoration. By studying herbivore impacts on planted seedlings, this research can also help anticipate obstacles for forest restoration.

The planted seedling study encountered a major setback, however. Roughly 6 months after initial planting, about 2/3 of the seedlings were destroyed, both inside and outside of the fenced enclosures.

Destroyed seedlings were dug up by the root, cut at the base of the stem, the stem and leaves left lying on the ground. This damage is not typical of deer, but instead suggested that small mammals are the culprits.

Figure 1: Live oak seedling (with pink zip tie wrapped around its stem and an upright pin flag) that was dug up. Arrow shows the cut stem. White flecks are from the nursery potting mix, which was scattered when the seedling root was excavated by the damage-causing animal.

This led to two follow-up studies, which are reported here:

1) to determine what animals were causing the observed damage; and
2) To determine if protective exclosures around individual seedlings would protect seedlings from herbivores.

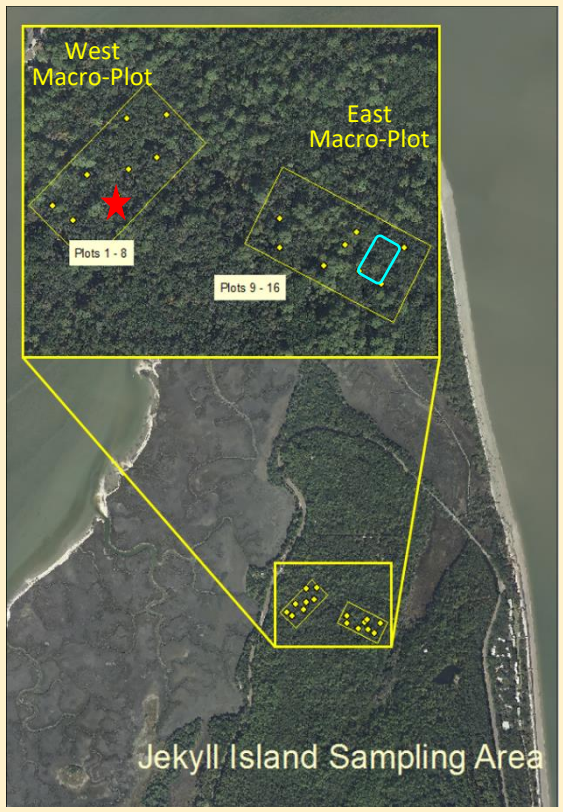
Objectives

We performed two studies to understand the effects of mammal herbivores on planted live oak seedlings.

STUDY A: The first study aimed to measure the levels of animal activity inside and outside of a 10x10m deer exclosures that still had original planted live oak seedlings. Motion activated camera traps were used to determine if visiting animals would return to feed on remaining seedlings. The study would also give a measure of relative activity levels of different animals at the site.

STUDY B: Because the seedlings in Study A all survived, Study B planted more live oak seedlings and used camera traps, aiming again to identify herbivores that kill seedlings, and to test whether individual seedling protection cages would be an effective way to prevent herbivores from killing seedlings.

Figure 2: Camera trap study locations at the northern MLO forest study site. Yellow dots are fenced and unfenced 10x10m herbivory plots. Red star is Study A site. Blue area is Study B site.



Experimental Design and Methods

STUDY A: In order to collect data about seedlings and animal visitation, 15 camera trai\ps were placed above 15 surviving live oak seedlings, 8 inside deer exclosures and 7 outside exclosures. Camera stands were made from 2x4 boards with PVC pipe legs about 1 m tall, onto which wildlife cameras were mounted facing downward (Figure 3). The study ran from Nov 2018 to May 2019. Photos were reviewed to record animal species, date, and time.

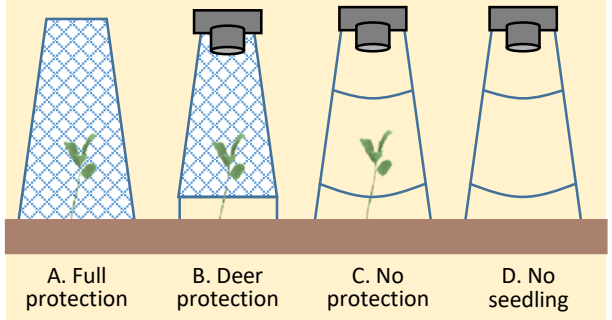
STUDY B: We planted 40 2-year old live oak seedlings widely spaced throughout a 30 x 50m area, and used wire tomato cages, some covered with plastic mesh, as treatments to create different levels of herbivores protection (Figure 4):

A: Protection from all mammal herbivores
B: Deer protection, but small mammal access
C. No protection; all mammals had access
D. No protection and no oak seedling.

The study ran from May 2019 to Jan 2020. We tracked seedling survival, herbivore damage, and water stress on all seedlings. We mounted cameras above 8 replicates of treatments B, C, and D.

Figure 3: Study A camera setup above live oak seedling, marked with flag

Figure 4: Study B treatments and camera setup above live oak seedlings.



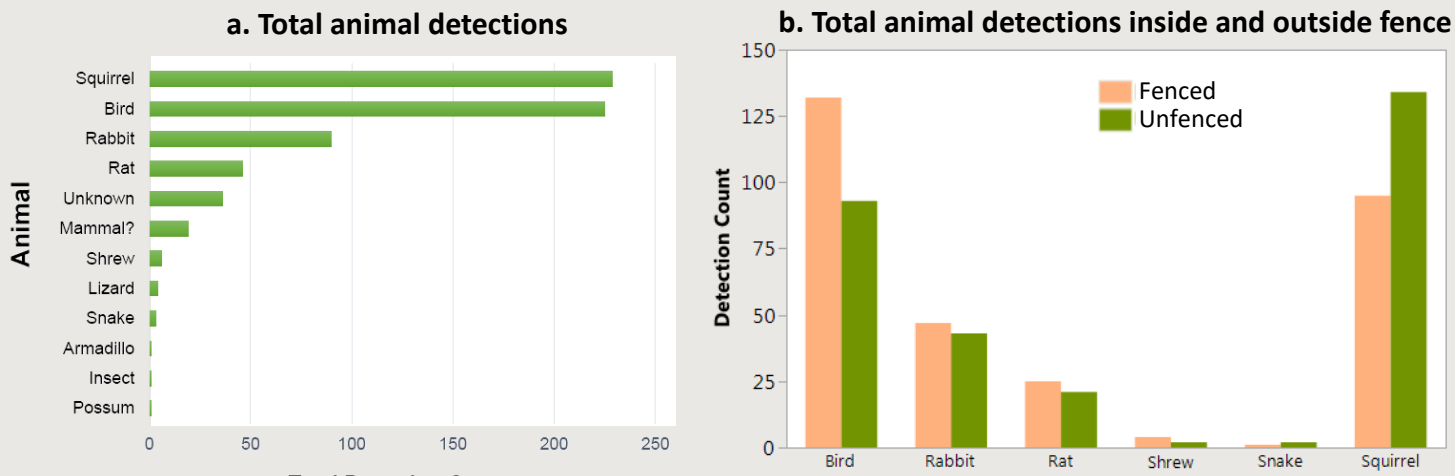
Study A Results: No herbivory on previously planted seedlings

During the course of this study, none of the 15 monitored seedlings were killed by herbivores. We do not know why the cluster of seedlings survived the first 6 months after planting, from April to October 2018, when such a large proportion (about 2/3)of all planted seedlings were killed. After live oak seedlings were initially planted, herbivory that had deckimated

There was a great deal of wildlife activity, however. We identified 661 images of animals across the 15 cameras used. The majority of animals detected were squirrels and birds, but we also saw other small mammals, repiles, and insects (Figure 5a).

Interestingly, about 25% more were birds detected inside the deer exclosure than outside, while squirrels were detected about 25% more frequently outside the exclosure than inside (Figure 5b).

Figure 5: (a) All categories of animals detected from wildlife camera photos, ranked by frequency; (b) comparison of detection counts of six animals,from cameras inside and outside the fenced deer enclosure.



No large mammals were detected by any of the wildlife cameras, but this does not mean that they were absent from the site. The wildlife cameras were mounted at a height of less than 1m, pointing downwards to cover an area about 50cm in diameter. If a deer had browsed within that area, the camera would have captured it. If they browsed anywhere else nearby, the cameras would not have detected them.

The culprits of the initial seedling damage remained unknown. Despite the large number of small mammals seen, none of them consumed the live oak seedlings. Many were even observed with their heads very close to the seedlings (Figure 6). It therefore seems unlikely that these seedlings survived was because they escpaped detection or because damaging wildlife was absent in their vicinity. A comparison of habitat in plots with high vs. low seedling mortality showed no general trends that would suggest a habitat difference. It is possible that seedlings are only attractive as food shortly after transplanting, or that consuming seedlings is seasonal.

Figure 6: Wildlife camera photos of a rabbit (left) and squirrel (right) within inches of a planted live oak seedling. Seedling stems highlighted with a yellow or white line).

Study B Results: Squirrels cut and killed many newly planted seedlings

Figure 6: Photos taken 90 seconds apart. Left: squirrel is pressing live oak stem to the side, and is likely chewing at its stem base. Right: seedling is lying down, soil around base is disturbed, and squirrel is departing.

Following the inconclusive results of Study A, we used freshly planted seedlings, cameras, and different exclosure types in attempts to decisively determine which animals were responsible for destroying planted seedlings.

In this study, we again saw the previously observed type of seedling destruction – with the seedling's stem cut at the base and its root dug up. By reviewing the associated motion-activated camera photos (e.g., Figure 6), we were able to verify that **squirrels were responsible for all herbivory-cased deaths.**

Survival of the newly planted seedlings varied depending on the type of protection (Figure 7). The unprotected seedlings suffered high mortality. All but one of the 8 seedlings were destroyed in the squirrel's signature fashion. **We did capture one deer in the unprotected seedling photos**, with its head inside the wire tomato cage. Subsequent photos revealed that **the seedling remained intact after the deer visit** (Figure 8), and was destroyed by a squirrel 4 weeks later.

In contrast, only one of the 8 fully enclosed seedlings died during the 7-month study. The series of photos revealed that it died slowly over 2 weeks after being planted, probably from water stress.

In the treatment meant to prevent deer but allow small mammal access, we observed intermediate rates of herbivory. Four seedlings were destroyed by squirrels, one died of non-herbivore related causes, and three survived. It is possible that the fencing partially deterred some squirrels.

Figure 7: Comparison of mortality rates in exclusion treatments, with 8 seedlings per treatment. The mortality observed in the full exclusion was not due to herbivory.

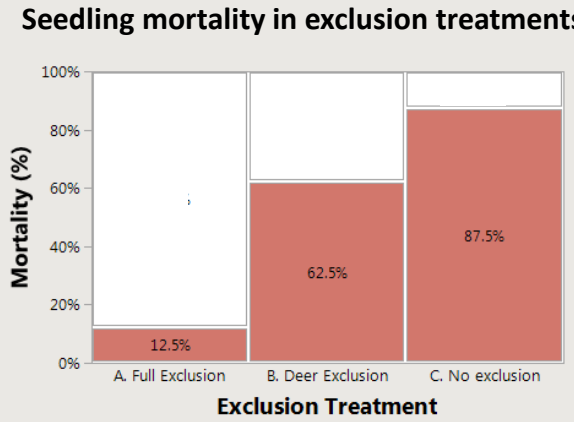


Figure 8: Photo capturing a young deer from above. The white arrow indicates leaves of a planted live oak seedling. The blurriness of oak leaves may indicate that the deer is bumping or browsing on the seedling. However, later photos showed that the seedling was not eaten.

In Study B, the freshly planted live oak seedlings were found and killed by squirrels rather rapidly. Most mortality occurred 18-22 days after planting (Figure 9). After 34 days, there were 4 remaining squirrel-accessible seedlings, which all survived without any further mortality until the end of the study.

Both Study A and Study B appear to indicate that there may be a seasonal pattern in squirrel consumption of seedlings, or possibly a window of time after transplantation during which squirrels are attracted to feed on the seedlings.

The particular way that squirrels damaged plants -- cutting off the stem, and digging out the upper part of the root – may also be informative. The upper part of the root has a different structure in live oaks than in other species of oaks. It has an elongated bulb, into which the seedling transfers and stores energy reserves from the acorn (Figure 10). (Most other oak seedlings instead remain attached to their acorn and draw nutrients from it as they grow.) This bulb is the target of the squirrel's foraging behavior. When we encountered thdestroyed seedlings, in most cases we also found the remains of the swollen root, torn open and frayed (Figure 11).

These bulbs are thought to persist for a few years, but we do not know how long the bulbs of our purchased seedlings actually persist once outplanted. Or whether they lose their palatablilty after transplanting or seasonally, or if squirrels only seek this food at certain times of year. It does seem clear, however, that freshly planted seedlings on Jekyll are vulnerable to squirrel damage.

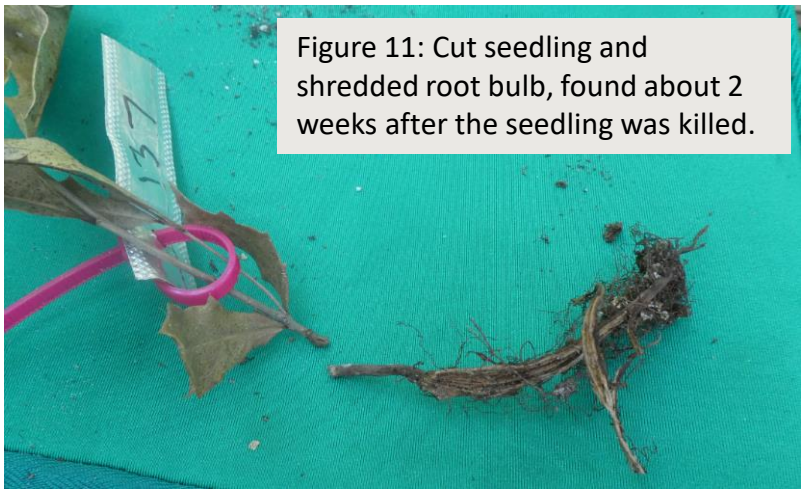


Figure 11: Cut seedling and shredded root bulb, found about 2 weeks after the seedling was killed.

Figure 9: Histogram of days of survival after planting for the 11 seedlings that were killed by herbivores during the study.

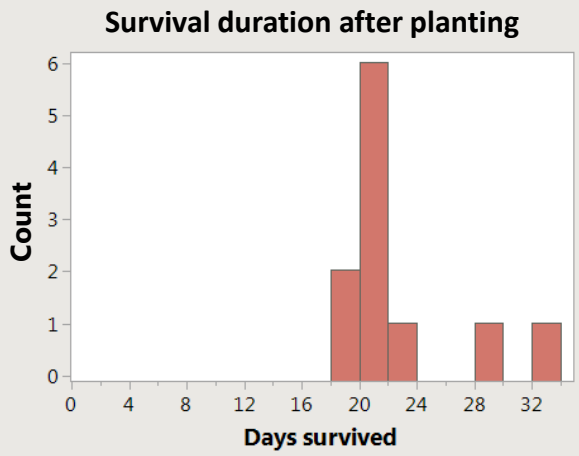


Figure 10: Plate showing elongated root bulbs on live oak seedlings, described in a 1912 publication: Coker, W. C. 1912. The seedlings of the live oak and white oak. *Journal of the Elisha Mitchell Scientific Society* 28:34-41.

Implications for Jekyll Island Management

Squirrels vs. Deer?

These studies address the particular issue of herbivore damage to *planted live oak seedlings*, which occurs over *a few months* after they are planted.

This study does NOT address the issue of herbivore impacts on *live oak regeneration*, which entails impacts on *naturally occurring oaks* at multiple life stages, i.e., acorns, seedlings, saplings, *over longer time periods*.

We found that squirrels consumed planted seedlings during the short periods of these studies. During these studies, we did not see deer destroying seedlings. Yet, deer are widely known for browsing on live oak seedlings and saplings.

At the study site, naturally occurring seedlings are rare, but present. Most (if not all) of these are not in fact seedlings from acorns; they are actually sprouts from mature trees' roots. These natural "seedlings" would therefore not have root bulbs, and are not likely to be impacted by squirrels.

The findings indicate that when planting live oak seedlings on Jekyll Island, protecting them from squirrels is very likely to increase seedling survival.

These findings do not mean that squirrels are a more important stressor than deer for natural live oak regeneration.

Despite no observed mortality caused by deer, their potential impact should still be considered when planting live oak seedlings.

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Protecting Planted Seedlings

Squirrels destroy seedlings to get at the root bulb. They did not appear to consume leaves.

In both studies, seedlings were planted in late spring or early summer, and squirrels caused mortality in the following months. After that time, squirrel-accessible seedlings generally survived without further mortality. We still do not understand exactly when or why squirrels seem to lose interest in planted seedlings over time.

Deer have been observed on other islands to heavily browse leaves and stems, and deer damage can kill or slow seedling growth until plants are tall enough to escape browsing.

- **We recommend that planted seedlings should be protected for at least 6 months to reduce squirrel damage.**
- **Protection needs to cover the base of the plant, and as a precaution, should also protect upper plant parts from deer.**
- **Individual cages or protective sleeves will prevent both deer and squirrel damage. Larger fenced enclosures will prevent deer, but seedlings may still need individual protection for several months to prevent squirrel damage.**

Live Oak Regeneration, Restoration and the Precautionary Principle

- There are very few naturally occurring juvenile live oak trees.
- Without juveniles, mature live oaks that die now cannot be replaced in the canopy.
- Planting seedlings is one way to ensure a pool of juveniles to replace canopy losses.
- Planted seedlings will benefit greatly from herbivore protection.